MORGAN OFFSHORE WIND PROJECT: GENERATION ASSETS

Environmental Statement

Volume 2, Chapter 3: Fish and shellfish ecology

Deadline: 6

Application Reference: EN010136

Document Number: MRCNS-J3303-RPS-10046

Document Reference: S_D6_18

27 February 2025

F02

Image of an offshore wind farm

www.morganandmona.com/morgan

Document status

Version	Purpose of document	Authored by	Reviewed by	Approved by	Review date
F01	Application	RPS	Morgan Offshore Wind Ltd.	Morgan Offshore Wind Ltd.	April 2024
F02	Deadline 6	RPS	Morgan Offshore Wind Ltd.	Morgan Offshore Wind Ltd.	February 2025

Prepared by:	Prepared for:
RPS	**Morgan Offshore Wind Ltd.**

Errata reference number	Deadline included	Document number	Volume and chapter	Paragraph/ Table/Figure	Description of errata	Correction
9	PD	APP-021	Volume 2, Chapter 3: Fish and shellfish	Paragraph 3.9.3.16	The inclusion of references to 135 dB re 1µPa2.s SELss and 160 dB re 1µPa SPLpk being roughly equivalent are included in error and should be disregarded; this statement is not reflected in the assessment outcomes and specific assessment content, and does not change the conclusions of the assessment. The assessment outcomes are based upon the maximum extent of behavioural contours presented, which are derived from the highly precautionary 135 dB re 1µPa2.s SELss contours, shown in Figure 3.6 of Volume 2, Chapter 3: Fish and shellfish ecology (APP-021).	The correct wording should read: 'Discrete high and low intensity mapped herring spawning grounds are located off the east coast of the IoM at Douglas Bank. Underwater sound at levels with potential to cause behavioural effects to herring (135 dB re 1µPa2.s SELss in line with the precautionary approach requested by stakeholders) from pile driving using a maximum hammer energy of 4,400 kJ overlap with these mapped grounds; the former encompasses both high and low intensity mapped spawning ground (54.9% of combined high and low intensity spawning grounds)'.
26	D3	APP-021	Volume 2, Chapter 3: Fish and shellfish ecology	Paragraph 3.8.1.2	References to 'section 3.7.1.2' for mitigation measures are incorrect.	The Applicant confirms the mitigation measures are in section (paragraph) 3.8.1.2.
27	D3	APP-021	Volume 2, Chapter 3: Fish and shellfish ecology	Paragraph 3.9.2.11	Paragraph 3.9.2.11 refers to the magnitude of impact on 'most subtidal IEFs', however this should state 'most fish and shellfish ecology IEFs'.	Paragraph 3.9.2.11 should refer to 'most fish and shellfish ecology IEFs'.

Errata reference number	Deadline included	Document number	Volume and chapter	Paragraph/ Table/Figure	Description of errata	Correction
30	D6	APP-021	Volume 2, Chapter 3: Fish and shellfish ecology	Table 3.18	References to 'pin piles' in the Maximum Design Scenario table.	The Maximum Design Scenario for fish and shellfish ecology should read 'driven pin piles'.

Contents

3 FISH AND SHELLFISH ECOLOGY 1
- 3.1 Introduction 1
  - 3.1.1 Overview 1
- 3.2 Legislative and policy context 1
  - 3.2.1 Legislation 1
  - 3.2.2 Planning policy context 2
  - 3.2.3 National Policy Statements 3
  - 3.2.4 North West Marine Plan 2021 11
  - 3.2.5 The Marine Strategy Framework Directive 14
  - 3.2.6 National Planning Policy Framework 15
- 3.3 Consultation 15
  - 3.3.1 Evidence plan 16
- 3.4 Baseline methodology 39
  - 3.4.1 Relevant guidance 39
  - 3.4.2 Scope of the assessment 39
  - 3.4.3 Methodology to inform baseline 41
  - 3.4.4 Fish and shellfish ecology study area 41
  - 3.4.5 Desktop study 44
  - 3.4.6 Identification of designated sites 47
  - 3.4.7 Site specific surveys 47
- 3.5 Baseline environment 48
  - 3.5.2 Herring 50
  - 3.5.3 Sandeel 51
  - 3.5.4 Elasmobranchs 54
  - 3.5.5 King and Queen Scallop 54
  - 3.5.6 Designated sites 55
  - 3.5.7 Important ecological features 56
  - 3.5.8 Future baseline scenario 62
  - 3.5.9 Data limitations 62
- 3.6 Impact assessment methodology 63
  - 3.6.1 Overview 63
  - 3.6.2 Impact assessment criteria 64
  - 3.6.3 Designated sites 67
- 3.7 Key parameters for assessment 67
  - 3.7.1 Maximum Design Scenario 67
- 3.8 Measures adopted as part of the Morgan Generation Assets 80
- 3.9 Assessment of significant effects 85
  - 3.9.1 Overview 85
  - 3.9.2 Temporary habitat loss/disturbance 85
  - 3.9.3 Underwater sound impacting fish and shellfish receptors 96
  - 3.9.4 Increased SSCs and associated sediment deposition 129
  - 3.9.5 Long term habitat loss 137
  - 3.9.6 Electro Magnetic Fields (EMFs) from subsea electrical cabling 143
  - 3.9.7 Introduction and colonisation of hard structures 150
  - 3.9.8 Disturbance/remobilisation of sediment-bound contaminants 156
  - 3.9.9 Injury due to increased risk of collision with vessels 160
  - 3.9.10 Future monitoring 163
- 3.10 Cumulative effects assessment methodology 163
  - 3.10.1 Methodology 163
  - 3.10.2 Maximum design scenario 171
- 3.11 Cumulative effects assessment 183
  - 3.11.1 Overview 183
  - 3.11.2 Temporary subtidal habitat loss 183

3.11.3 Underwater sound impacting fish and shellfish receptors 192
3.11.4 Increased SSCs and associated sediment deposition 199
3.11.5 Long term habitat loss 205
3.11.6 EMFs from subsea electrical cabling 212
3.11.7 Introduction and colonisation of hard structures 217
3.11.8 Injury due to increased risk of collision with vessels (basking shark only) 222
3.12 Transboundary effects 228
3.13 Inter-related effects 228
3.15 References 246

Tables

Table 3.1: Summary of the NPS EN-1 and NPS EN-3 provisions relevant to fish and shellfish ecology. 3
Table 3.2: Summary of NPS EN-1 and NPS EN-3 policy on decision making relevant to fish and shellfish ecology. 11
Table 3.3: North-West Inshore and North-West Offshore Marine Plan policies of relevant to Fish and Shellfish Ecology. 12
Table 3.4: High level MSFD descriptors of Good Environmental Status GES relevant to fish and shellfish ecology. 14
Table 3.5: English National Planning Policy Framework. 15
Table 3.6: Summary of key matters raised during consultation activities undertaken for the Morgan Generation Assets relevant to fish and shellfish ecology. 18
Table 3.7: Issues considered within this assessment. 39
Table 3.8: Impacts scoped out of the assessment for fish and shellfish ecology. 40
Table 3.9: Summary of key desktop reports. 44
Table 3.10: Summary of site-specific survey data. 48
Table 3.11: Key species with spawning and nursery grounds overlapping the Morgan Generation Assets Array Area (Coull *et al*., 1998; Ellis *et al*., 2012). 49
Table 3.12: Designated sites and relevant qualifying fish and shellfish ecology interests. 55
Table 3.13: Defining criteria for IEFs (adapted from CIEEM, 2018, updated in 2022). 57
Table 3.14: IEF species and representative groups within the Morgan Generation Assets. 58
Table 3.15: Definition of terms relating to the magnitude of an impact. 65
Table 3.16: Definition of terms relating to the sensitivity of the receptor. 66
Table 3.17: Matrix used for the assessment of the significance of the effect. 67
Table 3.18: Maximum design scenario considered for the assessment of potential impacts on fish and shellfish ecology. 69
Table 3.19: Measures adopted as part of the Morgan Generation Assets. 81
Table 3.20: Criteria for onset of injury to fish due to impulsive piling (Popper *et al*., 2014). 106
Table 3.21: Fish injury ranges for single pin pile installation based on the SPL_{pk} metric (4,400 kJ hammer energy). 107
Table 3.22: Fish injury ranges for single pin pile installation at 4,400 kJ based on the SEL_{cum} metric for moving fish (N/E – threshold not exceeded). 108
Table 3.23: Fish injury ranges for single pin pile installation at 4,400 kJ based on the SEL_{cum} metric for static fish (N/E – threshold not exceeded). 108
Table 3.24: TTS injury ranges for fish moving away from the source due to single and concurrent pin pile installation based on the SEL_{cum} metric. 109
Table 3.25: TTS injury ranges for static fish due to single and concurrent pin pile installation based on the cumulative SEL metric. 109
Table 3.26: Injury ranges for all fish groups relating to varying orders of detonation. 114
Table 3.27: Potential risk for the onset of behavioural effects in fish from piling (Popper *et al*., 2014)[a]. 115
Table 3.28: Typical magnetic field levels over AC undersea power cables (buried at target depth of 0.9 to 1.8 m) from offshore wind energy projects (CSA, 2019). 144
Table 3.29: Relationship between geomagnetic field detection electro sensitivity, and the ability to detect 50/60-Hz AC fields in common marine fish and shellfish species (adapted from CSA, 2019). 145
Table 3.30: Relationship between geomagnetic field detection electro sensitivity, and the ability to detect 50/60-Hz AC fields in diadromous fish species (adapted from CSA, 2019). 149

Table 3.31: List of other projects, plans and activities considered within the CEA. 166
Table 3.32: Maximum design scenario considered for the assessment of potential cumulative effects on fish and shellfish ecology. 172
Table 3.33: Cumulative tier 1 temporary habitat loss for the Morgan Generation Assets along with relevant projects and plans during the construction phase. 184
Table 3.34: Temporary subtidal habitat loss and disturbance. 187
Table 3.35: Underwater sound impacting fish and shellfish receptors. 195
Table 3.36: Increased SSCs and associated sediment deposition. 202
Table 3.37: Long term habitat loss. 209
Table 3.38: EMFs from subsea electrical cabling. 215
Table 3.39: Colonisation of hard structures. 220
Table 3.40: Injury due to increased risk of collision with vessels (basking shark). 225
Table 3.42: Summary of potential environmental effects, mitigation and monitoring. 231
Table 3.43: Summary of potential cumulative environmental effects, mitigation and monitoring. 236

Figures

Figure 3.1: Fish and shellfish ecology study area. 43
Figure 3.2: Herring spawning habitat preference classifications from EMODnet, OneBenthic and site-specific survey data, with spawning ground intensity (Coull *et al.*, 1998). 52
Figure 3.3: Sandeel habitat preference classifications from EMODnet, OneBenthic and site-specific survey data, with spawning ground intensity (Ellis *et al*., 2012). 53
Figure 3.4: Example concurrent piling scenario based upon piling using a 3,000 kJ hammer energy at two locations including the west modelled location. Figure shows herring spawning grounds and NINEL aggregated herring larval densities (2012 to 2021, larvae/m^2; Coull *et al.*, 1998). ... 98
Figure 3.5: Cod spawning grounds with subsea 5 dB sound SPL_{pk} contours for pin pile at 4,400 kJ hammer energy at the north modelled location (Ellis *et al.*, 2012). 101
Figure 3.6: Herring spawning grounds and aggregated larval density (larvae/m^2; 2012 to 2021) with subsea 5 dB re 1µPa^2.s sound SEL_{ss} contours for pin pile at 4,400 kJ hammer energy at the west location (Coull *et al.*, 1998). 103
Figure 3.7: Herring spawning grounds and aggregated larval density (larvae/m^2; 2012 to 2021) with subsea 5 dB re 1µPa sound SPL_{pk} contours for pin pile at 4,400 kJ hammer energy at the west location (Coull *et al.*, 1998). 104
Figure 3.8: Modelled TTS, recoverable injury and mortality ranges for moving group 3 and 4 fish in response to single piling with a 4,400 kJ hammer energy at the west location within the Morgan Array Area, shown with mapped herring spawning grounds (Coull *et al*., 1998) 110
Figure 3.9: Modelled TTS, recoverable injury and mortality ranges for moving group 3 and 4 fish in response to single piling with a 4,400 kJ hammer energy at the north location within the Morgan Array Area, shown with mapped cod spawning grounds (Ellis *et al*., 2012) 111
Figure 3.10: Modelled TTS, recoverable injury and mortality ranges for static group 3 and 4 fish in response to single piling with a 4,400 kJ hammer energy at the west location within the Morgan Array Area, shown with mapped herring spawning grounds (Coull *et al*., 1998) 112
Figure 3.11: Modelled TTS, recoverable injury and mortality ranges for static group 3 and 4 fish in response to single piling with a 4,400 kJ hammer energy at the north location within the Morgan Array Area, shown with mapped cod spawning grounds (Ellis *et al*., 2012) 113
Figure 3.12: Herring spawning grounds and aggregated larval density (larvae/m^2; 2012 to 2021) with subsea 5 dB 1µPa^2.s sound SEL_{ss} contours for pin pile at 3,000 kJ hammer energy at the west location. 119
Figure 3.13: Herring spawning grounds and aggregated larval density (larvae/m^2; 2012 to 2021) with subsea 5 dB re 1µPa sound SPL_{pk} contours for pin pile at 3,000 kJ hammer energy at the west location. 120
Figure 3.14: Cod spawning grounds with subsea 5 dB re 1µPa sound SPL_{pk} contours for pin piling at 3,000 kJ hammer energy at the north modelled location. 122
Figure 3.15: Other projects, plans and activities screened into the cumulative effects assessment. 165

Annexes

Annex number	Annex title
3.1	Fish and shellfish ecology technical report

Glossary

Term	Meaning
Demersal fish	Demersal fish are species that live and feed on or near the seabed.
Demersal spawning species	Species which deposit eggs onto the seabed during spawning.
Elasmobranch	The term refers to cartilaginous fishes which include sharks, rays, and skates.
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 Statement.
Evidence Plan Process	The Evidence Plan process is a mechanism to agree upfront what information the Applicant needs to supply to the Planning Inspectorate as part of the Development Consent Order (DCO) applications for the Morgan Generation Assets.
Expert Working Group (EWG)	Expert working groups set up with relevant stakeholders as part of the Evidence Plan process.
Important Ecological Features	Habitats, species, ecosystems and their functions/processes that are considered to be important and potentially impacted by the Proposed Development.
K-strategist	Relatively slow-growing organisms which invest greater resources into raising a small number of offspring.
Masking	Masking occurs when sound emissions interfere with a marine animal's ability to hear a sound of interest.
Nursery habitat	A habitat where juveniles of a species regularly occur as a population.
Pelagic fish	Pelagic fish are species which live and feed within the water column.
Shellfish	For the purposes of this assessment, shellfish is considered a generic term to define molluscs and crustaceans.
Spawning grounds	Spawning grounds are the areas of water or seabed where fish spawn or produce their eggs.

Acronyms

Acronym	Description
AC	Alternating Current
BNG	Biodiversity Net Gain
CBRA	Cable Burial Risk Assessment
CEA	Cumulative Effects Assessment
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CIEEM	Chartered Institute of Ecology and Environmental Management
CMACS	Centre for Marine and Coastal Studies Ltd
CSIP	Cable Specification and Installation Plan

Acronym	Description
CTV	Crew Transfer Vessels
DC	Direct Current
DCO	Development Consent Order
DDV	Drop Down Video
Defra	Department for Environment, Food and Rural Affairs
EcIA	Ecological Impact Assessment
EIA	Environmental Impact Assessment
EMF	Electromagnetic Field
EMODnet	European Marine Observation and Data Network
EMU	Ecological Marine Unit
EWG	Expert Working Group
GES	Good Environmental Status
HDD	Horizontal Directional Drilling
HRA	Habitat Regulations Assessment
HVAC	High Voltage Alternation Current
ICES	International Council for the Exploration of the Sea
IEF	Important Ecological Features
IEMA	Institute of Environmental Management and Assessment
IFCA	Inshore Fisheries and Conservation Authority
INNS	Invasive Non-Native Species
IoM	Isle of Man
IUCN	International Union for Conservation of Nature
JNCC	Joint Nature Conservation Committee
MarLIN	Marine Life Information Network
MCZ	Marine Conservation Zone
MDS	Maximum Design Scenario
MMO	Marine Management Organisation
MMMP	Marine Mammal Mitigation Protocol
MNR	Marine Nature Reserve
MPA	Marine Protected Area
MPCP	Marine Pollution Contingency Plan
MSFD	Marine Strategy Framework Directive
NBN	National Biodiversity Network
NEQ	Net Explosive Quantity
NINEL	Northern Ireland Herring Larvae Survey

Acronym	Description
NPS	National Policy Statement
NRW	Natural Resources Wales
NSIPs	Nationally Significant Infrastructure Projects
OSP	Offshore Substation Platform
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
PEIR	Preliminary Environmental Information Report
PSA	Particle Size Analysis
PTS	Permanent Threshold Shift
SAC	Special Area of Conservation
SEL_{ss}	Single Strike Sound Exposure Level
SSSI	Site of Special Scientific Interest
SNCB	Statutory Nature Conservation Body
SOV	Service Operation Vessels
SPA	Special Protection Area
SPI	Species of Principal Importance
SPL_{pk}	Peak Sound Pressure Level
SPM	Suspended Particulate Matter
SSC	Suspended Sediment Concentration
TTS	Temporary Threshold Shift
UXO	Unexploded Ordnance
ZoI	Zone of Influence

Units

Unit	Description
%	Percentage
mm	Millimetres
cm	Centimetres
dB	Decibel
kJ	Kilojoules
m	Metres
kg	Kilograms
km	Kilometres
m^2	Square metres
km^2	Square kilometres

Unit	Description
m^3	Cubed metres
m/h	Metres per hour
m/s	Metres per second
mg/l	Milligrams per litre
MW	Megawatts
nm	Nautical miles
µPa	Micropascal
kV	Kilovolts
mG	Milligauss
Hz	Hertz
kHz	Kilohertz
˚C	Degrees Celsius
µT	Microtesla
µV/m	Microvolt per metre
µV/cm	Microvolt per centimetre
V/m	Volts per metre

3 Fish and shellfish ecology

3.1 Introduction

3.1.1 Overview

3.1.1.1 This chapter of the Environmental Statement presents the assessment of the potential impact of the Morgan Offshore Wind Project: Generation Assets (hereafter referred to as the Morgan Generation Assets) on fish and shellfish ecology. Specifically, this chapter considers the potential impact of the Morgan Generation Assets, with a study area encompassing the area seaward of Mean High Water Springs (MHWS) during the construction, operations and maintenance and decommissioning phases.

3.1.1.2 The assessment presented is informed by the following technical chapters:

- Volume 2, Chapter 1: Physical processes of the Environmental Statement
- Volume 2, Chapter 2: Benthic subtidal ecology of the Environmental Statement
- Volume 2, Chapter 4: Marine mammals of the Environmental Statement.

3.1.1.3 This chapter also draws upon information contained within:

- Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement
- Volume 4, Annex 1.1: Physical processes technical report of the Environmental Statement
- Volume 4, Annex 2.1: Benthic subtidal ecology technical report of the Environmental Statement
- Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement
- Volume 4, Annex 6.1: Commercial fisheries technical report of the Environmental Statement.

3.2 Legislative and policy context

3.2.1 Legislation

3.2.1.1 The policy context for the Morgan Generation Assets is set out in Volume 1, Chapter 2: Policy and legislative context of the Environmental Statement. The policy and legislation set out below is the most relevant to fish and shellfish ecology.

Habitats Regulations

3.2.1.2 The Conservation of Habitats and Species Regulations 2017 and the Conservation of Offshore Marine Habitats and Species Regulations 2017 (collectively known as the 'Habitats Regulations') require the assessment of significant effects on internationally important nature conservation sites, including the following:

- Special Areas of Conservation (SACs) or candidate SACs
- Special Protection Areas (SPAs) or potential SPAs
- Sites of Community Importance
- Ramsar sites.

3.2.1.3 These designated sites have been given full consideration in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement and are given further consideration within this chapter where the impacts are assessed as likely to have an effect. As a matter of policy, in the UK, Ramsar sites are given the same protection as sites covered by the Habitats Regulations (Department for Energy Security & Net Zero, 2023a). Additionally the potential impacts of the Morgan Generation Assets on all habitats, species and sites protected under the Habitats Regulations are assessed in the HRA Phase 1 Screening Report (Document Reference E1.4) and HRA Stage 2 Information to Support the Appropriate Assessment (ISAA) Part 2 – SAC assessments (Document Reference E1.2).

Marine and Coastal Access Act 2009

3.2.1.4 Parts three and four of the Marine and Coastal Access Act 2009 introduced a new marine planning and licensing system for overseeing the marine environment and a requirement to obtain a marine licence for certain activities and works at sea. Section 149A of the Planning Act 2008 allows applicants for development consent to apply for ‘deemed marine licences’ as part of the consenting process.

3.2.1.5 Part five of the Marine and Coastal Access Act 2009 enables the designation of Marine Conservation Zones (MCZs) in England and Wales as well as UK offshore areas. Consideration of MCZs is required for any marine licence application or an application for development consent which includes a deemed marine licence.

3.2.1.6 The potentially impacted designated sites have been given full consideration in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement as well as in the MCZ Assessment and are given further consideration within this chapter where the impacts are deemed likely to have a potential effect.

Environment Act 2021

3.2.1.7 The Environment Act 2021 sets out targets, plans and policies for environmental protection in England. Schedule 15 of the Environment Act 2021 sets out provisions for Biodiversity Net Gain (BNG) in respect of nationally significant infrastructure projects (NSIPs) and amends the Planning Act 2008. These provisions propose to include the requirement for the production of BNG statements for NSIPs, however these provisions are not expected to take effect until at least November 2025. Such provisions will only apply to applications that are submitted after the date that these provisions take effect for NSIPs.

3.2.1.8 The Biodiversity Benefit Statement (Document Reference J18) outlines the approach of the Morgan Generation Assets to biodiversity enhancement.

3.2.2 Planning policy context

3.2.2.1 The Morgan Generation Assets will be located in English offshore waters (beyond 12 nm from the English coast). As set out in Volume 1, Chapter 1: Introduction of the Environmental Statement. As the Morgan Generation Assets is an offshore generating station with a capacity of greater than 100 MW located in English waters, it is a NSIP as defined by Section 15(3) of the Planning Act 2008. As such, there is a requirement to submit an application for a Development Consent Order (DCO) to the Planning Inspectorate to be decided by the Secretary of State for the Department for Energy Security and Net Zero.

3.2.3 National Policy Statements

3.2.3.1 There are currently six energy National Policy Statements (NPSs), two of which contain policy relevant to offshore wind development and the Morgan Generation Assets, specifically:

- Overarching NPS for Energy (NPS EN-1) which sets out the UK Government's policy for the delivery of major energy infrastructure (Department for Energy Security and Net Zero, 2023a).
- NPS for Renewable Energy Infrastructure (NPS EN-3) (Department for Energy Security and Net Zero, 2023b).
- NPS EN-1 and NPS EN-3 include guidance on what matters are to be considered in the assessment.

3.2.3.2 These are summarised in Table 3.1 below. NPS EN-1 and NPS EN-3 also highlight a number of factors relating to the determination of an application and in relation to mitigation.

Table 3.1: Summary of the NPS EN-1 and NPS EN-3 provisions relevant to fish and shellfish ecology.

Summary of NPS EN-1 and EN-3 provision	How and where considered in the chapter
NPS EN-1	
In considering any proposed development, in particular when weighing its adverse impacts against its benefits, the Secretary of State should take into account: • Its potential benefits including its contribution to meeting the need for energy infrastructure, job creation, reduction of geographical disparities, environmental enhancements, and any long-term or wider benefits • Its potential adverse impacts, including on the environment, and including any long-term and cumulative adverse impacts, as well as any measures to avoid, reduce, mitigate or compensate for any adverse impacts, following the mitigation hierarchy. (NPS EN-1, paragraph 4.1.5)	The existing ecology of the fish and shellfish ecology study area is laid out in the baseline environment (section 3.5), with all relevant information used to inform the associated assessment of significant effects on this baseline (section 3.9). This can be used to allow weighing of impacts and benefits in the decision-making process.
In this context, the Secretary of State should take into account environmental, social and economic benefits and adverse impacts, at national, regional and local levels. These may be identified in this NPS, the relevant technology specific NPS, in the application or elsewhere (including in local impact reports, marine plans, and other material considerations as outlined in Section 1.1). (NPS EN-1, paragraph 4.1.6)	Nearby designated sites, and their associated habitats and species of principal importance (SPI), have been identified in Volume 4: Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement and are listed in section 1.11, with the identified important ecological features (IEFs) listed in section 1.12.3. These can be used in accounting for national, regional, and local impacts of these projects.
The energy NPSs have taken account of the National Planning Policy Framework (NPPF), the Planning Practice Guidance (PPG) for England, and Planning Policy Wales and Technical Advice Notes (TANs) for Wales, where appropriate. (NPS EN-1, paragraph 4.1.11)	All guidance and policy frameworks in relation to fish and shellfish ecology have been identified in section 3.2 and complied with throughout.
The Regulations require an assessment of the likely significant effects of the proposed project on the environment, covering the direct effects and any indirect, secondary, cumulative, transboundary, short, medium, and long-term, permanent and temporary, positive and negative	The impacts on fish and shellfish ecology have been assessed in section 3.9, with all other impacts assessed throughout the chapters.

Summary of NPS EN-1 and EN-3 provision	How and where considered in the chapter
effects at all stages of the project, and also of the measures envisaged for avoiding or mitigating significant adverse effects. (NPS EN-1, paragraph 4.3.3)	
To consider the potential effects, including benefits, of a proposal for a project, the applicant must set out information on the likely significant environmental, social and economic effects of the development, and show how any likely significant negative effects would be avoided, reduced, mitigated or compensated for, following the mitigation hierarchy. This information could include matters such as employment, equality, biodiversity net gain, community cohesion, health and well-being. (NPS EN-1, paragraph 4.3.4)	The impacts on fish and shellfish ecology have been assessed in section 3.9, with all other impacts assessed throughout the chapters, with mitigation measures identified in section 3.7.1.2.
For the purposes of this NPS and the technology specific NPSs the Environmental Statement should cover the environmental, social and economic effects arising from pre-construction, construction, operation and decommissioning of the project. (NPS EN-1, paragraph 4.3.5)	The assessment of significant effects (section 3.9) examines the impacts of all stages of the project on the environmental factors, and specifically the fish and shellfish ecology receptors, impacted by Morgan Generation Assets.
The applicant must provide information proportionate to the scale of the project, ensuring the information is sufficient to meet the requirements of the Environmental Impact Assessment (EIA) Regulations. (NPS EN-1, paragraph 4.3.10)	Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement; the baseline (section 1.12.2); Maximum Design Scenario (MDS), and assessment of impacts sections examine the scale of potential impacts on the fish and shellfish ecology receptors.
Where some details are still to be finalised, the Environmental Statement should, to the best of the applicant's knowledge, assess the likely worst-case environmental, social and economic effects of the proposed development to ensure that the impacts of the project as it may be constructed have been properly assessed. (NPS EN-1, paragraph 4.3.12)	The MDS (Table 3.18) provides the calculated maximum design scenario impacts on fish and shellfish ecology.
Applicants for a development consent order must take account of any relevant Marine Plans and are expected to complete a Marine Plan assessment as part of their project development, using this information to support an application for development consent. Applicants are encouraged to refer to Marine Plans at an early stage, such as in preapplication, to inform project planning, for example to avoid less favourable locations as a result of other uses or environmental constraints. (NPS EN-1, paragraphs 4.5.8 to 4.5.9)	All relevant Marine Plans and guidelines are outlined in section 3.2 with compliance to relevant fish and shellfish ecology clauses highlighted.
In certain circumstances, measures implemented to ensure a scheme can adapt to climate change may give rise to additional impacts, for example as a result of protecting against flood risk, there may be consequential impacts on coastal change. In preparing measures to support climate change adaptation applicants should take reasonable steps to maximise the use of nature-based solutions alongside other conventional techniques. (NPS EN-1, paragraph 4.10.5)	The potential future impact of climate change on fish and shellfish ecology is examined in the future baseline scenario (3.5.8).
Applicants should consult the Marine Management Organisation (MMO) (or Natural Resources Wales (NRW) in	The consultation process is outlined in section 3.3 of this chapter, including any communications with the

Summary of NPS EN-1 and EN-3 provision	How and where considered in the chapter
Wales) on energy NSIP projects which would affect, or would be likely to affect, any relevant marine areas as defined in the Planning Act 2008 (as amended by section 23 of the Marine and Coastal Access Act 2009). Applicants are encouraged to consider the relevant marine plans in advance of consulting the MMO for England or the relevant policy teams at the Welsh government. Applicants should make early contact with relevant regulators, including the Environment Agency or NRW and the MMO, to discuss their requirements for Environmental Protections and other consents such as marine licences. (NPS EN-1, paragraphs 4.12.5, 4.12.7)	MMO, the Environment Agency and NRW, the Expert Working Groups (EWGs), and stakeholder consultation.
Where the development is subject to EIA the applicant should ensure that the Environmental Statement clearly sets out any effects on internationally, nationally, and locally designated sites of ecological or geological conservation importance (including those outside England), on protected species and on habitats and other species identified as being of principal importance for the conservation of biodiversity, including irreplaceable habitats. (NPS EN-1, paragraph 5.4.17)	Designated sites are set out in section 3.5.6, with IEFs defined in section 3.5.7 based on their conservation, ecological and commercial importance. The impact assessment (section 3.9) has been undertaken to consider the potential effects of each project on these IEFs.
The applicant should show how the project has taken advantage of opportunities to conserve and enhance biodiversity and geological conservation interests. (NPS EN-1, paragraph 5.4.19)	The conservation of biodiversity interests has been considered directly in the impacts assessment (section 3.9), with designed in mitigation measures (section 3.7.1.2) proposed to reduce potential impacts where possible. The Biodiversity Benefit Statement (Document Reference J18) outlines the approach of the Morgan Generation Assets to biodiversity enhancement.
The design process should embed opportunities for nature inclusive design. Energy infrastructure projects have the potential to deliver significant benefits and enhancements beyond Biodiversity Net Gain, which result in wider environmental gains. The scope of potential gains will be dependent on the type, scale, and location of each project. (NPS EN-1, paragraph 5.4.21)	The Biodiversity Benefit Statement (Document Reference J18) outlines the approach of the Morgan Generation Assets to biodiversity enhancement.
The design of Energy NSIP proposals will need to consider the movement of mobile/migratory species such as birds, fish and marine and terrestrial mammals and their potential to interact with infrastructure. (NPS EN-1, paragraph 5.4.22)	Diadromous and migratory fish species have been identified as IEFs in section 1.12.3 and are considered in each relevant impact assessment in section 3.9.
Energy projects will need to ensure vessels used by the project follow existing regulations and guidelines to manage ballast water. (NPS EN-1, paragraph 5.4.23)	Vessels will operate under the Outline plan for rafting birds and marine mammals (Document Reference J15) as part of the Environmental Management Plan (EMP) and will adhere to an Invasive Non-Native Species (INNS) management plan at all times, as detailed in section 3.7.1.2.
Applicants should include appropriate avoidance, mitigation, compensation and enhancement measures as an integral part of the proposed development. In particular, the applicant should demonstrate that: • During construction, they will seek to ensure that activities will be confined to the minimum areas required for the works	The MDS has been developed with project engineers to ensure it is appropriately precautionary and not over-conservative to ensure habitat loss is minimised wherever possible. It represents a realistic scenario without overcompensating for any one activity, in this sense it represents the maximum area required to work in the construction, operation and maintenance

Summary of NPS EN-1 and EN-3 provision	How and where considered in the chapter
- The timing of construction has been planned to avoid or limit disturbance - During construction and operation best practice will be followed to ensure that risk of disturbance or damage to species or habitats is minimised, including as a consequence of transport access arrangements - Habitats will, where practicable, be restored after construction works have finished. - Opportunities will be taken to enhance existing habitats rather than replace them, and where practicable, create new habitats of value within the site landscaping proposals. Where habitat creation is required as mitigation, compensation, or enhancement the location and quality will be of key importance. In this regard habitat creation should be focused on areas where the most ecological and ecosystems benefits can be realised. - Mitigations required as a result of legal protection of habitats or species will be complied with. (NPS EN-1, paragraph 5.4.35)	and decommissioning phases (Table 3.18and section 3.7.1). Any specific mitigation measures to minimise disturbance or damage to habitats and biodiversity have been identified and justified (Table 3.19). The Biodiversity Benefit Statement (Document Reference J18) outlines the approach of the Morgan Generation Assets to biodiversity enhancement.
Applicants should produce and implement a Biodiversity Management Strategy as part of their development proposals. This could include provision for biodiversity awareness training to employees and contractors so as to avoid unnecessary adverse impacts on biodiversity during the construction and operation stages. (NPS EN-1, paragraph 5.4.36)	The need for a biodiversity benefit strategy has been addressed in Table 3.2 (refer to the Biodiversity Benefit Statement (Document Reference J18)). Any specific mitigation measures to minimise disturbance or damage to habitats and biodiversity have been identified and justified (Table 3.19).
Where relevant, applicants should undertake coastal geomorphological and sediment transfer modelling to predict and understand impacts and help identify relevant mitigating or compensatory measures. The Environmental Statement should include an assessment of the effects on the coast, tidal rivers and estuaries. In particular, applicants should assess: - The effects of the proposed project on marine ecology, biodiversity, protected sites and heritage assets. (NPS EN-1, paragraph 5.6.10 to 5.6.11)	The potential impacts of suspended sediment concentrations have been modelled, with their impacts on fish and shellfish ecology receptors assessed in section 3.9.4
Where noise impacts are likely to arise from the proposed development, the applicant should include the following in the noise assessment: - A description of the noise generating aspects of the development proposal leading to noise impacts, including the identification of any distinctive tonal, impulsive, low frequency or temporal characteristics of the noise - Identification of noise sensitive receptors and noise sensitive areas that may be affected - The characteristics of the existing noise environment - A prediction of how the noise environment will change with the proposed development – In the shorter term, such as during the construction period – In the longer term, during the operating life of the infrastructure	Sources of potential sound impacts have been identified in the MDS in section 3.7.1, and the impacts on fish and shellfish ecology receptors have been assessed alone in section 3.9.3, and cumulatively in section 3.11.3. Specific mitigation measures, including soft-starts for piling to reduce this impact, have been identified and discussed in Table 3.19.

Summary of NPS EN-1 and EN-3 provision	How and where considered in the chapter
– At particular times of the day, evening and night (and weekends) as appropriate, and at different times of year • An assessment of the effect of predicted changes in the noise environment on any noise-sensitive receptors, including an assessment of any likely impact on health and well-being where appropriate, and noise-sensitive areas • If likely to cause disturbance, an assessment of the effect of underwater or subterranean noise. (NPS EN-1, paragraph 5.12.6)	
In the marine environment, applicants should consider noise impacts on protected species, both at the individual project level and in-combination with other marine activities. Applicants should submit a detailed impact assessment and mitigation plan as part of any development plan, including the use of noise mitigation and noise abatement technologies during construction and operation. (NPS EN-1, paragraphs 5.12.11 to 5.12.12)	All relevant protected fish and shellfish ecology receptors which could be impacted by sound generated during construction, operation and maintenance and decommissioning activities have been identified in section 3.5, and the impacts have been assessed alone in section 3.9.3, and cumulatively in section 3.11.3. Mitigation measures to reduce this impact, including soft-starts for piling activities, have been identified and discussed in section 3.7.1.2. In addition, the project plans to develop an Underwater Sound Management Strategy post-consent and in discussion with stakeholders to support reduction of the impact magnitude associated with underwater sound from piling. An Outline underwater sound management strategy (Document Reference J13) will be provided with the Application.
NPS EN-3	
Where details are still to be finalised applicants should explain in the application which elements of the proposal have yet to be finalised, and the reason why this is the case. Where flexibility is sought in the consent as a result, applicants should, to the best of their knowledge, assess the likely worst-case environmental, social and economic effects of the proposed development to ensure that the impacts of the project as it may be constructed have been properly assessed. Full guidance on how applicants and the Secretary of State should manage flexibility is set out in Section 4.2 of EN-1. (NPS EN-3, paragraphs 2.6.1 to 2.6.3)	The possible maximum magnitude of impacts on fish and shellfish ecology receptors have been identified in the MDS in section 3.7.1, based on the Project Design Envelope.
The onus is on the applicant to ensure that the foundation design is technically suitable for the seabed conditions and that the application caters for any uncertainty regarding the geological conditions. Whilst the technical suitability of the foundation design is not in itself a matter for the Secretary of State, the Secretary of State will need to be satisfied that the foundations will not have an unacceptable adverse effect on marine biodiversity, the physical environment or marine heritage assets. (NPS EN-3, paragraphs 2.8.32 to 2.8.33)	Potential impacts from the range of possible foundation design parameters are addressed in the MDS calculation (section 3.7.1and Table 3.18), with the levels of impact on ecologically important fish and shellfish receptors assessed in the assessment of significant effects (section 3.9).
Applicants are encouraged to work collaboratively with those other developers and sea users on co-existence/co-location opportunities, shared mitigation, compensation and monitoring where appropriate. Where applicable, the creation of statements of common ground between developers is recommended. Work is ongoing between	Relevant developers have been consulted where appropriate. Other stakeholders have been consulted prior to application directly and through the EWG, as outlined in section 3.3. A range of fishers operating within the vicinity of the projects have been consulted on potential impacts and mitigation strategies.

Summary of NPS EN-1 and EN-3 provision	How and where considered in the chapter
government and industry to support effective collaboration and find solutions to facilitate to greater co-existence/co-location. (NPS EN-3, paragraph 2.8.48)	
Given the scale of offshore wind deployment required to meet 2030 and 2050 ambitions, applicants will need to give close consideration to impacts on marine protected areas (MPAs), either alone or in combination, in addition to mitigation measures and/or compensation (both individually and in combination with other plans or projects) which may be needed to approve their projects. It is likely that these may include proactive measures to reduce the impact of deployment e.g. micrositing of cable routes to avoid vulnerable habitats, alternatives piling or trenching techniques, noise abatement technology, collision avoidance methods or compensation for habitat loss. (NPS EN-3, paragraph 2.8.52 to 2.8.53)	Potentially impacted nearby designated sites have been identified in section 3.5.6 and are assessed throughout this chapter. Mitigation measures to minimise impacts on these designated sites have been identified and discussed in section 3.7.1.2.
Applicants should have regard to the specific ecological and biodiversity considerations that pertain to proposed offshore renewable energy infrastructure developments, namely: • Fish (see Section 2.8.250 of this NPS) • Intertidal and subtidal seabed habitats and species (see Section 2.8.233 of this NPS) • Marine mammals (see Section 2.8.237 of this NPS) • Birds (see Section 2.8.240 of this NPS) • Wider ecosystem impacts and interactions. Applicants must undertake a detailed assessment of the offshore ecological, biodiversity and physical impacts of their proposed development, for all phases of the lifespan of that development, in accordance with the appropriate policy for offshore wind farm EIAs, Habitat Regulations Assessments (HRAs) and MCZ assessments. (NPS EN-3, paragraph 2.8.98 and 2.8.101)	The existing ecology and biodiversity of the projects fish and shellfish ecology study area has been examined in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement and the baseline assessment (section 3.5). Any changes expected have been identified in the MDS calculation (section 3.7.1and Table 3.18), with the levels of impact on fish and shellfish receptors assessed in the assessment of significant effects (section 3.9).
Applicants need to consider environmental and biodiversity net gain as set out in Section 4.5 of EN-1 and the Environment Act 2021. Applicants should assess the potential of their proposed development to have net positive effects on marine ecology and biodiversity, as well as negative effects. (NPS EN-3, paragraphs 2.8.102 to 2.8.103)	Both potential maximum design scenario and positive effects on fish and shellfish ecology have been considered in the impact assessment presented in section 3.9.
Applicants should consult at an early stage of pre-application with relevant statutory consultees, as appropriate, on the assessment methodologies, baseline data collection, and potential avoidance, mitigation and compensation options should be undertaken. In developing proposals applicants must refer to the best practice advice provided by the Offshore Wind Enabling Action Programme, and/or their relevant Statutory Nature Conservation Body (SNCB). Any relevant data that has been collected as part of post-construction ecological monitoring from existing, operational offshore wind farms should be referred to where appropriate.	Consultation has been undertaken through the Benthic Ecology, Fish and Shellfish Ecology and Physical Processes EWG as detailed in section 3.3. The impact assessment (section 3.9) has been undertaken taking into account published post-construction monitoring from offshore wind farms in the UK and overseas and all relevant guidance identified in section 3.4.1. Where required based upon the assessment outcomes to ensure impacts are managed, appropriate post-construction monitoring will be considered for the Morgan Generation Assets.

Summary of NPS EN-1 and EN-3 provision	How and where considered in the chapter
(NPS EN-3, paragraphs 2.8.104 to 2.8.106)	
The applicant should identify fish species that are the most likely receptors of impacts with respect to: • Spawning grounds • Nursery grounds • Feeding grounds • Over-wintering areas for crustaceans • Migration routes • Protected sites Applicant assessments should identify the potential implications of underwater noise from construction and unexploded ordnance including, where possible, implications of predicted construction and soft start noise levels in relation to mortality, permanent threshold shift (PTS), temporary threshold shift (TTS) and disturbance and addressing both sound pressure and particle motion) and Electromagnetic Fields (EMF) on sensitive fish species. (NPS EN-3, paragraphs 2.8.150 to 2.8.151)	Important habitats for fish and shellfish, including spawning, nursery and migration routes have been considered in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement and summarised in section 3.4.1.3. Potential effects on these have been assessed in section 3.9.
Applicants should engage with interested parties in the potentially affected offshore sectors early in the pre-application phase of the proposed offshore wind farm, with an aim to resolve as many issues as possible prior to the submission of an application. (see paragraphs 2.8.56, 2.8.273/4 and 2.8.267 of this NPS for further guidance). Such stakeholder engagement should continue throughout the life of the development including construction, operation and decommissioning phases where necessary. As many offshore industries are regulated by government, the relevant Secretary of State should also be a consultee where necessary. Such engagement should be taken to ensure that solutions are sought that allow offshore wind farms and other uses of the sea to successfully co-exist. (NPS EN-3, paragraphs 2.8.200 to 2.8.203)	Relevant stakeholders have been consulted prior to application, and through the EWGs, as outlined in section 3.3. A range of fishers operating within the vicinity of the projects have been consulted on potential impacts and mitigation strategies.
Applicants must always employ the mitigation hierarchy, in particular to avoid as far as is possible the need to find compensatory measures for coastal, inshore and offshore developments affecting HRA sites and/or MCZs. It is essential that applicants involve SNCBs and Department for Environment, Food and Rural Affairs (Defra) as early as possible in the planning process to enable discussions of what is and isn't a significant and/or adverse effect, subsequent implications, and if required, mitigation and/or compensation. At the earliest possible stage alternative ways of working and use of technology should be employed to avoid environmental impacts. Where impacts cannot be avoided, measures to reduce and mitigate impacts should be employed, for example using trenching techniques or noise abatement technology. Applicants should undertake a review of up-to-date research and all potential avoidance, reduction and mitigation options presented for all receptors.	Mitigation measures to reduce potential impacts on fish and shellfish receptors have been identified in section 3.7.1.2. Relevant SNCBs and other stakeholders have been consulted prior to application, and the EWG, as outlined in section 3.3. A range of fishers operating within the vicinity of the projects have been consulted on potential impacts and mitigation strategies.

Summary of NPS EN-1 and EN-3 provision	How and where considered in the chapter
Only once all feasible alternatives and mitigation measures have been employed, should applicants explore possible compensatory measures to make good any remaining significant adverse effects to site integrity. (NPS EN-3, paragraphs 2.8.213 to 2.8.216)	
Applicants are advised to develop an ecological monitoring programme to monitor impacts during the pre-construction, construction and operational phases to identify the actual impacts caused by the project and compare them to what was predicted in the EIA/HRA. Should impacts be greater than those predicted, an adaptive management process may need to be implemented and additional mitigation required, to ensure that so far as possible the effects are brought back within the range of those predicted. Monitoring should be of sufficient standard to inform future decision-making. Increasing the understanding of the efficacy of alternatives and mitigation will deliver greater certainty on applicant requirements. (NPS EN-3, paragraphs 2.8.221 to 2.8.223)	Mitigation measures are in place to reduce the significance of impacts where possible, as outlined in section 3.7.1.2. Recommendations for any potential future monitoring, where appropriate, are outlined in section 3.11.
Applicants should undertake a review of up-to-date research and all potential avoidance, reduction and mitigation options presented for all receptors. EMF in the water column during operation, is in the form of electric and magnetic fields, which are reduced by use of armoured cables for inter array and export cables. Burial of the cable increases the physical distance between the maximum EMF intensity and sensitive species. However, what constitutes sufficient depth to reduce impact will depend on the geology of the seabed. It is unknown whether exposure to multiple cables and larger capacity cables may have a cumulative impact on sensitive species. It is therefore important to monitor EMF emissions which may provide the evidence to inform future EIAs. (EN-3, paragraphs 2.8.215, 2.8.245 to 2.8.247)	Cable burial and any cable protection specifications have been examined in the MDS (section 3.7.1), with specific impacts of EMFs assessed in section 3.9.6.
Detailed discussions between the applicant for the offshore wind farm and the relevant consultees should have progressed as far as reasonably possible prior to the submission of an application. As such, appropriate mitigation should be included in any application, and ideally agreed between relevant parties. In some circumstances, the Secretary of State may wish to consider the potential to use requirements involving arbitration as a means of resolving how adverse impacts on other commercial activities will be addressed. (EN-3, paragraphs 2.8.261 to 2.8.262)	Relevant SNCBs and other stakeholders have been consulted prior to application, and the EWG, as outlined in section 3.3. A range of fishers operating within the vicinity of the projects have been consulted on potential impacts and mitigation strategies.

Table 3.2: Summary of NPS EN-1 and NPS EN-3 policy on decision making relevant to fish and shellfish ecology.

Summary of NPS EN-1 and EN-3 provision	How and where considered in the chapter
The aim is to halt overall biodiversity loss, support healthy well-functioning ecosystems and establish coherent ecological networks, with more and better places for nature for the benefit of wildlife and people. This aim needs to be viewed in the context of the challenge presented by climate change. Healthy, naturally functioning ecosystems and coherent ecological networks will be more resilient and adaptable to climate change effects. Failure to address this challenge will result in significant adverse impact on biodiversity and the ecosystem services it provides. (NPS EN-1, paragraph 5.4.2)	The conservation status of habitats and species is considered throughout this chapter, with the baseline section 3.4, and assessment of significant effects (section 3.9) examining this in detail. The potential future impact of climate change is examined in the future baseline scenario (section3.5.8). The Biodiversity Benefit Statement (Document Reference J18) outlines the approach of the Morgan Generation Assets to biodiversity enhancement.
If significant harm to biodiversity resulting from a development cannot be avoided (for example through locating on an alternative site with less harmful impacts), adequately mitigated, or, as a last resort, compensated for, then the Secretary of State will give significant weight to any residual harm. (NPS EN-1, paragraph 5.4.43)	Mitigation is broadly assessed in the measures adopted as part of the Morgan Generation Assets (section 3.7.1.2), and where appropriate in each impact assessment if the impact was deemed to be moderate or above.
In taking decisions, the Secretary of State should ensure that appropriate weight is attached to designated sites of international, national and local importance; protected species; habitats and other species of principal importance for the conservation of biodiversity; and to biodiversity and geological interests within the wider environment. (NPS EN-1, paragraph 5.4.48)	Nearby designated sites, and their associated habitats and SPIs, have been identified in Volume 4: Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement, with the identified IEFs listed in section 3.5.7.
The Secretary of State should consider the effects of a proposal on marine ecology and biodiversity taking into account all relevant information made available to it. (NPS EN-3, paragraph 2.11.53)	The existing ecology is laid out in the baseline environment (section 3.5), with all relevant information used to inform the associated assessment of significant effects on this baseline (section 3.9).

3.2.4 North West Marine Plan 2021

3.2.4.1 The impact assessment on fish and shellfish ecology has also been made with consideration to the specific policies set out in the North West Inshore and North West Offshore Coast Marine Plans (MMO, 2021). Key provisions are set out in Table 3.3 along with details as to how these have been addressed within the assessment.

Table 3.3: North-West Inshore and North-West Offshore Marine Plan policies of relevant to Fish and Shellfish Ecology.

Policy	Key provisions	How and where considered in the chapter
NW-FISH-3	Proposals that enhance essential fish habitat, including spawning, nursery and feeding grounds, and migratory routes, should be supported. Proposals that may have significant adverse impacts on essential fish habitat, including spawning, nursery and feeding grounds, and migratory routes, must demonstrate that they will, in order of preference: a) avoid b) minimise c) mitigate – adverse impacts so they are no longer significant.	The areas of essential fish habitat potentially impacted have been identified in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement; the baseline (section 3.5) and assessed in detail in section 3.9.
NW-MPA-1	Proposals that support the objectives of marine protected areas and the ecological coherence of the marine protected area network will be supported. Proposals that may have adverse impacts on the objectives of marine protected areas must demonstrate that they will, in order of preference: a) avoid b) minimise c) mitigate – adverse impacts, with due regard given to statutory advice on an ecologically coherent network.	MPAs with fish and shellfish features have been identified in section 3.6.3. Assessment of impacts on features of these sites, where relevant, are presented in section 3.9, with site specific assessments presented in section 3.4.3, and section 8.10 of Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement. Mitigation follows the mitigation hierarchy, and is broadly assessed in the measures adopted as part of the Morgan Generation Assets (section 3.7.1.2), and where appropriate in each impact assessment if the impact was deemed to be moderate or above.
NW-BIO-2	Proposals that enhance or facilitate native species or habitat adaptation or connectivity, or native species migration, will be supported. Proposals that may cause significant adverse impacts on native species or habitat adaptation or connectivity, or native species migration, must demonstrate that they will, in order of preference: a) avoid b) minimise c) mitigate - adverse impacts so they are no longer significant d) compensate for significant adverse impacts that cannot be mitigated.	Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement presents a detailed characterisation of the fish and shellfish ecology in the fish and shellfish ecology study area, which is summarised in section 3.5 Assessment of impacts, with consideration of mitigation measures, on these receptors is presented in section 3.9. Mitigation follows the mitigation hierarchy and is broadly assessed in the measures adopted as part of the Morgan Generation Assets (section 3.7.1.2).

Policy	Key provisions	How and where considered in the chapter
NW-INNS-1	Proposals that reduce the risk of introduction and/or spread of non-native invasive species should be supported. Proposals must put in place appropriate measures to avoid or minimise significant adverse impacts that would arise through the introduction and transport of invasive non-native species, particularly when: 1) moving equipment, boats or livestock (for example fish or shellfish) from one water body to another 2) introducing structures suitable for settlement of invasive non-native species, or the spread of invasive non-native species known to exist in the area.	The prevention of the spread of INNS has been highlighted and considered in section 3.7.1.2, dealing with measures adopted as part of the Morgan Generation Assets, with justifications given. These are also considered in the impact assessment section 3.9.
NW-DIST-1	Proposals that may have significant adverse impacts on highly mobile species through disturbance or displacement must demonstrate that they will, in order of preference: a) avoid b) minimise c) mitigate – adverse impacts so they are no longer significant.	This has been examined specifically in the impacts of sound during all phases of the development, as detailed in section 3.9.3, as well as the whole of section 3.9 more broadly. Mitigation follows the mitigation hierarchy and is broadly assessed in the measures adopted as part of the Morgan Generation Assets (section 3.7.1.2), and where appropriate in each impact assessment if the impact was deemed to be moderate or above.
NW-UWN-2	Proposals that result in the generation of impulsive or non-impulsive noise must demonstrate that they will, in order of preference: a) avoid b) minimise c) mitigate – adverse impacts on highly mobile species so they are no longer significant. If it is not possible to mitigate significant adverse impacts, proposals must state the case for proceeding.	The potential impacts of sound resulting from the construction, operation and maintenance, and decommissioning phases have been considered in the sound impact assessment (section 3.9.3). Mitigation follows the mitigation hierarchy and is broadly assessed in the measures adopted as part of the Morgan Generation Assets (section 3.7.1.2), and where appropriate in each impact assessment if the impact was deemed to be moderate or above.
NW-CE-1	Proposals which may have adverse cumulative effects with other existing, authorised, or reasonably foreseeable proposals must demonstrate that they will, in order of preference: a) avoid b) minimise c) mitigate – adverse cumulative and/or in-combination effects so they are no longer significant.	The potential impacts on other existing, authorised, or reasonably foreseeable proposals have been examined in the Cumulative Effects Assessment (CEA) (section 3.11). Mitigation follows the mitigation hierarchy and is broadly assessed in the measures adopted as part of the Morgan Generation Assets (section 3.7.1.2), and where appropriate in each impact assessment if the impact was deemed to be moderate or above.

Policy	Key provisions	How and where considered in the chapter
NW-CBC-1	Proposals must consider cross-border impacts throughout the lifetime of the proposed activity. Proposals that impact upon one or more marine plan areas or terrestrial environments must show evidence of the relevant public authorities (including other countries) being consulted and responses considered.	Any potential cross-border impacts have been assessed in the transboundary effects (section 3.12) and inter-related effects (section 3.13) sections.

3.2.5 The Marine Strategy Framework Directive

3.2.5.1 The Marine Strategy Framework Directive (MSFD) aims to protect more effectively the marine environment across Europe. A summary of the descriptors relating to Good Environmental Status (GES) relevant to fish and shellfish ecology is given in Table 3.4, outlining where these are considered within this chapter.

Table 3.4: High level MSFD descriptors of Good Environmental Status GES relevant to fish and shellfish ecology.

MSFD descriptor relevant to fish and shellfish ecology	How and where considered in the Environmental Statement
Descriptor 1: Biological diversity: Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.	The potential effects on biological diversity have been described and considered within the assessment for the Morgan Generation Assets, both alone (section 3.9) and in Cumulative Effects Assessment (section 3.11). A detailed baseline assessment which describes the distribution and abundance of fish and shellfish species in the study area has been undertaken in Volume 4, Annex 3.1: Fish and shellfish technical report of the Environmental Statement, and a summary presented in section 1.12 of that report. Appropriate and precautionary densities to take forward to the assessment have been agreed in consultation with stakeholders (Table 3.6).
Descriptor 4: Elements of marine food webs: All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long term abundance of the species and the retention of their full reproductive capacity.	The potential effects on the abundance and distribution of fish and shellfish receptors within the regional fish and shellfish ecology study area has been described and considered within the assessment for the Morgan Generation Assets both alone (section 3.9) and in the CEA (section 3.11).
Descriptor 6: Sea floor integrity: Seafloor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.	The potential effects on temporary and long term habitat loss and introduction of new habitat on benthic ecosystems and associated benthic species have been considered within Volume 2, Chapter 2: Benthic subtidal ecology and within this Environmental Statement.
Descriptor 8: Contaminants: Concentrations of contaminants are at levels not giving rise to pollution effects.	The potential effects of contaminants on fish and shellfish receptors are considered within the alone assessment for the Morgan Generation Assets (section 3.9)
Descriptor 11: Energy including underwater noise: Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.	The potential effects of underwater sound from piling of wind turbine foundations, and Offshore Substation Platform (OSP) foundations, from other construction activities (e.g. cable installation) and from vessel sound have been considered alongside a range of thresholds within the assessment for the Morgan Generation Assets both alone (section 3.9) and in the CEA (section 3.11). MSFD

MSFD descriptor relevant to fish and shellfish ecology	How and where considered in the Environmental Statement
	percentage area thresholds are discussed in paragraph 3.9.3.38.

3.2.6 National Planning Policy Framework

3.2.6.1 The Morgan Generation Assets study area includes areas of the English Mainland. The National Planning Policy Framework (NPPF; September 2023) provides overarching advice regarding development. The aim of achieving sustainable development is the main theme of the NPPF. Those sections of particular relevance to fish and shellfish are set out in Table 3.5, below.

Table 3.5: English National Planning Policy Framework.

Summary of NPPF provision	How and where considered in the Environmental Statement
Planning policies and decisions should contribute to and enhance the natural and local environment by minimising impacts on and providing net gains for biodiversity, including by establishing coherent ecological networks that are more resilient to current and future pressures. (Paragraph 180)	The potential impacts on fish and shellfish ecology receptors have been identified in Table 3.18 and assessed for the project alone in section 3.9 and cumulatively with other projects in section 3.10, taking into account the nearby designated sites identified in section 3.5.6.
Plans should: distinguish between the hierarchy of international, national and locally designated sites and take a strategic approach to maintaining and enhancing networks of habitats and green infrastructure. (Paragraph 181)	Designated sites with these designations have been identified in section 3.5.6 and assessed throughout, and the identification of IEFs takes into account local, regional, national or international importance and value in section 3.6.2.
To protect and enhance biodiversity and geodiversity, plans should identify, map and safeguard components of local wildlife-rich habitats and wider ecological networks, including the hierarchy of international, national and locally designated sites of importance for biodiversity and areas identified by national and local partnerships for habitat management, enhancement, restoration or creation, and promote the conservation, restoration and enhancement of priority habitats, ecological networks and the protection and recovery of priority species; and identify and pursue opportunities for securing measurable net gains for biodiversity. (Paragraph 185)	Priority habitats and IEFs have been identified in section 3.5.7, with these assessed for impacts and any potential improvement in biodiversity from the development of the Morgan Generation Assets in section 3.9.

3.3 Consultation

3.3.1.1 A summary of the key matters raised during consultation activities undertaken to date specific to fish and shellfish ecology is presented in Table 3.6 below, together with how these issues have been considered in the production of this Environmental Statement chapter. Further detail is presented within Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement.

3.3.1 Evidence plan

3.3.1.1 The purpose of the Evidence Plan process is to agree the information the Morgan Generation Assets needs to supply to the Secretary of State, as part of a DCO application for Morgan Generation Assets. The Evidence Plan seeks to ensure compliance with the HRA and EIA. The development and monitoring of the Evidence Plan and its subsequent progress is being undertaken by the Evidence Plan Steering Group. The Steering Group comprises the Planning Inspectorate, the Applicant, NRW, Natural England, the Joint Nature Conservation Committee (JNCC) and the MMO as the key regulatory and SNCBs. To inform the EIA and HRA process during the pre-application stage of the Morgan Generation Assets, consultation on the fish and shellfish ecology topic was undertaken via the Benthic Ecology, Fish and Shellfish Ecology and Physical Processes EWG, with meetings held prior to the Preliminary Environmental Information Report (PEIR) in February 2022 and November 2022. In addition to the Evidence Plan process, consultation was also undertaken in June 2021 with Natural England, NRW and the JNCC with regards to the subtidal benthic ecology survey scope, which included consideration for fish and shellfish ecology (particularly herring spawning and sandeel substrate suitability assessment).

3.3.1.2 The first EWG meeting (February 2022) provided an update on current site-specific surveys and approach to baseline characterisation (including desktop data sources), as set out in the Scoping Report for the Morgan Generation Assets. A summary of discussions and key issues raised is set out in Table 3.6 below.

3.3.1.3 The second EWG (November 2022) outlined the most up-to-date assessments of potential impacts likely to be caused by the construction, operation and maintenance, and decommissioning of the Morgan Generation Assets and highlighted to all relevant stakeholders the potential significant impact of underwater sound on a range of fish species including herring with important spawning grounds within the local area.

3.3.1.4 The third EWG meeting (March 2023) was held during the PEIR finalisation process and dealt primarily with the Morgan Generation Assets for fish and shellfish receptors. However, advice was sought on the suitability of the 135 dB re 1µPa^2.s SEL$_{ss}$ (single strike Sound Exposure Level) metric as a behavioural threshold for underwater sound impacts on herring spawning grounds for both the Morgan Generation Assets, and Mona Offshore Wind Project. This sound level is presented on all relevant sound contour figures at the request of the MMO and has been discussed throughout the text alongside other relevant thresholds. Otherwise, this EWG dealt with presenting updated baselines for herring, sandeel, and scallops as was previously requested following EWG02. It was confirmed by RPS that a maximum design scenario of two vessels piling at the same time had been modelled, which includes TTS ranges.

3.3.1.5 The fourth EWG meeting (July 2023) followed the conclusion of the statutory Section 42 consultation period, with responses from a wide range of stakeholders received and given consideration. Responses related to fish and shellfish ecology involved requests for incorporation of more recent datasets into the baseline characterisation; the presentation of herring and sandeel density data as aggregated heat maps, and the expansion of the queen and king scallop fisheries baseline and assessments by using local knowledge and data. This and a range of recommendations on appropriate underwater sound impact thresholds will be incorporated into this Environmental Statement.

3.3.1.6 The fifth EWG occurred in October 2023 was focussed on updated benthic ecology assessments and did not encompass any fish and shellfish ecology elements.

3.3.1.7 The sixth EWG meeting was undertaken in December 2023, and included the updated fish and shellfish ecology assessment for impacts from underwater sound associated with pile driving. The meeting was attended by the MMO, Centre for Environment, Fisheries and Aquaculture Science (Cefas), NRW, Natural England, the JNCC, the Isle of Man Government, The Wildlife Trust and North Wales Wildlife Trust. Discussion was held relating to fish and shellfish ecology surrounded potential effects from underwater sound during the construction phase from piling. A summary of key feedback received and proposed actions were presented regarding impacts of underwater sound on herring and cod, along with updated modelling outputs based upon the refined project design and maximum design scenario. The Outline underwater sound management strategy (Document Reference J13) was also discussed. Development of an Underwater sound management strategy is planned post-consent, to define measures to reduce the magnitude of underwater sound thereby minimising the residual impact significance for cod and herring.

Table 3.6: Summary of key matters raised during consultation activities undertaken for the Morgan Generation Assets relevant to fish and shellfish ecology.

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
February 2022	Cefas – First Benthic Ecology, Fish and Shellfish and Physical Processes EWG meeting	Walney and Ormond have data from surveys. The desktop data sources listed appear appropriate. Landings and VMS data for the region would also be a good source of data for the region.	Full details of the baseline characterisation, including those additional data sources indicated, are presented in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement.
February 2022	Cefas – First Evidence Plan Expert Working Group	Cod should be specifically considered for piling noise impacts.	Cod *Gadus morhua* included as an IEF in the Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement and baseline (section 3.5), and cod sensitivity has been given consideration throughout the impact assessment (section 3.9) including underwater sound.
February 2022	Cefas – First Evidence Plan Expert Working Group	Elasmobranchs (e.g. basking shark) around the Isle of Man (IoM) may be present. This would be something that the IoM would have more information on (rather than Cefas).	Nearby and IoM elasmobranch sightings datasets assessed in the baseline (section 3.4.1.1), with sensitivities examined in relation to possible impacts in the sound impact assessment section (section 3.9.3).
February 2022	Cefas – First Evidence Plan Expert Working Group	In terms of migratory fish, particularly at the north coast of Wales and coast of Cumbria there are some SACs and MCZ for lamprey and salmon.	Lamprey and salmonid species included as IEFs, and Marine Conservation Zones MCZs and Special Areas of Conservation SACs) within the fish and shellfish ecology study area have been examined in detail in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement, and where relevant within this chapter.
February 2022	Cefas – First Evidence Plan Expert Working Group	Cefas would advise that the underwater sound assessment treats fish as a static receptor rather than a fleeing receptor for spawning fish within the spawning season.	This has been examined in the underwater sound impact assessment (section 3.9.3).

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
February 2022	Natural Resources Wales – First Evidence Plan Expert Working Group	The Zone of Influence (ZoI) was shown as one tidal excursion. For a lot of fish species, underwater sound may be a key impact. Noise contours may go outside one tidal excursion therefore impacts may go beyond that definition of the ZoI.	Comment was noted and a wider ZoI has been used for the underwater sound assessment. Potential effects of underwater sound on fish and shellfish receptors is presented in section 3.9.3.
February 2022	Natural Resources Wales – First Evidence Plan Expert Working Group	Consider use of data from Cefas PELTIC surveys in baseline characterisation.	Full details of the baseline characterisation are presented in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement.
February 2022	Natural Resources Wales – First Evidence Plan Expert Working Group	NRW Advisory support the approach of treating fish as static receptors of underwater sound within the spawning season and further advise that where fish are modelled as fleeing receptors, the fleeing speed and timeframes should be evidence-based and species specific.	This has been examined in the underwater sound impact assessment (section 3.9.3).
February 2022	Natural Resources Wales – First Evidence Plan Expert Working Group	The fish and shellfish main receptors in the region will be scallop and *Nephrops*.	King scallop *Pecten maximus*, and queen scallop *Aequipecten opercularis*, and *Nephrops* included as IEFs, with a specific paragraph for scallop in baseline (3.5), with details given in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement.
February 2022	Natural Resources Wales – First Evidence Plan Expert Working Group	Bangor University and the IoM government have undertaken surveys for scallop and may provide a useful data source.	Examined in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement for all relevant IEFs and included in the baseline (section 3.4) of this chapter.
June 2022	The Planning Inspectorate – Scoping Opinion	Seabed preparation - The Environmental Statement should provide further detail on the proposed seabed preparation activities and identify the worse-case scenario assessed in relation to seabed disturbance. The need for dredging, quantities of material and likely disposal location should be identified, and likely significant effects assessed in the Environmental Statement. The Inspectorate understands that the requirements for Unexploded Ordnance (UXO) clearance are not	Seabed preparation activities have been outlined in the MDS (section 3.7.1), with details of potential temporary habitat loss (section 3.9.2) and UXO (section 3.9.3) impacts of fish and shellfish receptors assessed.

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
		known at this stage and that a dedicated UXO survey will be conducted prior to construction. The Environmental Statement must explain the informed assumptions applied to establish the worst-case scenario assessed.	
June 2022	The Planning Inspectorate – Scoping Opinion	The Environmental Statement should provide a full description of the nature of the operation and maintenance activities, including type, frequency, and potential for overlapping activities with those associated with existing and planned wind farms in the area, or set out the assumptions made where exact information is not known.	The potential effects of operations and maintenance activities have been assessed for the project alone in section 3.9 for the Morgan Generation Assets and, where relevant, cumulatively with other projects (section 3.11).
June 2022	The Planning Inspectorate – Scoping Opinion	In light of the number of ongoing developments within the vicinity of the Proposed Development application site, the Environmental Statement should clearly state which developments will be assumed to be part of the baseline and those which are to be considered as other development for the purposes of the cumulative effects assessment. It is noted from the Scoping Report that the proposed onshore operations and maintenance base will be progressed under a separate consent application (it is not stated as intended to be part of the transmission assets application). The Environmental Statement should take this into account in the cumulative effects assessment. Respondents to the Scoping Report have identified proposed developments or provided advice on the types of projects, plans, or activities that should be included; these should be taken into account in the cumulative effects assessment. The Applicant should seek to agree the scope of the projects assessed with these consultation bodies.	Section 3.10.1 sets out the approach and methodology for the cumulative effects assessment, which has been undertaken in line with the Planning Inspectorate Advice Note Seventeen: Cumulative effects assessment (August 2019). All relevant projects are detailed in the cumulative MDS (section 3.10.2).

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
June 2022	The Planning Inspectorate – Scoping Opinion	Effects of the particle motion element of underwater sound on fish and shellfish receptors during operation. The assessment of particle motion on fish and shellfish is restricted to construction and decommissioning, but the reasoning for this is unclear. In the absence of information such as evidence demonstrating clear agreement with relevant consultation bodies, the Inspectorate is not in a position to agree to scope these matters out from the assessment. Accordingly, the Environmental Statement should include an assessment of these matters, or the information referred to demonstrating agreement with the relevant consultation bodies and the absence of a likely significant effect.	The potential impacts of both particle motion and pressure elements of underwater sound have been assessed in section 3.9.3, with specifically provided references incorporated where relevant. Operational wind turbine sound has been scoped out, as justified in section 3.6.2, which includes consideration of additional site-specific modelling of underwater sound from operational wind turbines.
June 2022	The Planning Inspectorate – Scoping Opinion	The Scoping Report proposes to assess the effects of underwater sound on marine life due to jacket or monopile cutting and removal during decommissioning. However, the Scoping Report does not specifically identify this potential impact within the Fish and shellfish ecology section. The outcomes of this assessment should be presented within the relevant Environmental Statement chapters.	Sound modelling in Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement indicates that cutting and removal sound levels during decommissioning will be significantly less than during construction, and therefore only potential construction impacts have been assessed in section 3.9.
June 2022	The Planning Inspectorate – Scoping Opinion	Section 3.2.7 Potential for injury and behavioural disturbance. The Environmental Statement should describe the PTS, TTS, and disturbance ranges used for all species assessed, as well as the potential for the disturbance impact footprints to overlap with the boundary of offshore designated sites.	These thresholds have been explained and used to indicate potential disturbance in the underwater sound impact assessment (section 3.9.3).
June 2022	The Planning Inspectorate – Scoping Opinion	The Environmental Statement should clearly identify all sources of underwater and vibration noise (piling, vessels, drilling), for all phases of the Proposed Development, and assess the impacts from these activities where significant effects are likely to occur. The Environmental Statement should set out the methodology and assumptions for all modelling undertaken.	This has been examined in the underwater sound impact assessment (section 3.9.3) based on Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement.

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
June 2022	The Planning Inspectorate – Scoping Opinion	Concurrent piling – The Scoping Report explains that piles may be being installed at two locations at the same time. The Environmental Statement should demonstrate that the worst-case scenario accounts for concurrent piling activities that are located as far apart from each other as would be possible in the design envelope, and thus result in the greatest potential extent of noise impacts.	The potential impacts of concurrent piling have been assessed in the underwater sound assessment (section 3.9.3).
June 2022	The Planning Inspectorate – Scoping Opinion	The MMO and Natural England both provide advice on fleeing fish swim speed in their consultation responses. The Environmental Statement should base modelling on a stationary rather than a fleeing receptor for fish unless otherwise agreed with the relevant consultation bodies.	Fish have been modelled as receptors both stationary and moving away from the sound source in Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement, with these results assessed in section 3.9.3.
June 2022	The Planning Inspectorate – Scoping Opinion	Accidental pollution during all phases of the development. The Scoping Report proposes to scope out accidental pollution resulting from all phases of the Proposed Development. The Inspectorate agrees that such effects are capable of mitigation through standard management practices and can be scoped out of the assessment. The Environmental Statement should provide details of the proposed mitigation measures to be included in the offshore Environmental Management Plan (EMP) and its constituent Marine Pollution Contingency Plan (MPCP). The Environmental Statement should also explain how such measures will be secured.	The proposed mitigation measures are listed and justified in section 3.7.1.2, including reference to management plans which are proposed to be secured as a condition of the deemed marine licence(s) within the Draft DCO (Document Reference C1).

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
June 2022	The Planning Inspectorate – Scoping Opinion	Underwater wind turbine noise during operation. This is scoped out on the basis that the impact of operational noise from wind turbines on marine species is generally small with behavioural responses occurring within meters of the wind turbines; this information is based on studies conducted in 2011 and 2014. Considering the age of the studies and the increase in size and capacity of wind turbines since 2014, the potential gaps in the baseline data due to a lack of fish/shellfish specific surveys being undertaken and the crossover of multiple nurseries and spawning grounds the Inspectorate is not content to scope this matter out. The Environmental Statement should quantify the extent of impact both alone and cumulatively with other developments on marine receptors and assess significant effects where they are likely to occur.	This impact has been scoped out based on site specific sound information and up to date research and post-construction monitoring of nearby wind farms, including modelling of sound emissions from the proposed wind turbines and potential effects on fish and shellfish receptors (section 3.9.3)
June 2022	The Planning Inspectorate – Scoping Opinion	Underwater vessel noise during operation – Impacts to fish and shellfish from underwater vessel noise during operation is scoped out on the basis that noise generation is likely to be low and effects would only occur if fish were within close proximity to the vessels. The Scoping Report has not provided any evidence to support this assertion. Provided the Environmental Statement demonstrates the number of vessels during operation, and reasoning as to why significant effects on fish and shellfish are unlikely (both alone and cumulatively with other development), the Inspectorate is content to scope this matter out.	This impact has been scoped out based on site specific sound information, including modelling of sound emissions from the vessels during all phases and potential effects on fish and shellfish receptors (section 3.6.2)

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
June 2022	The Planning Inspectorate – Scoping Opinion	Impacts from sediment-bound contaminants. Impacts from contaminant release are proposed to be scoped out on the basis that baseline levels are low and based on the projected results of site-specific surveys and consultation with SNCBs. Since the surveys and consultation have not yet been undertaken, the Inspectorate does not have enough evidence to support scoping out this matter. The Environmental Statement should include an assessment of significant effects where they are likely to occur.	The potential impacts of resuspension of sediment-bound contaminants in all phases on fish and shellfish receptors has been assessed in section 3.9.4.
June 2022	The Planning Inspectorate – Scoping Opinion	Baseline surveys proposed are not specific to fish and shellfish species and utilise surveys characterising baselines for the benthic and marine mammal chapters to establish the baseline for fish and shellfish based on incidental observations of species and particle size analysis (PSA) to inform habitat suitability for sandeel and herring. No further surveys are proposed to characterise the baseline. The baseline is supported by a desk-based analysis of multiple records set out in Scoping Report Table 4.7 and any records are assumed to occur in the Morgan study area for generation assets. However, considering the age of previous surveys within the area and that the proposed surveys are not specific to fish and shellfish, there is a risk that the baseline may not be robust. This also does not take into account the effectiveness of the surveys (for example, trawl surveys are not designed to capture shellfish) or the behaviour of species (for example, herring are also known to change specific locations of spawning each year and do not necessarily return to the same spot). Effort should be made to agree the approach to baseline characterisation with the relevant consultation bodies and the approach should be sufficiently justified in the Environmental Statement.	Up to date datasets and publications have been incorporated into the baseline, providing a robust and up to date desktop review baseline, including data and reports from the IoM government and Bangor university, post-construction surveys of offshore wind farms in the local area, recent International Council for the Exploration of the Sea (ICES) fish ecology data, and recent data on fish spawning and nursery habitats. This was supplemented by opportunistically collected fish and shellfish data from benthic site-specific surveys and commercial fisheries data (as presented in Volume 4, Annex 6.1: Commercial fisheries technical report of the Environmental Statement).

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
June 2022	The Planning Inspectorate – Scoping Opinion	Mitigation measures adopted as part of the project specify that soft- start piling and ramp-up measures will be implemented during construction. The Applicant should consider controlling the timing of activities during construction and operation to avoid key and sensitive periods to species, for example fish spawning and migration periods. The Environmental Statement should describe the proposed mitigation measures and signpost where they are secured in the application based on a worst-case scenario of noise impact, and this should include any overlapping sources of noise e.g. multiple piles and UXO detonation, with relevant mitigation measures. Effort should be made to agree the approach with the relevant consultation bodies.	Mitigation measures have been outlined and justified in section 3.7.1.2, with relevant mitigation measures recommended where impacts are found likely to be significant. Information on spawning periods is provided for consideration in the baseline (section 3.5), with more detailed descriptions provided in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement.
June 2022	The Planning Inspectorate – Scoping Opinion	The Inspectorate considers that direct damage and disturbance to mobile demersal and pelagic fish and shellfish species should be scoped into the assessment for all phases of the development. Accordingly, the Environmental Statement should include an assessment of these matters or evidence demonstrating agreement with the relevant consultation bodies that significant effects are not likely to occur.	Direct damage and disturbance have been considered in the impact assessments (section 3.9).
June 2022	The Planning Inspectorate – Scoping Opinion	Fish feeding grounds and overwintering areas for crustaceans. The Scoping Report does not address potential impacts on fish feeding grounds or over-wintering areas for crustaceans. The Environmental Statement should assess these impacts where significant effects are likely to occur.	Potential effects from the project activities on all fish habitats, including fish feeding, spawning and nursery habitats and crustacean overwintering grounds have been considered throughout the impact assessment in section 3.9.
June 2022	The Planning Inspectorate – Scoping Opinion	Vessel collision with basking shark - The Environmental Statement should assess the potential for vessel collision on basking shark and any significant effects that are likely to occur.	This was scoped in for basking shark and has been assessed in the potential for injury due to vessel collisions (section 3.9.8).

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
June 2022	The Planning Inspectorate – Scoping Opinion	Geophysical surveys cumulative noise - Geophysical surveys are a source of underwater sound and should be assessed in the Environmental Statement where significant effects are likely to occur, both alone and cumulatively with other noise sources.	The potential impacts of these surveys have been assessed in the underwater sound assessment section (section 3.9.3).
July 2022	Marine Management Organisation – Scoping Opinion	The MMO is content that the following impacts can be scoped out of further assessment at EIA stage: • Accidental pollution during construction, operation and maintenance and decommissioning phases • Underwater sound from wind turbine operation during operation and maintenance phase • Underwater sound from vessels during all phases • Impacts from the release of sediment-bound contaminants.	The majority of these impacts have been scoped out and justified in section 3.7, but the impacts from the release of sediment-bound contaminants was scoped in upon further stakeholder consultation and has been assessed in section 3.9.4.
July 2022	Marine Management Organisation – Scoping Opinion	The MMO agree that Boyle and New (2018) herring larval survey data present the most up to date information and provide the greatest confidence for determining areas where active spawning is taking place, it is unclear from reviewing the scoping report how the Applicant intends to make use of the particle size analysis data for the purpose of determining herring spawning habitat suitability, this is of relevance because historic herring spawning grounds can be recolonised over time (Corten, 1999) and although herring will return to a broad area to spawn annually, the exact locations change year on year. I recommend that the Applicant also reviews and adapts their herring and also sandeel spawning habitat suitability assessment using the method described by MarineSpace (2013) which uses a suite of data to determine habitat suitability including PSA data, British Geological Survey (BGS) data, Regional Seabed Monitoring Plan (RSMP) data, herring larval survey data, as well as fishing fleet data and scientific publications, and then assigns a score to the heat map outputs based on confidence of the data.	Long-term Northern Ireland Herring Larvae Survey (NINEL) herring larvae survey data from the north Irish Sea have been presented as bubble plots in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement, with this data supplemented by relevant up to date references and guidance notes recommended by stakeholders and described alongside PSA data in the baseline (section 3.5). Sandeel were also identified as IEFs and assessed in the baseline, similarly considering the guidelines of Latto *et al*. (2013) as recommended. Data limitations were identified and assessed in section 3.5.9.

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
July 2022	Marine Management Organisation – Scoping Opinion	The MMO supports the use of Popper *et al*. (2014) guidelines in assessing underwater sound impacts on fish and shellfish. However, the MMO does have major concerns regarding the proposed use of a generic swim speed for fish of 0.5 m/s for the purpose of underwater sound modelling. The MMO do not support the use of a fleeing animal model for fish the reasons outlined below: • I. Fish will respond to loud noise and vibration, through observed reactions including schooling more closely; moving to the bottom of the water column; swimming away, and; burying in substrate (Popper et al. 2014). However, this is not the same as fleeing, which would require a fish to flee directly away from the source over the distance shown in the modelling. We are not aware of scientific or empirical evidence to support the assumption that fish will flee in this manner • II. The assumption that a fish will flee from the source of noise is overly simplistic as it overlooks factors such as fish size and mobility, biological drivers, and philopatric behaviour which may cause an animal to remain/return to the area of impact. This is of particular relevance to herring, as they are benthic spawners which spawn in a specific location due to its substrate composition. III. Eggs and larvae have little to no mobility, which makes them vulnerable to barotrauma and developmental effects. Accordingly, they should also be assessed and modelled as a stationary receptor, as per the Popper *et al.* (2014) guidelines. The MMO therefore recommend that all underwater modelling is based on a stationary rather than a fleeing receptor for fish as the MMO is not aware of any supporting peer- reviewed literature for fleeing in fish.	The modelling in Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement has considered fish as both moving away from the sound source and static receptors, with these both presented in section 3.9.3. Behaviour in response to potential sound impacts has also been assessed using up to date scientific literature for various fish and shellfish species.

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
July 2022	Marine Management Organisation – Scoping Opinion	For the purpose of modelling behavioural responses in herring at their spawning ground, the MMO recommend the inclusion of a 135 dB threshold based on startle responses observed in sprat by Hawkins *et al.* (2014). Sprat is considered a suitable proxy species for herring for the purpose of modelling likely behavioural responses in gravid herring at the spawning ground. It would be useful if the 135 dB noise contour was presented in mapped form (i.e. as an additional contour to the 186 dB, 203 dB and 207 dB, as per Popper *et al. (*2014)).	This has been included where relevant in the underwater sound assessment (section 3.9.3).
July 2022	Marine Management Organisation – Scoping Opinion	The Applicant has identified a range of suitable data sources of various timescales. The MMO would expect to see data collected within the last five years as the primary data source used as this data will provide the most accurate view of current baseline conditions. This should be updated in the Environmental Statement.	The most up-to-date literature available has been incorporated into Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement, the baseline (section 3.5) and the impact assessments (section 3.9), and generally throughout the entire chapter.
July 2022	Marine Management Organisation – Scoping Opinion	The MMO would expect to see MMO Landings Data for the relative ICES rectangles used to support survey data. Landings data will highlight species of commercial importance and general areas of high abundance. This should be provided in the Environmental Statement.	The Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement and the baseline (section 3.4) identify IEF species based on relevant data sources and stakeholder recommendations.

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
July 2022	Marine Management Organisation – Scoping Opinion	The MMO notes trawl survey data has been used to highlight which shellfish species were present at site. The applicant has stated that Queen Scallops were the most numerous. While this maybe what the data shows at face value, this is not a scientifically robust interpretation of the data. Trawl fishing gear is not designed to capture shellfish species and therefore does not present an accurate representation of the quantities of shellfish present at a site. Information on shellfish caught using anything other than gear designed to catch the species should be used only for presents/absence data and not an assessment of abundance. This data should be modified for presentation in the Environmental Statement to reflect the correct scientific interpretation. It is also considered good practice to caveat any data used that has been collected using non-shellfish specific fishing gears.	The Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement and the baseline (section 3.5 assess queen and king scallop populations based on relevant data sources and stakeholder recommendations).
July 2022	Natural England – Scoping Opinion	Natural England consider that the transmission assets are an integral part of the project and therefore the Environmental Statement should, at the point of submission, be in a position to consider the project as a whole. Therefore the final Environmental Statement, when considering the project as a whole, will include additional impacts and designated sites than those mentioned within the Morgan Offshore Wind Farm Generation Assets Scoping Report.	The potential impacts of the construction of the Morgan and Morecambe Offshore Wind Farms: Transmission Assets have been assessed for all impacts where relevant in the cumulative assessment (section 3.11). These have been considered separately from the Morgan Generation Assets and Morecambe Offshore Windfarm: Generation Assets as part of the Pathways to 2030 Offshore Transmission Network Review, to improve transmission assets coordination between developers. As and when more information becomes available on this project, this will be incorporated into the cumulative effects assessment, in the final DCO application.
July 2022	Natural England – Scoping Opinion	The Environmental Statement should be fully informed by the recommendations in the Best Practice Advice and we will increasingly be appraising Environmental Statements with respect to the extent to which the guidance has been followed.	All relevant guidance has been taken into account, as highlighted in the impact assessment methodology (section 3.6).

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
July 2022	Natural England – Scoping Opinion	We advise that secondary scour protection impacts on seabed habitats are scoped in until further detailed methods and impacts can be assessed, and justification provided to scope out of the Environmental Statement.	Potential impacts from this and other infrastructure have been examined in the colonisation of hard structures (section 3.9.7).
July 2022	Natural England – Scoping Opinion	We recommend that underwater sound modelling of the operational wind farm noise is undertaken using the best available evidence and reasonable assumptions based on wind turbines that are of representative size for the Morgan Offshore Wind Farm. The size of the wind turbines proposed for this project are significantly larger than those that were the subject of the various referenced studies. Discussion and agreement should be sought through the Evidence Plan process with the relevant EWG.	This impact has been scoped out and justified based on site specific sound modelling information (section 3.4.2)
July 2022	Natural England – Scoping Opinion	In regard to modelling fish for the purpose of exposure, we advise that all fish hearing groups (Group 1 to 4 fish) should be assessed as static receptors for the purpose of exposure modelling.	Fish have been modelled as receptors both stationary and moving away from the sound source in Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement, with these results assessed in section 3.9.3.
July 2022	Natural England – Scoping Opinion	We do not agree, at this stage, that sufficient evidence has been provided to scope out impacts to benthic invertebrates due to electromagnetic fields or the release of sediment-bound contaminants.	The potential impacts of EMFs surrounding cables have been assessed in section 3.9.6.

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
July 2022	Natural England – Scoping Opinion	It will be important for any assessment to consider the potential cumulative effects of this proposal, including all supporting infrastructure, with other similar proposals and a thorough assessment of the 'in combination' effects of the proposed development with any existing developments and current applications – specifically including existing, approved, and ongoing projects, and applications and foreseeable projects. A full consideration of the implications of the whole scheme should be included in the Environmental Statement. All supporting infrastructure and activities should be included within the assessment.	This has been examined and assessed using a tiered system to describe levels of potential impact in the cumulative effects assessment (section 3.10).
July 2022	Natural England – Scoping Opinion	Natural England advises that the potential impact of the proposal upon features of nature conservation interest and opportunities for habitat creation/enhancement should be included within this assessment in accordance with appropriate guidance on such matters (e.g. Ecological Impact Assessment (EcIA) from the Chartered Institute of Ecology and Environmental Management (CIEEM), and the National Planning Policy Framework).	All relevant guidance has been taken into account, as highlighted in the impact assessment methodology (section 3.6).
July 2022	Natural England – Scoping Opinion	The Environmental Statement should thoroughly assess the potential for the proposal to affect designated sites. Internationally designated sites (e.g. designated SACs and SPAs) fall within the scope of the Conservation of Habitats and Species Regulations 2017 (as amended), and under regulation 8 of the National Planning Policy Framework. The Environmental Statement should identify such mitigation measures as may be required in order to avoid, minimise or reduce any adverse significant effects on these sites.	Nearby potentially impacted designated sites have been identified in Volume 4, Annex 3.1: Fish and shellfish technical report of the Environmental Statement, and in section 3.5.6 Mitigation measures to reduce or prevent impacts have been outlined in section 3.7.1.2.

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
July 2022	Natural England – Scoping Opinion	The Environmental Statement should assess the impact of all phases of the proposal on fish and shellfish species protected by the Wildlife and Countryside Act 1981 (as amended); the Conservation of Habitats and Species Regulations 2017 (as amended); the England Biodiversity List; published under the requirements of S41 of the Natural Environment and Rural Communities (NERC) Act 2006; the Habitats and Species of Principal Importance Biodiversity Action Plan, and Part IV and Annex A of Government Circular 06/2005 Biodiversity and Geological Conservation: Statutory Obligations.	Protected and ecologically important species have been identified through extensive desktop review of relevant literature and guidance, and stakeholder consultation, and are listed as IEFs in section 3.5.7 and assessed where relevant in section 3.9.
July 2022	Natural England – Scoping Opinion	The area likely to be affected by the proposal should be thoroughly surveyed at optimal times and based on best practice guidance by competent ecologists at appropriate times of year for relevant species and the survey results, impact assessments and appropriate accompanying mitigation strategies included as part of the Environmental Statement.	Baseline characterisation surveys have been performed in line with Natural England best practice advice with some data collected on fish and shellfish receptors incorporated into the baseline (section 3.5).
July 2022	Natural England – Scoping Opinion	Records of protected species should be sought from appropriate local biological record centres, nature conservation organisations, National Biodiversity Network (NBN) Atlas, groups and individuals; and consideration should be given to the wider context of the site, for example in terms of habitat linkages and protected species populations in the wider area, to assist in the impact assessment.	Extensive desktop review and stakeholder consultation has been undertaken to allow incorporation of the most up to date scientific literature and datasets at all stages throughout the chapter.
November 2022	Cefas – Second Benthic Ecology, Fish and Shellfish and Physical Processes EWG meeting	Will simultaneous and concurrent piling be modelled if that is a potential construction plan.	Output injury ranges from modelled simultaneous and concurrent piling are presented in section 3.9.3.23 to 3.9.3.34. The full results of the underwater sound modelling are presented in Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement.

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
November 2022	Cefas – Second Benthic Ecology, Fish and Shellfish and Physical Processes EWG meeting	We generally expect to see spatial and temporal maximum design scenarios presented, however we don't provide specific advice on how to do this.	Temporal and spatial maximum design scenario parameters for underwater sound in relation to fish and shellfish receptors are presented in Table 3.18.
November 2022	Cefas – Second Benthic Ecology, Fish and Shellfish and Physical Processes EWG meeting	In reference to the 'high recoverability' of herring, we assume that means recoverability of herring populations. If this is the case, the Applicant must provide appropriate peer-reviewed literature to support this statement. Herring are considered to be highly sensitive to noise and vibration in terms of physiological and behavioural effects. It should be noted that physiological effects caused by changes in pressure from explosions and impulsive sounds such as piling include death and potential mortal injuries such as barotrauma, blood gases coming out of solution, rapid expansion and contraction of swim bladders, damage to tissue and organs, and potential rupture of the swim bladder (Popper *et al.,* 2014). Barotrauma can result in lethal injury through either immediate, or delayed mortality (McKinstry *et al.,* 2007). Whilst some physical injuries such as fin hematomas, capillary dilation, and loss of sensory hair cells are potentially recoverable, they can still lead to death either through a decreased level of fitness or through predation and disease (Halvorsen, 2011; 2012). For these reasons, herring, as a receptor, are considered to have low recoverability to underwater sound from pile driving, explosions and other impulsive sounds.	High recoverability is referred to in terms of disturbance to herring populations and their return to activities following disturbance from sound and other impacts, and it is appreciated that where injury occurs to individuals, recovery may not be possible, including through increased susceptibility to predation through decreased fitness. Herring are fully assessed in relation to the potential effects of underwater sound in relation to pile driving and explosions in section 3.9.3 where they are considered of high sensitivity to underwater sound impacts, and a review of the existing literature surrounding herring is presented in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement.
November 2022	Cefas – Second Benthic Ecology, Fish and Shellfish and Physical Processes EWG meeting	The recommendation was for modelling to be carried out based on a 135 dB threshold (rather than 145 dB) as this is recommended by Cefas fisheries advisors as a conservative indicator for determining the impact range in which clupeid species (including herring) are likely to exhibit behavioural responses. The 135 dB threshold is based on research by Hawkins *et al.* (2014), who exposed wild schooling sprat to short sequences of repeated impulsive playback sounds at	Modelling has been carried out based upon both 135 dB SEL_{ss} re 1 µPa^2.s and 160 dB re 1µPa SPL_{pk} (peak sound pressure level) thresholds. The outputs of which are presented in section 3.9.3. The full results of the underwater sound modelling are presented in Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement.

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
		different sound pressure levels, to resemble that of a percussive pile driver. Observed behavioural responses included the break-up of fish schools. The sound pressure levels to which the fish schools responded on 50% of the presentations were 163.2 and 163 dB re 1 µPa (peak-to-peak), and as a result the concluded single strike sound exposure level was 135 dB re 1µPa^2.. Cefas Fisheries and Noise and Bioacoustics advisors recognise that this is a conservative threshold as the Hawkins study was carried out in an enclosed, quiet coastal sea loch, where fish were not accustomed to heavy disturbance from shipping and other sounds (Hawkins *et al*., 2014). However, sprat is a clupeid species, closely related and anatomically similar to herring, and similarly sensitive to underwater sound (sprats also possess a swim bladder involved in hearing). Given an absence of other peer-reviewed empirical evidence of behavioural responses in clupeid fishes to support an alternative threshold for impulsive noise, Hawkins *et al.* (2014) is currently considered the best available scientific evidence by Cefas Fisheries and Underwater sound specialists, and as such a 135 dB threshold is deemed appropriate.	
November 2022	Isle of Man Government – Second Benthic Ecology, Fish and Shellfish and Physical Processes EWG meeting	Have the angel shark areas off north Wales been considered?	An extensive desktop review has been undertaken to incorporate angel shark records from the fish and shellfish ecology study area to determine whether this species needed to be taken forward as an IEF. This information is presented in provided in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement.
November 2022	Natural England – Second Benthic Ecology, Fish and Shellfish and Physical Processes EWG meeting	Natural England broadly agree with the scoping of impacts for the EIA and HRA for Fish and Shellfish Ecology, as presented at the expert working group meeting on 29 November 2022.	This has been noted and used to define the scope of the assessment (section 3.4.2) and inform the impact assessment methodology (section 3.6).

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
November 2022	Natural England – Second Benthic Ecology, Fish and Shellfish and Physical Processes EWG meeting	Natural England agree to the approach to noise modelling and approach to assessment as presented at the expert working group meeting on 29 November 2022.	This has been noted and used to inform the sound modelling approach and assessment in section 3.9.3.
November 2022	Natural Resources Wales – Second Benthic Ecology, Fish and Shellfish and Physical Processes EWG meeting	Are spawning areas for cod considered.	Spawning areas for cod are presented and discussed in the underwater sound assessment in section 3.9.3.
November 2022	Natural Resources Wales – Second Benthic Ecology, Fish and Shellfish and Physical Processes EWG meeting	The slides presented that sensitivity of herring to underwater sound is medium. We would assume that herring have the highest sensitivity to underwater sound.	An extensive desktop study has been undertaken to review and ensure inclusion of the most up-to-date and appropriate scientific literature regarding the sensitivity of herring to underwater sound. The desktop study is provided in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement. A detailed assessment of the potential effects to herring, and other fish and shellfish from underwater sound is presented in section 3.9.3
March 2023	Cefas – Third Benthic Ecology, Fish and Shellfish and Physical Processes EWG meeting	Cefas recommend that the 135 dB SEL_{ss} (SEL single strike) threshold be used in assessing the sensitivity of herring to underwater noise, based on currently available evidence.	This recommendation has been carried forward and caveated based on the limitations of the original study this threshold was derived from and is presented in sound contours in section 3.9.3 and assessed throughout the text alongside other standard behavioural thresholds.
June 2023	Isle of Man Government, National Federation of Fishermen's Organisation (NFFO) and Welsh Fishermen's Association (WFA) – Section 42 consultation	Questions were raised about the suitability of using the potentially outdated Coull *et al*. (1998) and Ellis *et al*. (2012) sources to characterise fish and shellfish spawning grounds within the fish and shellfish ecology study area, with the recommendation to use more recent references.	These sources have been used extensively throughout and have been checked against recent literature and long-term studies in the baseline environment (section 3.5) to confirm they remain up to date and representative of current fish and shellfish population distributions.

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
June 2023	MMO – Section 42 consultation	The MMO has requested that the herring and sandeel suitability assessments include heat maps following the MarineSpace methodology, with 'prime' and 'sub-prime' suitability also being changed to follow more relevant guidance.	The existing suitability has been changed to 'preferred', 'marginal' and 'unsuitable' to align with the categories derived from the European Marine Observation and Data Network (EMODnet) seabed substrates data, but heat mapping for each year was deemed to be unsuitable due to low data values and density. Instead, a ten-year aggregated dataset was mapped, with this presented in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement.
July 2023	Cefas, NRW (EWG consultation)	Acknowledgment of the limitations of the 135 dB SEL_{ss} (SEL single strike), but request to keep in as a conservative threshold to ensure all potential impacts from noise are fully investigated.	This threshold has been included in the assessment in section 3.9.3 alongside all other thresholds, with explanations of its limitations and benefits.
December 2023	NRW, JNCC – Expert Working Group 6	Asked for clarification as to why SEL_{ss} is modelled instead of SEL_{cum}, and why the 5 dB contours have been presented.	Both SEL_{ss} and SEL_{cum} are modelled, with full details provided within Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement. Modelling data was also presented as contour plots for SEL_{ss}, SPL_{pk} and SEL_{cum} (mortality, recoverable injury and TTS only) and discussed in the EWG meeting directly and is shown in the underwater sound impact assessment in section 3.9.3. The 5 dB contours were presented to assess the potential impacts at the 135 dB re 1µPa^2.s SEL_{ss} contour.
December 2023	Isle of Man Government – Expert Working Group 6	Asked for clarification as to whether we had received additional advice on the larval phases of herring post spawning and how these will be impacted by sound.	The underwater sound impact assessment in section 3.9.3 includes fish eggs and larvae (static) mortality ranges, which are outlined both in a table and fully in text in the chapter. They don't specifically relate to herring eggs and larvae, but are considered applicable. The herring larval data used to inform important spawning grounds for assessment of impacts from underwater sound in section 3.9.3 was provided by the Agri-food and Bioscience Institute (ICES, 2022a).

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
	Cefas and NRW – Expert Working Group 6	Cefas asked for confirmation as to whether a potential scenario for concurrent piling at Mona and Morgan Generation Assets at the same time has been modelled to inform cumulative impact assessment. NRW asked if we have considered increased areas of ensonification and the presence of multiple areas of ensonification in the cumulative impact assessment.	It is possible that Mona and Morgan Generation Assets may undertake piling within the same time period, however based upon the very low likelihood that the two projects will be simultaneously piling, with both projects incurring hammer blows at the same moment, no modelling has been undertaken to investigate concurrent piling across the two projects. Full details of the underwater sound modelling undertaken is available within Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement, with relevant information presented within the underwater sound impact assessment in section 3.9.3 for Morgan Generation Assets. The potential for increased areas of ensonification and potential presence of multiple areas of ensonification has been qualitatively considered within the cumulative effects assessment for underwater sound presented in section 3.11.3. An Outline underwater sound management strategy (Document Reference J13) is provided with the Application. Development of the Underwater sound management strategy is planned post-consent, to further define measures to reduce the magnitude of underwater sound thereby minimising the residual impact significance for cod and herring.

Date	Consultee and type of response	Comment	Response to comment raised and/or where considered in this chapter
December 2023	Cefas – Expert Working Group 6	In response to the post-meeting MMO request to stakeholders to confirm whether the Underwater sound management strategy is an acceptable approach to manage underwater sound impacts, Cefas raised the following: • The Applicant's suggestion of an Underwater sound management strategy is welcome given the potential impacts of underwater noise to herring and cod. This is also appropriate given the need to manage cumulative impacts of underwater sound produced by multiple projects in the region. Any measures that may reduce these impacts, such as reduced number of foundations and/or hammer energies would be welcome. However, it should be noted that the final underwater sound scenarios/modelling needs to be presented in the Environmental Statement so that full extent of noise disturbance at the herring and cod spawning grounds can be understood and appropriate mitigation measures can be applied (where applicable). Mitigation for cod and herring from underwater noise should be agreed at the time of consent, rather than post-consent and should be agreed before any Underwater sound management strategy is accepted.	Final underwater sound modelling is fully detailed in Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement, with relevant information presented within the underwater sound impact assessment in section 3.9.3 for the Morgan Generation Assets. No further underwater sound modelling is proposed. The extent of impact on herring and cod spawning grounds is fully assessed within the underwater sound impact assessment in section 3.9.3 for the Morgan Generation Assets and in section 3.11.3 cumulatively with other projects and plans. An Outline underwater sound management strategy (Document Reference J13) is provided within the Application with the full strategy to be developed post-consent with input from relevant stakeholders to finalise the appropriate mitigation measures to manage the potential effects from underwater sound during construction on herring and cod.

3.4 Baseline methodology

3.4.1 Relevant guidance

3.4.1.1 A number of guidance documents have been considered when compiling the baseline.

3.4.1.2 The Oslo-Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) guidance on Environmental Considerations for Offshore Wind Farm Development has a primary aim to provide scientific guidance to those involved with the gathering, interpretation and presentation of data within an EIA as part of the consents application process in England and Wales (OSPAR, 2008). In this chapter this guidance has informed the baseline characterisation focus for fish and shellfish ecology, such as spawning and nursery grounds, and incorporation of International Union for Conservation of Nature (IUCN) Red List information for key species when defining IEFs.

3.4.1.3 The identification of sensitive and protected habitats is a key feature of this chapter; these include mapped spawning and nursery grounds, particularly for those species which are highly substrate specific. Key information sources used to guide the identification of mapped spawning and nursery grounds which overlap the Morgan Generation Assets include Coull *et al.* (1998) and Ellis *et al.* (2012).

3.4.2 Scope of the assessment

3.4.2.1 The scope of this Environmental Statement has been developed in consultation with relevant statutory and non-statutory consultees as detailed in Table 3.6. This consultation process involved the scoping opinion, a number of regular EWGs to develop a Steering Group and the statutory Section 42 consultation period. The consultation added detail to the range of potential impacts which could affect fish and shellfish ecology receptors, taking into account local and national views about adequate coverage of important species within the fish and shellfish ecology study area.

3.4.2.2 Taking into account the scoping and consultation process, Table 3.7 summarises the issues considered as part of this assessment.

Table 3.7: Issues considered within this assessment.

Activity	Potential effects scoped into the assessment
Construction phase	
Jack-up events, cable installation, sandwave clearance deposition, anchor placements, cable removal	Temporary habitat loss/disturbance Underwater sound during the construction phase impacting fish and shellfish receptors Increased suspended sediment concentrations (SSCs) and associated sediment deposition Long term habitat loss Introduction of artificial structures and colonisation of hard structures Disturbance/remobilisation of sediment-bound contaminants Injury due to increased risk of collision with vessels (basking shark only)
Piling for offshore substation platforms (OSPs) and wind turbine foundations, geophysical site investigation surveys, UXO clearance	
Vessel traffic and other sound-producing activities	
Sandwave clearance, foundation installation and cable installation	
Foundations and scour protection, cable protection and cable crossing protection	
Vessels movements	

Activity	Potential effects scoped into the assessment
Operation and maintenance	
Jack-ups at OSPs and wind turbine and associated foundations and cables, seabed preparation	Temporary habitat loss/disturbance Increased SSCs and associated sediment deposition Long term habitat loss EMFs from subsea electrical cabling Introduction of artificial structures and colonisation of hard structures Disturbance/remobilisation of sediment-bound contaminants Injury due to increased risk of collision with vessels (basking shark only)
Vessel traffic and other sound-producing activities	
Repair of cables	
Foundations and scour protection, cable protection and cable crossing protection	
Presence of cables	
Vessels movements	
Decommissioning	
Jack-up events, cable removal, anchor placements	Temporary habitat loss/disturbance Increased SSCs and associated sediment deposition Long term habitat loss Introduction of artificial structures and colonisation of hard structures Disturbance/remobilisation of sediment-bound contaminants Injury due to increased risk of collision with vessels (basking shark only)
Vessel traffic and other sound-producing activities	
Suction caissons removal, cables removal	
Scour and cable protection left *in situ*	
Vessels movements	

3.4.2.3 Effects which are not considered likely to be significant have been scoped out of the assessment. A summary of the effects scoped out, together with the justification for scoping them out and whether the approach has been agreed with key stakeholders through either scoping or consultation is presented in Table 3.8.

Table 3.8: Impacts scoped out of the assessment for fish and shellfish ecology.

Potential impact	Justification
Accidental pollution during construction, operations and maintenance and decommissioning phases	There is a risk of pollution being accidentally released during the construction, operations and maintenance and decommissioning phases from sources including vessels/vehicles and equipment/machinery. However, the risk of such events is managed by the implementation of measures set out in standard post-consent plans, secured through conditions within the deemed marine licence(s) (e.g. Offshore EMP, including a MPCP). These plans include planning for accidental spills, address all potential contaminant releases and include key emergency contact details. It will also set out industry good practice and OSPAR, International Maritime Organisation (IMO) and International Convention for the Prevention of Pollution from Ships (MARPOL) guidelines for preventing pollution at sea. Therefore, the likelihood of an accidental spill occurring is very low and in the unlikely event that such events did occur, the magnitude of these will be minimised through measures such as MPCP. This approach was agreed during the scoping phase. As such, this impact will be scoped out of further consideration within the fish and shellfish ecology Environmental Statement chapter.

Potential impact	Justification
Underwater sound from wind turbine operation during operations and maintenance phase	Sound generated by operational wind turbines is of a very low frequency and low sound pressure level (Andersson, 2011). Studies have found that sound levels are only high enough to possibly cause a behavioural reaction within metres from a wind turbine (Wahlberg and Westerberg, 2005; Sigray and Andersson, 2011; Vandendriessche *et al.*, 2015) and therefore such levels are not considered to have potentially significant effects on fish and shellfish receptors. Further studies have shown increases in fish abundance surrounding operational wind turbines, supporting the suggestion that behavioural effects are apparent at very close range (Van Hal *et al.*, 2017). The MMO (MMO, 2014) review of post-consent monitoring at offshore wind farms found that available data on the operational wind turbine sound, from the UK and abroad, in general showed that sound levels from operational wind turbines are low and the spatial extent of the potential impact of the operational sound is low. This is supported by project specific modelling which indicated that effects on fish (e.g. injury or behavioural effects) are unlikely to occur for the modelled operational wind turbines. See Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement for further detail. This approach was agreed in the scoping phase and reaffirmed during consultation during EWGs as part of the Evidence Plan Process. As such, this impact will be scoped out of further consideration within the fish and shellfish ecology Environmental Statement chapter.
Underwater sound from vessels during all phases	Operational underwater sound generated from vessels, including dredging sound, is likely to be low and potential effects would only occur if fish species remained within immediate vicinity of the vessel (i.e. within metres). Specifically, project specific modelling indicated that for injuries on fish to occur individuals would need to be in close proximity (i.e. tens of metres) to vessels for extended periods (i.e. recoverable injury for 48 hours of continuous exposure and TTS would require 12 hours of continuous exposure). At larger ranges, the level of disturbance is less well identified and understood but would be expected to be smaller than impacts at close distances. See Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement for further detail. This approach was agreed during the scoping phase. As such, this impact will be scoped out of further consideration within the fish and shellfish ecology Environmental Statement chapter for construction, operations and maintenance, and decommissioning phases.

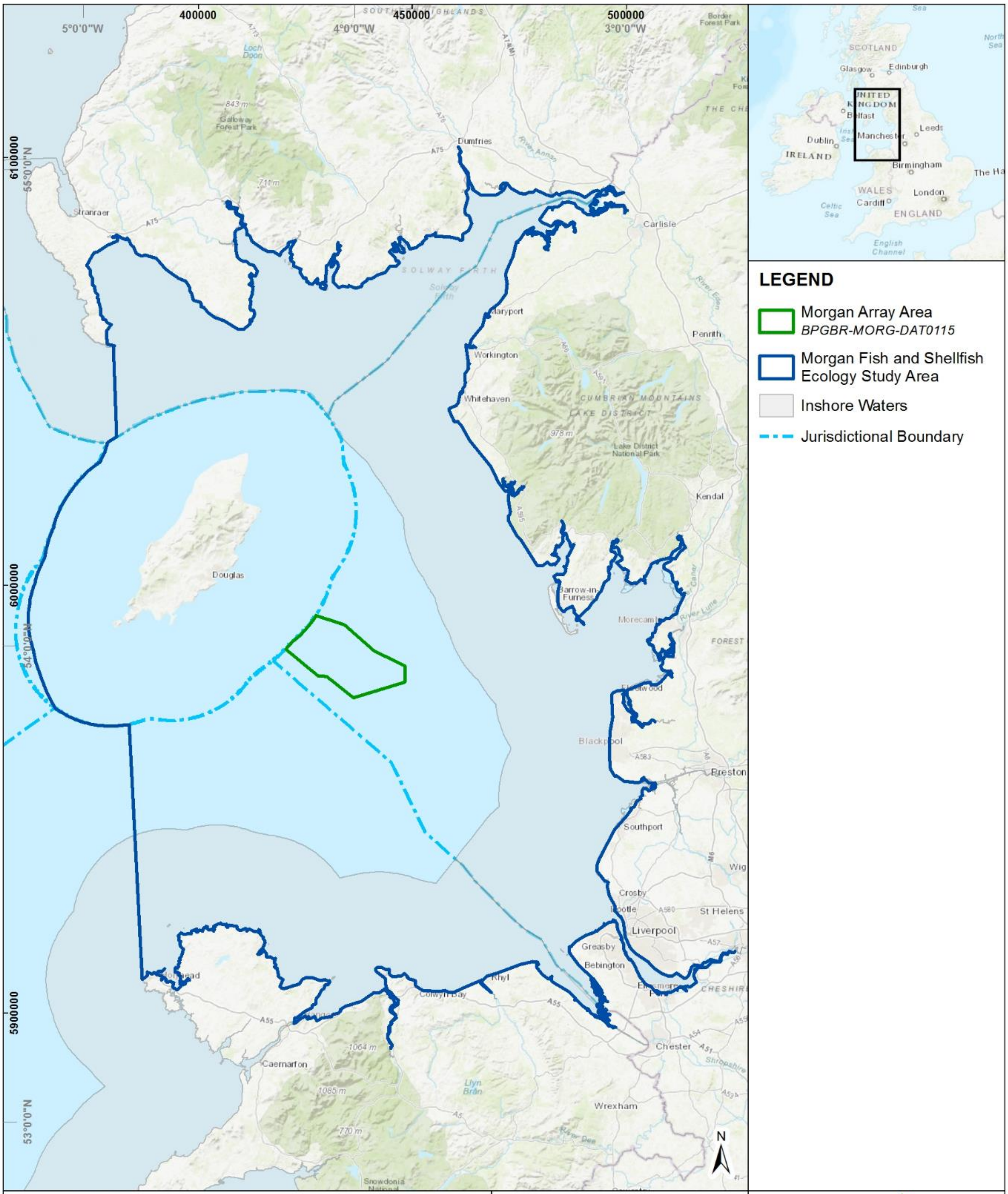
3.4.3 Methodology to inform baseline

3.4.4 Fish and shellfish ecology study area

3.4.4.1 Fish and shellfish are spatially and temporally variable, therefore for the purposes of the fish and shellfish ecology characterisation, a broad study area has been defined. This is shown in Figure 3.1, as agreed with stakeholders through consultation (see section 3.3).

3.4.4.2 The fish and shellfish ecology study area covers the east Irish Sea, extending from MHWS west from the Mull of Galloway in Scotland to the western tip of Anglesey, following the territorial waters 12 nm limit of the Isle of Man (IoM), based on consultation with the EWG and all relevant stakeholders. This study area has been selected to account for the spatial and temporal variability of all relevant fish and shellfish populations, including fish migration. This area was considered appropriate as it will ensure the characterisation of all fish and shellfish receptors within the east Irish Sea and is therefore large enough to consider all direct (e.g. habitat loss/disturbance within project boundaries) and indirect impacts (e.g. underwater sound over a wider area) associated with the Morgan Generation Assets on the identified receptors.

3.4.4.3 The fish and shellfish ecology study area includes intertidal habitats up to MHWS, although these habitats at the landfall are likely to be less important for fish and shellfish species. More specific effects on intertidal ecology receptors are assessed in detail in Volume 2, Chapter 2: Benthic subtidal ecology of the Environmental Statement. Although the intertidal zone is included as part of the fish and shellfish ecology study area, the Morgan Generation Assets do not directly overlap with this area.



Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Data Sources: Client

Project Name:
MORGAN OFFSHORE WIND PROJECT

0 2.5 5 10 15 20 nm
0 5 10 20 30 40 km

Drawing Number:
RPSE-MG-ES-FAS-E001-00

Drawing Title:
MORGAN FISH AND SHELLFISH ECOLOGY STUDY AREA

Geodetic Information:
Datum: ETRS 1989
Projection: ETRS 1989 UTM Zone 30N
Scale@160mmx220mm: 1:1,500,000

VER	DATE	DETAILS	BY	CHECK
00	14/11/23	First Issue	MJ	CB

Figure 3.1: Fish and shellfish ecology study area.

3.4.5 Desktop study

3.4.5.1 Information on fish and shellfish ecology within the fish and shellfish ecology study area was collected through a detailed desktop review of existing studies and datasets. These are summarised at Table 3.9 below, with full details presented in Volume 6, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement.

Table 3.9: Summary of key desktop reports.

Title	Source	Year	Author
Manx Basking Shark Watch, 1987 to 2022	Manx Whale and Dolphin Watch	1987 to 2022	Manx Whale and Dolphin Watch
Fisheries Sensitivity Maps in British Waters	United Kingdom Offshore Operators Association Ltd.	1998	Coull *et al*.
Rhyl Flats Offshore Wind Farm, Fish and Fisheries Baseline Study, 2002 to 2006	Marine Data Exchange	2002, 2005, 2006a	Coastal Fisheries Conservation and Management, Centre for Marine and Coastal Studies Ltd (COWL, 2002; CMACS, 2005, 2006a)
Effects of climate variability on basking shark abundance off southwest Britain	Fisheries Oceanography	2005	Cotton *et al*.
Walney and West of Duddon Sands Offshore Wind Farms, Baseline Benthic Survey – Epifaunal Beam Trawl Results	Marine Data Exchange	2005	Titan Environmental Surveys Ltd.
Herring larvae surveys of the north Irish Sea 1993 to 2021	The Agri-Food and Biosciences Institute (AFBI)	2006 to 2022	AFBI (ICES, 2006; Dickey-Collas *et al*., 2010; ICES, 2022b)
Burbo Bank Offshore Wind Farm, Pre-construction Commercial Fish Survey (2 m Beam Trawl)	Marine Data Exchange	2006b, c	CMACS
Burbo Bank Offshore Wind Farm, Electromagnetic Fields and Marine Ecology Study	Marine Data Exchange	2007	CMACS
Walney Offshore Wind Farm Pre-Construction Fish Survey	Marine Data Exchange	2009a	Brown and May Marine Ltd.
Ormonde Offshore Wind Farm Pre-Construction Juvenile and Adult Fish Survey	Marine Data Exchange	2009b, c	Brown and May Marine Ltd.
Burbo Bank Offshore Wind Farm, Post-construction (Year 3) Commercial Fish Survey	Marine Data Exchange	2010	CMACS
Ormonde Offshore Wind Farm, Construction (Year 1) Environmental Monitoring	Marine Data Exchange	2010	RPS Energy

Title	Source	Year	Author
Rhiannon Wind Farm Round 3 Autumn Fish Trawl Survey	Marine Data Exchange	2010	CMACS
Burbo Bank Extension Offshore wind farm: Adult and Juvenile Fish Characterisation Survey	Marine Data Exchange	2011a, b	Brown and May Marine Ltd.
Gwynt y Mor Offshore Wind Farm, Pre-construction Baseline Beam Trawl Data	Marine Data Exchange	2011	CMACS
Ormonde Offshore Wind Farm, Adult and Juvenile Fish and Epi-benthic Post-construction Survey, 2012 to 2014	Marine Data Exchange	2012a, 2014	Brown and May Marine Ltd.
West of Duddon Sands Offshore Wind Farm, Adult and Juvenile Fish and Epibenthic Pre-Construction Surveys	Marine Data Exchange	2012b	Brown and May Marine Ltd.
Mapping the Spawning and Nursery Grounds of Selected Fish for Spatial Planning	Cefas	2012	Ellis *et al*.
Walney Offshore Wind Farm, Year 2 Post-construction Monitoring Fish and Epibenthic Survey	Marine Data Exchange	2013a	Brown and May Marine Ltd.
Welsh waters scallop survey – Cardigan Bay to Liverpool Bay July-August 2013	Bangor University	2013	Lambert *et al.*
Celtic Array – Rhiannon wind farm preliminary environmental information chapter 10: fish and shellfish ecology	Marine Data Exchange	2013	Celtic Array Ltd.
Updating Fisheries Sensitivity Maps in British Waters	Scottish Marine and Freshwater Science Report	2014	Aires *et al.*
ICES Celtic Seas ecoregion fisheries overview	Summary of commercial fisheries in the Celtic Sea	2018a, b	ICES
Manx Marine Environmental Assessment	Isle of Man Government – Fisheries Division	2018	Howe *et al*.
Isle of Man scallop surveys, 1992 to 2022	Bangor University – Sustainable Fisheries Isle of Man	2022	Bloor *et al.*
Welsh Waters Scallop Surveys and Stock Assessment	Bangor University	2019	Delargy *et al*.
ICES scallop assessment working group	ICES	2019b	ICES
Bass and Ray Ecology in Liverpool Bay	Bangor University Sustainable Fisheries and Aquaculture Group.	2020	Moore *et al.*
Annual Fisheries Science Report	Bangor University Sustainable Fisheries and Aquaculture Group	2017	Bloor *et al.*

Title	Source	Year	Author
Spawning and nursery grounds of forage fish in Welsh and surrounding waters	Cefas	2021	Campanella and van der Kooij
UK Sea Fisheries Annual Statistics Report	MMO	2022	MMO
SeaLifeBase	https://www.sealifebase.ca/	2022	Palomares and Pauly
Northern Irish Ground Fish Trawl Survey (NIGFS), data reviewed for years 2012 to 2022	International Council for the Exploration of the Sea (ICES)	2022a	ICES
International council for the exploration of the sea (ICES) working group on surveys on ichthyoplankton in the North Sea and adjacent seas	ICES	2022b	ICES
Awel y Môr Offshore Wind Farm. Category 6: Environmental Statement	Awel y Môr Offshore Wind Farm Ltd.	2022	RWE Renewables UK
National Biodiversity Network (NBN) Atlas	NBN Atlas	2023	NBN Atlas
Marine Recorder Public UK Snapshot	JNCC	2023	JNCC
JNCC Marine Protected Area (MPA) Mapper	JNCC	2023	JNCC
Cefas OneBenthic Application	Cefas	2017	Cooper and Martinez
Morecambe Offshore Windfarm: Generation Assets PEIR Volume 1 Chapter 10: Fish and shellfish ecology	Morecambe Offshore Windfarm Ltd	2023	Morecambe Offshore Windfarm Ltd
Morgan Offshore Wind Project: Generation Assets PEIR Volume 2 Chapter 8: Fish and shellfish ecology	Morgan Offshore Wind Ltd	2023	Morgan Offshore Wind Ltd
Marine Life Information Network (MarLIN)	Mar(LIN)	2023	Tyler Walters *et al.*
Cefas Pelagic ecosystem in the western English Channel and eastern Celtic Sea (PELTIC) surveys	Cefas	Various	Cefas
Fish and shellfish survey results for the east Irish Sea	Environment Agency	Various	Environment Agency
Fish and shellfish sensitivity reports	https://www.marlin.ac.uk/activity/pressures_report	Various	Various

3.4.6 Identification of designated sites

3.4.6.1 All designated sites within the fish and shellfish ecology study area and qualifying interest features that could be affected by the construction, operations and maintenance, and decommissioning phases of the Morgan Generation Assets were identified using the three-step process described below:

- Step 1: All designated sites of international, national and local importance within the fish and shellfish ecology study area were identified using a number of sources. These sources included the JNCC MPA mapper (JNCC, 2019), and the IoM Government Fisheries Division publications (Howe *et al*., 2018)
- Step 2: Information was compiled on the relevant fish and shellfish ecology qualifying interests for each of these sites, such as protected, vulnerable, and commercially important species, and protected habitat types
- Step 3: Using the above information and expert judgement, sites were included for further consideration if:
  - A designated site directly overlaps with the Morgan Generation Assets – specifically the Morgan Array Area
  - Sites and associated qualifying interests were located within the potential ZoI for impacts associated with the Morgan Generation Assets
  - Sites which are designated to protect mobile features (e.g. diadromous fish) and where the range of those features has the potential to overlap with either the Morgan Generation Assets and/or the ZoI of impacts associated with the development.

3.4.7 Site specific surveys

3.4.7.1 In order to inform the Environmental Statement, site-specific surveys were undertaken, as agreed with the members of the Benthic Ecology, Fish and Shellfish and Physical Processes EWG (see section 3.3.1 for further details). A summary of the surveys undertaken to inform the fish and shellfish ecology impact assessment is outlined in Table 3.10 below. Note that the surveys were primarily designed to inform the benthic subtidal ecology baseline characterisation, but provide useful information on general seabed types, sediment suitability for fish spawning and/or habitat for benthic species. These also provide opportunistic fish and shellfish records which have been extracted to inform the baseline characterisation.

Table 3.10: Summary of site-specific survey data.

Title	Extent of survey	Overview of survey	Survey contractor	Date	Reference to further information
Benthic Subtidal Survey	Morgan Array Area and Mona Array Area	Grab samples, visual survey outputs (Drop Down Video (DDV) sampling) and laboratory testing	Gardline Ltd.	2021	Gardline Ltd., 2022
Benthic Subtidal Survey	Morgan Array Area and ZoI and Mona Array Area, Offshore Cable Corridor and ZoI.	Grab samples, visual survey outputs (DDV sampling) and laboratory testing	Gardline Ltd.	2022	Gardline Ltd., 2023

3.5 Baseline environment

3.5.1.1 The baseline environment has been described in detail within Volume 4, Annex 3.1: Fish and shellfish ecology of the Environmental Statement. The fish and shellfish ecology receptors that could be potentially impacted by the Morgan Generation Assets have been determined by the desktop review of available data/information as detailed in Table 3.9, and through use of fish and shellfish ecology data from site-specific surveys, as detailed in Table 3.10 (see Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement for further detail regarding baseline data collection and site-specific surveys). Through this process several demersal, pelagic, elasmobranch and diadromous fish species were identified, along with shellfish species. The baseline environment was described for the fish and shellfish ecology study area. Spawning and nursery areas within the vicinity of the fish and shellfish ecology study area were also described, followed by detailed characterisation of particularly sensitive and important fish and shellfish species, including sandeel Ammodytidae spp., herring *Clupea harengus* (focusing on spawning habitats), elasmobranchs, king and queen scallop, and diadromous species.

3.5.1.2 Species identified as likely to be found within the fish and shellfish ecology study area include:

- Demersal species – sandeel, whiting *Merlangius merlangus*, lemon sole *Microstomus kitt*, ling *Molva molva*, plaice *Pleuronectes platessa*, cod, and European hake *Merluccius merluccius*
- Pelagic species – herring, mackerel *Scomber scombrus*, sprat *Sprattus sprattus*, and European sea bass *Dicentrarchus labrax*
- Elasmobranch species – basking shark *Cetorhinus maximus*, lesser spotted dogfish *Scyliorhinus canicular*, tope shark *Galeorhinus galeus*, spurdog *Squalus acanthias*, common skate *Dipturus batis*, spotted ray *Raja montagui*, and thornback ray *Raja clavata*, angel shark *Squatina squatina*
- Diadromous species – Atlantic salmon *Salmo salar*, European eel *Anguilla anguilla*, sea trout *Salmo trutta*, river lamprey *Lampetra fluviatilis*, sea lamprey *Petromyzon marinus*, Allis shad *Alosa alosa*, twaite shad *Alosa fallax*, sparling/European smelt *Osmerus eperlanus*; and freshwater pearl mussel *Margaritifera margaritifera* (included here due to reliance on Atlantic salmon and sea trout at specific life stages)

- Shellfish species – king scallop, queen scallop, European lobster *Homarus gammarus*, edible crab *Cancer pagurus*, velvet swimming crab *Necora puber*, squid Loliginidae spp. and Ommastrephidae spp., common whelk *Buccinum undatum*, and *Nephrops*.

3.5.1.3 The spawning and nursery habitats present in the fish and shellfish ecology study area are summarised in Table 3.11 and are based on Ellis *et al*. (2012) and Coull *et al*. (1998) with the seasonality of each species covered in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement. Nursery and spawning habitats were categorised by Ellis *et al. (*2012) as either high or low intensity dependent on the level of spawning activity or abundance of juveniles recorded. Spawning grounds identified by Coull *et al. (*1998) are classified as low, high or undetermined, again based on the level of spawning activity. Intensity of nursery grounds were not specified by Coull *et al*. (1998). Further detail on nursery and spawning grounds is presented in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement.

3.5.1.4 However, the particular sensitivities of herring, sandeel, and elasmobranch species to offshore wind development impacts, and the commercial importance of king and queen scallop mean these species require specific attention and more detailed characterisation. A summary of the baseline characterisation for each of these groups as presented in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement is presented below.

Table 3.11: Key species with spawning and nursery grounds overlapping the Morgan Generation Assets Array Area (Coull *et al*., 1998; Ellis *et al*., 2012).

Common Name	Species Name	Spawning	Nursery
Anglerfish	*Lophius piscatorius*		✓
Cod	*Gadus morhua*	✓	✓
Haddock	*Melanogrammus aeglefinus*		✓
Herring	*Clupea harengus*		✓
Horse Mackerel	*Trachurus trachurus*	✓	
Lemon Sole	*Microstomus kitt*	✓	✓
Ling	*Molva molva*	✓	
Mackerel	*Scomber scombrus*	✓	✓
Nephrops	*Nephrops norvegicus*	✓	✓
Plaice	*Pleuronectes platessa*	✓	✓
Sandeels	Ammodytidae spp.	✓	✓
Sole	*Solea solea*	✓	✓
Spotted Ray	*Raja montagui*		✓
Sprat	*Sprattus sprattus*	✓	
Spurdog	*Squalus acanthias*		✓
Thornback Ray	*Raja clavata*		✓
Tope Shark	*Galeorhinus galeus*		✓
Whiting	*Merlangius merlangus*	✓	✓

3.5.1.5 European seabass is known to support an important commercial and recreational fishery within the UK (Moore *et al*., 2021). Bass caught within the Irish Sea fisheries consistently showed a significant bias (79.8% of catches) towards females, findings which were supported by data collected from North Wales, suggesting potential localised spawning within the area (Moore *et al*., 2021). Monthly landings data between 2019 and 2020 illustrated that the bass fishery within Liverpool Bay is highly seasonal, with the majority of spawning occurring before May and peak landings reported between July and November (Moore *et al*., 2021). Within the Irish Sea, at least two broad spawning grounds are predicted: the central Irish Sea and the southern Irish Sea/Celtic Sea (Lincoln *et al*., 2024), with further evidence collated for spawning in the area of Liverpool Bay collated by Moore *et al.* (2021). Migratory behaviour is reported for European seabass, with an annual trend of inshore feeding in summer, and offshore migration during winter and spring for spawning (Pawson *et al.*, 2007). O’Neill *et al.* (2018) undertook a tagging study of European seabass in the Celtic Sea which also demonstrated periods of offshore migration corresponding to spawning movements described above, although the specific movements undertaken by the individual fish tagged were variable and based upon a small sample size. This study reported one tagged specimen moving between the south coast of Ireland in the Celtic Sea into the east Irish Sea and back again between the period of February and June (O’Neill *et al.,* 2018). European seabass are known to form spatio-temporally restricted annual spawning aggregations with temperature and the hours of daylight/darkness reported to be key triggers for spawning activity (de Pontual *et al.*, 2019; Lincoln *et al.*, 2024). During spawning, pelagic eggs are released into the water column, with eggs and larvae dispersing into coastal nursery grounds (e.g. estuaries or salt marsh areas; Jennings and Pawson, 1992; Food and Agriculture Organisation (FAO), 2009; Lincoln *et al.*, 2024).

3.5.2 Herring

3.5.2.1 Herring utilise specific benthic habitats during spawning, specifically coarse gravelly sediments with a minimal fine sediment fraction, (Dickey-Collas *et al.*, 2001), which increases their vulnerability to activities impacting the seabed (ICES, 2006). Further, as a hearing specialist, herring are vulnerable to impacts arising from underwater sound. Herring spawning grounds have been identified by Coull *et al*. (1998) as being present within the fish and shellfish ecology study area. Data presented by Coull *et al*. (1998) is broad scale, and therefore confidence in, and resolution of, data showing the presence of spawning grounds can be increased through spawning assessments using larval data available from the NINEL for understanding spatial distribution and interannual variation and using International Bottom Trawl Survey Working Group acoustic data for population sizes (ICES, 2021a).

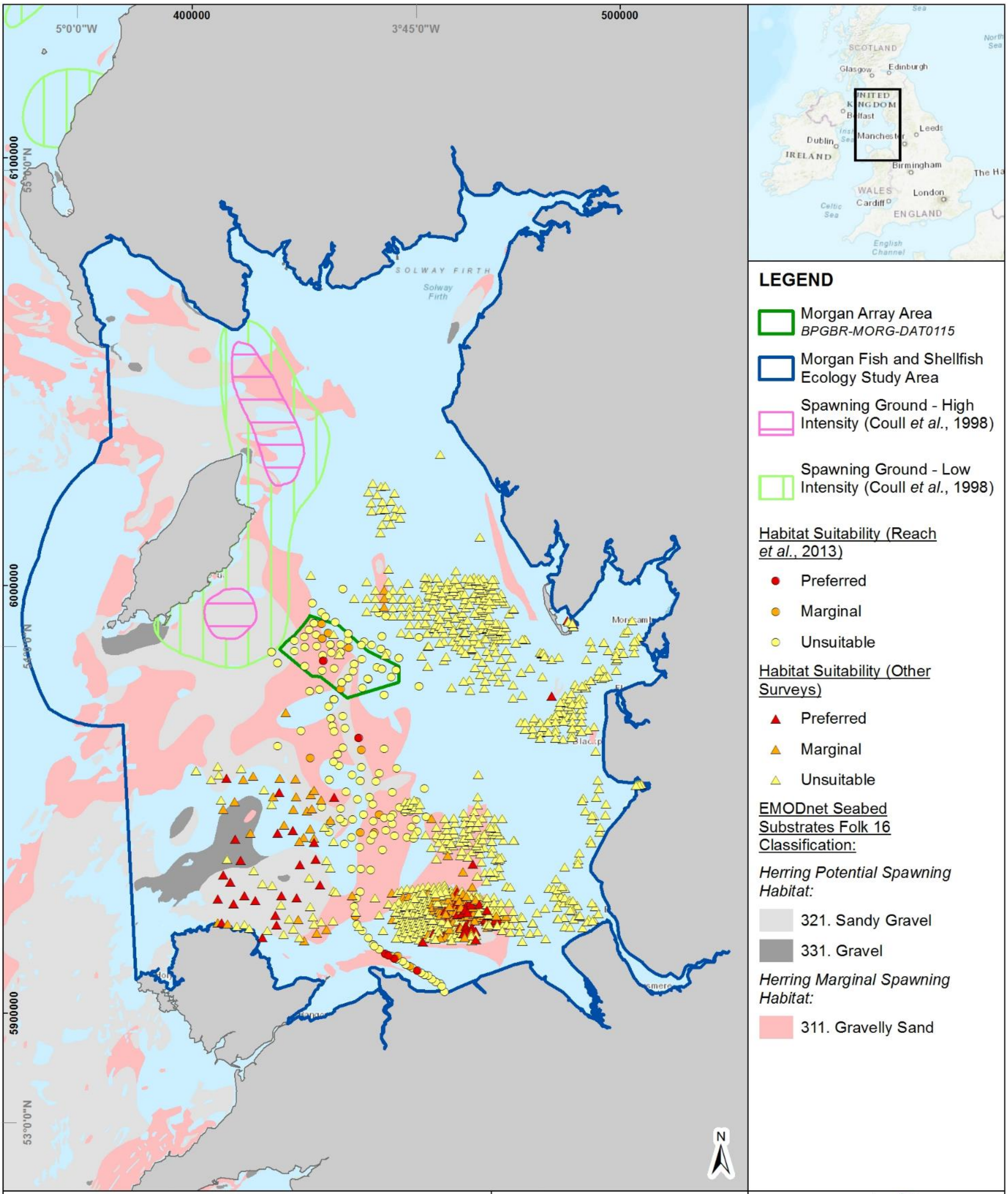
3.5.2.2 Monitoring of herring larval abundances and sediment type data can be used to identify herring spawning grounds, with NINEL having conducted an annual survey across the northeast Irish Sea in November since 1993, immediately after the peak herring spawning period every year. This approach ensured that collected data was consistent and comparable between years, with the number of larvae per m^2 able to be calculated for this analysis. Larvae are identified based on size, with small larvae <10 mm (in line with standard International Herring Larvae Survey (ICES, 2020) practice) assumed to have recently been spawned near to the area they were caught, as these will not have drifted far from the location where eggs were spawned on the seabed. High abundances of these larvae are therefore a good indication of recent spawning activity local to where these were sampled. Due to population underestimations compared to acoustic data (see section 3.5.1.3), the NINEL data is most useful as an indicator of spatial distribution of spawning grounds, although does not give an indication of the size of the herring spawning population.

3.5.2.3 The larval densities were mapped and compared to the spatial distribution of spawning grounds presented in the Coull *et al*. (1998) data and the PSA data from the benthic surveys within and around the Morgan Array Area (Figure 3.2). This PSA data, when presented alongside EMODnet seabed substrate data in Figure 3.2, can be used to assess habitat suitability for herring spawning. This data demonstrated overlaps between the spawning ground datasets, with year-to-year variability in preferred spawning locations accounted for by the relatively high resolution and consistency of the data collection process. Specifically, both the Coull *et al*. (1998) and NINEL datasets showed significant spawning areas to the west and northwest of the fish and shellfish ecology study area, and to the north, east and northeast of the IoM. The most suitable spawning grounds were located entirely outside of, but within 10 km of the north and northwest of the Morgan Array Area. The predominant absence of suitable substrates within the Morgan Array Area is further supported by results from detailed site-specific survey PSA data (see Volume 4, Annex 8.1: Fish and shellfish ecology technical report of the Environmental Statement for full results). As shown in Figure 3.2, the site-specific survey data (labelled as 'Habitat Suitability, Reach' in Figure 3.2 below) found that the majority of the fish and shellfish ecology study area had unsuitable sediment for herring spawning, with only small patches of suitable habitat mainly in the north section of the Morgan Array Area.

3.5.3 Sandeel

3.5.3.1 Sandeel high and low intensity spawning grounds have been identified by Ellis *et al*. (2012) as being present throughout the fish and shellfish ecology study area. However, data presented by Ellis *et al*. (2012) is relatively broad scale, and therefore, confidence in the presence of spawning grounds can be increased through completing analysis on site-specific surveys and drawing on more recently published data which can provide increased resolution and any differences based on seasonal population changes.

3.5.3.2 Figure 3.3 shows the results of site-specific PSA survey data alongside EMODnet seabed substrate data which can also be used to assess habitat suitability for sandeel. To appropriately assess the suitability of habitats for sandeel spawning across the fish and shellfish ecology study area, gravelly sand, (gravelly) sand, and sand were classified from the EMODnet data as preferred habitat, and sandy gravel as marginal habitat (see Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement for further details). No shading in the figure represents unsuitable spawning habitat, while the PSA results were categorised into unsuitable, suitable, subprime, and prime, based on mud and sand ratios in grab samples, as defined by Latto *et al*. (2013). The site-specific benthic surveys and EMODnet seabed substrate data shows overall good alignment within the Morgan Array Area, showing that the majority of stations sampled represented unsuitable habitat. However in the west and south of the Morgan Array Area a number of suitable and sub-prime habitats were identified, with further sparse prime habitats dispersed throughout. Benthic site-specific surveys found no sandeel within the Morgan Array Area, although this particular survey was not designed to target sandeel species and would not be appropriate to inform overall abundance without further studies to specifically sample sandeel.



Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Data Sources: Client, CEFAS, EMODnet, OneBenthic

Project Name:
MORGAN OFFSHORE WIND PROJECT

0 2.5 5 10 15 20 nm
0 5 10 20 30 40 km

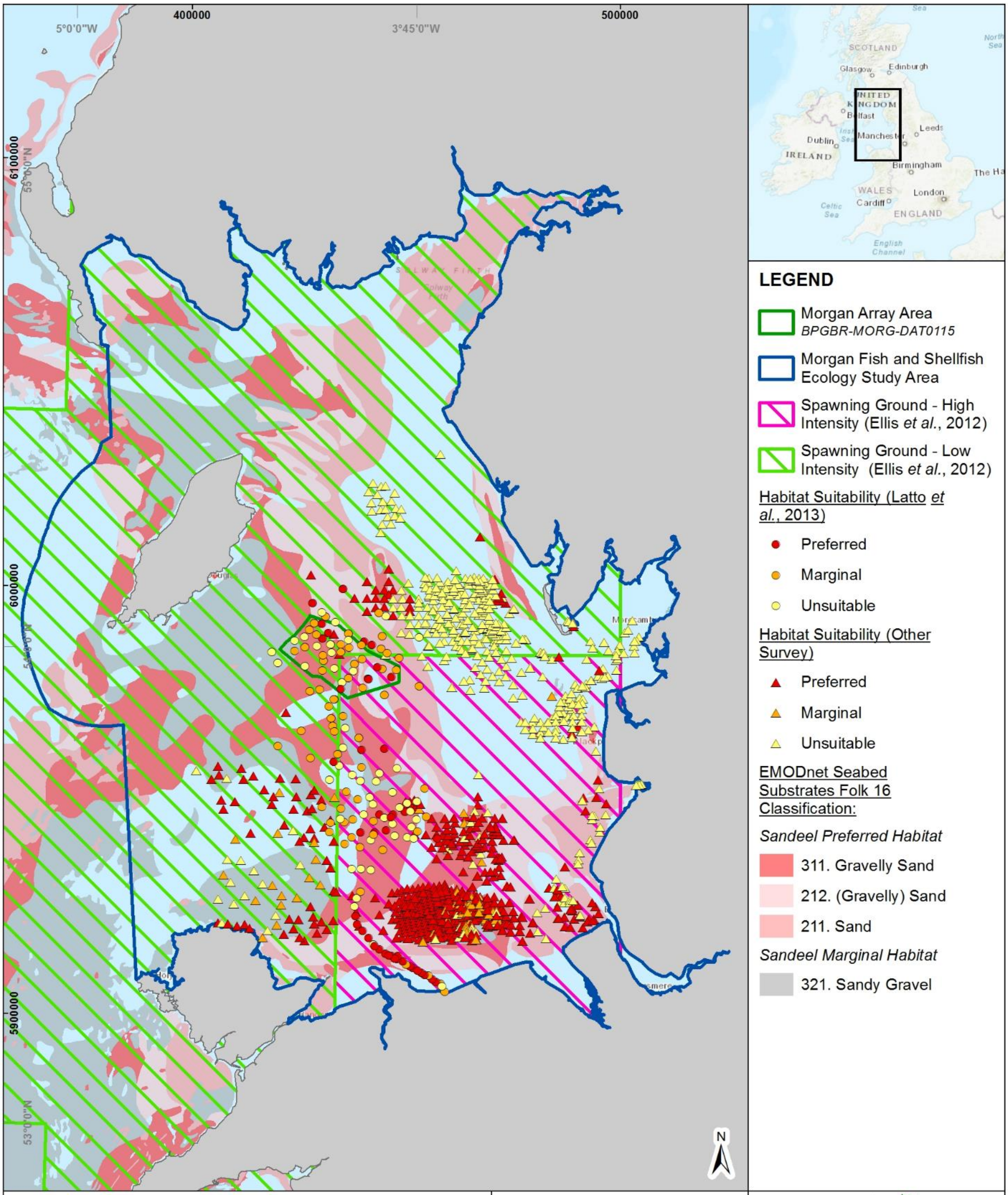
Drawing Number:
RPSE-MG-ES-FAS-E002-00

Drawing Title:
HERRING SPAWNING SUBSTRATE SUITABILITY CLASSIFICATION – ONEBENTHIC

Geodetic Information:
Datum: ETRS 1989
Projection: ETRS 1989 UTM Zone 30N
Scale@160mmx220mm: 1:1,500,000

VER	DATE	DETAILS	BY	CHECK
00	14/11/23	First Issue	MJ	CB

Figure 3.2: Herring spawning habitat preference classifications from EMODnet, OneBenthic and site-specific survey data, with spawning ground intensity (Coull *et al.*, 1998).



Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Data Sources: Client, CEFAS, EMODnet, OneBenthic

Project Name:
MORGAN OFFSHORE WIND PROJECT

0 2.5 5 10 15 20 nm
0 5 10 20 30 40 km

Drawing Number:
RPSE-MG-ES-FAS-E003-00

Drawing Title:
SANDEEL SPAWNING SUBSTRATE SUITABILITY CLASSIFICATION – ONEBENTHIC

Geodetic Information:
Datum: ETRS 1989
Projection: ETRS 1989 UTM Zone 30N
Scale@160mmx220mm: 1:1,500,000

VER	DATE	DETAILS	BY	CHECK
00	14/11/23	First Issue	MJ	CB

Figure 3.3: Sandeel habitat preference classifications from EMODnet, OneBenthic and site-specific survey data, with spawning ground intensity (Ellis *et al*., 2012).

3.5.4 Elasmobranchs

3.5.4.1 Elasmobranch species occurring within the Irish Sea include the spotted and thornback ray. Inshore Fisheries Conservation Authority (IFCA) data has indicated these species inhabit the fish and shellfish ecology study area year-round, with stable population levels despite regular fishery activity, peaking in August (Moore *et al*., 2020). Thornback ray have important spawning grounds in the east Irish Sea around Anglesey, within the fish and shellfish ecology study area (Ellis *et al*., 2012). Other species, including the lesser spotted dogfish and cuckoo ray, are also found throughout the east Irish sea, with both preferring gravelly or coarse sandy substrates for feeding. Spawning occurs in shallow coastal waters or on sessile invertebrates in deeper water for the lesser spotted dogfish (Ellis *et al.,* 1996), and in deep offshore waters for the cuckoo ray (Moriarty *et al*., 2015), potentially overlapping with the fish and shellfish ecology study area. Also, angel shark are known to have a preference for shallow coastal and continental shelf soft sediment habitats for feeding (Lawson *et al*., 2019), and a small group of up to 100 individuals are known to feed in the south west of the fish and shellfish ecology study area intermittently during the spring and summer months (Barker *et al*., 2022).

3.5.4.2 Basking shark migrate north to south through the Irish and Celtic Seas in August to October while travelling between north Africa and Scotland to overwinter in the 50 to 200 m continental shelf depth range (Doherty *et al.*, 2017). They pass through the same region in March to June while returning, and thus have the potential to be encountered in the fish and shellfish ecology study area during both of these periods. Specifically, high numbers have been sighted near the IoM (NBN Atlas, 2019), with 28 tagged individuals travelling a median distance of 1057 km each in their post-summer migration within a single tracking period of 165 days in one year (Doherty *et al*., 2017), including through the fish and shellfish ecology study area. However, during site-specific aerial surveys to inform the topic assessments and presented in Volume 4, Annex 4.1: Marine mammals technical report of the Environmental Statement no sightings of basking shark were recorded during the investigated time-period, although this does not rule out their presence, as basking shark are known to spend a majority of time in depths of 0 to 200 m (Doherty *et al*., 2017), and therefore could be present within the Morgan Array Area, where depths average <50 m. Evidence exists of their regular migration in small numbers through the area near to the Morgan Generation Assets (Shark Trust, 2022; Manx Whale and Dolphin Watch, 2023).

3.5.5 King and Queen Scallop

3.5.5.1 King and queen scallop both show preferences for clean firm sand, fine or sandy gravel, and are found in high densities on muddy sand (Marshall and Wilson, 2008; Carter, 2008). High levels of commercial fishing for king scallop have been recorded within the wider fish and shellfish ecology study area (ICES, 2020), and for queen scallop in the west of the Morgan Array Area, as examined in detail with relevant mapping from fisheries data in Volume 4, Annex 6.1: Commercial fisheries technical report of the Environmental Statement. Queen scallop have been reported by Bloor *et al*. (2019) to be found in densities of 1 to 11 individuals per 100 m^2 within IoM territorial waters west and northwest of the Morgan Array Area, with potential for overlap between these areas due to the relative mobility of queen scallop in the summer months (see Volume 4, Annex 6.1: Commercial fisheries technical report of the Environmental Statement for additional information).

3.5.5.2 King and queen scallop are the most important fisheries by sale values in Manx waters, around the IoM (Murray *et al*., 2009; Duncan and Emmerson, 2018). However, since

2011, the stock assessment within the Manx waters indicates a decreasing trend of queen scallop biomass which is also illustrated by lower commercial landings (ICES, 2019).

3.5.6 Designated sites

3.5.6.1 Designated sites identified for the fish and shellfish ecology chapter are described below in Table 3.12.

Table 3.12: Designated sites and relevant qualifying fish and shellfish ecology interests.

* IoM designated site.

** Note that references to scallops are collectively to the species within the family Pectinidae, and do not reflect a specific genus or species within this group. References within the same table to sandeel refer to the family Ammodytidae and do not reflect a specific genus or species within this group.

Designated site	Closest distance to the Morgan Array Area (km)	Relevant qualifying interest
Langness Marine Nature Reserve (MNR)	16.7	• European eel • Basking shark • Lobster nursery ground • Cod spawning and nursery ground.
Little Ness Marine MNR*	20.41	• Basking shark • European eel • Scallops** • Whelk.
Douglas Bay MNR*	22.22	• European eel • Scallops** • Whelk.
Laxey Bay MNR*	22.42	• Atlantic salmon • European eel • Sea trout • Scallops** • Whelk.
Ramsey Bay MNR*	26.42	• European eel • European bass nursery • Sandeel** • Scallops** • Whelk.
Baie ny Carrickey MNR	30.3	• European eel • Basking shark • Spiny lobster (Paniluridae sp.).
Calf of Man and Wart Bank MNR	35.7	• European eel • Basking shark • Sandeel** • Spiny lobster.

Designated site	Closest distance to the Morgan Array Area (km)	Relevant qualifying interest
Port Erin Bay MNR	40.2	• Basking shark • Plaice nursery.
West Coast MNR	42.2	• European eel • Basking shark • Sandeel** • European bass nursery • Scallops** • Whelk.
Niarbyl Bay MNR	45.7	• Basking shark.
Wyre Lune MCZ	47.06	• Sparling.
Ribble Estuary MCZ	58.44	• Sparling.
River Ehen SAC	62.77	• Atlantic salmon • Freshwater pearl mussel.
Dee Estuary SAC/Aber Dyfrdwy SAC	70.09	• Sea lamprey • River lamprey.
River Derwent and Bassenthwaite Lake SAC	71.28	• Sea lamprey • River lamprey • Atlantic salmon • Brook lamprey.
Solway Firth SAC	84.32	• Sea lamprey • River lamprey.
River Dee and Bala Lake/Afon Dyfrdwy a Llyn Tegid SAC	91.60	• Sea lamprey • River lamprey • Atlantic salmon • Brook lamprey.
Solway Firth MCZ	98.90	• Sparling.

3.5.7 Important ecological features

3.5.7.1 IEFs are habitats, species, ecosystems, and their functions/processes that are considered to be important and potentially impacted by the Morgan Generation Assets. Guidance from the CIEEM was used to assess IEFs within the area (CIEEM, 2018, updated in 2022). IEFs can be attributed to individual species (such as plaice) or species groups (for example flat fish species). Each IEF is assigned a value or importance rating which are based on commercial, ecological and conservation importance, including SPI and qualifying features of SACs. SPIs are those species most threatened, in greatest decline, or where England and Wales hold a significant proportion of the world’s total population in some cases, as defined under Section 41 of the Natural Environment and Rural Communities (NERC) Act 2006. Table 3.13

details the criteria used for determining IEFs and Table 3.14 applies the defining criteria to specific species, providing justifications for importance rankings. Specific reference is made to each species' commercial, conservation and ecological importance, where this is known. These species will be taken forward for assessment. Diadromous species refer to specific species that migrate between fresh water and the marine environment, and marine fish and shellfish species refer to all other IEF species identified within this chapter (Table 3.14).

Table 3.13: Defining criteria for IEFs (adapted from CIEEM, 2018, updated in 2022).

Value of IEF	Defining Criteria
International	Internationally designated sites. Species protected under international law (i.e. Annex II species listed as qualifying interests of SACs under Annex II of the EU Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (The Habitats Directive).
National	Nationally designated sites. Species protected under national law. Annex II species which are not listed as qualifying interests of SACs in the Morgan fish and shellfish ecology study area. OSPAR List of Threatened or Declining Species, and IUCN) Red List species that have nationally important populations within the Morgan Generation Assets, particularly in the context of species/habitat that may be rare or threatened in English and Welsh waters. SPIs have been deemed features characteristic of the English and Welsh marine environment and where nationally important habitats/communities are present in the fish and shellfish ecology study area. Species that have spawning or nursery areas within or in the immediate vicinity of the Morgan Generation Assets that are important nationally (e.g. may be primary spawning/nursery area for that species).
Regional	OSPAR List of Threatened or Declining Species, and IUCN Red List species that have regionally important populations within the Morgan Generation Assets (i.e. are locally widespread or abundant). SPIs have been deemed features characteristic of the English and Welsh marine environment. Species that are of commercial value to the fisheries which operate within the Morgan Generation Assets. Species that form an important prey item for other species of conservation or commercial value and that are key components of the fish assemblages within the Morgan Generation Assets. Species that have spawning or nursery areas within the Morgan Generation Assets that are important regionally (i.e. species may spawn in other parts of English and Welsh waters, but this is a key spawning/nursery area within the Morgan Generation Assets).
Local	Species that are of commercial importance but do not form a key component of the fish assemblages within the Morgan Generation Assets (e.g. they may be exploited in deeper waters outside the Morgan Generation Assets). The spawning/nursery area for the species are outside the Morgan Generation Assets. The species is common throughout English and Welsh waters but forms a component of the fish assemblages in the Morgan Generation Assets.

Table 3.14: IEF species and representative groups within the Morgan Generation Assets.

IEF	Specific name/ representative species	Importance	Justification
Plaice	*Pleuronectes platessa*	Regional	Listed as a SPI. High intensity spawning and low intensity nursery grounds identified throughout the Morgan Generation Assets. Plaice is an important commercial species throughout the Morgan Generation Assets and within the surrounding east Irish Sea.
Lemon Sole	*Microstomus kitt*	Local	Spawning and nursery grounds are undetermined and unspecified within the Morgan Generation Assets and wider east Irish Sea. It is an important and abundant commercial fish species, but not in the immediate vicinity of the Morgan Generation Assets and within the surrounding east Irish Sea.
Sole	*Solea solea*	Regional	Listed as a SPI. High intensity spawning and nursery grounds identified throughout the Morgan Generation Assets. Sole is an important commercial species throughout the Morgan Generation Assets and within the surrounding east Irish Sea.
Other flatfish species		Local	Other flatfish species including common dab, (*Limanda limanda*), solenette (*Buglossidium luteum*), and flounder (*Platichthys flesus*) are likely to occur within the Morgan Generation Assets. These species either have no known spawning or nursery grounds or low intensity/undetermined spawning and nursey grounds within the area.
Cod	*Gadus morhua*	Regional	Listed as a SPI. Listed by OSPAR as threatened or declining and listed as vulnerable on the IUCN Red List. High intensity spawning and nursery grounds are present throughout the Morgan Generation Assets. It is an important commercial fish species, but not in the immediate vicinity of the Morgan Generation Assets and in the wider east Irish Sea following stock collapse and subsequent poor recovery.
Whiting	*Merlangius merlangus*	Regional	Listed as a SPI. Low intensity spawning and high intensity nursery grounds identified throughout the Morgan Generation Assets. Whiting is an important commercial species throughout the Morgan Generation Assets and within the surrounding east Irish Sea.
Other demersal species		Local	Species including anglerfish *Lophius piscatorius,* ling *Molva molva,* hake *Merluccius merluccius* and European seabass *Dicentrarchus labrax* are common throughout English and Welsh waters and are likely to be in the Morgan Generation Assets. The first three species listed are also Species of Principal Importance. They are important commercial species, but not in the immediate vicinity of the Morgan Generation Assets and in the wider east Irish Sea.

IEF	Specific name/ representative species	Importance	Justification
Sandeel species	Ammodytidae spp.	Regional	Listed as a SPI. There are five species of sandeel found in UK waters with lesser sandeel *Ammodytes tobianus* and greater sandeel *Hyperoplus lanceolatus* being the most commonly found species in British waters. Sandeel are important prey species for fish, birds and marine mammals. High intensity spawning grounds and low intensity nursery grounds are present throughout the Morgan Generation Assets. Identified as likely to be present in the Morgan Generation Assets based on historic data and habitat preference.
Herring	*Clupea harengus*	National	Listed as a SPI. Low intensity spawning grounds present immediately outside of the Morgan Generation Assets and within the Fish and shellfish ecology study area. High intensity nursery grounds present within the Morgan Generation Assets. Although herring spawning grounds do not directly overlap the Morgan Array Areas, this specific area of the Irish Sea has been denoted as key spawning habitat for the species. Herring is an important commercial species, but not in the immediate vicinity of the Morgan Generation Assets or in the wider east Irish Sea. They are also an important prey species for birds, other fish, and marine mammals.
Mackerel	*Scomber scombrus*	Regional	Listed as a SPI. Important prey species for larger fish, birds and marine mammals. Low intensity spawning and nursery grounds throughout the Morgan Generation Assets and the wider east Irish Sea. Mackerel is an important commercial species, but not in the immediate vicinity of the Morgan Generation Assets or in the wider east Irish Sea.
Sprat	*Sprattus sprattus*	Regional	Important prey species for larger fish, birds and marine mammals. Unspecified intensity spawning and nursery grounds within the Morgan Generation Assets. Sprat is an important commercial species, but not in the immediate vicinity of the Morgan Generation Assets or in the wider east Irish Sea.
Basking Shark	*Cetorhinus maximus*	International	Listed as a SPI. The northeast Atlantic population are classed as Endangered on the IUCN Red List. Additionally, they are listed under Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Annex II and classified as a Priority Species under the UK Post-2010 Biodiversity Framework. Protected in the UK under the Wildlife and Countryside Act. Basking shark are likely to be present in low abundances if present at all near the IoM and in proximity to the Morgan Generation Assets.

IEF	Specific name/ representative species	Importance	Justification
Tope	*Galeorhinus galeus*	Regional	Listed as a SPI. Listed as Vulnerable by the IUCN Red List and is a Priority Species under the UK Post-2010 Biodiversity Framework. Low intensity nursery grounds within the Morgan Generation Assets.
Spurdog	*Squalus acanthias*	Regional	Listed as a SPI. Listed as Vulnerable by the IUCN Red List and is a Priority Species under the UK Post-2010 Biodiversity Framework. High intensity nursery grounds within the Morgan Generation Assets.
Ray species		Regional	Ray species including spotted ray, and thornback ray. These species either have low intensity nursery grounds and/or no known spawning grounds within the Morgan Generation Assets.
Shellfish IEF Species			
Edible crab	*Cancer pagurus*	Regional	Commercially important species. Identified as being likely to be present within the Morgan Generation Assets.
Norway lobster	*Nephrops norvegicus*	Regional	Commercially important species. Identified as being likely to be present within the Morgan Generation Assets.
European lobster	*Homarus gammarus*	Regional	Commercially important species. Identified as being likely to be present within the Morgan Generation Assets.
King scallop	*Pecten maximus*	Regional	Commercially important species. Identified as being present within the Morgan Generation Assets.
Queen scallop	*Aequipecten opercularis*	Regional	Commercially important species. Identified as being present within the Morgan Generation Assets.
Velvet swimming crab	*Necora puber*	Local	Commercially important species. Identified as being likely to be present within the Morgan Generation Assets.
Other shellfish		Local	Other shellfish including, swimming crab, spider crab and shrimp have been identified as being likely to occur within the Morgan Generation Assets. These are all important commercial species, but not in the immediate vicinity of the Morgan Generation Assets (i.e. in the wider east Irish Sea).
Diadromous Fish IEF Species			
Sea trout	*Salmo trutta*	National	Listed as a SPI. Listed as a species of Least Concern by the IUCN Red List. Listed as a OSPAR threatened/declining species. Likely to migrate through the Morgan Generation Assets. Not a feature of any designated sites in the vicinity of the Morgan Generation Assets.

IEF	Specific name/ representative species	Importance	Justification
European eel	*Anguilla anguilla*	National	Listed as a SPI. Listed as Critically Endangered by the IUCN Red List. Listed as an OSPAR threatened/declining species. Likely to migrate through the Morgan Generation Assets. This species is a qualifying feature of multiple MNRs in the vicinity of the Morgan Generation Assets.
Sea lamprey	*Petromyzon marinus*	International	Listed as a SPI. Listed as a species of Least Concern by the IUCN Red List. Annex II species and listed as qualifying features of a number of SACs in the vicinity of the Morgan Generation Assets. Likely to migrate through the Morgan Generation Assets.
River lamprey	*Lampetra fluviatilis*	International	Listed as a SPI. Listed as a species of Least Concern by the IUCN Red List. Annex II species and listed as qualifying features of a number of SACs in the vicinity of the Morgan Generation Assets. Likely to migrate through the Morgan Generation Assets, although only in coastal/estuarine areas.
Twaite shad	*Alosa fallax*	National	Listed as a SPI. Listed as a species of Least Concern by the IUCN Red List and is a Priority Species under the UK Post-2010 Biodiversity Framework. Likely to migrate through the Morgan Generation Assets.
Allis shad	*Alosa alosa*	National	Listed as a SPI. Listed as a species of Least Concern by the IUCN Red List and is a Priority Species under the UK Post-2010 Biodiversity Framework. Likely to migrate through the Morgan Generation Assets.
Atlantic salmon	*Salmo salar*	International	Listed as a SPI. Listed as Vulnerable by the IUCN Red List. Annex II species and listed as qualifying features of a number of SACs in the vicinity of the Morgan Generation Assets. Likely to migrate through the Morgan Generation Assets.
Sparling/ European smelt	*Osmerus eperlanus*	National	Listed as a SPI. Listed as a species of Least Concern by the IUCN Red List. This species is a qualifying feature of multiple MCZs in the vicinity of the Morgan Generation Assets. Likely to migrate through the Morgan Generation Assets, although only in coastal/estuarine areas.
Freshwater pearl mussel	*Margaritifera margaritifera*	International	Listed in Annexes II and V of the Habitats Directive and Annex III of the Bern Convention. Listed as Endangered on the IUCN Red List. Annex II species and listed as qualifying features of a number of SACs in the vicinity of the Morgan Generation Assets.

3.5.8 Future baseline scenario

3.5.8.1 The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 require that 'an outline of the likely evolution thereof without implementation of the development as far as natural changes from the baseline scenario can be assessed with reasonable effort on the basis of the availability of environmental information and scientific knowledge' is included within the Environmental Statement. In the event that the Morgan Generation Assets does not come forward, an assessment of the future baseline conditions has been carried out and is described within this section.

3.5.8.2 The current baseline environment is accurately represented in the given description, accounting for seasonality and interannual variability. However, the baseline will exhibit larger degrees of natural change over longer time periods, due to naturally occurring cycles and processes and any potential changes resulting from climate change. This long-term change will occur even if the Morgan Generation Assets does not come forward. When undertaking any impact assessments, it will be necessary to place any potential impacts into the context of the envelope of change that might occur over the expected operational lifetime of the Morgan Generation Assets.

3.5.8.3 Variability and long-term changes within the Irish Sea, including projected increases of average sea surface temperature of up to 1.9°C and changes in the timing of maximum and minimum temperatures (Olbert *et al*., 2012) may bring direct and indirect changes to fish and shellfish populations and communities. As sea temperatures rise, species adapted to cold water such as cod (Drinkwater, 2005) and herring will begin to seek cooler waters, while warm water adapted species will become more established in the previous locations, representing a shift in biodiversity and fishing activities and a potential reduction in range for some species. This potential future change will occur against the background of known overall dampening of production and stock recovery in Irish Sea fish populations due to the present impacts of climate change (Bentley *et al*., 2020). Future changes are expected to be exacerbated by increasing temperatures and extreme weather events causing increased stratification of phytoplankton food sources in the Irish Sea leading to decoupling of predator and prey interactions and impacting fish population survivability (Morrison *et al*., 2019).

3.5.8.4 Increasing temperatures can also potentially expand the geographical range and virulence of diseases affecting economically important shellfish populations (Rowley *et al*., 2014), causing potential threats to long-term survivability, and thus negatively impacting overall population levels. A combination of this increasing temperature, and ocean acidification could also negatively impact shell strength (Mackenzie *et al*., 2014) and thus reduce their protection against predators, with significant reductions in the economic value projected from these impacts to the shellfish population (Narita *et al*., 2012).

3.5.8.5 Climate change presents many uncertainties as to how the marine environment will change in the future; therefore, the future baseline scenario is difficult to predict with accuracy. Any changes that may occur during the proposed operational lifespan of the Morgan Generation Assets development should be considered in the context of both greater variability and sustained trends occurring on national and international scales in the marine environment.

3.5.9 Data limitations

3.5.9.1 The data sources used in this chapter are detailed in Table 3.9 and Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement. This largely comprises a desk-based assessment of the fish and shellfish ecology study area, although the desktop data used is the most up to date publicly available information which can be obtained from the applicable data sources as cited. Data that has been collected is based on long-term existing literature and survey datasets (including scientific literature, grey literature, and commercial fisheries information); consultation with stakeholders, and identification of habitats which may support fish and shellfish species, and to ensure all relevant IEFs were appropriately identified and assessed within the defined fish and shellfish ecology study area, to be carried forward into the EIA.

3.5.9.2 Site-specific surveys were carried out for benthic ecology requirements (Volume 2, Chapter 2: Benthic subtidal ecology of the Environmental Statement) and were used to determine suitable herring spawning and sandeel habitats within the Morgan Array Area. While these may not provide the same information as targeted fish and shellfish surveys, the collected data was reviewed alongside wider long-term existing datasets and stakeholder consultation (including commercial fisheries organisations), to characterise the fish and shellfish ecology study area most appropriately. Similarly, the data available from Coull *et al*. (1998) and Ellis *et al*. (2012) provide a general overview of spawning grounds and times for many species in the area but might not fully represent current habitat preferences alone. As such these have been supplemented with the most up to date information available (e.g. NINEL herring larvae surveys and site-specific seabed sediment data) during the desk-based study to best overcome this limitation and ensure a robust Environmental Statement. Recent modelling based on collated survey data in the English and surrounding waters (including the IoM territorial waters; Campanella and van der Kooij, 2021) provides up-to-date evidence to support the distribution of the previously identified spawning and nursery grounds for a range of foraging species, with any slight changes in mapped species distribution likely being due to natural interannual variation. Broadly, these studies all describe the same patterns of spawning and nursery habitat within the fish and shellfish ecology study area, and thus the maps available from Coull et al. (1998) and Ellis et al. (2012) data can be considered reliable and of continued relevance.

3.5.9.3 One other limitation identified was that the NINEL herring larvae survey was benchmarked in 2012, and no longer used in Irish Sea herring stock assessments after that point, due to underestimating spawning populations significantly compared to higher resolution acoustic data. However, this data continued to be collected using the same methodology and was still mapped and assessed within Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement due to being a useful indicator of the spatial distribution of the spawning population, alongside Coull *et al*. (1998) and Ellis *et al*. (2012). The underestimation limitation was dealt with through incorporation of recent acoustic survey and stock assessment data (ICES, 2021a), which is further examined in Volume 4, Annex 3.1: Fish and shellfish technical report of the Environmental Statement and should not represent a significant impact on the predictability of the EIA.

3.6 Impact assessment methodology

3.6.1 Overview

3.6.1.1 The fish and shellfish ecology impact assessment has followed the methodology set out in Volume 1, Chapter 5: EIA methodology of the Environmental Statement. Specific to the fish and shellfish ecology impact assessment, the following guidance documents have also been considered:

- The Planning Inspectorate Advice Note Seven: Environmental Impact Assessment: Preliminary Environmental Information, Screening and Scoping (the Planning Inspectorate, 2020a)
- The Planning Inspectorate Advice Note Nine: Rochdale Envelope (the Planning Inspectorate, 2018)
- The Planning Inspectorate Advice Note Twelve: Transboundary Impacts and Process (the Planning Inspectorate, 2020b)
- The Planning Inspectorate Advice Note Seventeen: Cumulative effects assessment (the Planning Inspectorate, 2019)
- Guidelines for EcIA in the UK and Ireland (CIEEM, 2019; updated in 2022)
- Environmental Impact Assessment Guide to: Delivering Quality Development (Institute of Environmental Management and Assessment (IEMA), 2016)
- Delivering Proportionate EIA, A Collaborative Strategy for Enhancing UK Environmental Impact Assessment Practice (IEMA, 2017)
- Cumulative Impact Assessment Guidelines, Guiding Principles for Cumulative Impact Assessment in Offshore Wind Farms (RenewableUK, 2013)
- Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects (Judd, 2012)
- Marine Evidence-based Sensitivity Assessment – A Guide (Tyler-Walters *et al*., 2023)
- Guidance on Environmental Considerations for Offshore Wind Farm Development (OSPAR, 2008)
- Offshore Wind Marine Environmental Assessments: Best Practice Advice for Evidence and Data Standards, Natural England, (Natural England and Defra, 2022)
    - Part 1: Baseline characterisation surveys
    - Part 2: Pre-application engagement and the evidence plan process
    - Part 3: Data and evidence expectations at examination
    - Part 4: Post-consent monitoring and other environmental requirements
- Guidance on EIS and Natura Impact Statement (NIS) Preparation for Offshore Renewable Energy Projects, Department of Communications, Climate Action and Environment, (Barnes, 2017)

3.6.1.2 In addition, the fish and shellfish ecology impact assessment has considered the legislative framework as defined by:

- The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 (as amended) (the 2017 EIA Regulations)
- The Planning Act 2008 (as amended).

3.6.2 Impact assessment criteria

3.6.2.1 The criteria for determining the significance of effects are based on a two-stage process that involves defining the magnitude of the impacts and the sensitivity of the receptors. This section describes the criteria applied in this chapter to assign values to the magnitude of potential impacts and the sensitivity of the receptors. The terms used to define magnitude and sensitivity are based on those which are described in further detail in Volume 1, Chapter 5: EIA methodology of the Environmental Statement.

3.6.2.2 The criteria for defining magnitude in this chapter are outlined in Table 3.15 below.

Table 3.15: Definition of terms relating to the magnitude of an impact.

Magnitude of impact	Definition
High	Loss of resource and/or quality and integrity of resource; severe damage to key characteristics, features or elements (Adverse).
	Large scale or major improvement or resource quality; extensive restoration or enhancement; major improvement of attribute quality (Beneficial).
Medium	Loss of resource, but not adversely affecting integrity of resource; partial loss of/damage to key characteristics, features or elements (Adverse).
	Benefit to, or addition of, key characteristics, features or elements; improvement of attribute quality (Beneficial).
Low	Some measurable change in attributes, quality or vulnerability, minor loss or, or alteration to, one (maybe more) key characteristics, features or elements (Adverse).
	Minor benefit to, or addition of, one (maybe more) key characteristics, features or elements; some beneficial impact on attribute or a reduced risk of negative impact occurring (Beneficial).
Negligible	Very minor loss or detrimental alteration to one or more characteristics, features or elements (Adverse).
	Very minor benefit to, or positive addition of one or more characteristics, features or elements (Beneficial).

3.6.2.3 The definitions of sensitivities of fish and shellfish IEFs have been informed by the Marine Evidence based Sensitivity Assessment (MarESA; MarLIN, 2021). The MarESA is part of MarLIN, which has been developed by the Marine Biological Association and is supported by Defra, Natural England, the JNCC, and NRW, and defines sensitivity as a product of the likelihood of damage (resistance) due to a pressure and the rate of recovery (recoverability) once the pressure has been removed. Recoverability is the ability of a habitat to return to the state of the habitat that existed before the activity or event which caused change. Full recovery does not necessarily mean that every component species has returned to its prior condition, abundance, or extent but that the relevant functional components are present, and the habitat is structurally and functionally recognisable as the initial habitat of interest. The MarESA defines pressures by a benchmark which describes the extent and duration of the pressure but does not consider the intensity, frequency of pressures or any cumulative impacts.

3.6.2.4 The sensitivities of fish and shellfish IEFs presented within this chapter of the Environmental Statement have therefore been defined by an assessment of the combined vulnerability (i.e. resistance, following MarESA) of the receptor to a given impact and the likely rate of recoverability to pre-impact conditions. Here, vulnerability is defined as the susceptibility of a species to disturbance, damage or death, from a specific external factor. Recoverability is the ability of the same species to return to a state close to that which existed before the activity or event which caused change. Recoverability is dependent on an IEFs ability to recover or recruit subject to the extent of disturbance/damage incurred. Information on these aspects of sensitivity of the fish and shellfish IEFs to given impacts has been informed by the best available evidence following environmental impact or experimental manipulation in the field and evidence from the offshore wind industry and analogous activities such as those associated with aggregate extraction, electrical cabling, and oil and gas industries. These assessments have been combined with the importance of the relevant IEFs as defined in section 3.5.7 and as presented in Table 3.14 for the fish and shellfish IEFs considered in this assessment.

3.6.2.5 The criteria for defining sensitivity in this chapter are outlined in Table 3.16 below.

Table 3.16: Definition of terms relating to the sensitivity of the receptor.

Sensitivity	Definition
Very High	Nationally and internationally important receptors with high vulnerability and low to no recoverability.
High	Regionally important receptors with high vulnerability and no ability to recover.
Medium	Nationally and internationally important receptors with medium vulnerability and medium recoverability. Regionally important receptors with medium to high vulnerability and low recoverability. Locally important receptors with high vulnerability and no ability to recover.
Low	Nationally and internationally important receptors with low vulnerability and high recoverability. Regionally important receptors with low vulnerability and medium to high recoverability. Locally important receptors with medium to high vulnerability and low recoverability.
Negligible	Locally important receptors with low vulnerability and medium to high recoverability. Receptor is not vulnerable to impacts regardless of value/importance.

3.6.2.6 The significance of the effect upon fish and shellfish ecology is determined by correlating the magnitude of the impact and the sensitivity of the receptor. The particular method employed for this assessment is presented in Table 3.17. Where a range of significance of effect is presented in Table 3.17, the final assessment for each effect is based upon expert judgement, with a clear justification provided in the impact assessment.

3.6.2.7 For the purposes of this assessment, any effects with a significance level of minor or less have been concluded to be not significant in terms of The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017.

Table 3.17: Matrix used for the assessment of the significance of the effect.

Sensitivity of Receptor	Magnitude of Impact			
	Negligible	**Low**	**Medium**	**High**
Negligible	Negligible	Negligible or Minor	Negligible or Minor	Minor
Low	Negligible or Minor	Negligible or Minor	Minor	Minor or Moderate
Medium	Negligible or Minor	Minor	Moderate	Moderate or Major
High	Minor	Minor or Moderate	Moderate or Major	Major
Very High	Minor	Moderate or Major	Major	Major

3.6.3 Designated sites

3.6.3.1 Where National Site Network sites (i.e. internationally designated sites) are considered, this chapter summarises the assessments made on the interest features of internationally designated sites as described within section 3.5.6 of this chapter (an assessment of the impact of the Morgan Generation Assets on the integrity of designated sites is contained within the Draft Information to Support Appropriate Assessment). A similar approach is taken for designated features of MCZs, with assessments made on the interest features of these sites presented in this chapter, but the assessment of the impact of the Morgan Generation Assets on the designated sites is contained within the Morgan Generation Assets MCZ Assessment. With respect to nationally and locally designated sites, where these sites fall within the boundaries of an internationally designated site (e.g. Sites of Special Scientific Interest (SSSIs) which have not been assessed within the Information to Support an Appropriate Assessment), only the international site has been taken forward for assessment. This is because potential effects on the integrity and conservation status of the nationally designated site are assumed to be inherent within the assessment of the internationally designated site (i.e. a separate assessment for the national site is not undertaken), and the features of any relevant SSSIs or nationally designated sites are considered by assessment of the internationally designated sites (as they are also designated as features for the international sites).

3.6.3.2 The Information to Support Appropriate Assessment (ISAA; Document Reference E1) has been prepared in accordance with Advice Note Ten: Habitats Regulations Assessment Relevant to Nationally Significant Infrastructure Projects (the Planning Inspectorate, 2022) and submitted as part of the Application for Development Consent.

3.7 Key parameters for assessment

3.7.1 Maximum Design Scenario

3.7.1.1 The MDSs identified in Table 3.18 have been selected as those having the potential to result in the greatest potential effect on an identified receptor or receptor group. These scenarios have been selected from the Project Design Envelope provided in

Volume 1, Chapter 3: Project description of the Environmental Statement. Effects of greater adverse significance are not predicted to arise should any other development scenario, based on details within the Project Design Envelope (e.g. different infrastructure layout), to that assessed here be taken forward in the final design scheme.

Table 3.18: Maximum design scenario considered for the assessment of potential impacts on fish and shellfish ecology.

[a] C=construction, O=operations and maintenance, D=decommissioning

Potential impact	Phase[a]			Maximum Design Scenario	Justification
	C	O	D		
Temporary habitat loss/disturbance.	✓	✓	✓	**Construction phase** Up to 61,422,400 m^2 of habitat loss/disturbance in total across the Morgan Array Area comprising: • Jack-up events: up to 825,600 m^2 of disturbance from the use of jack-up vessels during foundation installation, with up to four jack-up events at each of 96 wind turbines (two jack-up events for wind turbines and two jack-up events for the foundations) and two jack-up events at each of four OSPs • Sandwave clearance for foundations: up to 818,960 m^2 of habitat disturbance associated with sandwave clearance comprising: – 721,561 m^2 of sandwave clearance associated with seabed preparation for wind turbine foundations – 97,399 m^2 of sandwave clearance associated with seabed preparation for OSP foundations • Cable installation (including sandwave clearance and pre-lay preparation): up to 21,384,000 m^2 of disturbance comprising: – Inter-array cables: up to 17,160,000 m^2 disturbance from installation of up to 390 km of inter-array cables (assumes 60% requires boulder clearance with a 20 m width of disturbance and 40% requires sandwave clearance with an 80 m width of disturbance) – Interconnector cables: up to 4,224,000 m^2 disturbance from installation of up to 60 km of interconnector cables (assumes 40% requires boulder clearance with a 20 m width of disturbance and 60% requires sandwave clearance with a 104 m width of disturbance) • Sandwave clearance material deposition: Up to 36,473,840 m^2 of habitat disturbance associated with the deposition of sandwave clearance material comprising: – 20,298,910 m^2 from deposition of 10,149,455 m^3 of sandwave clearance material associated with seabed preparation for wind turbine and OSP foundations – 10,053,302 m^2 from deposition of 5,026,651 m^3 of sandwave clearance material associated with seabed preparation for inter-array cables	Construction phase Maximum footprint which would be affected during the construction, operations and maintenance and decommissioning phases. The MDS assumes 100% of all cables are buried. The MDS assumes that the width of disturbance for sandwave and pre-lay preparation (boulder and debris clearance) also includes subsequent burial. For the purposes of the MDS, and to avoid double counting of the total footprint with sandwave clearance activities, the MDS assumes up to 60% of inter-array and 40% of interconnector will be subject to pre-lay preparation (boulder and debris clearance) only. The MDS assumes that the remainder of the cables will be subject to sandwave clearance. The area of seabed affected by the placement of sandwave clearance material has been calculated based on the maximum volume of sediment to be placed on the seabed, assuming all this sediment is coarse material (i.e. is not dispersed through tidal currents; see ‘Increased suspended sediment concentrations’ impact assessment below). The total footprint of seabed affected has been calculated, for the purposes of the MDS, assuming a mound of uniform thickness of 5 m height. The MDS assumes temporary loss of benthic habitat is beneath this.

Potential impact	Phase[a]			Maximum Design Scenario	Justification
	C	O	D		
				– 6,121,628 m² from deposition of 3,060,814 m³ of sandwave clearance material associated with seabed preparation for interconnectors cables • Anchor placement: Up to 1,000,000 m² of habitat disturbance from two 100 m² anchor set placements (five anchors per set) every 500 m per inter-array cable link during installation • Cable removal: Up to 920,000 m² from the removal of 46,000 m of disused cables. • UXO removal: clearance of up to 13 UXOs within the Morgan Generation Assets ranging from 25 kg up to 907 kg with 130 kg the most likely (common) maximum. Maximum duration of the offshore construction phase is up to four years. **Operations and maintenance phase** Up to 11,362,800 m² of temporary habitat disturbance in total across the Morgan Array Area due to: • Up to 1,822,800 m² of temporary habitat disturbance due to jack-ups at wind turbines and OSPs, over the lifetime of the Morgan Generation Assets for the following: – up to 840 major component replacements (one every four years for each location) for wind turbines – 12 major component replacements (three over the lifetime per OSP) for OSPs – four access ladder replacements and four modifications to/replacement of J-tubes for wind turbines – four access ladder replacements and four modifications to/replacement of J-tubes for OSPs. • Up to 4,720,000 m² of temporary habitat disturbance due to inter-array cable maintenance associated with: – 2,800,000 m² from seven reburial events (one every five years) affecting up to 20,000 m per reburial event – 1,920,000 m² from 12 repair events (one every three years) affecting up to 8,000 m per cable repair event – Assuming 20 m width seabed disturbance for repair and remedial burial. • Up to 4,820,000 m² of temporary habitat disturbance due to interconnector cable maintenance associated with:	The disturbance width is driven by the need to survey for UXO over the cable route. The actual disturbance width for cable installation is likely to be considerably less. Maximum number and maximum size of UXOs encountered in the Morgan Array Area. Due to uncertainties in size of UXOs the assessment presents a range, highlighting the most likely size (common) to be encountered. Operations and maintenance phase: The MDS for habitat disturbance associated with inter-array and interconnector cable maintenance includes repairs/reburial of subtidal cables. Decommissioning phase: Parameters for decommissioning will be significantly lower than for the construction phase as sandwave clearance and pre-lay preparations will not be required in advance of cable removal and cable protection and scour protection are assumed to be left *in situ*. MDS assumes the complete removal of all wind turbine and OSP foundations and cables; piles will be cut below the seabed.

Potential impact	Phase[a]			Maximum Design Scenario	Justification
	C	O	D		
				– 420,000 m^2 from seven reburial events (one every five years) affecting up to 3,000 m per reburial event – 4,400,000 m^2 from 12 repair events (three every 10 years) affecting up to 20,000 m per cable repair event – Assuming 20 m width seabed disturbance for repair and remedial burial. Operations and maintenance phase up to 35 years. **Decommissioning phase** Temporary subtidal habitat loss/disturbance due to: • Cable removal: disturbance from the removal of 390 km of inter-array cables and 60 km of interconnector cables • Jack-up events: disturbance from the use of jack-up vessels during foundation removal • Anchor placements: habitat disturbance from anchor placements during cable removal.	
Underwater sound during the construction phase impacting fish and shellfish receptors	✓	×	×	**Construction phase** Piling • Pin piles – Wind turbine foundations – jackets: installation up to 64 x four-legged jacket foundations with one pile per leg (a total of up to 256 piles), and each pile with a diameter of 3.8 m installed by impact piling – Wind turbine foundations – gravity base foundations: ground strengthening at up to 10 x gravity base foundations with up to 15 piles per foundation (a total of up to 150 piles), and each pile with a diameter of 4m installed by impact piling – OSP foundations: installation of four OSPs with four-legged jacket foundations, with three piles per leg (a total of 48 piles) and each pile with a diameter of 3.5 m installed by impact piling – Maximum hammer energy of up to 4,400 kJ – Up to two vessels piling concurrently (minimum distance 1,400 m, maximum distance 15 km, between piling vessels) – Wind turbine foundations – jackets: average duration of up to 4.5 hours piling per pile, total duration of piling per wind turbine foundation =18 hours of piling per day (with a cumulative total of up to 1,152 hours)	For pin piling, the largest hammer energy and maximum spacing between concurrent piling events would lead to the largest spatial extent of ensonification at any one time. Drilling may also be undertaken during foundation installation which would also produce potential underwater sound impacts, but piling still represents the maximum design scenario for this impact. Minimum spacing between concurrent piling represents the highest risk of injury to fish and shellfish as sound from adjacent foundations could combine to produce a greater radius of effect compared to a single piling event. The maximum separation distance of 15 km is used to limit received sound levels by reducing the area of overlapping sound emission from each of the piling activities.

Potential impact	Phase[a]			Maximum Design Scenario	Justification
	C	O	D		
				– Wind turbine foundations – gravity base foundations: average duration of up to 4 hours piling per pile, total average duration of piling per gravity base foundation = 60 hours (with a cumulative total of up to 600 hours for 10 x foundations) – OSP foundations: average duration of up to 4.5 hours piling per pile with a cumulative total of up to 216 hours; installation of OSP foundations over 12 days (=18 hours piling per day) – Consecutive piling over a maximum of 24 hours – Single piling of 94 days for wind turbine foundations (jacket and gravity base foundations) plus 12 days for OSP foundations = 114 days (maximum temporal) or 57 days for two vessels (maximum spatial). Total piling phase (foundation installation) of up to two years within a four-year construction programme. <u>Geophysical site investigation</u> • Geophysical site investigation activities will include the following activities: – Multi-beam echo-sounder (MBES) – Side Scan Sonar (SSS) – Single Beam Echosounder (SBES) – Sub-Bottom Profilers (SBP) – Ultra High Resolution Seismic (UHRS, e.g. sparker) For further detail regarding geophysical sound sources and levels, see Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement. <u>UXO</u> • Clearance of estimated up to 13 UXOs within the Morgan Array Area • A range of UXO sizes assessed from 25kg up to 907kg with 130kg the most likely maximum • For high order detonation donor charges of 1.2kg (most common) and 3.5kg (single barracuda blast charge) • Up to 0.5kg net explosive quantity (NEQ) clearance shot for neutralisation of residual explosive material at each location • Clearance during daylight hours only. MDS is for high order clearance but assessment also considered:	For both pin piled and gravity base foundations, the maximum temporal scenario was assessed on the greatest number of days on which piling could occur based on the number of piles that could be installed within a 24-hour period. Consecutive piling is assumed over a maximum period of 24 hours. For geophysical site investigation we consider the range of geophysical survey activities likely to be undertaken using equipment typically employed for these types of surveys. For UXO clearance we consider the maximum number and maximum size of UXOs encountered in the Morgan Array Area. Due to uncertainties in size of UXOs the assessment presents a range, highlighting the most likely size (common) to be encountered. Most likely and maximum donor charges assessed for high order detonation. Assumption of a clearance shot of up to 0.5kg at all locations although noting that this may not always be required. For low order/low yield clearance, charges are based on the maximum required to initiate a clearance event.

Potential impact	Phase[a] C	O	D	Maximum Design Scenario	Justification
				• Low order clearance charge size of 0.08 kg • Low yield clearance configurations of 0.75 kg charges (up to 4 x 0.75 kg).	
Increased suspended sediment concentrations (SSCs) and associated sediment deposition	✓	✓	✓	**Construction phase** Site preparation: Sandwave clearance: • Sandwave clearance activities undertaken over an approximate 12-month duration within the wider four-year construction programme • Wind turbine and OSP foundations: sandwave clearance has been calculated on the basis of wind turbine foundations and an assumption of clearance at up to 60% of locations. Spoil volume per location has been calculated on the basis of 41 locations supporting the largest suction bucket four-legged jacket foundation with an associated base diameter of 205 m to an average depth of 7.5 m. This equates to a total spoil volume of 10,149,455 m^3 and a volume of 247,548 m^3 per location • Inter-array cables: sandwave clearance along 156 km of cable length, with a width of 80 m, to an average depth of 3 m. Total spoil volume of 5,026,651 m^3 • Interconnector cables: sandwave clearance along 36 km of cable length, with a width of 104 m, to an average depth of 5.1 m. Total spoil volume of 3,060,814 m^3 • Removal of up to 46 km of disused cables. Foundation installation: • Undertaken over an approximate 12-month duration with a 24-month period. • Wind turbine foundations: – installation of 45 with three-legged jacket piles of 5.5 m diameter, drilled to a depth of 75 m at a rate of up to 1.45 m/h. Spoil volume of 2,107 m^3 per pile – installation of 23 conical gravity base foundations with a caisson diameter of 37 m and a sea surface diameter 15 m. Installation requires dredging of a maximum area of 32,761 m^2 to a maximum depth of 10 m • OSPs: installation of one large OSP with six legs with three piles per leg, each 5.5 m drilled to a depth of 75 m at a rate of up to 1.45 m/h. Spoil volume of 2,107 m^3 per pile Cable installation:	**Construction phase** Site preparation: • The volume of material to be cleared from individual sandwaves will vary according to the local dimensions of the sandwave (height, length, and shape) and the level to which the sandwave must be reduced. Based on the available data, it is anticipated that the sandwaves requiring clearance in the array area are likely to be in the range up to 15 m in height. This will be confirmed pre-construction. In all cases the material cleared from the sandwave will be sidecast, (i.e. placed in close proximity) in order that the sediment is readily available for supply for sandwave recovery by natural physical processes. • Site clearance activities may be undertaken using a range of techniques. The suction hopper dredger will result in the greatest increase in suspended sediment and largest plume extent as material is released near the water surface during the relocation of material. In reality plough dredging may be implemented however the volume of material brought into suspension would be reduced as material is ploughed along the bed. • Boulder clearance activities will result in minimal increases in suspended sediment concentrations and have

Potential impact	Phase[a]			Maximum Design Scenario	Justification
	C	O	D		
				• Inter-array cables: Installation via trenching of up to 390 km of cable, with a trench width of up to 3 m and a depth of up to 3 m. Total maximum spoil volume of 1,755,000 m^3. Installed over a period of approximately 12 months. • Interconnector cables: installation via trenching of up to 60 km of cable, with a trench width of up to 3 m and a depth of up to 3 m with a V-shaped cross-section. Total spoil volume of 270,000 m^3. Installed over a period of approximately four-months. **Operations and maintenance phase** Project lifetime of 35-years. • Inter-array cables: repair of up 8 km of cable in one event every three years. Reburial of up to 20 km of cable in one event every five years • Interconnector cables: repair of up to 19.6 km of cable in each of three events every 10 years. Reburial of up to 3 km of cable in one event every five years. **Decommissioning phase** • Scour and cable protection will remain *in situ*. If suction caissons are removed using the overpressure to release them then suspended sediment concentration will be temporarily increased • Inter-array and interconnector cables will be removed and disposed of onshore.	therefore not been considered in the assessment. Foundation installation: • The dredging and site preparation associated with conical gravity base foundations may involve the use of up to 7,000 m^3 of this material as ballast within the structure. The remaining material will be sidecast in close proximity to be available within the sediment cell for transport and sandwave regeneration through natural processes. • Installation of foundations via augured (drilled) operations results in the release of the largest volume of sediment unrestrained through the water column. The greatest volume of sediment disturbance by drilling at individual locations is associated with the largest diameter pile for wind turbine foundations. The selected OSP foundation scenario represents the greatest volume of sediment to be released for a drilling event. Drilling for piles may occur at two locations concurrently. • The greatest drilling rate associated with the largest pile diameter represents the maximum level of increase in suspended sediment concentration. • The MDS assumes that piles may require drilling to the full depth however it is noted that driven piling is more likely for, at least, part of the required depth.

Potential impact	Phase[a] C	O	D	Maximum Design Scenario	Justification
					- The maximum number of three legged jacket pile foundations to be installed for the largest wind turbine generators is 45 out of an array of 68 wind turbine generators. Therefore, for the holistic approach of SSC assessment the remaining 23 foundations are conical gravity based foundations with associated dredging activities. Cable installation: - Cable routes inevitably include a variety of seabed material and in some areas 3 m depth may not be achieved or may be of a coarser nature, which settles in the vicinity of the cable route. The assessment therefore considers the upper bound in terms of suspended sediment and dispersion potential. - Cables may be buried by ploughing, trenching or jetting with trenching or jetting mobilising the greatest volume of material to increase suspended sediment concentrations. **Operations and maintenance phase** - The greatest foreseeable number of cable reburial and repair events is considered to be the MDS for sediment dispersion. **Decommissioning phase** - The removal of cables may be undertaken using similar techniques to those employed during installation, therefore the potential increases in SSC

<table>
<tr><th rowspan="2">Potential impact</th><th colspan="3">Phase[a]</th><th rowspan="2">Maximum Design Scenario</th><th rowspan="2">Justification</th></tr>
<tr><th>C</th><th>O</th><th>D</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>and deposition would be in-line with the construction phase.</td></tr>
<tr><td>Long term habitat loss.</td><td>✓</td><td>✓</td><td>✓</td><td>Construction and operations and maintenance phase
Up to 1,309,252 m² of long-term habitat loss in total across the Morgan Array Area over the lifetime of the Morgan Generation Assets associated with the following:
• Presence of foundations and scour protection: up to 760,452 m² of habitat loss comprising:
– Wind turbine foundations: up to 735,488 m² from the presence of up to 68 wind turbine foundations on suction bucket four-legged jacket foundations with associated scour protection
– OSP foundations: up to 24,964 m² from four OSPs on suction bucket four-legged jacket foundations with associated scour protection
• Presence of cable protection for inter-array and interconnector cables: up to 510,000 m² of habitat loss comprising:
– Inter-array cable protection: 390,000 m² associated with up to 10% of 390 km of inter-array cables (10 m width of cable protection)
– Interconnector cable protection: 120,000 m² for up to 20% of 60 km of interconnector cables (10 m width of cable protection)
• Presence of cable crossing protection: up to 38,800 m² of habitat loss comprising:
– Cable protection for cable crossings for inter-array cables: 28,800 m² from 10 cable crossings (each up to 80 m in length and 36 m in width)
– Cable protection for cable crossings for interconnector cables: 10,000 m² from 10 cable crossings (each up to 50 m in length and 20 m in width).
• Presence of mooring systems (e.g. gravity based anchors) for:
– Up to 25 light buoys and marker buoys (cardinal buoys, although the final number will be determined by MCA/Trinity House requirements
– Up to four power utility buoys for electrified vessel charging
• Presence of mooring systems (e.g. gravity based anchors) for:
– Up to 25 light buoys and marker buoys (cardinal buoys, although the final number will be determined by MCA/Trinity House requirements
– Up to four power utility buoys for electrified vessel charging
Operations and maintenance phase up to 35 years.</td><td>Maximum number of wind turbine and OSP foundations and associated scour protection, maximum length of cables and cable protection resulting in greatest surface area for colonisation.
The estimate of area associated with the introduction of artificial structures from the presence of foundations has been calculated as if the foundations were a solid structure. This is, therefore, likely to be a conservative estimate of the introduction of artificial structures on the basis that the jacket foundations will have a lattice design rather than a solid surface.
The MDS for decommissioning assumes removal of the foundations but that cable and scour protection could be left <i>in situ</i> after decommissioning.</td></tr>
</table>

Potential impact	Phase[a]			Maximum Design Scenario	Justification
	C	O	D		
				Decommissioning phase • Up to 1,252,116 m^2 of permanent subtidal habitat loss due to scour and cable protection left *in situ* post decommissioning.	
EMFs from subsea electrical cabling.	×	✓	×	**Operations and maintenance phase** Presence of inter-array and interconnector cables: • Inter-array cables: between 390 km of inter-array cables of 66 kV to 132 kV • Interconnector cables: up to 60 km of 275 kV high voltage alternation current (HVAC) cables • Minimum burial depth 0.5 m • The MDS assumes up to 10% of inter-array cables and 20% of interconnector cables may require cable protection • Cable protection: cables will also require cable protection at asset crossings (up to 10 crossings for inter-array cables and up to 10 crossings for interconnector cables) • Operations and maintenance phase of up to 35 years.	Maximum length of cables across the array area routes and minimum burial depth (the greater the burial depth, the more the EMF is attenuated).
Introduction and colonisation of hard structures	✓	✓	✓	**Construction and operations and maintenance phase** Introduction of up to 1,791,198 m^2 of artificial structures over the lifetime of the Morgan Generation Assets comprising: • Wind turbine and OSP foundations: Presence of up to 68 wind turbines and four OSPs on suction bucket jacket foundations • Scour protection: Presence of scour protection for wind turbine foundations and OSP foundations • Cable protection: Presence of cable protection associated with up to 10% of the 390 km of inter-array cables and up to 20% of the 60 km of interconnector cables • Cable crossing protection: Presence of cable protection for cable crossings, 10 cable crossings for inter-array cables (each up to 80 m in length and 36 m in width) and 10 cable crossings for interconnector cables (each up to 50 m in length and 20 m in width). Operations and maintenance phase up to 35 years	Maximum number of wind turbine and OSP foundations and associated scour protection, maximum length of cables and cable protection resulting in greatest surface area for colonisation. The estimate of area associated with the introduction of artificial structures from the presence of foundations has been calculated as if the foundations were a solid structure. This is, therefore, likely to be a conservative estimate of the introduction of artificial structures on the basis that the jacket foundations will have a lattice design rather than a solid surface. The MDS for decommissioning assumes removal of the foundations but that cable and scour protection could be left *in situ* after decommissioning.

Potential impact	Phase[a] C	O	D	Maximum Design Scenario	Justification
				Decommissioning phase • Up to 1,252,116 m^2 of artificial structures remaining post-decommissioning due to scour and cable protection being left *in situ*.	
Disturbance/ remobilisation of sediment-bound contaminants	✓	×	✓	**Construction phase** Maximum design scenario as described above for increased SSC and associated deposition during the construction phase. **Decommissioning phase** Maximum design scenario as described above for increased SSC and associated deposition during the decommissioning phase.	The justification for the disturbance/remobilisation of sediment-bound contaminants MDS is the same as for the increased SSC and associated deposition impact above, as this MDS results in the release of the largest volume of sediment and associated contaminants.
Injury due to increased risk of collision with vessels (basking shark only)	✓	✓	✓	**Construction phase** • Up to a total of 69 construction vessels on site at any one time (22 main installation and support vessels, eight tug/anchor handlers, seven cable lay installation and support vessels, one guard vessel, six survey vessels, eight seabed preparation vessels, 12 Crew Transfer Vessels (CTVs), three scour protection installation vessels and two cable protection installation vessels) • Up to 1,929 installation vessel movements (return trips) during construction (521 main installation and support vessels, 74 tug/anchor handlers, 56 cable lay installation and support vessels, 50 guard vessels, 31 survey vessels, 19 seabed preparation vessels, 1,135 CTVs, 41 scour protection installation vessels and two cable protection installation vessels) • Maximum offshore construction duration of up to 4 years. **Operations and Maintenance Phase** • Up to a total of 16 operations and maintenance vessels on site at any one time (five CTVs/workboats, three jack-up vessels, three cable repair vessels, four Service Operation Vessels (SOV) or similar and one excavators/backhoe dredgers) • Up to 719 operations and maintenance vessel movements (return trips) each year (608 CTVs/workboats, 25 jack-up vessels, six cable repair vessels, 78 SOVs or similar and two excavators/backhoe dredgers) • Operational lifetime of up to 35 years.	The MDS considers the maximum number of vessels on site at any one time and largest numbers of round trips during each phase of the Morgan Generation Assets. This represents the broadest range of vessel types and movements, and therefore greatest potential for collision risk.

Potential impact	Phase[a]			Maximum Design Scenario	Justification
	C	O	D		
				Decommissioning Phase • Vessels used for a range of decommissioning activities such as removal of foundations.	

3.7.1.2 The MDS when considering the impact on fish and shellfish ecology relates to the largest amount of seabed area disturbance/loss (i.e. resulting from the greatest footprint of wind turbine foundations, longest cable route and largest OSP area etc.), the maximum release of material into the water column (i.e. for increases in SSC), the greatest numbers of vessels and vessel trips during each project phase, and the largest spatial areas and temporal ensonification. The MDS has been defined for each impact pathway using the parameters in Volume 1, Chapter 3: Project description of the Environmental Statement as those having the potential to result in the greatest effect for that particular pathway and therefore may differ between impact pathways.

3.8 Measures adopted as part of the Morgan Generation Assets

3.8.1.1 For the purposes of the EIA process, the term ‘measures adopted as part of the project’ is used to include the following measures (adapted from IEMA, 2016):

- Measures included as part of the project design. These include modifications to the location or design envelope for the Morgan Generation Assets which are integrated into the application for consent. These measures are secured through the consent itself through the description of the development and the parameters secured in the DCO and/or marine licence (referred to as primary mitigation in IEMA, 2016)
- Measures required to meet legislative requirements, or actions that are generally standard practice used to manage commonly occurring environmental effects and are secured through the DCO requirements and/or the conditions of the marine licence (referred to as tertiary mitigation in IEMA, 2016).

3.8.1.2 A number of measures (primary and tertiary) have been adopted as part of the Morgan Generation Assets to reduce the potential for impacts on fish and shellfish ecology. These are outlined in Table 3.19 below. As there is a secured commitment to implementing these measures for the Morgan Generation Assets they have been considered in the assessment presented in section 3.9 below (i.e. the determination of magnitude and therefore significance assumes implementation of these measures).

3.8.1.3 Where significant effects have been identified, further mitigation measures (referred to as secondary mitigation in IEMA, 2016) have been identified to reduce the significance of effect to acceptable levels following the initial assessment. These are measures that could further prevent, reduce and, where possible, offset any adverse effects on the environment. These measures are set out, where relevant, in section 3.9 below.

3.8.1.4 The Morgan Generation Assets design has been revised from the PEIR to the Environmental Statement following stakeholder consultation, including a reduction in the number of wind turbine foundations from 107 to 96. The number of wind turbine foundations has been reduced by approximately 10% subsequently reducing the number of foundations that require piling. Monopile foundations (as presented in the PEIR) have also been removed from the Project Design Envelope (PDE), and pin piles only have been considered in the Environmental Statement. As such, the maximum hammer energy of 5,500 kJ (presented in the PEIR for monopiles) has not been taken forward to the Environmental Statement. A proportion of hammer energy is converted into waterborne acoustic energy going into the water column and large hammer energies may result in increased peak sound levels received by fish. As such, the removal of monopile foundations and the maximum hammer energy of 5,500 kJ from the design envelope has reduced the range at which instantaneous injury, mortality and behavioural effects could occur to fish from received sound.

Table 3.19: Measures adopted as part of the Morgan Generation Assets.

Measures adopted as part of the Morgan Generation Assets	Justification	How the measure will be secured
Primary measures: Measures included as part of the project design		
Development of and adherence to a Marine Mammal Mitigation Protocol (MMMP), based on the Outline MMMP (Document Reference J17) that requires implementation of an initiation stage of a piling soft start and ramp-up.	This measure will minimise the likelihood of injury from elevated underwater sound to marine mammal and some fish species in the immediate vicinity of piling operations, allowing reactive individuals to move away from the area before sound levels reach a level at which injury may occur.	MMMP secured as a condition of the deemed marine licence(s) within the Draft DCO (Document Reference C1).
Development of and adherence to a MMMP (to be developed in accordance with the Outline MMMP (Document Reference J17)) which sets a maximum separation limit of 15 km for concurrent piling.	Commitments made around maximum separation during concurrent piling will minimise the likelihood of disturbance to marine mammal and fish species in the immediate vicinity of piling operations, by limiting the ensonified area during concurrent piling. Where piling occurs concurrently a maximum separation distance of 15 km is used to limit the ensonified area as there is greater overlap when closer together.	MMMP secured as a condition of the deemed marine licence(s) within the Draft DCO (Document Reference C1).
Development of and adherence to a MMMP (to be developed in accordance with the Outline MMMP (Document Reference J17)) which sets a minimum separation limit of 1.4 km for concurrent piling.	Commitments made around minimum separation during concurrent piling will minimise the likelihood of injury to marine mammal and fish species in the immediate vicinity of piling operations, by limiting the spatial overlap of areas of ensonification during concurrent piling. Where piling occurs concurrently, a minimum separation distance of 1.4 km is used to minimise the potential for effects due to direct overlap of concurrent piling.	MMMP secured as a condition of the deemed marine licence(s) within the Draft DCO (Document Reference C1).
Development of and adherence to a MMMP (to be developed in accordance with the Outline MMMP (Document Reference J17)) which sets the limit on maximum hammer energy used during concurrent piling at 3,000 kJ and during the single event piling at 4,400 kJ.	Commitments made around concurrent piling will minimise the likelihood of injury to marine mammal and fish species in the immediate vicinity of piling operations, by reducing the ensonified area during concurrent piling.	MMMP secured as a condition of the deemed marine licence(s) within the Draft DCO (Document Reference C1).

Measures adopted as part of the Morgan Generation Assets	Justification	How the measure will be secured
Development and adherence to a MMMP (to be developed in accordance with the Outline MMMP (Document Reference J17) that requires implementation of a mitigation hierarchy with regard to UXO clearance that follows: • Avoid UXO • Clear UXO with low order techniques • Clear UXO with high order techniques. Low order techniques or avoidance of confirmed UXO are not always possible and are dependent upon the individual situations surrounding each UXO.	Low order techniques generate less underwater sound than high order techniques and therefore present a lower risk to sound-sensitive receptors such as marine mammals and fish during UXO clearance. Noting the position statement from statutory authorities on UXO clearance (UK Government, 2022), the option to clear UXOs with low order techniques has been considered as a potential primary mitigation measure as part of this assessment. Note, however, that low order techniques are not always possible and are dependent upon the individual situations surrounding each UXO. Given that it is possible that high order detonation may be used, the Outline MMMP includes mitigation to reduce the likelihood of injury from UXO clearance. Please see below. The Outline underwater sound management strategy (Document Reference J16) includes potential further mitigation options, should the measures in the MMMP (Document Reference J17) not reduce impacts, such that there will be no residual significant effect from the project.	MMMP secured as a condition of the deemed marine licence(s) within the Draft DCO (Document Reference C1).
Development and adherence to an Offshore Construction Method Statement (CMS) including Cable Specification and Installation Plan (CSIP) which will include cable burial where possible and cable protection.	To minimise potential impact from the cables and removal of cables a commitment to bury cables where possible has been made in accordance with the specific policies set out in the Welsh Marine Plan (Welsh Government, 2019) and additionally the North West Inshore and North West Offshore Coast Marine Plans (MMO, 2021). The Applicant recognises that the best form of cable protection is achieved through cable burial to the required depths, according to the results of a Cable Burial Risk Assessment and Burial Assessment Study, which will be included within the CSIP. The burial methodology should select the appropriate tools to endeavour to achieve burial to the required depth of lowering in a single pass, seeking to avoid burial methods that require multiple passes with a burial tool in order to achieve lowering of the cable. While burial of cables will not reduce the strength of EMF, it does increase the distance between cables and fish and shellfish receptors, thereby potentially reducing the potential effect on those receptors.	Offshore CMS secured as a condition of the deemed marine licence(s) within the Draft DCO (Document Reference C1).

Measures adopted as part of the Morgan Generation Assets	Justification	How the measure will be secured
Development and adherence to an Offshore CMS which includes a CSIP which require material arising from drilling and/or sandwave clearance to be deposited in close proximity to the works.	To retain material within the sediment cell and maintain sediment transport regimes.	Offshore CMS is as a condition of the deemed marine licence(s) within the Draft DCO (Document Reference C1).
Tertiary measures: Measures required to meet legislative requirements, or adopted standard industry practice		
Development of and adherence to a MMMP, which will be developed in accordance with the Outline MMMP (Document Reference J17) included as part of the application. The Outline MMMP (Document Reference J17) present appropriate mitigation for activities that could potentially lead to injurious effects on marine mammals including: piling, UXO clearance and some types of geophysical activities. Piling: for the purpose of developing the MMMP (Document Reference J17) as an annex of the Underwater sound management strategy (Document Reference J13), a mitigation zone will be defined based on the maximum predicted injury range from the dual metric sound modelling for the maximum spatial scenario (pin piles) and across all marine mammal species. The Outline MMMP (Document Reference J17) sets out the measures to apply in advance of and during piling activity including the use of: • Marine Mammal Observers (MMOs) • Passive Acoustic Monitoring (PAM) • Acoustic Deterrent Devices (ADD) Therefore following the latest JNCC guidance (JNCC, 2010a). UXO clearance: Measures including visual and acoustic monitoring, the use of an ADD and soft start charges will be applied to deter animals from the mitigation zone as defined by sound modelling for the largest possible UXO following the latest JNCC guidance (JNCC, 2010b). Geophysical surveys: Mitigation for injury during high resolution geophysical surveys using a sub-	The implementation of an approved MMMP will mitigate for the risk of physical or permanent auditory injury to marine mammals within a pre-defined ‘mitigation zone’ for each activity. The mitigation zone is determined considering the largest injury zone across all species for each relevant activity. The use of an approved MMMP will also minimise the potential for collision risk, or potential injury to, marine mammals and other marine megafauna (e.g. basking shark and sea turtles). The MMMP will include visual and acoustic monitoring as a minimum over the defined mitigation zones to ensure animals are clear before the activity commences. Additional measures to deter animals from injury risk zones may be applied in some instances (e.g. ADDs or soft start charges). The MMMP will be developed on the basis of the most recent published statutory guidance and in consultation with key stakeholders. Benefits derived from the MMMP are also expected to apply to some fish species.	MMMP secured as a condition of the deemed marine licence(s) within the Draft DCO (Document Reference C1).

Measures adopted as part of the Morgan Generation Assets	Justification	How the measure will be secured
bottom profiler from a conventional vessel will involve the use of MMOs and PAM to ensure that the risk of injury over the defined mitigation zone is reduced in line with JNCC guidance (JNCC, 2017). Soft start is not possible for some SBP equipment but will be applied for other high resolution surveys where possible. Note also, some multi-beam surveys in shallow waters (<200 m) are not subject to the development of and adherence requirements of mitigation.		
Development of, and adherence to, an Offshore Environmental Management Plan (EMP). The Offshore EMP will include development of a MPCP which will include planning for accidental spills, address all potential contaminant releases and include key emergency details.	Measures will be adopted to ensure that the potential for release of pollutants from construction, operations and maintenance, and decommissioning plant is minimised. In this manner, accidental release of potential contaminants from rigs and supply/service vessels will be strictly controlled, thus providing protection for marine life across all phases of the Morgan Offshore Wind Project development.	Offshore EMP secured as a condition of the deemed marine licence(s) within the Draft DCO (Document Reference C1).
The Offshore EMP will include actions to minimise INNS, including a biosecurity plan to limit spread and introduction of INNS.	These measures will aim to manage and reduce the risk of potential introduction and spread of INNS so far as reasonably practicable to best protect the biological integrity of the local natural environment and communities.	Offshore EMP secured as a condition of the deemed marine licence(s) within the Draft DCO (Document Reference C1).
Offshore EMP will be issued to all Project vessel operators, requiring them to: • not deliberately approach basking sharks and other marine megafauna • keep vessel speed to a minimum where deemed to be appropriate • avoid abrupt changes in course or speed should basking sharks or other marine megafauna approach the vessel, where appropriate and possible taking into account all technical considerations. Codes of Conduct within the Outline plan for rafting birds and marine mammals (Document Reference J15) will be adhered to at all times.	To minimise the potential for collision risk, or potential injury to, basking shark and other marine megafauna.	Offshore EMP secured as a condition of the deemed marine licence(s) within the Draft DCO (Document Reference C1).

Measures adopted as part of the Morgan Generation Assets	Justification	How the measure will be secured
Development of and adherence to an Outline underwater sound management strategy (Document Reference J13) that includes consideration of Noise Abatement Systems (NAS) as part of mitigation options. A commitment to considering Noise Abatement Systems (NAS) as part of mitigation options in the Underwater sound management strategy, which will be developed in accordance with the Outline underwater sound management strategy (Document Reference J13), will be made as part of a stepped strategy post consent and following the mitigation hierarchy – avoid, reduce, mitigate.	To mitigate for the likelihood of physical or permanent auditory injury or behavioural impacts to fish and marine mammals.	Underwater sound management strategy as a condition of the deemed marine licence(s) within the Draft DCO (Document Reference C1).

3.9 Assessment of significant effects

3.9.1 Overview

3.9.1.1 The impacts of the construction, operations and maintenance, and decommissioning phases of the Morgan Generation Assets have been assessed on fish and shellfish ecology. The potential impacts arising from the construction, operations and maintenance and decommissioning phases of the Morgan Generation Assets are listed in Table 3.18, along with the MDS against which each impact has been assessed.

3.9.1.2 A description of the potential effect on fish and shellfish ecology receptors caused by each identified impact is given below.

3.9.2 Temporary habitat loss/disturbance

3.9.2.1 The construction, operations and maintenance, and decommissioning activities on the wind turbine foundations and OSP foundations, and inter-array and interconnector cables may lead to temporary habitat loss/disturbance. The MDS is represented by jack-up events, cable installation, sandwave clearance, anchor placement, and cable removals, and is summarised in Table 3.18.

Construction phase

Magnitude of impact

3.9.2.2 The installation of the Morgan Generation Assets infrastructure within the fish and shellfish ecology study area will lead to temporary habitat loss/disturbance. The MDS accounts for up to 61,422,400 m^2 of temporary habitat loss/disturbance during the construction phase (Table 3.18). This equates to approximately 6.43% of the Morgan Generation Assets area overall, although only a small proportion of this will be impacted at any one time.

3.9.2.3 Jack-up events for the installation of the foundations for the wind turbines and OSPs will result in up to 825,600 m^2 of temporary habitat loss/disturbance. Up to four jack-up events will be necessary for each of the 96 wind turbine foundations as well as two jack-up events for each of the four OSP foundations.

3.9.2.4 The depressions resulting from jack-up events will infill over time, although may remain on the seabed for a number of years, as demonstrated by monitoring studies of UK offshore wind farms (BOWind, 2008; EGS, 2011). Monitoring at the Barrow offshore wind farm showed depressions were almost entirely infilled 12 months after construction (BOWind, 2008). Monitoring at the Lynn and Inner Dowsing offshore wind farm also showed some infilling of the footprints, although the depressions were still visible two years post-construction (EGS, 2011). In areas where mobile sands are present, such as in the Morgan Array Area, jack-up depressions are likely to be temporary features which will only persist for a period of months to a small number of years. Specifically, evidence from the three years post-construction survey of the nearby Walney Wind Farm Extension showed that fine sands and muds in this area were highly mobile and likely to return to a uniform relatively undisturbed habitat within this short period of time (CMACS, 2014a).

3.9.2.5 Cable installation (including pre-lay preparation such as boulder and sandwave clearance) of inter-array and interconnector cables may result in up to 21,384,000 m^2 temporary habitat loss/disturbance. The components of this activity include the installation of 390 km of inter-array cable, and 60 km of interconnector (assuming 100% of the cable is buried). Seabed preparation activities are expected to be required for inter-array cables and interconnector cables and for the purpose of the MDS, boulder clearance has been expected to occur for up to 60% of inter-array cables, and 40% of interconnector cables. Sandwave clearance is expected to be required for up to 40% of inter-array cables, and 60% of interconnector cables in line with the MDS.

3.9.2.6 Sand wave clearance and deposition may result in up to 36,473,840 m^2 of temporary habitat loss/disturbance as a result of the deposition of 10,149,455 m^3 of material associated with seabed preparation for wind turbine and OSP foundations, 5,026,651 m^3 of material associated with seabed preparation for inter-array cables, and 3,060,841 m^3 of material associated with seabed preparation for interconnector cables. The total footprint of seabed affected has been calculated, for the purposes of modelling MDS, assuming a mound of 86ornicam thickness of 0.5 m height, although it should be noted that real mounds may be taller and more unevenly distributed. Any mounds of cleared material will, however, erode over time and displaced material will re-join the natural sedimentary environment, gradually reducing the size of the mounds.

3.9.2.7 Anchor placement may result in up to 1,000,000 m^2 of habitat disturbance from two 100 m^2 anchor set placements every 500 m per inter-array cable link during installation.

3.9.2.8 Additionally, the removal of disused cables within the fish and shellfish ecology study area may result in up to 920,000 m^2 of temporary habitat loss/disturbance from the removal of 46,000 m of disused cables.

3.9.2.9 A recent study reviewed the effects of cable installation on subtidal sediments and habitats, drawing on monitoring reports from over 20 UK offshore wind farms (RPS, 2019). This review showed that sandy sediments recover quickly following cable installation, with trenches infilling quickly following cable installation and little or no evidence of disturbance in the years following cable installation. It also presented evidence that remnant cable trenches in coarse and mixed sediments were conspicuous for several years after installation. However, these shallow depressions were of limited depth (i.e. tens of centimetres) relative to the surrounding seabed, over a horizontal distance of several metres and therefore did not represent a large shift from the baseline environment (RPS, 2019). Remnant trenches (and anchor drag marks) were observed years following cable installation within areas of muddy sand sediments, although these were also found to be relatively shallow features (i.e. a few tens of centimetres).

3.9.2.10 The maximum duration of the offshore construction phase for the Morgan Generation Assets is up to four years. Within this time period, construction activities will occur intermittently and will be spread across the full allotted four years with only a small proportion of the MDS footprint being affected at any one time.

3.9.2.11 The impact on most subtidal IEFs is predicted to be of local spatial extent, short to medium-term duration, intermittent and of high reversibility. It is predicted that the impact will affect only some of the receptors directly. The magnitude is therefore, considered to be **low**.

3.9.2.12 The magnitude of impact on herring and sandeel, due to their ecological and commercial importance, are considered in terms of direct impact from the infrastructure in the broader context of potential spawning and habitation grounds within the fish and shellfish ecology study area.

3.9.2.13 For herring, most stations sampled during site-specific surveys throughout the Morgan Generation Assets were composed of unsuitable sediment types for herring spawning due to elevated mud content above the threshold of 5% (Reach *et al.*, 2013, Figure 3.2; Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement). In the context of the fish and shellfish ecology study area, this represents a very small proportion of preferred sediment, and the Morgan Generation Assets does not overlap with any recorded important herring spawning or nursery grounds (Coull *et al*., 1998). Therefore, for herring, the magnitude is considered to be **negligible**.

3.9.2.14 For sandeel, most (77%) of the surveyed stations comprised mud content in excess of 4% and were therefore outside of preferred sandeel habitat composition. In terms of overlap with sandeel spawning grounds, 39.5% of the Morgan Generation Assets overlaps high intensity sandeel spawning ground and 60.4% overlaps low intensity spawning ground. It is acknowledged that these percentages refer to overlap with mapped spawning grounds, which do not represent a ‘hard’ boundary and are subject to change over time; these percentages are provided as purely contextual information to support the assessment. In the context of the regional fish and shellfish ecology study area, which is almost entirely encompassed by low and high intensity sandeel spawning grounds, this represents a proportionally small area of disturbance to potential spawning habitats; equating to 7.8% of high intensity spawning grounds and 0.6% of low intensity spawning grounds within the fish and shellfish ecology study area. On the basis of the widespread nature of mapped spawning and habitation grounds for sandeel, and the comparatively small footprint of temporary habitat loss and/or disturbance associated with the Morgan Generation Assets the magnitude is considered to be **low**.

Sensitivity of receptor

Marine species

3.9.2.15 In general, mobile fish species can avoid areas subject to temporary habitat disturbance (Ecological Marine Unit (EMU), 2004). The most vulnerable species are likely to be shellfish which are much less mobile than fish, with fragile slow-recruiting species being most highly impacted by short-term disturbance events (MacDonald *et al*., 1996). For example, egg bearing lobster are thought to be more restricted to an area based on a mark and recapture study in Norway which showed that 84% of berried female lobster remained within 500 m of their release site (Agnalt *et al*., 2007). Evidence from other stocks around the world are less clear, with limited movement recorded for some stocks and long-distance migrations documented for other stocks (Campbell and Stasko,1985; Comeau and Savoie, 2002).

3.9.2.16 Indirect effects on fish and shellfish species also include loss of feeding habitat and reduced prey availability. For example, crab and other crustaceans and small benthic fish species (as well as other benthic species; see Volume 2, Chapter 2: Benthic subtidal ecology of the Environmental Statement) are considered important prey species for larger fish. However, since this impact arising from construction is predicted to affect only a small proportion of seabed habitats in the fish and shellfish ecology study area at any one time, with similar habitats (and prey species) occurring throughout the fish and shellfish ecology study area (see Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement for habitat distributions and extents), these effects are likely to be limited and reversible. Conversely, benthic disturbance during the construction phase will also expose benthic infaunal species from the sediment (see Volume 4, Annex 2.1: Benthic subtidal ecology technical report of the Environmental Statement), potentially offering foraging opportunities to some opportunistic scavenging fish and shellfish species immediately after completion of works. The implications of changes in fish and shellfish prey species in the short-term are also discussed for higher trophic level receptors (i.e. marine mammals and birds) in Volume 2, Chapter 4: Marine mammals of the Environmental Statement, and Volume 2, Chapter 5: Offshore ornithology of the Environmental Statement, respectively.

3.9.2.17 Within the Irish Sea, the year one post-construction monitoring of the Walney Wind Farm Extension found a significantly degraded benthic and demersal fish and shellfish community overall surrounding the installed generation assets infrastructure compared to pre-construction baseline reference sites within the Walney Array Area (CMACS, 2012). No significant difference was found between the biodiversity indices for communities associated with the pre-construction and post-construction Walney transmission assets, including inter-array cables (CMACS, 2012). Follow-up surveys three years post-construction showed a similar pattern, with a significantly reduced abundance within the communities recorded. However, the difference between pre-construction and three year post-construction studies was smaller than the difference between pre-construction and year one post-construction surveys, indicating a slow trend of recovery towards baseline conditions and there was little change noted in the communities present overall (CMACS, 2014a).

3.9.2.18 The recoverability and rate of recovery of an area after large scale seabed disturbance (e.g. dredging or trawling activities) is linked largely to the substrate type (Newell *et al*., 1998; Desprez, 2000), with recovery rates improved by the presence of conspecifics within a radius of 6 km following habitat disturbance (Lambert *et al.*, 2014), which applies to some species of interest within the fish and shellfish ecology study area (see Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement for detailed habitat distributions and spawning grounds). Gravelly and sandy habitats, similar to those found in the fish and shellfish ecology study area, have been shown to return to baseline species abundance after approximately 5 to 10 years (Foden *et al*., 2009), depending on replenishment rates related to tidal stress, currents, and availability and transference of conspecifics from less impacted to more impacted environments. The early stages of this process were noted in the Walney Wind Farm Extension year 3 post-construction survey (CMACS, 2014a).

Shellfish species

3.9.2.19 A number of commercially important shellfish species such as edible crab, European lobster, *Nephrops,* king and queen scallop, and velvet swimming crab are known to inhabit the fish and shellfish ecology study area. Habitat loss in this area during construction activities will represent a low magnitude overall during cable laying and seabed preparation. While the total habitat loss/disturbance footprint represents a relatively large proportion of the area of the Morgan Generation Assets only a small proportion of this area would be affected at any one time with relatively rapid recovery of sediments following these disturbances based on analysis of recovery trends at other offshore wind farms (RPS, 2019). Following this, recovery of associated communities is also expected (see Volume 2, Chapter 2: Benthic subtidal ecology of the Environmental Statement) including shellfish populations moving back into these impacted areas.

3.9.2.20 King and queen scallop are known to be present within the fish and shellfish ecology study area and are targeted by commercial fisheries activities (see Volume 2, Chapter 6: Commercial fisheries of the Environmental Statement). Scallop are predominantly sessile organisms, however, they do have the ability to swim, which is ordinarily used as an escape response, although limited in distance (Marshall and Wilson, 2008). With increased size and age of queen scallop individuals were found to be able to travel increased distances in response to a disturbance event (Schmidt *et al*., 2008), although repeated disturbances of up to four events within 28 days has been found to significantly decrease reaction times to disturbances (Laming *et al*., 2013). It has been documented that scallop have been able to move up to 30 m from a release site during a tagging study (Howell and Fraser, 1984). This response may allow improved resilience to temporary habitat loss/disturbance compared to other sessile organisms, by being able to avoid areas of direct disturbance and relocate to areas nearby.

3.9.2.21 Both king and queen scallop tend to occur in aggregations as their larval distribution is reliant on relatively unpredictable hydrodynamics (Brand, 1991, Delargy*,* 2019). As both king and queen scallop are expected to continue spawning outside the project boundaries, and within unimpacted areas of the fish and shellfish ecology study area, and suitable habitat for settlement will remain following cessation of construction, it is predicted that scallop will continue to be recruited into the Morgan Array Area. King and queen scallop will likely recover well from any disturbance due to short term habitat loss. This is supported by the MarLIN sensitivity assessment for king scallop (Marshall and Wilson, 2008) which concluded king scallop have a high recovery potential (i.e. recovery within months, with full recovery in a small number of years).

3.9.2.22 Reported recovery potential differed between king and queen scallop, with king scallop found to recover to their population carrying capacity within less than three years following temporary habitat loss in areas both closed and open to fishing (Kaiser *et al*., 2018). For queen scallop however, numbers of individuals remained consistent pre- and post-disturbance, with full recovery noted by the first re-sampling one-year post-disturbance. These relatively rapid recovery times are known to be broadly typical of soft sediment epifauna following disturbance events resulting in temporary habitat loss such as trawling or dredging (Hiddink *et al*., 2017). Based on these relatively rapid recovery times into recently disturbed habitats, commercially important queen and king scallop populations are expected to show resilience to temporary habitat loss and/or disturbance (Dignan *et al*., 2014). Queen and king scallop are protected under IoM management schemes, wherein queen scallop are protected against unlicenced towed gear fishing under IoM bylaws (SD 2018/0186 – IoM Government, 2018), and king scallop are protected by a range of measures, such as the IoM King Scallop Long-Term Management Plan 2021 (IoM Government, 2021), which specified alterations to fishing rights and technical specifications of dredges and tow-bars to minimise damage where possible. These measures have the potential to combine with natural resilience to temporary habitat disturbance to aid in the protection of these commercially important scallop populations.

3.9.2.23 Larger crustacea (e.g. *Nephrops* and European lobster) are classed as equilibrium species (Newell *et al*., 1998) and are only capable of recolonising an area once the original substrate type has returned. The sensitivity of these fish and shellfish IEFs is therefore higher than for smaller benthic organisms which move in and colonise new substrate immediately after the effect. Therefore, although recovery of benthic assemblages may occur over relatively fast timescales (i.e. within one to two years; see Volume 2, Chapter 2: Benthic subtidal ecology of the Environmental Statement), recovery of the equilibrium species may take up to ten years in some areas of coarse sediments (Phua *et al*., 2002). It is notable that the absence of larger crustacean and flatfish species due to habitat disturbance can increase overall benthic abundance, due to a lowered rate of predation (Skold *et al*., 2018), suggesting resilience among smaller fish and shellfish species which could contribute to a minor short-term change in ecosystem function, which is likely to recover to the baseline in the long-term.

3.9.2.24 Construction activities (including inter-array and interconnector cable installation) within the fish and shellfish ecology study area may also impact on undetermined spawning and nursery habitats for *Nephrops* (Coull *et al*., 1998), as these areas overlap with the entire fish and shellfish ecology study area (Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement), and any impact will affect these *Nephrops* individuals and habitats directly. Larval settlement will also increase the rate of recovery in an area (Phua *et al*., 2002), with shellfish (*Nephrops*) spawning and nursery habitats in the vicinity of the fish and shellfish ecology study area (see Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement) potentially increasing the rate of recovery in disturbed areas.

3.9.2.25 A recent study by Roach *et al*. (2018) undertaken during construction of the Westermost Rough Offshore Wind Farm located on the northeast coast of England, within a European lobster fishing ground, found that the size and abundance of lobster individuals increased following temporary closure or the area for construction of the windfarm. This study indicates that the activities associated with construction of the wind farm, which included installation of wind turbine foundations and cables, did not negatively impact on resident lobster populations, and instead allowed some respite from fishing activities for a short time-period before reopening following construction (Roach *et al*., 2018).

Fish species

3.9.2.26 The fish species within the fish and shellfish ecology study area are likely to be most sensitive to temporary habitat loss are those species that spawn on or near the seabed (e.g. herring, sandeel and elasmobranchs, including spotted ray). Other species are less likely to be impacted by temporary habitat loss from construction activities, especially most highly mobile elasmobranch species. Spotted ray (and other ray species), which spawn in demersal habitats, have broadscale low intensity spawning grounds overlapping the Morgan Array Area (Ellis *et al*., 2012), and these species have significant amounts of other habitat available to it within the rest of the fish and shellfish ecology study area, suggesting resilience in the local population to temporary habitat loss.

Herring and sandeel

3.9.2.27 Of the IEF fish species that spawn on or near the seabed, sandeel and herring are known to spawn at low to high intensities within the fish and shellfish ecology study area (see Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement). Therefore, any significant seabed disturbance activities carried out during spawning periods may result in mortality of eggs and reduced spawning opportunity due to removal of suitable habitat. Further, physical disturbance to sandeel habitats may also lead to direct effects on adult and juvenile sandeel (e.g. increased mortality), where individuals are not able to colonise viable sandy habitats in the immediate vicinity, or where habitats may be at carrying capacity (Wright *et al.,* 2000). It has been noted that sandeel species have high sensitivity to the impact of direct physical disturbance (Wright *et al.,* 2000). Sandeel may also be particularly vulnerable during their winter hibernation period when they bury themselves in the seabed substrates and are therefore less mobile.

3.9.2.28 However, the Morgan Array Area was found to be largely unsuitable for both herring and sandeel and therefore the potential effects of habitat loss/disturbance on these species is expected to be limited within the Morgan Array Area. Given the presence and extent of suitable substrate types across the wider fish and shellfish ecology study area, the proportion of suitable habitats with potential to be affected by the Morgan Generation Assets is considered relatively small.

3.9.2.29 Recovery of sandeel populations would be expected following construction activities, with the rate of recovery dependent on the recovery of sediments to a condition suitable for sandeel recolonisation. Effects of offshore wind farm construction (Jensen *et al*., 2004) and operations and maintenance (i.e. post-construction) activities (van Deurs *et al*., 2012) on sandeel populations have been examined through short term and long-term monitoring studies at the Horns Rev offshore wind farm in the Baltic Sea, Denmark. These monitoring studies have shown that offshore wind farm construction and operations and maintenance activities have not led to significant adverse effects on sandeel populations and that recovery of sandeel occurs quickly following construction activities.

3.9.2.30 The recovery potential of sandeel populations can also be inferred from a study by Jensen *et al*. (2010), which found sandeel populations mix within fishing grounds to distances of up to 28 km. This suggests that some recovery of adult populations is likely following construction activities, with adults recolonising suitable sandy and gravelly substrates where available from adjacent un-impacted habitats. Recovery may also occur through larval recolonisation of suitable sandy sediments with sandeel larvae likely to be distributed throughout the fish and shellfish ecology study area during spring months following spawning in winter/spring (see Ellis *et al*., 2012; and Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement).

3.9.2.31 A recent monitoring study conducted at the Beatrice Offshore Wind Farm completed a post construction sandeel survey where sandeel abundance were compared pre and post construction (BOWL, 2021a). The results showed that sandeel abundance either increased or remained at similar levels when comparing abundance from 2014 to 2020, with offshore construction commencing in April 2017. The study concluded that there was no evidence that the construction of Beatrice Offshore Wind Farm resulted in adverse impacts on the local sandeel population. This conclusion should be seen in the context of general increase in sandeel populations in the area surrounding the Beatrice Offshore Wind Farm (using ICES set Total Allowable Catch (TAC) as an indicator), and an increase in bycatch abundance from the sandeel dredging, which may indicate the Beatrice Offshore Wind Farm site was generally healthier in 2020 than it was in 2014 (BOWL, 2021a). This study builds on previous work conducted by Stenberg *et al*. (2011) which concluded that the construction of the Horns Rev 1 Offshore Wind Farm posed neither a threat nor direct benefit to sandeel over a seven-year period.

3.9.2.32 Infrastructure installation will not occur simultaneously across the full Morgan Generation Assets during the construction phase, and once construction/infrastructure installation works are complete in a specific area, recovery of sediments and associated communities are expected to begin soon after. Drawing on information from the monitoring studies above, it is highly likely that the displaced individuals will repopulate these previously disturbed areas, with recovery occurring throughout the construction phase rather than once the entire construction phase is completed.

3.9.2.33 As effects on sandeel (and other prey species) are predicted to be limited in extent (particularly in the context of available habitats in the fish and shellfish ecology study area), temporary and reversible, with recovery of sandeel populations occurring during and post-construction, species reliant on sandeel and other small prey species (e.g. sea trout and cod) would similarly not be expected to be significantly affected. The implications of changes in fish and shellfish prey species are also discussed for higher trophic level receptors (i.e. marine mammals and birds) in Volume 2, Chapter 4: Marine mammals of the Environmental Statement and Volume 2, Chapter 5: Offshore ornithology of the Environmental Statement.

3.9.2.34 Most fish and shellfish ecology IEFs in the fish and shellfish ecology study area are deemed to be of low vulnerability, high recoverability and local to national importance. The sensitivity of the receptor is therefore considered to be **low**.

3.9.2.35 King and queen scallop are deemed to be of medium vulnerability, high recoverability, and of regional importance. The sensitivity of the receptor is therefore considered to be **low**.

3.9.2.36 European lobster and *Nephrops* are deemed to be of high vulnerability, medium to high recoverability and of regional importance. The sensitivity of these fish and shellfish IEFs is therefore considered to be **medium**.

3.9.2.37 Sandeel are deemed to be of high vulnerability (due to their substrate specificity), high recoverability and of regional importance. The sensitivity of sandeel is therefore considered to be **high**.

3.9.2.38 Herring are deemed to be of high vulnerability, medium recoverability and of national importance, The sensitivity of herring to this impact is therefore considered to be **high**.

Diadromous species

3.9.2.39 Diadromous fish species are highly mobile and therefore are generally able to avoid areas subject to temporary habitat loss. Diadromous species that are likely to interact with the fish and shellfish ecology study area are only likely to do so by passing through the area during migrations to and from rivers located on the west coast of England and Wales, such as to rivers with designated sites with diadromous fish species listed as qualifying features (see Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement). The habitats within the fish and shellfish ecology study area are not expected to be particularly important for diadromous fish species and therefore habitat loss during the construction phase of the fish and shellfish ecology study area is unlikely to cause any direct impact to diadromous fish species and would not affect migration to and from rivers.

3.9.2.40 Indirect impacts on diadromous fish species may occur due to impacts on prey species, for example larger fish species for sea lamprey and sandeel for sea trout. As outlined for marine species above, the majority of large fish species would be able to avoid potential habitat loss effects due to their greater mobility but would recover into the areas affected following cessation of construction. Sandeel (and other less mobile prey species) would be affected by temporary habitat loss, although recovery of this species is expected to occur quickly as the sediments recover following installation of infrastructure and adults recolonise and also via larval recolonisation of the sandy sediments, which are known to occur throughout the fish and shellfish ecology study area and are known to recover quickly following cable installation (RPS, 2019).

3.9.2.41 Diadromous fish species are deemed to be of low vulnerability, high recoverability and national to international importance. However, the relatively short construction period and location of the Morgan Generation Assets likely reduces the probability of either spatial or temporal overlap with many migrating diadromous species, and so the sensitivity of the receptor is therefore considered to be **negligible**.

Significance of effect

Marine species

3.9.2.42 Overall, the magnitude of the impact is deemed to be low, and the sensitivity of most fish IEFs is considered to be low. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.2.43 For king and queen scallop, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.2.44 For European lobster and *Nephrops*, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be medium. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.2.45 For sandeel, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be high. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms. This is due to the low overlap of sandeel grounds and the high recoverability of sandeels to temporary habitat loss or disturbance.

3.9.2.46 For herring, the magnitude of the impact is deemed to be negligible, and the sensitivity of the receptor is considered to be high. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

Diadromous species

3.9.2.47 Overall, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered negligible. The effect will, therefore, be of **negligible** significance, which is not significant in EIA terms.

Operations and maintenance phase

Magnitude of impact

3.9.2.48 Operations and maintenance activities within the fish and shellfish ecology study area will result in temporary habitat disturbance. The MDS accounts for up to 11,362,800 m^2

of temporary habitat disturbance within this phase (Table 3.18). This equates to a small proportion (1.19%) of the Morgan Generation Assets area. It should also be noted that only a small proportion of the total temporary habitat loss/disturbance is likely to occur at any one time, with the MDS for temporary habitat loss/disturbance spread over the 35-year operational lifetime and therefore individual maintenance activities will be small scale and intermittent events.

3.9.2.49 Of the 11,362,800 m^2 of temporary habitat disturbance, 1,822,800 m^2 is attributed to jack-up events at wind turbine and OSP foundations over the 35-year lifetime of the Morgan Generation Assets. This temporary habitat disturbance is the result of up to 840 major component replacements (one every four years for each location) for wind turbines, and 12 major component replacements (three over the lifetime of each OSP) for OSP foundations. This figure also accounts for four access ladder replacements and four modifications to/replacement of J-tubes for both wind turbine and OSP foundations.

3.9.2.50 Inter-array cable and interconnector cable reburial may also contribute up to 4,720,000 m^2 and 4,820,000 m^2 of temporary habitat disturbance, respectively. For inter-array cables, this value includes 2,800,000 m^2 of disturbance from seven reburial events (one every five years) and 1,920,000 m^2 from 12 cable repair events (one every three years). For interconnector cables, this value includes 420,000 m^2 of disturbance from seven reburial events (one event every five years) and 4,400,00 m^2 from 12 cable repair events (three every 10 years). For both inter-array and interconnector cables, these figures assume a 20 m width seabed disturbance for repair and remedial burial.

3.9.2.51 The impacts of jack-up vessel activities will be similar to those identified for the construction phase above and will be restricted to the immediate area around the wind turbine foundation or cable repair sites, where the spud cans are placed on the seabed, with recovery occurring following removal of spud cans. The spatial extent of this impact is small in relation to the total fish and shellfish ecology study area, although there is the potential for repeat disturbance to the habitats in the immediate vicinity of the foundations because of these activities. The repair and reburial of array and OSP interconnector cables will also affect benthic habitats and thus demersal IEFs in the immediate vicinity of these activities, with potential effects on seabed habitats and associated benthic communities expected to be similar to the construction phase, although much lower magnitude.

3.9.2.52 As in the construction phase, sandeel and herring are assessed based on their potential spawning ground overlap with the Morgan Generation Assets in the wider context of spawning grounds within the fish and shellfish ecology study area. The criteria remain the same as in the construction phase, and therefore the magnitude for sandeel is considered to be **low** and the magnitude for herring is considered to be **negligible**.

3.9.2.53 For other marine and diadromous IEFs, the impact is predicted to be of local spatial extent, short term duration, intermittent and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **low**.

Sensitivity of receptor

3.9.2.54 The sensitivity of the fish and shellfish IEFs, for both marine and diadromous species, can be found in the construction phase assessment (paragraph 3.9.2.15 to paragraph 3.9.2.41), ranging from **low to high** sensitivity, and these will equally apply in the operations and maintenance phase.

Significance of effect

Marine species

3.9.2.55 Overall, the magnitude of the impact is deemed to be low, and the sensitivity of most fish IEFs is considered to be low. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.2.56 For king and queen scallop, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.2.57 For European lobster and *Nephrops*, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be medium. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.2.58 For sandeel, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be high. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.2.59 For herring, the magnitude of the impact is deemed to be negligible, and the sensitivity of the receptor is considered to be high. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

Diadromous species

3.9.2.60 Overall, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be negligible. The effect will, therefore, be of **negligible** significance, which is not significant in EIA terms.

Decommissioning

Magnitude of impact

3.9.2.61 Decommissioning activities within the fish and shellfish ecology study area will result in temporary habitat loss/disturbance. The MDS for the decommissioning phase assumes that all foundations and cables will be removed and that the decommissioning sequence will generally be a reverse of the construction sequence. This includes up to four jack-up events for each of the up to 96 wind turbine foundations (two jack-up events for wind turbines and two jack-up events for the foundations), and two jack-up events at each of the four OSP foundations.

3.9.2.62 The extent of temporary habitat disturbance that may occur as a result of decommissioning activities is predicted to be in line with that described for the construction phase in paragraph 3.9.2.2 to 3.9.2.11. On the basis that there will be no requirement for sandwave clearance or pre-lay preparation during decommissioning, the magnitude of the impact is likely to be lower than during construction.

3.9.2.63 As in the construction phase, sandeel and herring are assessed based on their potential spawning ground overlap with the Morgan Generation Assets in the wider context of spawning grounds within the fish and shellfish ecology study area. The criteria remain the same as in the construction phase, and therefore the magnitude for sandeel is considered to be **low** and the magnitude for herring is considered to be **negligible**.

3.9.2.64 For the remaining marine and diadromous species IEFs, the impact is predicted to be of local spatial extent, medium term duration, intermittent and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **low**.

Sensitivity of receptor

3.9.2.65 The sensitivity of the fish and shellfish IEFs, for both marine and diadromous species, can be found in the construction phase assessment (paragraph 3.9.2.15 to paragraph 3.9.2.41), ranging from **low to high** sensitivity, and these will equally apply in the decommissioning stage.

Significance of effect

Marine species

3.9.2.66 Overall, the magnitude of the impact is deemed to be low, and the sensitivity of most fish IEFs is considered to be low. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.2.67 For king and queen scallop, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.2.68 For European lobster and *Nephrops*, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be medium. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.2.69 For sandeel, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be high. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.2.70 For herring, the magnitude of the impact is deemed to be negligible, and the sensitivity of the receptor is considered to be high. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

Diadromous species

3.9.2.71 Overall, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be negligible. The effect will, therefore, be of **negligible** significance, which is not significant in EIA terms.

3.9.3 Underwater sound impacting fish and shellfish receptors

3.9.3.1 The construction of the generation assets may lead to underwater sound impacting fish and shellfish receptors. The MDS is represented by the installation of pin piles for wind turbine and OSP foundations and is summarised in Table 3.18. Further, the MDS also includes UXO clearance activities and geophysical survey.

Construction phase

Magnitude of impact

3.9.3.2 To understand the magnitude of sound emissions from piling and UXO clearance during construction activity, underwater sound modelling has been undertaken considering the key parameters summarised below. Full details of the modelling undertaken are presented in Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement.

3.9.3.3 Piling activities were modelled for pin piling of jacket foundations at three locations within the Morgan Array Area taking into account the varying bathymetry and sediment type across the model areas (see Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement). Underwater sound modelling included the use of ‘soft start’ mitigation to reduce the potential for injury effects (as set out in Table 3.19). The implications of the modelling for fish and shellfish injury and behaviour are outlined in the following sensitivity section.

3.9.3.4 Modelling was undertaken for both single piling and concurrent piling (i.e. piling at more than one location simultaneously). Concurrent piling modelling demonstrated that sound level values in terms of a dB metric are not mathematically additive, with a typical increase of just approximately 3 dB when adding together two equal sound levels (e.g. 10 dB + 10 dB = approximately 13 dB, not 20 dB). An example of a concurrent piling scenario (SEL_{cum}) based on a 3,000 kJ hammer energy at the west modelled locations (15 km apart, see Table 3.18) is given in Figure 3.4; this can be loosely compared to the SEL_{ss} single piling scenario for a 3,000 kJ hammer energy presented in Figure 3.12, noting that we would expect to see a slight difference in the contour ranges between the two figures due to different metrics applied.

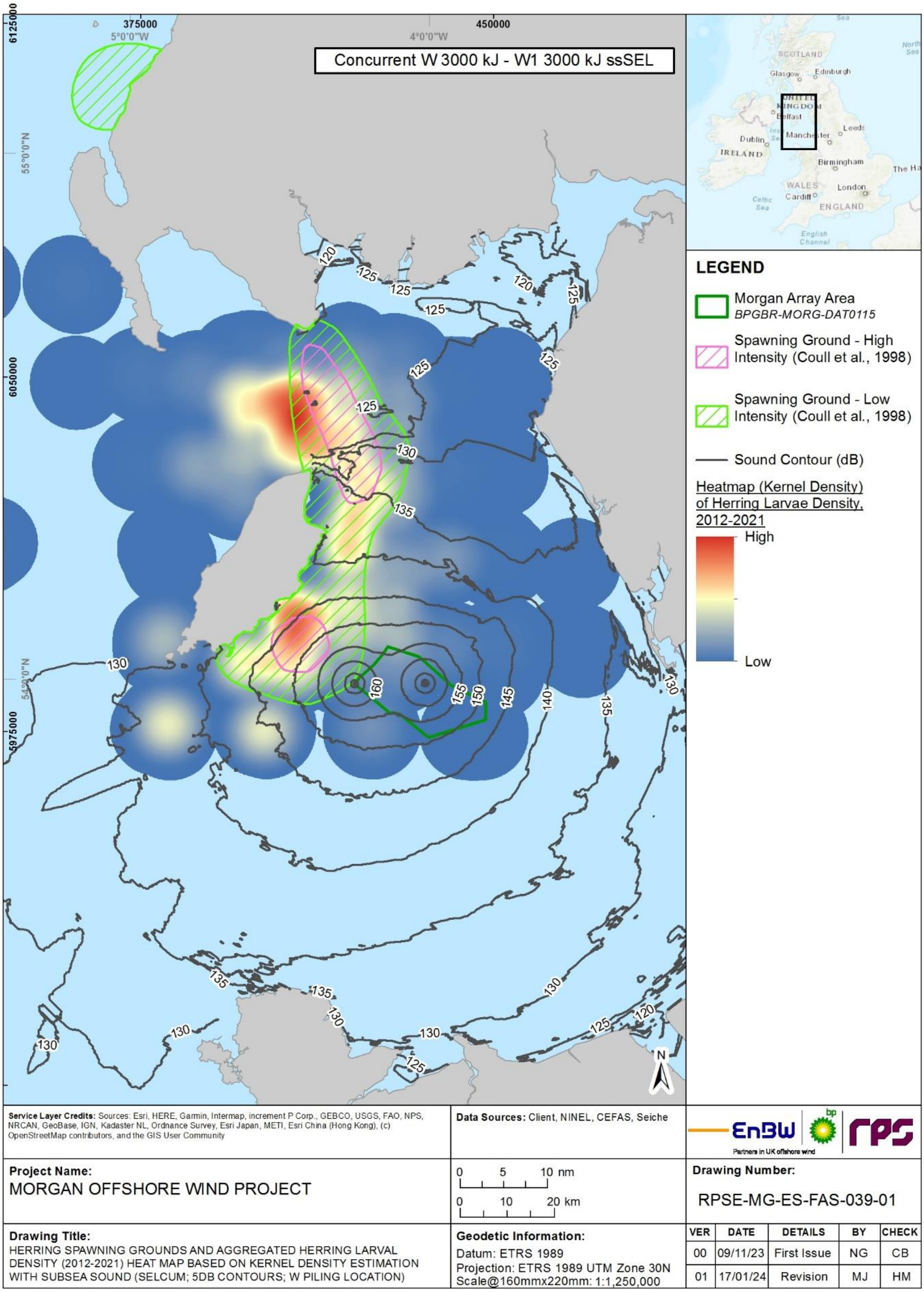


Figure 3.4: Example concurrent piling scenario based upon piling using a 3,000 kJ hammer energy at two locations including the west modelled location. Figure shows herring spawning grounds and NINEL aggregated herring larval densities (2012 to 2021, larvae/m^2; Coull *et al.*, 1998).

3.9.3.5 Potential impacts associated with underwater sound are assessed using the Peak Sound Pressure Level (SPL_{pk}), Cumulative Sound Exposure Level (SEL_{cum}) metrics. SPL_{pk} refers to the overall maximum amplitude of a sound averaged over a specified time-period, while SEL_{cum} corresponds to the received level of sound energy and the duration of exposure computed over multiple pulses or signals to generate a value equivalent to a single exposure. Further explanation of these metrics are provided in Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement. These two measures can be used to refer to the same sound event and are presented using approximations of both metrics for clarity throughout where relevant to the assessment.

3.9.3.6 All other sound sources including cable installation and foundation drilling are non-percussive and will result in much lower sound levels and therefore much smaller injury ranges (in most cases no injury is predicted) than those predicted for piling operations. For further information on other sound sources see Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement, however these are not considered further here as the potential effect on fish and shellfish receptors will be negligible.

Pin piling

3.9.3.7 The installation of foundations within the Morgan Array Area may lead to injury and/or disturbance to fish and shellfish species due to underwater sound during pile driving. The MDS considers the greatest potential effect from underwater sound on fish and shellfish IEFs, considering the greatest hammer energy for pin piling installation, the numbers of piles to be installed across various scenarios, and the total duration of piling expected for both single and concurrent piling. A maximum hammer energy of 4,400 kJ for pin piles was modelled.

3.9.3.8 The pin piling activities are represented by the installation of up to 64 pin-piled four-legged jacket foundations with one pile per leg (up to 256 piles total), with a 3.8 m diameter installed by impact piling. Pin pile installation for jacket foundations will take place over a period of a maximum of 4.5 hours per pile, for both wind turbine and OSP foundations, with up to two vessels piling concurrently. For each wind turbine foundation, there will be a total duration of 18 hours of pin piling activity (1,152 hours cumulatively for all wind turbine foundations). For the OSP foundations, the total pin piling duration will be 216 hours with a total installation period of up to 12 days.

3.9.3.9 Up to 96 gravity base foundations will be installed. The MDS is based upon up to 10 gravity base foundations requiring ground strengthening using pin piles. Up to 15 pin piles are required per foundation, up to a maximum of 150 x 4 m diameter piles installed by impact piling. The maximum hammer energy will be 3,000 kJ for gravity base foundations.

3.9.3.10 Overall, pin piling for the wind turbine (both jacket and gravity base foundations) and OSP foundations will equal 114 days for a single vessel (temporal maximum), or 57 days for two vessels (spatial maximum), with a piling phase of up to two years within the four-year construction programme.

UXO clearance

3.9.3.11 UXO clearance (including detonation) also has the capability to cause injury and/or disturbance to fish and shellfish IEFs. UXO clearance will be completed prior to the construction phase (pre-construction). Until detailed pre-construction surveys are completed within the Morgan Array Area, the precise number of potential UXO which will need to be cleared is unknown. For the purposes of this assessment, it has been assumed that the MDS will be clearance of UXO with a NEQ of 907 kg cleared by either low order or high order techniques (the assessed MDS is for high order clearance as low order techniques are not always possible and high order techniques are considered to have the largest impact when compared with low order techniques, as detailed in Table 3.18). Many UXO may be left *in situ* and micro-sited around to avoid the need to undertake clearance. Detonation of UXO would represent a short term (i.e. seconds) increase in underwater sound (i.e. sound pressure levels and particle motion) which will be elevated to levels which may potentially result in injury or behavioural effects on fish and shellfish species.

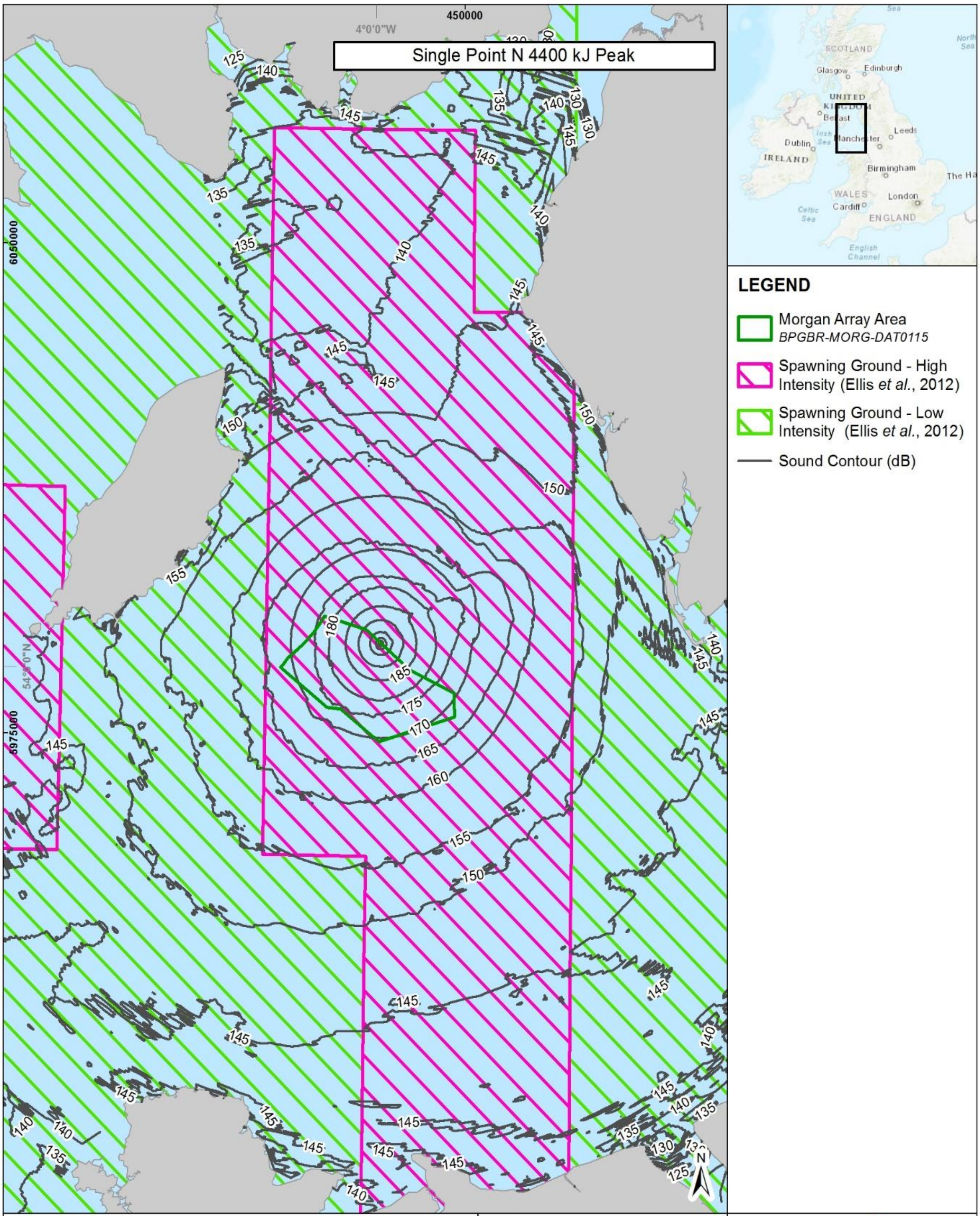
Geophysical site investigation surveys

3.9.3.12 The pre-construction geophysical surveys, using any of the available techniques outlined in Table 3.18, are likely to be very short term and spatially limited at any one time, reducing the magnitude of their likely impact on fish and shellfish receptors. They will also operate largely outside of the hearing frequencies of most fish and shellfish IEFs, thereby significantly reducing the potential for impacts to low or negligible levels.

Summary

3.9.3.13 The impact of underwater sound on most fish and shellfish receptors during the construction phase is predicted to be of regional spatial extent, relatively short-term duration, intermittent and of high reversibility, with the soundscape returning to near-baseline conditions upon completion of construction activities. It is predicted that the impact will affect the receptor directly. The magnitude is therefore considered to be **low**.

3.9.3.14 Cod high and low intensity spawning grounds are located across almost the entire fish and shellfish ecology study area. Based on modelling at the east location, underwater sound at levels with potential to cause behavioural effects (approximately 160 dB re 1 µPa SPL_{pk}) from piling using a 4,400 kJ hammer energy (Table 3.18) is expected to travel across approximately a maximum of 21.9% of mapped high intensity cod spawning ground. However, this potential maximum impact equates to a small proportion of cod spawning habitat available in the context of both the regional fish and shellfish ecology study area and the wider Irish Sea which is almost entirely used for spawning at various intensities by this species (Figure 3.5). It is acknowledged that spawning grounds are not fixed boundaries, and spawning does not occur at an equal density across the mapped grounds, with variation inside and outside mapped grounds annually and throughout the spawning season, therefore percentage overlaps with spawning grounds must be interpreted with caution. These are therefore used to advise the assessment of magnitude where appropriate, alongside key factors including expert judgement and project design parameters, but do not underpin the assessment for sensitivity or significance.



Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Data Sources: Client, NINEL, CEFAS, Seiche

Project Name:
MORGAN OFFSHORE WIND PROJECT

0 5 10 nm
0 10 20 km

Drawing Number:
RPSE-MG-ES-FAS-055-01

Drawing Title:
COD SPAWNING GROUNDS WITH SUBSEA SOUND (SPLPK; 5DB CONTOURS; N)

Geodetic Information:
Datum: ETRS 1989
Projection: ETRS 1989 UTM Zone 30N
Scale@160mmx220mm: 1:1,000,000

VER	DATE	DETAILS	BY	CHECK
00	09/11/23	First Issue	NG	CB
01	17/01/24	Revision	MJ	HM

Figure 3.5: Cod spawning grounds with subsea 5 dB sound SPL$_{pk}$ contours for pin pile at 4,400 kJ hammer energy at the north modelled location (Ellis *et al.*, 2012).

3.9.3.15 For cod, the impact of underwater sound during the construction phase is predicted to be of regional spatial extent, relatively short-term duration (with spawning of cod occurring from January to April), intermittent and of high reversibility, with the soundscape returning to near-baseline conditions upon completion of construction activities. It is predicted that the impact will affect the receptor directly. Based on the extent of area available for cod spawning outside of the modelled impacted Zone, the magnitude is therefore considered to be **low** during the cod spawning season. Outside of this period, the magnitude in respect of cod is considered **negligible**.

3.9.3.16 Discrete high and low intensity mapped herring spawning grounds are located off the east coast of the IoM at Douglas Bank. Underwater sound at levels with potential to cause behavioural effects to herring (approximately 135 dB re 1µPa^2.s SEL$_{ss}$ or approximately 160 dB re 1µPa SPL$_{pk}$) from pile driving using a maximum hammer energy of 4,400 kJ overlap with these mapped grounds; the former encompasses both high and low intensity mapped spawning ground (54.9% of combined high and low intensity spawning grounds). Underwater sound contours are presented in Figure 3.6 (SEL$_{ss}$) and Figure 3.7 (SPL$_{pk}$) alongside the Coull *et al.* (1998) mapped high and low intensity spawning grounds and the NINEL aggregated ten year larval density heat map to demonstrate spatial overlap based on a hammer energy of 4,400 kJ.

3.9.3.17 For herring, the impact of underwater sound during the construction phase is predicted to be of regional spatial extent (however overlapping with mapped high and low intensity spawning ground), relatively short-term duration (noting that spawning of Manx herring is reported to consistently occur over three to four weeks from late September; Dickey-Collas *et al.*, 2001), intermittent and of high reversibility, with the soundscape returning to near-baseline conditions upon completion of construction activities. It is predicted that the impact will affect the receptor directly. The magnitude is therefore considered to be **medium** during the herring spawning season. Outside of this period the magnitude in respect of herring is considered **negligible**.

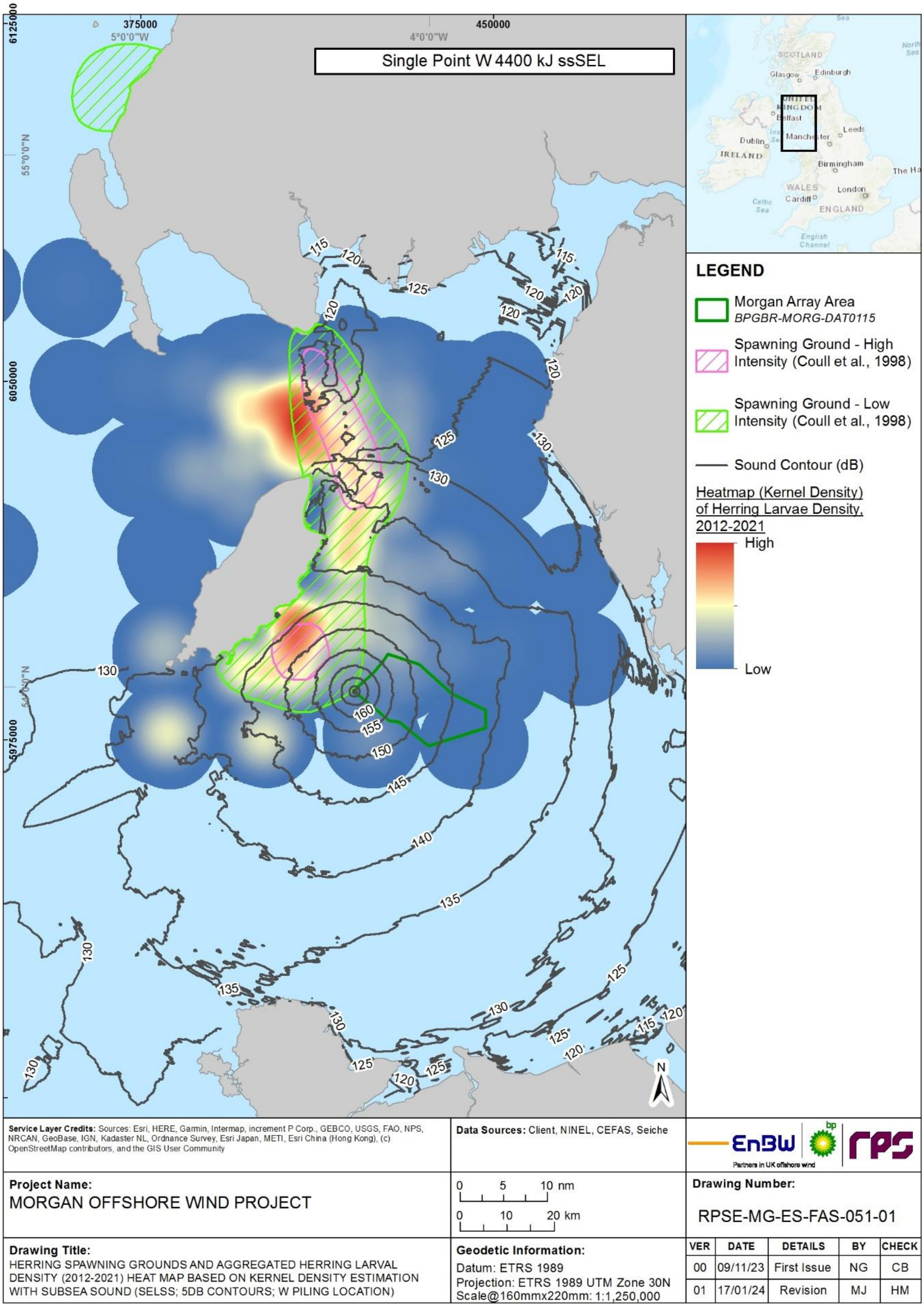


Figure 3.6: Herring spawning grounds and aggregated larval density (larvae/m^2; 2012 to 2021) with subsea 5 dB re 1µPa^2.s sound SEL$_{ss}$ contours for pin pile at 4,400 kJ hammer energy at the west location (Coull *et al.*, 1998).

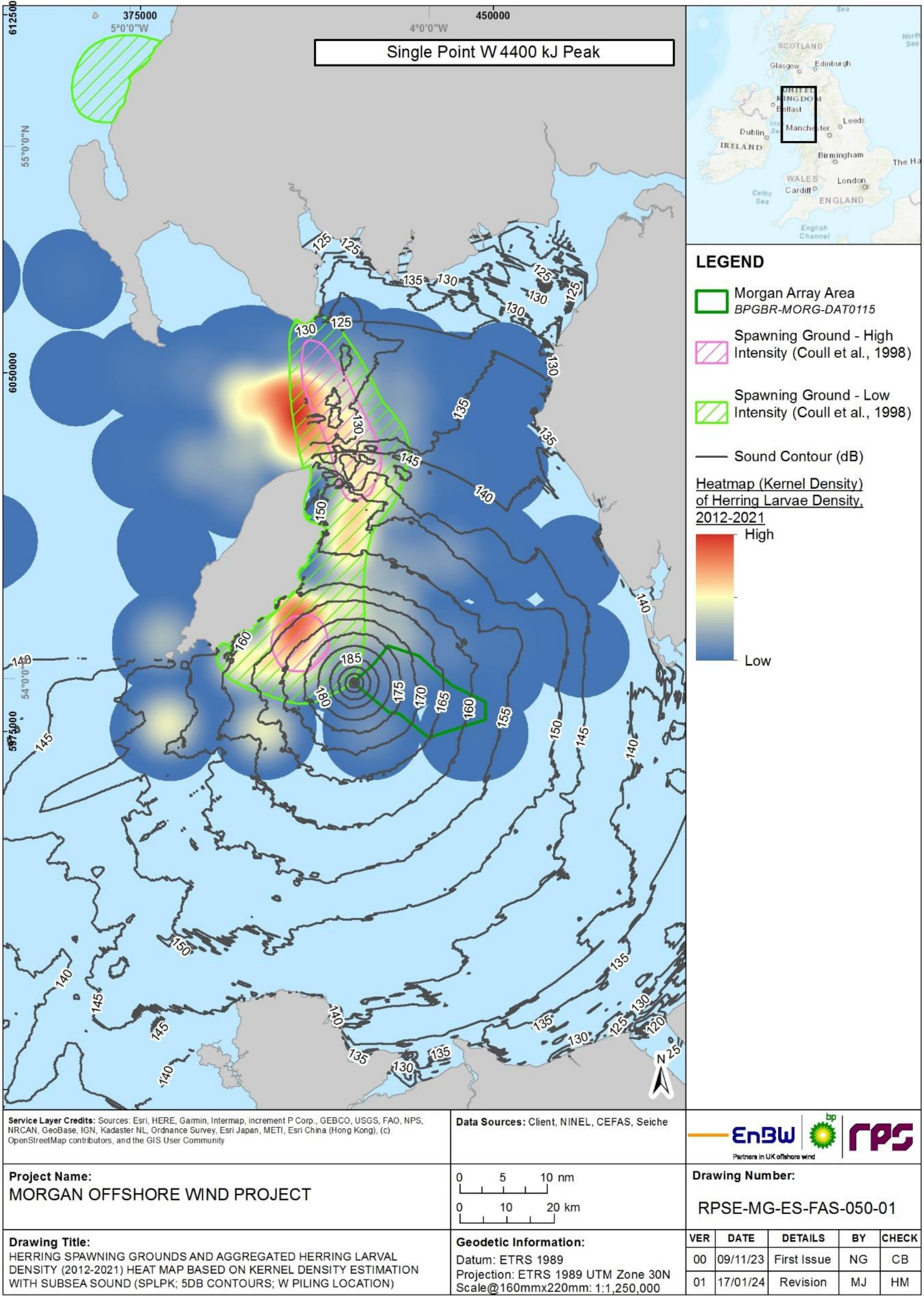


Figure 3.7: Herring spawning grounds and aggregated larval density (larvae/m^2; 2012 to 2021) with subsea 5 dB re 1μPa sound SPL$_{pk}$ contours for pin pile at 4,400 kJ hammer energy at the west location (Coull *et al.*, 1998).

Sensitivity of receptor

3.9.3.18 The following sections apply to marine fish and shellfish species, and diadromous fish species, with a summary for each of these receptor groups provided below.

3.9.3.19 Underwater sound can potentially have an adverse impact on fish species ranging from physical injury/mortality to behavioural effects. Recent peer reviewed guidelines have been published by the Acoustical Society of America (ASA) and provide directions and recommendations for setting criteria (including injury and behavioural criteria) for fish. The Sound Exposure Guidelines for Fishes and Sea Turtles (Popper *et al*., 2014) are considered most relevant and best available guidelines for impacts of underwater sound on fish species (see Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement). The Popper *et al*. (2014) guidelines broadly group fish into the following categories according to the presence or absence of a swim bladder and on the potential for that swim bladder to improve the hearing sensitivity and range of hearing:

- Group 1: Fishes lacking swim bladders (e.g. elasmobranchs and flatfish, lamprey). These species are only sensitive to particle motion, not sound pressure and show sensitivity to only a narrow band of frequencies
- Group 2: Fishes with a swim bladder but the swim bladder does not play a role in hearing (e.g. salmonids and some Scombridae). These species are considered more sensitive to particle motion than sound pressure and show sensitivity to only a narrow band of frequencies
- Group 3: Fishes with swim bladders that are close, but not connected, to the ear (e.g. gadoids and eels). These fishes are sensitive to both particle motion and sound pressure and show a more extended frequency range than Groups 1 and 2, extending to about 500 Hz
- Group 4: Fishes that have special structures mechanically linking the swim bladder to the ear (e.g. clupeids such as herring, sprat and shad). These fishes are sensitive primarily to sound pressure, although they also detect particle motion. These species have a wider frequency range, extending to several kHz and generally show higher sensitivity to sound pressure than fishes in Groups 1, 2 and 3.

3.9.3.20 Relatively few studies have been conducted on impacts of underwater sound on invertebrates, including crustacean species, and little is known about the potential effects of anthropogenic underwater sound upon them (Hawkins and Popper, 2016; Morley *et al*., 2013; Williams *et al*., 2015). There are therefore no injury criteria that have been developed for shellfish (Hawkins *et* al., 2014) however, these are expected to be less sensitive than fish species and therefore injury ranges of fish could be considered conservative estimates for shellfish species (risk of behavioural effects are discussed further below for shellfish).

3.9.3.21 An assessment of the potential for injury/mortality and behavioural effects to be experienced by fish and shellfish IEFs with reference to the sensitivity criteria described above is presented in turn below.

Piling – mortality and injury

3.9.3.22 Table 3.20 summarises the fish injury criteria recommended for pile driving based on the Popper *et al. (*2014) guidelines, noting that dual criteria are adopted in these guidelines to account for the uncertainties associated with effects of underwater sound on fish.

Table 3.20: Criteria for onset of injury to fish due to impulsive piling (Popper *et al.*, 2014).

[a] Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near field (N; i.e. 10s of metres), intermediate (I; i.e. 100s of metres), and far field (F; i.e. 1000s of metres); Popper et al. (2014).

Group	Type of Animal	Parameter	Mortality and potential mortal injury	Recoverable injury
1	Fish: no swim bladder (particle motion detection)	SEL, dB re 1 µPa^{2}s	>219	>216
		Peak, dB re 1 µPa	>213	>213
2	Fish: where swim bladder is not involved in hearing (particle motion detection)	SEL, dB re 1 µPa^{2}s	210	203
		Peak, dB re 1 µPa	>207	>207
3 and 4	Fish: where swim bladder is involved in hearing (primarily pressure detection)	SEL, dB re 1 µPa^{2}s	207	203
		Peak, dB re 1 µPa	>207	>207
N/A	Eggs and larvae	SEL, dB re 1 µPa^{2}s	>210	(*Near*) Moderate[a] (*Intermediate*) Low (*Far*) Low
		Peak, dB re 1 µPa	>207	

3.9.3.23 The full results of the underwater sound modelling are presented in Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement. To inform this assessment, Table 3.21 displays the predicted injury ranges associated with the installation of one 5.5 m diameter pile, for peak sound pressure levels (SPL_{pk}). Also, the predicted injury ranges for cumulative sound exposure level (SEL_{cum}) are displayed for when fish are modelled as a receptor moving away from the sound source in Table 3.22, and as a static receptor in Table 3.23.

3.9.3.24 For peak pressure sound levels when piling energy is at its maximum (i.e. 4,400 kJ), mortality and recoverable injury to fish may occur within a maximum of 394 m of the piling activity (smaller ranges for Group 1 fish species, highest range for Group 4 species; Table 3.21). The potential for mortality or mortal injury to fish eggs would also occur at distances of up to 394 m (Table 3.21), with a low to moderate risk of recoverable injury to eggs and larvae within the range of hundreds of metres (see Table 3.20 for qualitative criteria). It should be noted that these ranges are the maximum ranges for the maximum hammer energy, and it is unlikely that injury will occur in this range due to the implementation of soft starts during piling operations (Table 3.19), which will allow some fish to move away from the areas of highest sound levels, before they reach a level that would cause an injury.

3.9.3.25 Stationary or passive eggs and larvae are predicted to be exposed to SEL_{cum} values associated with mortality impacts at distances up to 1,490 m. This close range will limit the proportion of fish eggs and larvae exposed to potential mortality from pin piling sound emissions at any given time.

3.9.3.26 For SEL_{cum}, injury ranges were calculated for piling activities wherein fish are treated as moving and static receptors. These ranges indicate that with the implementation of soft start initiation, when fish are modelled as receptors moving away from the source, the mortality and injury ranges are considerably smaller than those predicted for SPL_{pk}, in that the mortality thresholds were exceeded only for fish eggs and larvae, within a range of up to 1.87 km from the source. Similarly, the recoverability ranges were much lower, with thresholds not exceeded for group 1 fish, and groups 2 to 4 had a maximum range of 254 m; see Table 3.22.

3.9.3.27 When fish were modelled as static receptors (Table 3.23), mortality and recoverable injury ranges were significantly higher than for when fish are modelled as receptors moving away from the sound source, with a maximum mortality range of up to 2.74 km in group 3 and 4 fish, and a recoverable injury range of up to 4.52 km.

3.9.3.28 The injury ranges presented indicate that injury may occur out to ranges of hundreds of metres (< 400 m) for SPL_{pk}. However, in reality, the risk of fish injury overall will be considerably lower due to the hammer energies being lower than the absolute maximum modelled, as demonstrated by the lower injury ranges associated with first strikes as part of the soft start procedure shown in Table 3.21. The expected behaviour of fish moving away from the area affected when exposed to high sound levels and the soft start procedure, modelled and presented in Table 3.22, mean that it is likely that some fish will have sufficient time to vacate the areas where injury may occur prior to sound levels reaching a level causing mortality, with only recoverable injury predicted for group 2, 3 and 4 fish out to 79 m. If the fish were to remain in the area and not have any behavioural response to the sound produced during piling, the potential range for both mortality and recoverable injury would be much greater, out to the range of thousands of metres, with this precautionary modelling approach shown in Table 3.23.

3.9.3.29 Note that the content of Table 3.21 is taken directly from Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement, Table 1.34.

Table 3.21: Fish injury ranges for single pin pile installation based on the SPL_{pk} metric (4,400 kJ hammer energy).

Hearing Group	Response	Threshold (SPL_{pk}, dB re 1 µPa)	Range (m)	
			First Strike	Max
Group 1 Fish: No swim bladder (particle motion detection)	Mortality	213	43	215
	Recoverable injury	213	43	215
Group 2 Fish: Swim bladder not involved in hearing (particle motion detection)	Mortality	207	79	394
	Recoverable injury	207	79	394
Group 3 and 4 Fish: Swim bladder involved in hearing (primarily pressure detection)	Mortality	207	79	394
	Recoverable injury	207	79	394
Sea turtles	Mortality	207	79	394
Fish eggs and larvae	Mortality	207	79	394

3.9.3.30 Note that the content of Table 3.22 is taken directly from Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement, Table 1.32.

Table 3.22: Fish injury ranges for single pin pile installation at 4,400 kJ based on the SEL$_{cum}$ metric for moving fish (N/E – threshold not exceeded).

Hearing Group	Response	Threshold (SEL, dB re 1 μPa^{2}s)	Range (m)
Group 1 Fish: No swim bladder (particle motion detection) – [*basking shark ranges shown in square brackets*].	Mortality	219	N/E
	Recoverable injury	216	N/E
Group 2 Fish: Swim bladder not involved in hearing (particle motion detection)	Mortality	210	N/E
	Recoverable injury	203	254
Group 3 and 4 Fish: Swim bladder involved in hearing (primarily pressure detection)	Mortality	207	N/E
	Recoverable injury	203	254

3.9.3.32 Note that the content of Table 3.23 is taken directly from Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement, Table 1.33.

Table 3.23: Fish injury ranges for single pin pile installation at 4,400 kJ based on the SEL$_{cum}$ metric for static fish (N/E – threshold not exceeded).

Hearing Group	Response	Threshold (SEL, dB re 1 μPa^{2}s)	Range (m)
Group 1 Fish: No swim bladder (particle motion detection)	Mortality	219	546
	Recoverable injury	216	830
Group 2 Fish: Swim bladder not involved in hearing (particle motion detection)	Mortality	210	1,870
	Recoverable injury	203	4,520
Group 3 and 4 Fish: Swim bladder involved in hearing (primarily pressure detection)	Mortality	207	2,740
	Recoverable injury	203	4,520
Fish eggs and larvae	Mortality	210	1,870

3.9.3.33 As outlined above, TTS is a temporary reduction in hearing sensitivity caused by exposure to intense sound. Normal hearing ability returns following cessation of the sound causing TTS, though the recovery period is variable, during which fish may have decreased fitness due to a reduced ability to communicate, detect predators or prey, and/or assess their environment. Table 3.24 shows the predicted ranges of effect for TTS for all fish groups modelled as moving receptors which may occur as a result of piling for one 5.5 m diameter pin pile, with TTS predicted to occur to a maximum range of 18.1 km from single piling operations. Table 3.25 shows the TTS ranges predicted for fish species modelled as static receptors, with consistently maximum ranges of 23.9 km from piling operations.

3.9.3.34 When concurrent piling is considered and modelled, the TTS ranges for fish modelled as moving receptors have a maximum range of 16.3 km, and fish modelled as stationary receptors have a maximum range of 22.1 km. These ranges are lower than the impacts of the single piling due to the lower hammer energy associated with concurrent piling (3,000 kJ) when compared to single piling (4,400 kJ), and that the concurrent sound levels in a mathematical sense are not additive, as described previously. Therefore, concurrent piling is not expected to increase the level of impact compared to the single piling scenario.

3.9.3.35 Note that the content of Table 3.24 is taken directly from Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement, Table 1.32 and Table 1.42.

Table 3.24: TTS injury ranges for fish moving away from the source due to single and concurrent pin pile installation based on the SEL_{cum} metric.

Hearing group	Response	Threshold (SEL, dB re 1 µPa^{2}s)	Range (m) – single piling	Range (m) concurrent piling
Group 1 Fish: No swim bladder (particle motion detection) – [*basking shark ranges shown in square brackets*].	TTS	186	18,100 [13,500]	16,300 [11,700]
Group 2 Fish: Swim bladder not involved in hearing (particle motion detection)	TTS	186	18,100	16,300
Group 3 and 4 Fish: Swim bladder involved in hearing (primarily pressure detection)	TTS	186	18,100	16,300

3.9.3.36 Note that the content of Table 3.25 is taken directly from Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement, Table 1.33 and Table 1.43.

Table 3.25: TTS injury ranges for static fish due to single and concurrent pin pile installation based on the cumulative SEL metric.

Hearing group	Response	Threshold (SEL, dB re 1 µPa^{2}s)	Range (m) – single piling	Range (m) concurrent piling
Group 1 Fish: No swim bladder (particle motion detection)	TTS	186	23,900	22,100
Group 2 Fish: Swim bladder not involved in hearing (particle motion detection)	TTS	186	23,900	22,100
Group 3 and 4 Fish: Swim bladder involved in hearing (primarily pressure detection)	TTS	186	23,900	22,100

3.9.3.37 TTS, recoverable injury and mortality ranges are presented in Figure 3.8 (showing mapped herring spawning grounds) and Figure 3.9 (showing mapped cod spawning grounds) for moving group 3 and 4 fish and in Figure 3.10 (herring) and Figure 3.11 (cod) for static group 3 and 4 fish based upon single piling at the north modelled location, with a hammer energy of 4,400 kJ (SEL_{cum}).

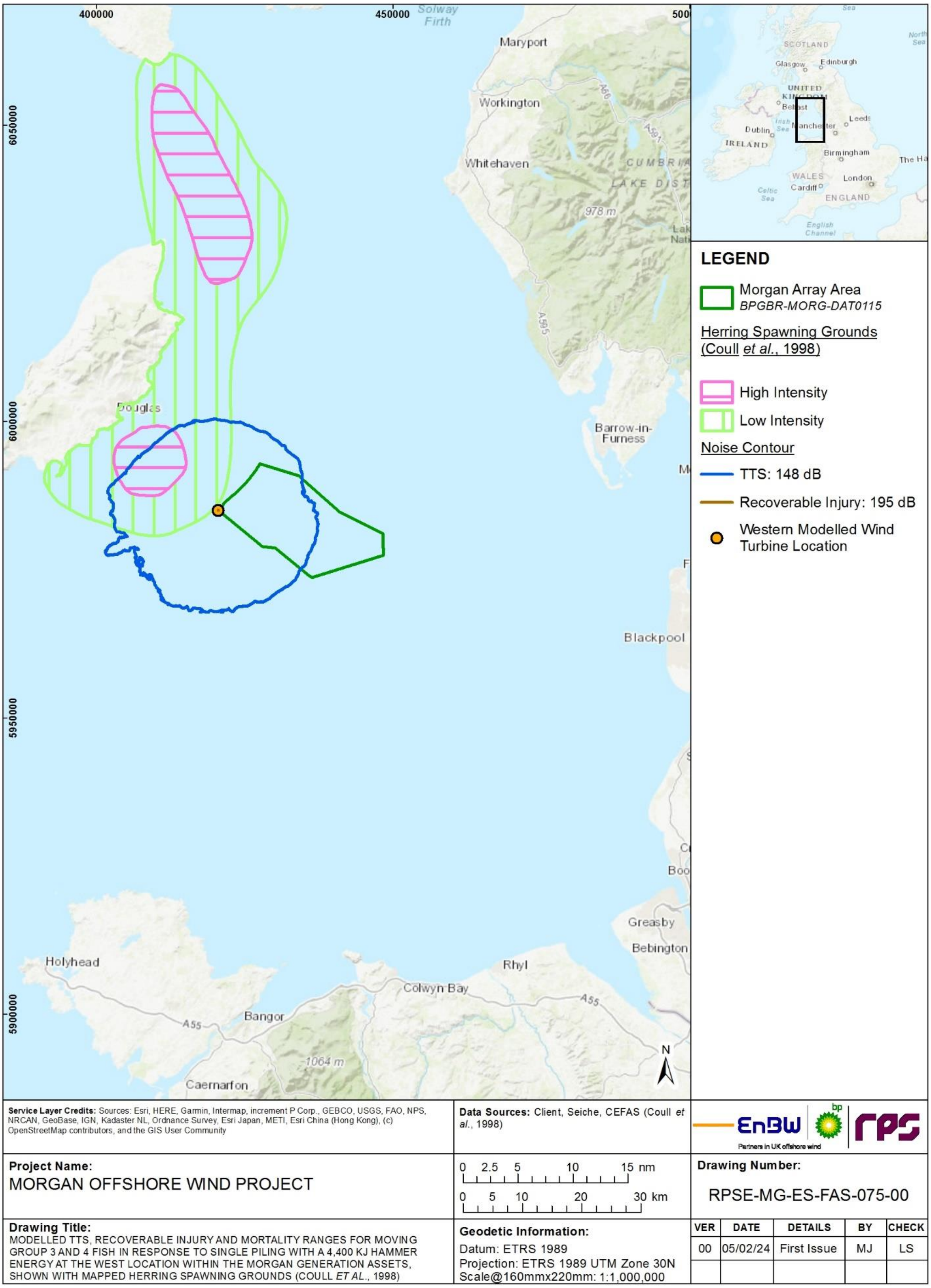


Figure 3.8: Modelled TTS, recoverable injury and mortality ranges for moving group 3 and 4 fish in response to single piling with a 4,400 kJ hammer energy at the west location within the Morgan Array Area, shown with mapped herring spawning grounds (Coull *et al*., 1998)

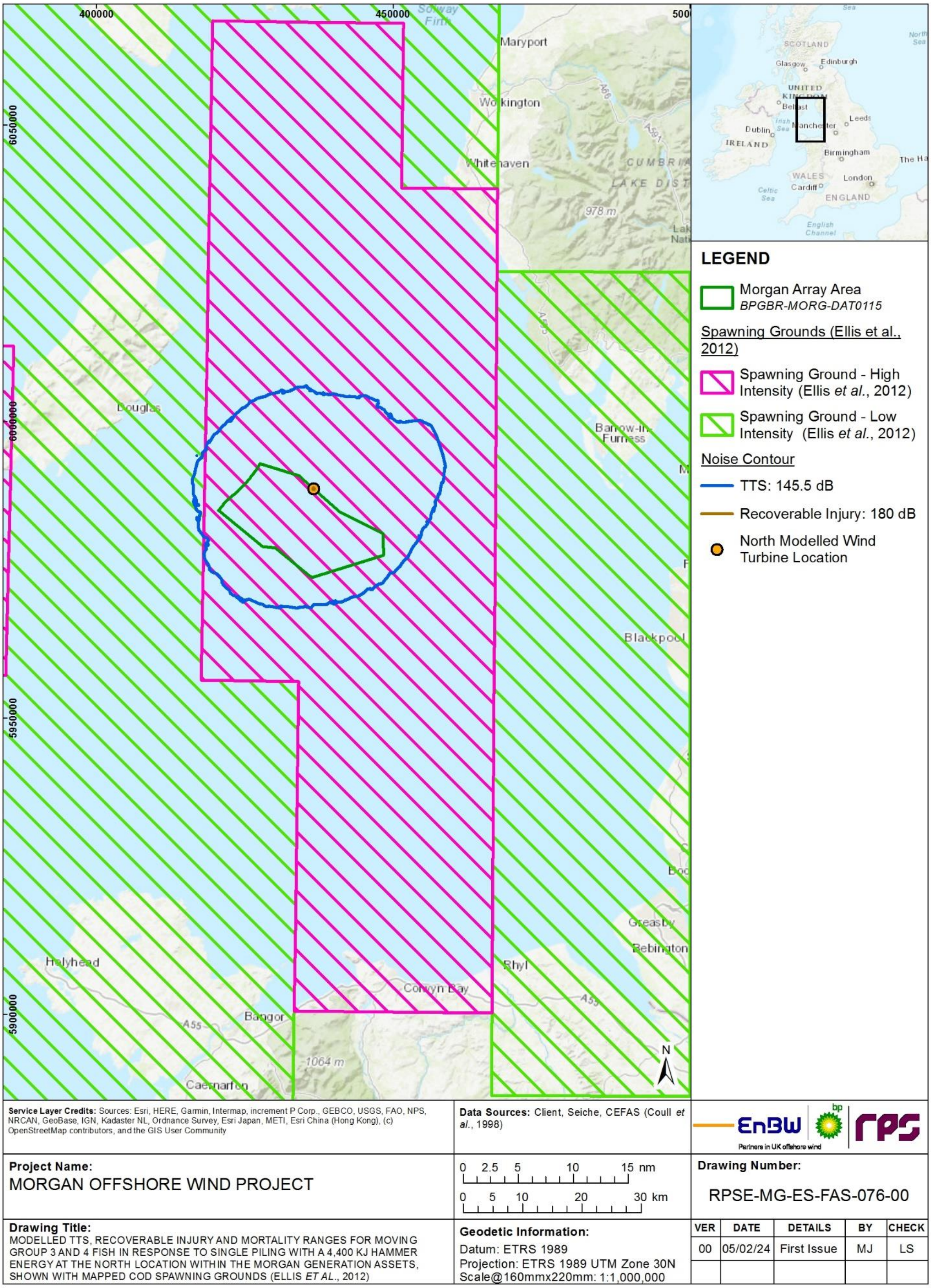


Figure 3.9: **Modelled TTS, recoverable injury and mortality ranges for moving group 3 and 4 fish in response to single piling with a 4,400 kJ hammer energy at the north location within the Morgan Array Area, shown with mapped cod spawning grounds (Ellis *et al.*, 2012)**

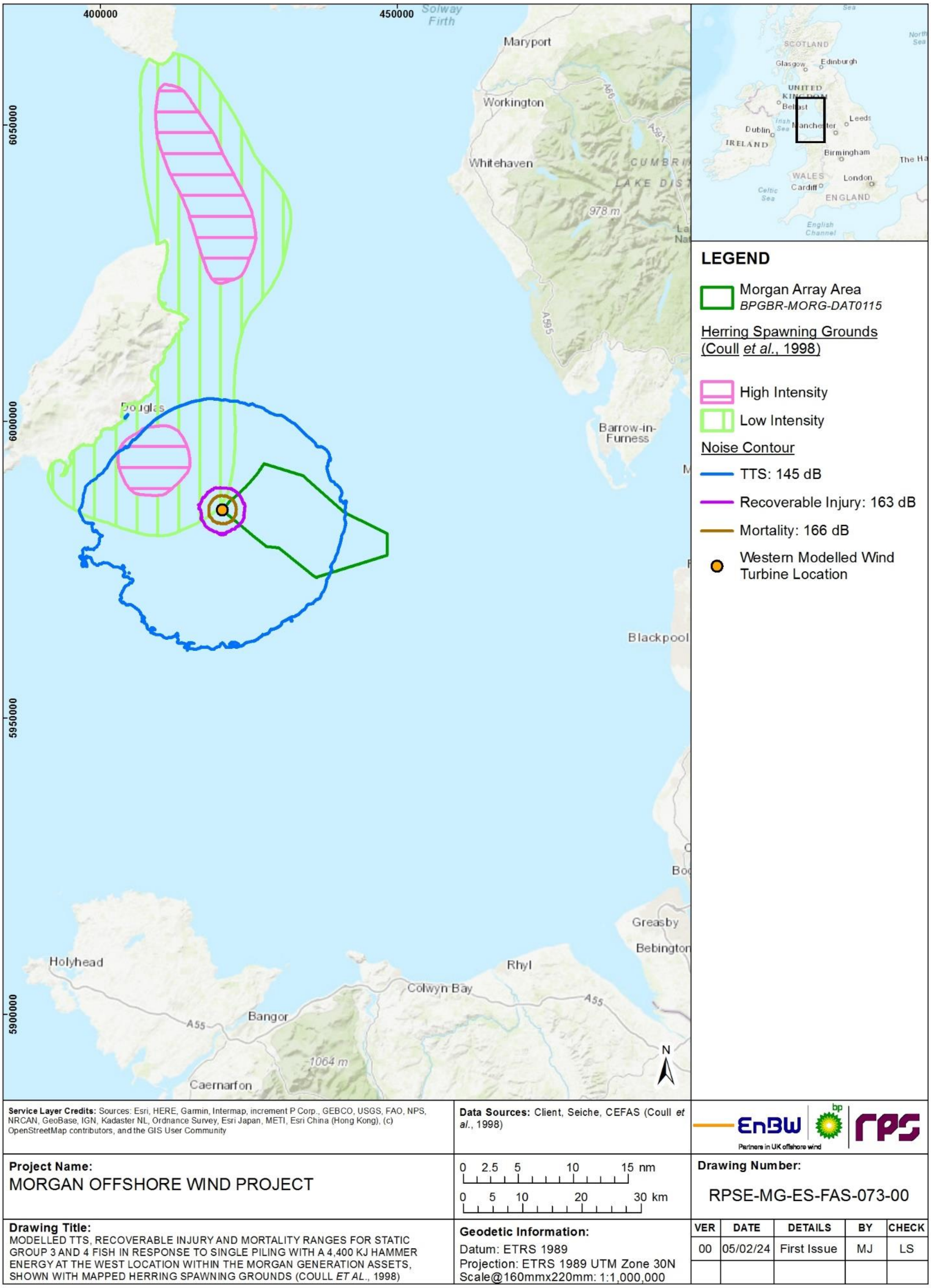


Figure 3.10: Modelled TTS, recoverable injury and mortality ranges for static group 3 and 4 fish in response to single piling with a 4,400 kJ hammer energy at the west location within the Morgan Array Area, shown with mapped herring spawning grounds (Coull *et al.*, 1998)

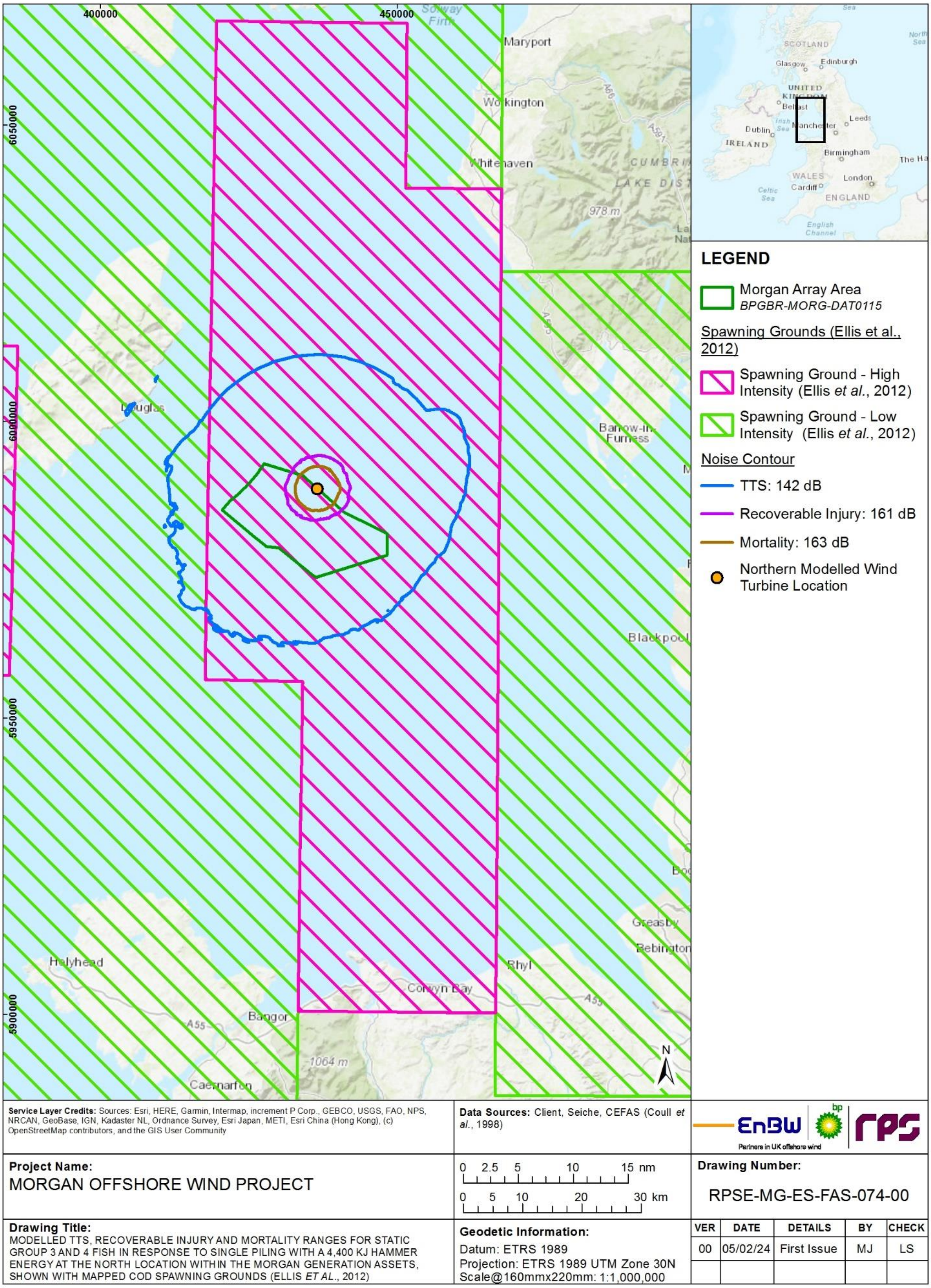


Figure 3.11: Modelled TTS, recoverable injury and mortality ranges for static group 3 and 4 fish in response to single piling with a 4,400 kJ hammer energy at the north location within the Morgan Array Area, shown with mapped cod spawning grounds (Ellis *et al*., 2012)

3.9.3.38 Another set of threshold values for exposure have been defined in the Marine Strategy Framework Directive (Sigray *et al*., 2023), with short term exposure of up to one day to impulsive sound affecting up to 20% of a habitat being acceptable, or 10% of a habitat for long term exposure of up to a year. These have not been directly applied to this assessment however, with group and species-specific thresholds applied where literature allows.

3.9.3.39 Underwater sound modelling has also been completed for underwater sound associated with UXO clearance and detonation, from a realistic worse case high order detonation to low order detonations (e.g. deflagration and clearance shots) to be used as mitigation to minimise sound levels. Table 3.26 details the injury ranges for fish of all groups in relation to various orders of detonation (see Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement for full details on UXO modelling assumptions and factors). For the purposes of this assessment, it has been assumed that the MDS will be clearance of UXO with a NEQ of 907 kg cleared by either low order or high order techniques.

3.9.3.40 Note that the content of Table 3.26 is taken directly from Volume 3, Annex 3.1: Underwater sound technical report of the Environmental Statement, Table 1.27 and Table 1.28.

Table 3.26: Injury ranges for all fish groups relating to varying orders of detonation.

[a] Note: Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near field (N; i.e. 10s of metres), intermediate (I; i.e. 100s of metres), and far field (F; i.e. 1000s of metres); Popper *et al*. (2014).

Detonation Size (kg)	PTS range (m)	
	Fish lower range	Fish higher range
Low Order and Low Yield Detonations		
0.08 (donor charge)	44	27
0.5 (clearing shot)	81	49
0.75 (x2)	117	70
0.75 (x4)	147	88
High Order Detonations		
1.2 (disposal donor)	108	65
3.5 (disposal donor)	154	93
25	297	179
130	514	309
907	985	590

Behaviour of marine fish in response to sound

3.9.3.41 Fish species responses to construction-related underwater sound include a wide variety of behaviours, including startle (C-turn) responses; strong avoidance behaviour; changes in swimming or schooling behaviour, or changes of position in the water column. The Popper *et al*. (2014) guidelines provide qualitative behavioural criteria for fish from a range of sound sources. These categorise the risks of effects in relative terms as ’high’, ’moderate’ or ’low’ at three distances from the source: ‘near’ (i.e. tens of metres), ’intermediate’ (i.e. hundreds of metres) or ’far’ (i.e. thousands of metres).

3.9.3.42 Any potential short-term sound effects on fish may not necessarily translate to population scale effect or disruption to fisheries, with a relatively low amount of information available about in-situ behavioural effects, and a review by Carroll *et al*. (2017) showed that sound impact experiments on caged fish can lead to highly variable results. Therefore, many laboratory experiments are more useful for providing evidence of potential physiological impacts than behavioural or population-level effects. Also, the response between and even within species to sound impacts is noted to be so variable that an evidence base that is sufficiently robust to propose quantitative criteria for behavioural effects is not currently available (Hawkins and Popper, 2016; Popper *et al*., 2014). As such the qualitative criteria for the four fish groups outlined in Table 3.27 are proposed, which propose risk ratings for behavioural effects and masking in the near field (i.e. tens of metres), intermediate field (hundreds of metres) and far field (thousands of metres).

Table 3.27: Potential risk for the onset of behavioural effects in fish from piling (Popper *et al*., 2014)[a].

Type of fish	Masking[a]	Behaviour[a]
Group 1 Fish: no swim bladder (particle motion detection)	N: Moderate risk I: Low risk F: Low risk	N: High risk I: Moderate risk F: Low risk
Group 2 Fish: swim bladder is not involved in hearing (particle motion detection)	N: Moderate risk I: Low risk F: Low risk	N: High risk I: Moderate risk F: Low risk
Groups 3 and 4 Fish: swim bladder involved in hearing (pressure and particle motion detection)	N: High risk I: High risk F: Moderate risk	N: High risk I: High risk F: Moderate risk
Eggs and larvae	N: Moderate risk I: Low risk F: Low risk	N: Moderate risk I: Low risk F: Low risk

3.9.3.43 Group 1 Fish (e.g. flatfish, elasmobranchs, and lamprey), and Group 2 Fish (e.g. salmonids) are less sensitive to sound pressure, with these species typically detecting sound in the environment through particle motion. However, sensitivity to particle motion in fish is also more likely to be important for behavioural responses rather than injury (Hawkins, 2009; Mueller-Blenkle *et al*., 2010; Hawkins *et al*., 2014). Group 3 (including gadoids such as cod and whiting) and Group 4 fish (herring, sprat, and shad) are more sensitive to the sound pressure component of underwater sound and, as indicated in Table 3.27, the risk of potential behavioural effects in the intermediate and far fields are therefore greater for these species.

3.9.3.44 As discussed above, in terms of physical effects, injury up to and including mortality for many marine and diadromous fish species is to be expected for individuals within very close proximity to piling operations. However, this is unlikely to result in significant mortality due to soft start procedures allowing individuals in close proximity to move away from the area, prior to maximum hammer energy levels which may cause injury to greater ranges.

3.9.3.45 Group 1 elasmobranch species do not possess a swim bladder, and thus will be most impacted by particle motion, with evidence of startle and moving away responses to piling sounds a minimum of 20 to 30 dB re 1 μPa above background conditions due to increased particle motion (Casper *et al*., 2012). It is likely that the designed-in soft start procedure will allow reactive individuals near the construction activities to avoid injury by moving away from the immediate area of the source, suggesting low vulnerability overall to this impact. In terms of recoverability, the construction activities will be temporary, and once they have ceased, elasmobranch species have been noted to gather around operational offshore built infrastructure (Stanley and Wilson, 1991), indicating a high recoverability after the end of the initial construction activities.

3.9.3.46 A number of studies have examined the behavioural effects of the sound pressure component of impulsive sound (including piling and seismic airgun surveys using airgun sound sources) on fish species. Seismic surveys are being used in this assessment as a proxy for piling where appropriate, and as such the findings should be interpreted with caution due to the sound produced having a higher decibel level but being more limited in scope and from a different source. Surveys using air gun seismic sources are not planned to be undertaken for the Morgan Generation Assets. A study by Pearson *et al*. (1994) on the effects of geophysical survey sound on caged Group 2 rockfish *Sebastes spp.* observed a startle (C-turn) response at peak pressure levels beginning around 200 dB re 1 µPa SPL_{pk}, although this was less common with the larger fish. Studies by Curtin University in Australia for the oil and gas industry by McCauley *et al*. (2000) exposed various fish species in large cages to sound from a physical seismic airgun approaching the cages and assessed behaviour, physiological and pathological changes, with a general fish behavioural response to move to the bottom of the cage during periods of high level exposure (greater than SPL Root-Mean-Square (RMS) levels of around 156 dB to 161 dB re 1 µPa; approximately equivalent to SPL_{pk} levels of around 168 dB to 173 dB re 1 µPa). This was followed by a return to baseline behaviour within 30 minutes of cessation of airgun activities, with no significant long-term physiological impacts noted, except for likely reversible hearing hair cell damage at shore range. The behaviour of moving towards the bottom of the water column was noted in-situ by Fewtrell and McCauley (2012), with significant alarm responses noted in all investigated species at sound levels exceeding 147 to 151 dB re 1µPa^2.s SEL in every case, although these responses were also temporary and returned to baseline behavioural conditions shortly thereafter.

3.9.3.47 Application of the abovementioned studies to wild fish should be interpreted with caution due to inherent differences in reactions expected between caged versus free-roaming fish and using seismic airgun impulse sound as a proxy for pile-driving and other sound sources, except for UXO clearance due to the lack of the shockwave mechanism associated with explosives. Piling and seismic surveys both result in highly repetitive impulsive sound emissions, whereas UXO clearance is likely to comprise singular, or a small series of blasts of gradually increasing sound levels (where high order techniques are used), therefore the real-world impacts between the two are likely to differ significantly. In addition, explosions create a shockwave which can lead to barotrauma effects; this is not a characteristic of airgun sources. Differences also apply between seismic airguns and pile driving, in terms of overall sound exposure levels and frequencies, with the source sound levels for piling typically being similar to, if not higher than, the seismic air gun arrays. However specific studies relating to the impacts of UXO clearance and pile driving on fish and shellfish receptors are limited and thus a proxy is used to support the evidence base for assessment.

3.9.3.48 As outlined above, behavioural effect thresholds proposed by Popper *et al.* (2014) are qualitative, however in order to provide a more quantitative estimation of the range at which behavioural effects may occur, sound modelling was undertaken for SPL_{pk} for single and concurrent scenarios around the Morgan Generation Assets (i.e. these sound contours are presented and discussed below relative to spawning habitats for key species in the fish and shellfish ecology study area. The contours show SPL_{pk} associated with the greatest hammer energy for a single pin pile. Based on the studies summarised above, it can be expected that behavioural effects could be expected within the 160 dB re 1 μPa SPL_{pk} contours, noting that this is likely to be conservative given McCauley *et al*. (2000) noted behavioural effects on a range of species at approximately 168 dB re 1μPa SPL_{pk}. For group 1 and group 2 fish species this is likely to be highly precautionary as they are known to be less sensitive to underwater sound (Popper *et al*., 2014). It is unlikely that the maximum hammer energy of 4,400 kJ would be used in most piling activities, potentially reducing the range of the sound contours. These ranges and the results discussed below broadly align with qualitative thresholds for behavioural effects on fish as set out in Table 3.27, with moderate risk of behavioural effects in the range of hundreds of metres to thousands of metres from the piling activity, depending on the species.

Behaviour, injury and mortality – herring

3.9.3.49 Herring are known to be particularly sensitive to underwater sound (i.e. group 4 species). Specifically, herring possess ancillary hearing structures which involve gas ducts extending into the skull, allowing detection of extremely high frequency sounds (Mann *et* al., 2001). Further, they have specific habitat requirements for spawning which makes them particularly vulnerable to disturbance. For herring, the core spawning grounds are located north and northwest of the Morgan Array Area, directly southeast and northeast of the IoM, with seabed sediments directly within the Morgan Array Area shown to be largely unsuitable for herring spawning. Sound contours shown in Figure 3.12 and Figure 3.13 indicate that there is overlap between the herring spawning grounds and the 160 dB re 1μPa SPL_{pk} sound contour at the north-most piling location, and most other planned piling locations. Significant but reversible diving reactions have been noted for sounds up to 168 dB re 1μPa SPL_{pk} (Doksaeter *et al*., 2012; based on impulsive sonar sound sources), which is above the 160 dB re 1μPa SPL_{pk} threshold suggested above.

3.9.3.50 To ensure a precautionary approach is taken for this sensitive species, it was recommended by the Cefas during the Benthic Ecology, Fish and Shellfish and Physical Processes EWG04 in July 2022 that a threshold of 135 dB re $1μPa^2$.s SEL_{ss} is used to assess herring spawning. This is based on Hawkins and Popper (2014), where the potential for behavioural responses including break up of schools and diving at this sound level were identified in sprat and mackerel in a naturally quiet coastal environment where fish were not habituated to sound from vessels or other significant sound sources. This environment and lack of habituation varies significantly from the baseline conditions known to exist in the Irish Sea, and the value of comparison to this sound level is therefore limited. Hawkins and Popper (2014) do not recommend that the data from this study is used as a standardised impact threshold. A threshold of 160 dB re 1μPa SPL_{pk} is therefore considered more appropriate for detecting real impacts, based on the evidence set out above.

3.9.3.51 For completeness and in response to stakeholder request, Figure 3.6 presents sound contours for SEL_{ss} for the maximum hammer energy associated with pin pile installation and indicates that, based on a threshold of 135 dB re $1μPa^2$ SEL_{ss}, up to 54.9% of combined high and low intensity herring spawning ground could be affected for piling at the west modelled piling location. Using the SPL_{pk} metric, up to 35.5% of combined high and low intensity herring spawning ground could be affected (Figure 3.7). When comparing this to the 3,000 kJ hammer energy which will be the applied maximum at 75% of jacket locations and for 100% of gravity based foundations, up to 50.2% and 28.7% of combined high and low intensity spawning ground could be affected, based on the SEL_{ss} (Figure 3.12) and SPL_{pk} metrics and thresholds (Figure 3.13), respectively. The assessment is based upon the MDS of 4,400 kJ hammer energy; however it is useful to highlight the difference in percentage overlap associated with the lower maximum hammer energy. However as noted above, any potential effects of piling will be temporary and intermittent (i.e. 114 days over a two year piling phase) and any potential effects on herring would only occur during the herring spawning season (late September for three to four weeks; Dickey-Collas *et al.*, 2001).

3.9.3.52 If herring are present within an area due to acting under other biological drivers, the disruption causes by underwater sound may be non-significant. This was found in an investigation into the impact of impulsive seismic air gun surveys on feeding herring schools, which found a slight but not significant reduction in swimming speed when exposed to the sound impact (Peña *et al*., 2013). The findings of this survey indicated that feeding herring did not display avoidance responses to seismic sound sources, even when the vessel came into close proximity to herring. This indicated an awareness of and response to impulsive anthropogenic sound, which would be expected in response to piling, but not a significant short term behavioural response when fish were highly motivated to remain within an area – in this case during feeding, but potentially also in spawning. It may therefore be expected that increased tolerance (and decreased sensitivity) to underwater sound may occur for some fish and shellfish during key life history stages, such as spawning or migration. Another example is from a spawning herring survey undertaken whilst piling was occurring at the Gunfleet Sands offshore wind farm within the relatively enclosed environment of the Thames estuary. Aggregations of spawning herring were caught within 10 to 15 km of active piling on the spawning grounds at Eagle Bank and Colne Bar, thus indicating that spawning was not entirely disrupted by piling at Gunfleet Sands offshore wind farm. This study suggests that herring's biological driver to use these grounds to spawn may have overridden the potential behavioural effects of percussive piling sound on herring (Brown and May Marine Ltd, 2009d).

3.9.3.53 For comparison to the single pin piling scenario, and in response to stakeholder requests, Figure 3.4 presents sound contours for the SEL_{cum} metric for concurrent piling at the maximum hammer energy of 3,000 kJ associated with pin pile installation at the west location. This figure indicates that, based on a threshold of 135 dB re 1 μPa^2 SEL_{cum} (which differs slightly to that of SEL_{ss}), approximately the same area of herring high and low intensity spawning grounds will be impacted as in the SEL_{ss} single piling at 4,400 kJ hammer energy scenario (Figure 3.6 also presents this data with the heat-mapped NINEL herring larval densities, based on 10 years of aggregated data). In either case, any potential effects of piling will be temporary and intermittent (i.e. 114 days over a two-year piling phase), and any potential effects on herring would only occur if piling occurs during the herring spawning season (late September for three to four weeks; Dickey-Collas *et al.*, 2001).

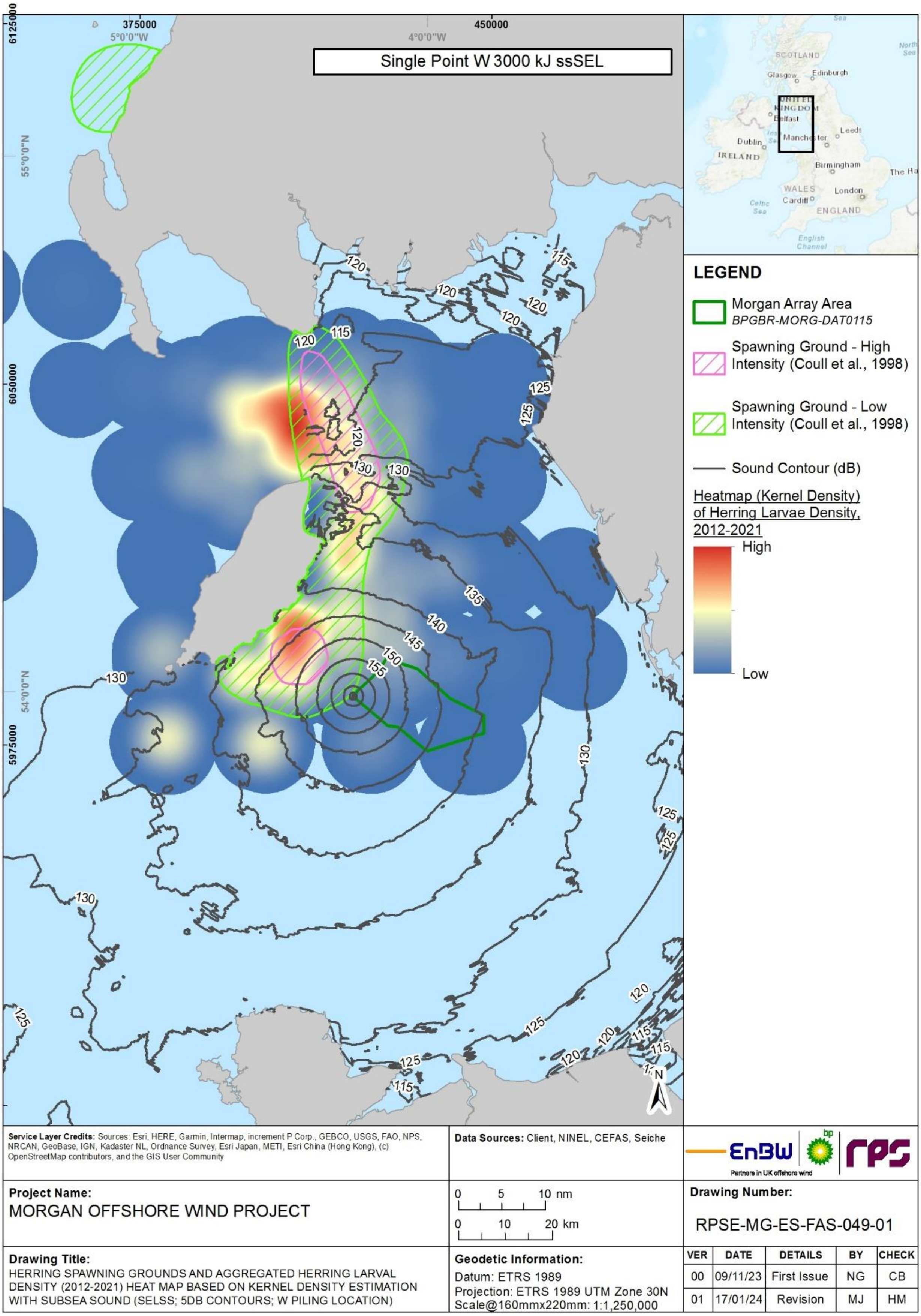
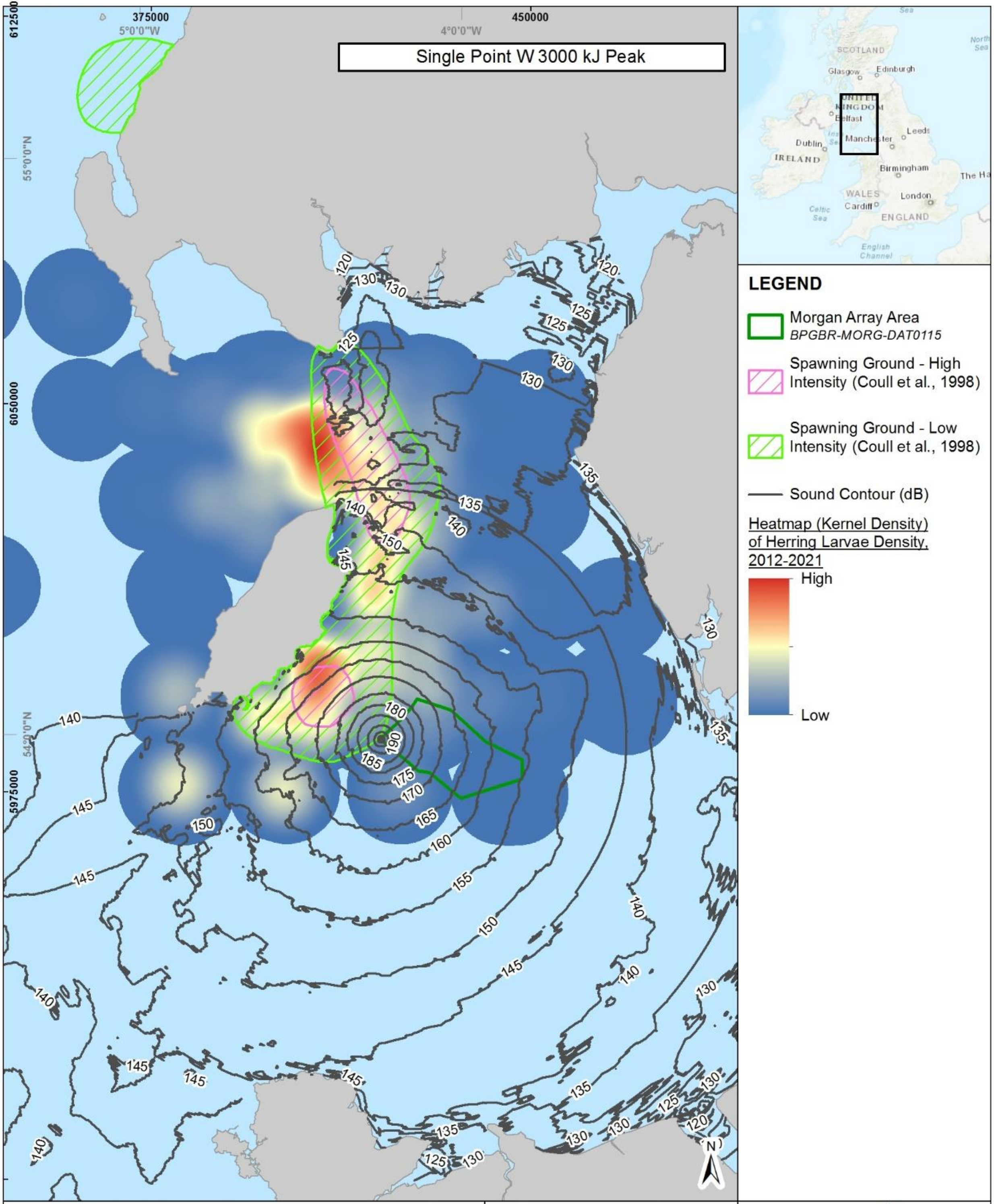


Figure 3.12: Herring spawning grounds and aggregated larval density (larvae/m^2; 2012 to 2021) with subsea 5 dB 1µPa^2.s sound SEL$_{ss}$ contours for pin pile at 3,000 kJ hammer energy at the west location.



Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Data Sources: Client, NINEL, CEFAS, Seiche

Project Name:
MORGAN OFFSHORE WIND PROJECT

0 5 10 nm
0 10 20 km

Drawing Number:
RPSE-MG-ES-FAS-048-01

Drawing Title:
HERRING SPAWNING GROUNDS AND AGGREGATED HERRING LARVAL DENSITY (2012-2021) HEAT MAP BASED ON KERNEL DENSITY ESTIMATION WITH SUBSEA SOUND (SPLPK; 5DB CONTOURS; W PILING LOCATION)

Geodetic Information:
Datum: ETRS 1989
Projection: ETRS 1989 UTM Zone 30N
Scale@160mmx220mm: 1:1,250,000

VER	DATE	DETAILS	BY	CHECK
00	09/11/23	First Issue	NG	CB
01	17/01/24	Revision	MJ	HM

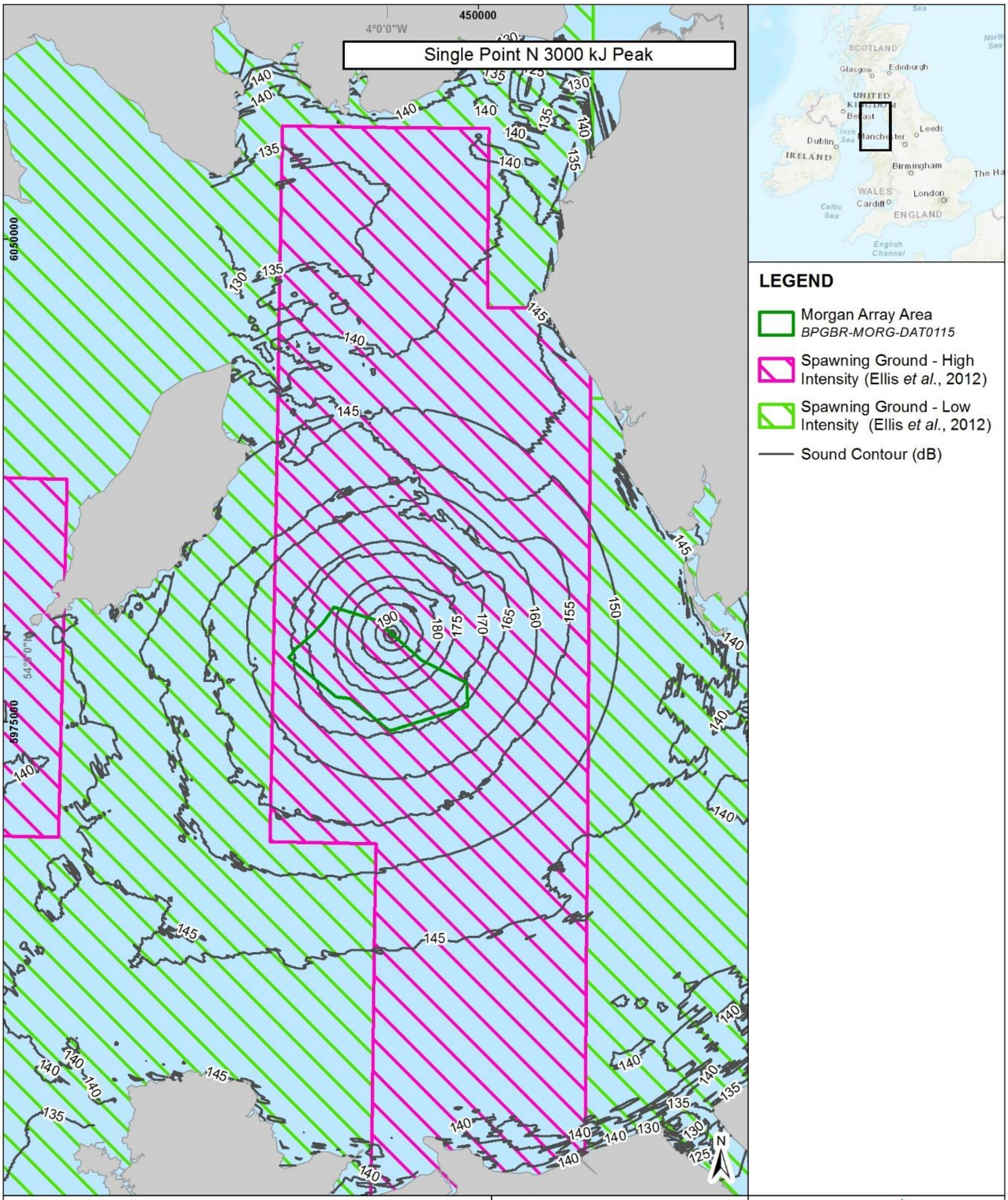
Figure 3.13: Herring spawning grounds and aggregated larval density (larvae/m^2; 2012 to 2021) with subsea 5 dB re 1μPa sound SPL$_{pk}$ contours for pin pile at 3,000 kJ hammer energy at the west location.

Behaviour, injury and mortality – cod

3.9.3.54 A number of studies have examined the behavioural effects of the sound pressure component of impulsive sound (including piling operations and seismic airgun surveys) on commercially important fish species such as Group 3 cod. Mueller-Blenkle *et al*. (2010) measured behavioural responses of cod and sole (*Solea solea*) to sounds representative of those produced during marine piling, with considerable variation across subjects (i.e. depending on the age, sex, condition etc. of the fish, as well as the possible effects of confinement in cages on the overall stress levels in the fish). This study concluded that it was not possible to find an obvious relationship between the level of exposure and the extent of the behavioural response, although an observable behavioural response was reported at 140 dB to 161 dB re 1 μPa SPL_{pk} for cod and 144 dB to 156 dB re 1 μPa SPL_{pk} for sole. However, these thresholds should not be interpreted as the level at which an avoidance reaction will be elicited, as the study was not able to show this.

3.9.3.55 More recent modelling work on cod has shown an expected decrease in population growth rates in response to loud piling sound (Soudijn *et al*., 2020), due to a decrease in food intake and an increase in energy expenditure as part of an avoidance response to sound impacts. However, this model likely underestimates cod fecundity, and this, combined with the short-term nature of the sound impact from piling (i.e. up to 114 days of piling over a two-year piling phase), suggests that long-term population-level effects are less likely to occur within the fish and shellfish ecology study area. Cod spawning behaviour was also monitored pre- and post-construction (which included piling operations) at the Beatrice wind farm site (BOWL, 2021b) and it was concluded that there was no change in the presence of cod spawning between pre- and post-construction surveys, with the caveat that spawning intensity was found to be low across both surveys. From these studies, it can be inferred that sound impacts associated with installation of an offshore wind development are temporary and that fish communities including cod in the case of Beatrice offshore wind farm show a high degree of recoverability following construction.

3.9.3.56 Figure 3.5 shows the overlap between sound contours from the north piling location relative to cod spawning habitat. This indicates that during piling at the maximum hammer energy, up to 21.9% of high intensity cod spawning habitat in the east Irish Sea could be affected; a similar overlap represents the east piling location too. When compared with piling at 3,000 kJ hammer energy (Figure 3.14; which is the maximum energy that will apply at 75% of jacket locations, and for 100% of gravity base foundations), up to 18.9% of high intensity cod spawning habitat may be subject to potential behavioural effects. When considered in the context of the mapped spawning habitat available for cod within both the fish and shellfish ecology study area and the wider Irish Sea, both these values represent only a small proportion of habitat which would be subject to potential behavioural effects during piling.



Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Data Sources: Client, NINEL, CEFAS, Seiche

Project Name:
MORGAN OFFSHORE WIND PROJECT

0 5 10 nm
0 10 20 km

Drawing Number:
RPSE-MG-ES-FAS-054-01

Drawing Title:
COD SPAWNING GROUNDS WITH SUBSEA SOUND (SPLPK; 5DB CONTOURS; N)

Geodetic Information:
Datum: ETRS 1989
Projection: ETRS 1989 UTM Zone 30N
Scale@160mmx220mm: 1:1,000,000

VER	DATE	DETAILS	BY	CHECK
00	09/11/23	First Issue	NG	CB
01	17/01/24	Revision	MJ	HM

Figure 3.14: Cod spawning grounds with subsea 5 dB re 1µPa sound SPL$_{pk}$ contours for pin piling at 3,000 kJ hammer energy at the north modelled location.

Mortality and injury – fish eggs and larvae

3.9.3.57 Potential effects on fish eggs and larvae are expected to be limited with only a low level of impacts anticipated which are limited in extent (relative to the wide-ranging nature of spawning and nursery habitats of the variety of species present within the fish and shellfish ecology study area) and with high recoverability expected where impacts do occur (Bolle *et al*., 2016). It is known that fish larvae tend to have low sensitivity to impulsive piling sound up to 210 dB re 1 µPa SPL_{pk} (Bolle *et al*., 2016). Although evidence exists of sound impacts significantly interfering with demersal larval settlement (Stanley *et al*., 2012), no significant mortality was noted for herring larvae compared to control groups after exposure to piling sound up to 216 dB re 1 μPa^2.s SEL_{cum} (Bolle *et al*., 2014).

Mortality and injury – other marine fish species

3.9.3.58 A range of other marine fish species are identified as IEFs within the fish and shellfish ecology study area (section 3.5.7), and these also have the potential to be impacted by the sound generated by piling activities. However, the relative proportion of these habitats affected by piling operations at any one time will be small in the context of the wider habitat available, and, as outlined above, piling operations will be temporary and intermittent throughout the construction phase of the Morgan Generation Assets, potentially limiting the impacts of the piling sound. It should also be noted that for all marine fish species, behavioural responses to underwater sound are highly dependent on a number of factors, such as species, sex, age, condition, life history state and other environmental stressors to which the affected individuals have been exposed.

3.9.3.59 For the ecologically important sandeel species in the fish and shellfish ecology study area previous modelling studies have indicated a possible temporary reduction in Group 1 sandeel populations in areas affected by piling sound (Serpetti *et al*., 2021). However, initial outputs of real-world post construction monitoring at the Beatrice Offshore Wind Farm (BOWL, 2021a) concluded that was no evidence of long-term adverse effects on sandeel populations between pre and post construction levels over a six-year period, demonstrating that any potential effect of sound from piling on sandeel is temporary and reversible.

3.9.3.60 Most marine fish IEFs species, including elasmobranchs, in the fish and shellfish ecology study area are deemed to be of low vulnerability, high recoverability and local to international importance. The sensitivity of the receptor is therefore, considered to be **low**.

3.9.3.61 Sprat are deemed to be of medium vulnerability, high recoverability and regional importance. The sensitivity of the receptor is therefore, considered to be **medium**. This is due to the recoverability of sprat, which are generally considered short-lived (rarely exceeding five years of age) and largely spawn actively from age two (although some individuals are reported to spawn from age one), with a moderate fecundity (ICES, 2005). Females release multiple batches of eggs (up to approximately 6,000 eggs per batch) throughout the spawning season (ICES, 2005).

3.9.3.62 Cod are deemed to be of high vulnerability, medium recoverability in the context of the Irish Sea stock, and regional importance, with overlap of sound contours from pile driving with both mapped high and low intensity spawning grounds. The sensitivity of the receptor is therefore, considered to be **high**.

3.9.3.63 Herring are deemed to be of high vulnerability, high recoverability and national importance, with strong reactions noted to relatively low levels of sound due to their hearing physiology. The sensitivity of the receptor is therefore, considered to be **high**.

It should be noted however, that evidence exists to suggest that biological drivers (i.e. those related to spawning) may override such responses to underwater sound, suggesting a potential lower sensitivity when highly motivated to continue or undertake a particular activity (Brown and May Marine, 2009d; Peña *et al.*, 2013).

Behaviour, injury and mortality – diadromous species

3.9.3.64 As with fully marine species, diadromous fish species within close proximity to piling operations may experience injury or mortality. However, the nature of diadromous fish species being highly mobile and tending to only utilise the environment within the fish and shellfish ecology study area to pass through during migration, it is unlikely to result in significant mortality of diadromous species. The use of soft start piling procedures (see Table 3.19), allowing individuals in close proximity to piling to move away from the sound source, further reduces the likelihood of injury and mortality on diadromous species.

3.9.3.65 Diadromous fish species may potentially experience behavioural effects in response to piling sound, including a startle response, disruption of feeding, or avoidance of an area. As discussed in preceding sections, these behavioural responses may occur within a range of hundreds of metres to several kilometres from piling operations, depending on the species and their relative sensitivities to underwater sound (i.e. in order of lowest to highest sensitivities.

3.9.3.66 Group 1 lamprey species, Group 2 Atlantic salmon and sea trout, Group 3 European eel, and Group 4 shad species. Lamprey species are known to have relatively simple ear structures (Popper and Hoxter, 1987), with very few responses to auditory stimuli noted overall (Popper, 2005), except a slight swimming speed increase and decrease in resting behaviour when exposed to continuous low frequency sound of 50 to 200 Hz (Mickle *et al*., 2019), suggesting a low vulnerability to sound impacts overall. The sound modelling outputs discussed in the previous sections indicated that piling related underwater sound would result in behavioural responses (e.g. as indicated by the 160 dB re 1 µPa SPL_{pk} contours, which is likely to be highly precautionary for lamprey) in the vicinity of the Morgan Array Area and these would not extend close to the coasts of north Wales or northwest England, and would have only minimal overlap with the IoM. Furthermore, the sound impacts will be short-term and intermittent in nature during the construction phase (i.e. piling occurring over approximately 114 days over a two-year piling phase). As such, there is negligible risk of disruption to migration of lamprey.

3.9.3.67 Group 2 sparling have the potential to be impacted by sound, possibly in terms of disruption to migration to their preferred spawning habitats, such as in the Ribble Estuary and Wyre Lune MCZs as outlined in section 3.5.6. However, this species is largely restricted to coastal and estuarine habitats and the extent of the sound contours modelled and plotted in Figure 3.14 demonstrate no overlap of the 160dB re 1 µPa SPL_{pk} contours with coastal areas of north Wales or northwest England. Further, evidence from a port sound study indicates that sparling are able to habituate to repeated sound impacts with no significant loss of ecological function (Jarv *et al*., 2015). As the sound from piling has little overlap with these habitats, and will be short term and intermittent, sparling are likely to have low vulnerability and high recoverability to this impact and are therefore at negligible risk to this impact.

3.9.3.68 The Group 2 Atlantic salmon responses to sound impacts have been investigated, with research from Harding *et al.* (2016) failing to produce physiological or behavioural responses in Atlantic salmon when exposed to playback of sound produced by piling. However, the sound levels tested were estimated at <160 dB re 1 µPa SPL rms, below the level at which injury or behavioural disturbance would be expected for Atlantic salmon. Nedwell *et al*. (2006) used the slightly less sensitive sea trout as a model for comparison to Atlantic salmon, and found no significant behavioural response from piling activities, with modelling suggesting a similar response in Atlantic salmon and sea trout. Physical impacts on migrating salmonids have been noted from piling producing sounds of 218 dB re 1μPa^2.s at one metre (Bagocius, 2015), although at these sound levels, it would be expected that avoidance reactions would occur, thus avoiding injury effects. The sound modelling outputs discussed in the previous sections indicated that piling related underwater sound would result in behavioural responses (e.g. as indicated by the 160 dB re 1 μPa SPL_{pk} contours; which is likely to be precautionary for Atlantic salmon and sea trout) in the vicinity of the Morgan Array Area and these would not extend close to the coasts of north Wales or northwest England, and would have only minimal overlap with the IoM. Further, the sound impacts will be short-term and intermittent in nature during the construction phase (i.e. piling occurring over approximately 114 days over a two-year piling phase). As such, there is negligible risk of disruption to migration of these species. The low risk of potential effects on migration of Atlantic salmon and sea trout extends to the freshwater pearl mussel, as part of its life stage is reliant on salmonid species.

3.9.3.69 The Group 3 European eel is known to have a wide hearing range (Jerko *et al*., 1989), with startle responses (Sand *et al*., 2000) and more than a doubling of short-term migration distances close to sources of infrasound deterrents (Piper *et al*., 2019). However, these impacts were noted on juveniles migrating towards the sea, with there being no significant impact expected on juveniles as a result. Eels are also known to be more vulnerable to predation due to difficulty in detecting predators compared to control groups when exposed to simulated underwater sound of shipping activity from harbours (Simpson *et al*., 2014), with recovery noted when the sound source was removed. As noted above, the sound modelling outputs discussed in the previous sections indicated that piling related underwater sound would result in behavioural responses (e.g. as indicated by the 160 dB re 1 μPa SPL_{pk} contours) in the vicinity of the Morgan Array Area and these would not extend close to the coasts of north Wales or northwest England and would have only minimal overlap with the IoM. Further, given the short-term and intermittent nature of any construction activities (i.e. piling occurring over approximately 70 days over a two-year piling phase) alongside the relatively short migration window of eels through the affected zones of the Morgan fish and shellfish ecology study area and the noted recovery when sound sources are removed or lessened, it is predicted that any impact to European eel will be **minor**.

3.9.3.70 The highly sensitive Group 4 shad species (i.e. allis and twaite shad), like herring, are known to be sensitive to underwater sound, particularly ultrasonic tones (e.g. these were found to be able to detect ultrasonic tones of 171 dB re: 1 μPa SPL_{pk} at a distance of up to 187 m (Mann *et al*., 1998) and evasive behaviours were commonly seen in direct response to ultrasonic stimuli (Platcha and Popper, 2003)). Due to this sensitivity and evasive response, it is unlikely that shad species will remain in the vicinity of construction activities for a long enough period to cause significant harm, which will be further minimised by the utilisation the soft-start procedure during piling activities. Disruption to migration may occur in the immediate vicinity of the Morgan Generation Assets during piling activities, but these will be short term and intermittent, and the sound levels which could cause a behavioural response are unlikely to extend to the coastlines from any of the piling scenarios modelled. Shad would have the highest potential to be affected if piling occurred during the entire migratory period for these species, which occurs over spring up until June, and peaks in April and May for both species (Acolas *et al.*, 2004). However, with the underwater sound mitigation measures proposed in section 3.7.1.2 including implementation of an Underwater sound management strategy (Outline strategy provided in Document Reference J13) and MMMP (to include requirements for soft start piling at all times; Document Reference J17), there is likely to be a low risk of disruption to migration of these species.

3.9.3.71 Most diadromous fish species IEFs in the fish and shellfish ecology study area are deemed to be of low vulnerability, high recoverability and national to international importance. The sensitivity of the receptor is therefore, considered to be **low**.

3.9.3.72 Allis shad and twaite shad are deemed to be of medium vulnerability, high recoverability, and national importance. The sensitivity of the receptor is therefore considered to be **high**.

Behaviour, injury and mortality – shellfish species

3.9.3.73 As information on the impact of underwater sound on marine invertebrates is scarce, no attempt has been made to set standardised exposure criteria (Hawkins *et al*., 2014). Studies on marine invertebrates have shown their general sensitivity to substrate borne vibration (Roberts *et al*., 2016), with aquatic decapod crustaceans possessing a number of receptor types potentially capable of responding to the particle motion component of underwater sound (e.g. the vibration of the water molecules which results in the pressure wave) and ground borne vibration (Popper *et al*., 2001). Sound is detected more as particle motion through stimulation of sensory setae within statoliths (Carroll *et al*., 2017), although these animals also have other mechanoreceptor systems which could be capable of detecting vibration. Broadly, evidence exists of crustaceans being sensitive to sounds of frequency <1 kHz (Budelmann, 1992). It has also been reported that the sound wave signature of piling sound can travel considerable distances through sediments (Hawkins and Popper, 2016), with implications for demersal and sediment dwelling shellfish species (e.g. *Nephrops*) in close proximity to piling activities.

3.9.3.74 Scott *et al*. (2020) provides a review of the existing published literature on the influence of anthropogenic sound and vibration and on crustaceans, including IEF species. The review concluded that some literature sources identified behavioural and physiology effects on crustaceans from anthropogenic sound, however, there were several that showed no effect. The paper notes that to date no effect or influence of sound or vibrations has been reported on mortality rates or fisheries catch rates or yields. In addition, no studies have indicated a direct effect of anthropogenic sound on mortality, immediate or delayed (Scott *et al*., 2020).

3.9.3.75 Of the shellfish IEF species within the fish and shellfish ecology study area, decapod crustaceans such as European lobster, edible crab, and *Nephrops* are believed to be physiologically resilient to sound as they lack gas filled spaces within their bodies (Popper *et al*., 2001). To date, no lethal effects of underwater sound have been described for edible crab, European lobster or *Nephrops*. Sub-lethal physiological effects have been reported among *Nephrops* and related species, with a reduction in burying, bioregulation and locomotion behaviour in response to simulated shipping and construction sound (Solan *et al*., 2016), although simulated shipping sound had no effect on the physiology of *Nephrops.* Caution should be applied in the application of laboratory study (i.e. those within a controlled environment) results to wild fish and shellfish species, due to inherent variance in reactions in such differing conditions. Laboratory studies provide a useful reference to potential reactions and effects but cannot fully simulate real-world scenarios. However, given the scarcity of published literature on the subject, these studies are considered valid reference points to support assessment.

3.9.3.76 Sub-lethal physiological effects have been identified from impulsive sound sources including bruised hepatopancreas and ovaries in snow crab exposed to seismic survey sound emissions (at unspecified SPLs; DFO, 2004). Changes in serum biochemistry and hepatopancreatic cells (Payne *et al*., 2007); increase in respiration in brown shrimp *Crangon crangon* (Solan *et al*., 2016); metabolic rate changes and reduced feeding behaviour in green shore crab *Carcinus maenas* (Wale *et al*., 2013), and evidence of oxidative stress in blue mussel (Wale *et al*., 2019) have also been identified.

3.9.3.77 Another study on brown shrimp found elevated SPL_{pk} sound levels are implicated in increased incidences of cannibalism and significantly delayed growth (Lagardère and Spérandio, 1981). The mud crab *Scylla paramamosain* and European spiny lobsters *Palinurus elephas* have been reported to have aspects of life history disrupted by anthropogenic sound (e.g. movement and anti-predation behaviour). In contrast to *Nephrops*, increased movement has been seen in these species in response to simulated shipping sound and offshore activities (Filiciotto *et al*., 2016; Zhou *et al*., 2016). Such findings have implications with regard to species fitness, stress and compensatory foraging requirements, along with increased exposure to predators. Although these species are not IEFs within the Morgan fish and shellfish ecology study area, this research provides useful context for the sub-lethal effects from sound impacts which the shellfish IEF species will likely similarly be exposed to.

3.9.3.78 Behavioural impacts have been noted in the giant scallop *Placopecten magellanicus*, with sound from piling travelling through the seabed out to 50 m and causing significant increases in valve closures with no acclimation to multiple piling exposures (Jezequel *et al*., 2022), which could potentially have significant impacts on feeding success during construction at night. However, this only occurred in very close proximity to the piling activity, and the scallop returned to baseline natural behaviour almost immediately following cessation of piling. Therefore, it is unlikely that impact piling will cause any significant long-term impact on shellfish populations within the Morgan Array Area, given the relatively small proportion of the overall scallop population in the fish and shellfish ecology study area potentially affected by this impact.

3.9.3.79 Other than piling and vessel sound, shellfish will likely be exposed to pre-construction geophysical surveys within the Morgan Array Area, which would include the use of sub-bottom profiling surveys. In evaluating this impact, a report by Christian *et al*. (2003) on the effects of seismic airgun exposure (a similar impulsive high amplitude sound source to piling; >189 dB re 1 µPa SPL_{pk} @ 1 m, although air guns will not be used in these surveys) upon adult snow crabs *Chionoecetes opilio* found no significant difference between exposed and control cage snow crabs, potentially indicating a low sensitivity to this source of sound.

3.9.3.80 Another study investigated whether there was a link between seismic surveys and changes in commercial rock lobster *Panulirus cygnus* based on catch rates of surviving individuals, thereby providing a measurement of acute to mid-term mortality over a 26-year period. This found no statistically significant correlative link (Parry and Gason, 2006). A review of seismic survey impact studies found that comparison between laboratory and field studies was difficult due to differing sound properties in these controlled and uncontrolled environments (Carroll *et al*., 2017), and therefore setting standardised minimum injury and mortality thresholds was difficult for this impact (Wright and Cosentino, 2015). Despite this difficulty, direct observation has shown that scallop species show no evidence of increased mortality within 10 months of seismic airgun exposure (Parry *et al*., 2002), and lobsters show the same trend eight months following exposure (Day *et al*., 2016), suggesting a low vulnerability and high recoverability to this sound source. These studies are presented as the sound produced by these survey methods are likely to be similar to the sound sources used in pre-construction surveys and can therefore be approximately compared.

3.9.3.81 Regarding shellfish eggs and larvae, there is no direct evidence to suggest they are at risk of direct harm from high amplitude anthropogenic underwater sound such as piling (Edmonds *et al*., 2016). Evidence exists of underwater sound significantly decreasing the capacity of benthic shellfish larvae to settle following their planktonic larval phase (Stanley *et al*., 2012), potentially impacting long-term population recruitment. Of the few studies that have focused on the eggs and larvae of shellfish species, evidence of impaired embryonic development and mortality has been found to arise from playback of sound from seismic air gun sources among scallop, with up to 46% of affected larvae developing abnormalities compared to control groups (De Soto *et al*., 2013). There is limited information on the effect of impulsive sound upon crustacean eggs, and no128ornicath has been conducted on commercially exploited decapod species in the UK, with all available studies focusing on seismic survey sound impacts. Similar to scallop larvae, exposure to sounds from seismic source arrays could be implicated in delayed hatching of snow crab eggs, causing resultant larvae to be smaller than controls (DFO, 2004). However, Pearson *et al*. (1994) found no statistically significant difference between the mortality and development rates of stage II Dungeness crab *Metacarcinus magister* larvae exposed to single field-based discharges (231 dB re 1μPa SPL_{pk} source level at 1 m) from a seismic airgun, highlighting the heterogeneity of results in this field, with further study required to refine this understanding. The existing evidence suggests a medium vulnerability of shellfish eggs and larvae to this impact, although recoverability of shellfish into spawning habitats is predicted to be high.

3.9.3.82 At a population level, monitoring of European lobster catch rates at the Westermost Rough Offshore Wind Farm indicated that there were no significant negative effects on shellfish species during and after construction compared to baseline conditions (Roach *et al*., 2018), with the respite from fishing activities from construction exclusion zones actually having short term benefits for some populations. While there may be some residual uncertainty with regard to potential behavioural effects while piling operations are ongoing, the limited available evidence suggests that long term effects will not occur, and any effects will be reversible.

3.9.3.83 All shellfish IEFs, including European lobster, *Nephrops* edible crab, and king and queen scallops are deemed to be of low vulnerability, high recoverability and local to regional importance. The sensitivity of the receptor is therefore considered to be **low**.

Significance of effect

3.9.3.84 For most marine fish, the magnitude of the impact is deemed to be low, and the sensitivity of most marine fish IEFs is considered low. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.3.85 For sprat, the magnitude of the impact is deemed to be low, and the sensitivity is considered medium. The effect will be of **minor adverse** significance, which is not significant in EIA terms.

3.9.3.86 For cod, the magnitude of the impact is deemed to be low, and the sensitivity is considered high. The effect will be of **minor adverse** significance, which is not significant in EIA terms. This significance is due to the small degree of overlap between widespread spawning grounds which extend across the Irish Sea (therefore indicating a wide area of available habitat suitable for spawning) and sound levels which may cause behavioural responses and considers the importance of cod within the fish and shellfish ecology study area following stock collapse and subsequent slow recovery.

3.9.3.87 For herring, the magnitude of the impact is deemed to be medium, and the sensitivity of herring is considered to be high. The effect will, therefore, be of **moderate adverse** significance, which is significant in EIA terms. This is due to the hearing sensitivity of herring, coupled with the presence of discrete high and low intensity spawning grounds within range of underwater sound levels which may give rise to behavioural effects.

3.9.3.88 For most diadromous fish species, the magnitude of the impact is deemed to be low, and the sensitivity of diadromous IEFs is considered low. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms, due to the minimal risk of disruption to migration of diadromous fish species.

3.9.3.89 For allis shad and twaite shad, the magnitude of the impact is deemed to be low, and the sensitivity of allis and twaite shad is deemed to be high. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms. This is due to the short term, intermittent nature of the impact being unlikely to affect migration to or from key rivers, and the lack of direct sound impact on freshwater spawning habitats.

3.9.3.90 For shellfish species, the magnitude of the impact is deemed to be low, and the sensitivity of all shellfish IEFs is considered low. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

Further mitigation and residual effects

3.9.3.91 The project alone assessment predicts significant effects to herring as a result of underwater sound generated by piling during the herring spawning period (late September for three to four weeks; Dickey-Collas *et al.*, 2001). Tertiary mitigation is secured through the Outline Underwater sound management strategy (Document Reference J13) which is secured as a condition of the deemed marine licence(s) within the Draft DCO (Document Reference C1). This strategy establishes a process of investigating options to manage underwater sound levels in consultation with the licensing authority and SNCBs and agreeing, prior to construction of those works which would lead to underwater sound impacts, which mitigation measures will be implemented to reduce impacts such that there will be no residual significant effect.

3.9.4 Increased SSCs and associated sediment deposition

3.9.4.1 The construction, operations and maintenance, and decommissioning activities on the wind turbine foundations, OSP foundations, and inter-array and interconnector cables of the Morgan Generation Assets may lead to increased SSCs and associated sediment deposition. The MDS is represented by sandwave clearance, cable installation and burial, and wind turbine and OSP foundation installation, and is summarised in Table 3.18. Volume 4, Annex 1.1: Physical processes technical report of the Environmental Statement provides a full description of the physical processes baseline characterisation, including numerical modelling used to inform the predictions made with respect to increases in suspended sediment and subsequent deposition.

3.9.4.2 For more generalised conditions the Cefas Climatology Report 2016 (Cefas, 2016) and associated dataset provides the spatial distribution of average non-algal Suspended Particulate Matter (SPM) for the majority of the UK Continental Shelf (UKCS). Between 1998 and 2005, the greatest plumes are associated with large rivers such as the Thames Estuary, The Wash and Liverpool Bay, which show mean values of SPM above 30 mg/l. Based on the data provided within this study, the SPM associated with the Morgan Generation Assets has been estimated as approximately 0.9 mg/l to 3 mg/l over the 1998 to 2005 period.

Construction phase

Magnitude of impact

3.9.4.3 For the purposes of this assessment, the following activities have been considered (see Table 3.18):

- Seabed preparation (sandwave clearance)
- Drilling for wind turbine and OSP foundation installation
- Installation of inter-array and interconnector cables.

3.9.4.4 The MDS for sandwave clearance activities are to be undertaken over an approximate 12-month duration within the wider four-year construction programme. Clearance for the inter-array cables accounts for up to an 80 m wide corridor along 156 km of cable length and to an average depth of 3 m, totalling a spoil volume of up to 5,026,651 m^3. The interconnector cables sandwave clearance activities account for a smaller total spoil volume of 3,060,814 m^3, based on clearance in a 104 m wide, 5.1 m deep corridor along up to 36 km of cable length.

3.9.4.5 Modelling of suspended sediment movement associated with the site preparation for the inter-array and interconnector cables assumed a speed of 100 m/h for a period of four hours. Material was then deposited over a 45-minute period. The dredging phase plumes were smaller than the dumping phase with concentrations of <50 mg/l. The release phase plume was larger than the dredging plume with concentrations reaching 3,000 mg/l at the release site. The 20 km tidal excursion surrounding the site will experience the greatest area of increased SSC, with re-mobilisation of 500 mg/l – 1,000 mg/l, with average levels of <500 mg/l on subsequent tides. Sedimentation one day following the cessation of the clearance activities results in deposited material at the site of release of up to 0.5 mm in depth (considered in temporary habitat loss section 3.9.2 above), whilst in the wider area, approximately 100 m from the release, deposited material reaches depths of typically 0.3 mm, still detectable above background levels of <0.01 mm, but expected to decrease on subsequent tidal cycles.

3.9.4.6 Sandwave clearance associated with wind turbine and OSP foundations is based upon clearance being required at up to 60% of locations. The spoil volume, based on 41 locations using the largest four-legged suction bucket jacket foundations with a diameter of 205 m to an average depth of 7.5 m, equates to 10,149,455 m^3.

3.9.4.7 The MDS for foundation installation assumes installation of 45 wind turbine foundations with three-legged jacket piles of 5.5 m diameter, drilled to a depth of 75 m at a rate of 1.45 m/h (Table 3.18), with an expected spoil volume of 2,107 m^3 per pile. A further 23 wind turbine foundations will be installed with conical gravity base foundations, which requires dredging of a maximum area of 32,761 m^2 to a maximum depth of 10 m. One OSP foundation will be installed with six legs and three piles per leg of 5.5 m diameter, drilled to a depth of 75 m at a rate of up to 1.45 m/h, resulting in 2,107 m^3 of spoil per pile. A sample of three representative pile installation scenarios (A – northwest, B – northeast, and C – southeast) were simulated to cover the range of conditions in terms of water depth, tidal currents and sediment grading. At each location modelling assessed two piles being installed simultaneously.

3.9.4.8 Modelling of suspended sediments was performed for multiple scenarios involving different piling locations and durations, and specific details of the outcomes of these scenarios is available in Volume 4, Annex 1.1: Physical processes technical report of the Environmental Statement, and in Volume 2, chapter 1: Physical processes of the Environmental Statement. Broadly, the modelling found that SSCs would increase by up to 50 mg/l in the area immediately surrounding the piling, with a rapid reduction back to background levels of sedimentation as time and distance from the piling activity increased.

3.9.4.9 The modelling of post-construction sedimentology showed that the majority of changes will occur within 100 m of the wind turbine foundation structures along the direction of principle tidal currents. This limited extent was derived from an expected ±10% change in local current speeds which was predicted to return to baseline conditions within days, and which is significantly below the changes associated with a standard storm event in the area. This indicates a low magnitude of impact associated with the wind turbine foundation installations.

3.9.4.10 The MDS for the installation of inter-array cables and interconnector cables assumes installation via trenching or jetting. Trenches are expected to have a width of 3 m and a depth of 3 m (Table 3.18), resulting in the mobilisation of up to 1,755,000 m^3 of material along the 390 km of inter-array cable routes, and up to 270,000 m^3 of mobilised material for the 60 km of interconnector cables. The modelling presented in Volume 4, Annex 1.1: Physical processes technical report of the Environmental Statement modelled peak increases in SSCs of 50 to 500 mg/l in the immediate vicinity of the works, with the higher concentration associated with the inter-array cables. This sediment is subsequently re-suspended and dispersed on subsequent tides giving rise to concentrations of up to 1,000 mg/l for the interconnector cables three days later. The material settles during slack water and then is re-suspended to form a secondary plume which becomes amalgamated. Sedimentation is predicted to be greatest at the location of the trenching and may be up to 50 mm in depth where the coarser material has settled within circa 100 m and will reduce significantly with distance to depths of <0.5 mm. Although the material is dispersed, it remains within the sediment cell and is therefore retained within the transport system.

3.9.4.11 The impact is predicted to be of local spatial extent, short term duration, intermittent and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore considered to be **low**.

Sensitivity of receptor

Marine species

3.9.4.12 In terms of SSC, adult fish species are more mobile than many of the other fish and shellfish IEFs, and therefore would be likely to show avoidance behaviour within areas affected by increased SSC (EMU, 2004), making them less susceptible to physiological effects of this impact. Juvenile fish are more likely to be affected by habitat disturbances such as increased SSC than adult fish, which is well researched for commercially important salmonid species (Bisson and Bilby, 1982; Berli *et al*., 2014). This is due to the decreased mobility of juvenile fish, with these animals therefore being less able to avoid impacts. Juvenile fish are likely to occur throughout the fish and shellfish ecology study area, with some species using offshore areas as nursery habitats, while inshore areas, especially within the IoM territorial waters and inshore English and Welsh waters, are more important as nurseries for other species (full list of species with spawning and nursery grounds overlapping the fish and shellfish ecology study area available in Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement).

3.9.4.13 The north Irish Sea experiences regular temporary increases in SSC, linked heavily to interannual changes in general meteorological conditions and the frequency of spring storms (White *et al*., 2003), and juveniles typically inhabit inshore areas (where SSCs are typically higher). Also, seasonal variation of SSC is known to occur in the Irish Sea, with an increase of up to a factor of 2.7 in winter compared to summer (Bowers *et al*., 2010). Given the extent of these natural changes, it can be expected that most fish juveniles expected to occur in the fish and shellfish ecology study area will be largely unaffected by the relatively low-level temporary increases in SSC resulting from the construction phase. These concentrations are likely to be within the range of natural variability – generally <5 mg/l, but this can increase to over 100 mg/l during storm events with increased wave heights and will likely reduce to background concentrations within a very short period (approximately two tidal cycles), leading to there being little to no impact on mobile species, such as the identified elasmobranch IEF species.

3.9.4.14 A study by Appleby and Scarratt (1989) found development of fish eggs and larvae have the potential to be affected by suspended sediments at concentrations of thousands of mg/l. Modelling undertaken of SSC associated with the fish and shellfish ecology study area construction phase identified peak maximum concentrations of approximately 3000 mg/l predicted in the inter-array cables and interconnector cables sandwave clearance phases. These concentrations of SSC may affect the development of eggs and larvae; however, these concentrations are only expected to be present in the immediate vicinity of the release site with dispersion of the released material continuing on successive tides. Average increases in SSC associated with sandwave clearance activities are predicted to be of the order of less than 300 mg/l. These levels are unlikely to affect the development of most eggs and larvae.

3.9.4.15 Many shellfish species, such as edible crab and king and queen scallop, have a high tolerance to SSC and are reported to be insensitive to increases in turbidity (Wilber and Clarke, 2001); however, they are likely to avoid areas of consistently increased SSC as they rely on visual acuity during predation and feeding (Neal and Wilson, 2008, Speiser and Johnsen, 2008). In the case of possible burial during settlement of SSC, both king and queen scallop have the potential to be impacted negatively.

3.9.4.16 Queen scallop have the potential to suffer 74.1% to 88.9% mortality following continual burial under less than 5 cm of sediment for two to four consecutive days (Hendrick *et al*., 2016). Emergence success was found to be lowest from burial beneath finer sediment fractions to this depth, and no emergence was found from the 5 cm or 7 cm tested burial depths over any time period (Hendrick *et al*., 2016). This indicates a high intolerance to high levels of sedimentation over relatively short time periods, with burial for longer than two days increasing mortality highly significantly. Sedimentation of greater than 5 cm thickness is expected in the immediate vicinity of the construction activities on the first day following cessation of construction encompassing a very small area around the source (see Volume 2, Chapter 1: Physical processes of the Environmental Statement for average sedimentation figures), which has the potential to lead to mortality to queen scallop present, based upon laboratory results from Hendrick *et al.* (2016). Sediment is expected to dissipate to background levels for the area by the action of tidal cycles within approximately two days following the cessation of construction, which will reduce the potential for mortality of individuals.

3.9.4.17 The Hendrick *et al.* (2016) study was laboratory-based, with any sediment removed after the set investigated time period and then mortality checked by measurement of shell gape one minute following direct disturbance. Therefore, the mortality and emergence values might be overestimates compared to a real-world scenario, where buried queen scallop would only survive if they were able to emerge on their own typically within two days, or via hydrodynamic redistribution of deposited materials, which is expected within this time frame. Therefore, as a precautionary approach, it should be considered that any sedimentation of greater than 5 cm thickness would lead to no emergence and likely full mortality within the footprint of sedimentation, and any burial under sedimentation thicknesses of up to at least approximately 5 cm will significantly increase mortality if queen scallop individuals have not emerged in under two days.

3.9.4.18 King and queen scallop both have high intensity spawning grounds almost fully overlapping the Morgan Generation Assets and are considered relatively mobile and are expected to avoid active events causing increases in SSC. This potential avoidance behaviour is less prevalent in juvenile king scallop when undergoing burial events, where burial from up to 5 cm of sediment deposition can reduce growth rates, potentially having impacts on future spawning times (Szostek, *et al*., 2013). However, the relatively low level of SSC and associated deposition, and the large area available outside of the immediate construction footprint for spawning, is unlikely to impact king scallop at a population level in the short or long term.

3.9.4.19 It has been found that for both species, survival is strongly linked to the ability to emerge from sediment (Last *et al*., 2011, Hendrick *et al*., 2016). Evidence exists that indicates that individuals of 1 mm in length have the potential to detach from the substrate in the event of disturbance, followed by recession into local sediments where possible, and where not possible this can lead to potential dispersal by currents and water turbulence (Minchin, 1992). Based on the findings of these studies, it is possible that juveniles and larvae of both species within the fish and shellfish ecology study area have the potential to survive short term increases in SSC and associated deposition. High levels of sedimentation are unlikely to occur outside of the immediate construction footprint at the Morgan Generation Assets based on the modelling presented in Volume 4, Annex 1.1: Physical processes technical report of the Environmental Statement (see average sedimentation figures). Whilst king and queen scallop should be considered in the context of being intolerant of burial under sediment for extended time periods, it is acknowledged that deposition levels of 50 mm will only occur in the immediate vicinity of the discharge point (e.g. the drilling location), whereas beyond this, deposition thickness is modelled to be just 0.3 to 0.5 mm therefore, it is unlikely that these bivalves would be affected beyond the point of sediment release.

3.9.4.20 Berried crustaceans (e.g. European lobster and *Nephrops*) are potentially more vulnerable to increased SSC as the eggs carried by these species require regular aeration. Increased SSC within the fish and shellfish ecology study area (potential habitat for egg bearing and spawning *Nephrops*, which overlaps with the entirety of the Morgan Array Area) is unlikely to impact *Nephrops*, as this species is not considered to be sensitive to increases in SSC or subsequent sediment deposition, since this is a burrowing species with the ability to excavate any sediment deposited within their burrows (Sabatini and Hill, 2008). Also, construction will only affect a small area at any one time and will be temporary in nature, with sediments settling to the seabed quickly following disturbance and becoming part of the background sediment transport regime (see assessment of magnitude above), therefore any impact on European lobster or *Nephrops* will be low within the Morgan Generation Assets fish and shellfish ecology study area.

3.9.4.21 The fish species likely to be affected by sediment deposition are those which either feed or spawn on or near the seabed. Demersal spawners within the fish and shellfish ecology study area include sandeel and herring. Spawning areas for sandeel occur within the fish and shellfish ecology study area, however sandeel and their eggs are likely to be tolerant to some level of sediment deposition due to the nature of re-suspension and deposition within their natural high energy preferred habitat and spawning environment within the Irish Sea (MarineSpace Ltd, 2013). Therefore, effects on sandeel spawning populations are predicted to be limited. Sandeel populations prefer coarse to medium sands (Wright *et al*., 2000), with sensitivity to changes in this habitat, and show reduced selection or avoidance of gravel and fine sediments (Holland *et al*., 2005). Therefore, any increase in the fine sediment fraction of their habitat may cause avoidance behaviour until such time that currents remove fine sediments from the seabed, although modelled deposition levels for fine sediments are expected to be highly localised and at very low levels (up to <5 mm, in close proximity to activities with lower sediment deposition across the wider area).

3.9.4.22 Herring occur mostly in entirely pelagic habitats, but utilise benthic environments for spawning, and are known to prefer gravelly and coarse sand environments for this purpose, specifically around the southeast and northeast of the IoM, both close to and west and northwest of the Morgan Array Area (Coull *et al*., 1998). With respect to the potential effects of sediment deposition on herring spawning activity, it has been shown that herring eggs may be tolerant of very high levels of SSC (Messieh *et al*., 1981; Kiorbe *et al*., 1981). Detrimental effects may be seen if smothering occurs and the deposited sediment is not removed by the currents (Birklund and Wijsmam, 2005), however this natural removal by the currents and tidal physical processes would be expected to occur quickly in this case (i.e. within a couple of tidal cycles), given the low levels of deposition expected close to the installed foundations. Furthermore, the limited amount of suitable sandy gravel sediments for herring spawning within the Morgan Array Area, with the majority of the sediment habitats being unsuitable (Figure 3.2), will likely limit the potential for effects of SSC on herring spawning. This is supported by the mapping of spawning grounds (as described in section 3.5.1.3), which shows the highest intensity of herring spawning within the IoM 12 nm territorial waters, just outside and to the west of the Morgan Array Area, reducing any potential for impact of SSC.

3.9.4.23 Based on the sensitivity of herring eggs to the smothering effects of sediment deposition, herring are deemed to be of medium vulnerability, medium recoverability and of national importance, and therefore the sensitivity of this receptor is considered to be **medium**.

3.9.4.24 Based on their intolerance to smothering, queen and king scallop are deemed to be of medium vulnerability, medium recoverability and of national importance; the sensitivity of these receptors is therefore considered **medium**. Queen scallop are considered of slightly higher vulnerability than king scallop to this impact, however overall, the sensitivity of both species is considered medium.

3.9.4.25 All other fish and shellfish ecology IEFs in the fish and shellfish ecology study area, including sandeel, *Nephrops*, and elasmobranch species, are deemed to be of low to medium vulnerability, high recoverability and local to national importance. The sensitivity of these IEFs is therefore considered to be **low**.

Diadromous species

3.9.4.26 Diadromous fish species known to occur in the area are also expected to have some tolerance to naturally high SSC, given their migration routes typically require them to travel through estuarine habitats, which have background SSC that are considerably higher than those expected in the offshore areas of the fish and shellfish ecology study area. As it is predicted that construction activities associated with the Morgan Generation Assets will produce temporary and short-lived increases in SSC, with levels well below those experienced in estuarine environments, it would be expected that any diadromous species should only be temporarily affected (if they are affected at all, based on the timing of the construction phase). Any potential negative effects on these species are likely to be short term behavioural effects, such as avoidance (Boubee, *et al*., 1996), or temporary slightly erratic alarmed swimming behaviour

(Chiasson, 2011), and are not expected to create any significant barrier to migration to rivers or estuaries used by these species in the fish and shellfish ecology study area. However, these studies were laboratory based, and do not cover the species found within the fish and shellfish ecology study area, so the potential for other responses does exist, but these are unlikely, given the naturally highly turbid nature of estuarine environments that these species are adapted to traverse. Investigations into the impacts of offshore increased suspended sediments on diadromous species such as Atlantic salmon are limited (Kjelland *et al*., 2015), although there is the potential for increased turbidity to improve salmon survival rates during migrations due to a lowering of predation rates from reduced visibility (Gregory and Levings, 1998).

3.9.4.27 Diadromous fish species IEFs in the fish and shellfish ecology study area are deemed to be of low vulnerability, high recoverability and national to international importance. The sensitivity of the receptors is therefore, considered to be **low.**

Significance of effect

Marine species

3.9.4.28 Overall, the magnitude of the impact is deemed to be low and the sensitivity of most fish and shellfish IEFs is considered to be low. The effect will therefore be of **minor adverse** significance, which is not significant in EIA terms.

3.9.4.29 For king and queen scallop and herring, the magnitude of the impact is deemed to be low, and the sensitivity is considered to be medium. The effect will therefore be of **minor adverse** significance, which is not significant in EIA terms.

Diadromous species

3.9.4.30 Overall, the magnitude of the impact is deemed to be low and the sensitivity of the diadromous fish IEF receptors is considered to be low. The effect is considered of **negligible** significance, which is not significant in EIA terms.

Operations and maintenance phase

Magnitude of impact

3.9.4.31 Maintenance activities within the fish and shellfish ecology study area may lead to increases in SSC and associated sediment deposition over the expected 35-year operational lifetime of the Morgan Generation Assets. The MDS describes the repair of up to 8 km of inter-array cable in one event every three years, and reburial of up to 20 km of inter-array cable in one event every five years. The MDS also describes the repair of 19.6 km of inter-array cable in each of three events every 10 years, and reburial of up to 3 km of interconnector cable in one event every five years.

3.9.4.32 The magnitude of the impacts would be a fraction of those quantified for the construction phase. The sediment plumes and sedimentation footprints would be dependent on which section of the cable is being repaired and the kind of sediment that the repairs took place in however, for the purposes of this assessment, the impacts of the operations and maintenance activities (i.e. cable repair and reburial) are predicted to be no greater than those for construction.

3.9.4.33 The impact is predicted to be of local spatial extent, short term duration, intermittent and of high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore considered to be **negligible**.

Sensitivity of receptor

Marine species

3.9.4.34 The sensitivity of the marine fish and shellfish IEFs can be found in the construction phase assessment (paragraph 3.9.4.12 to paragraph 3.9.4.24), ranging from **low to medium** sensitivity, and these will equally apply in the operations and maintenance phase.

Diadromous species

3.9.4.35 The sensitivity of the diadromous fish and shellfish IEFs can be found in the construction phase assessment (paragraph 3.9.4.26 to paragraph 3.9.4.27), with **low** sensitivity, and this will equally apply in the operations and maintenance phase.

Significance of effect

Marine species

3.9.4.36 Overall, the magnitude of the impact is deemed to be negligible and the sensitivity of most fish and shellfish IEFs is considered to be low. The effect will therefore be of **negligible** significance, which is not significant in EIA terms.

3.9.4.37 For king and queen scallop and herring, the magnitude of the impact is deemed to be negligible and the sensitivity is considered to be medium. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

Diadromous species

3.9.4.38 Overall, the magnitude of the impact is deemed to be negligible, and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **negligible** significance, which is not significant in EIA terms.

Decommissioning phase

Magnitude of impact

3.9.4.39 Decommissioning of the Morgan Generation Assets infrastructure may lead to increases in SSCs and associated sediment deposition. The MDS states that if the suction caisson foundations were to be removed this would result in a temporary increase in SSC. Scour and cable protection will remain *in situ*. Inter-array and interconnector cables will be removed and disposed of onshore.

3.9.4.40 Decommissioning would result in increases in suspended sediments and associated deposition that was no greater than what was produced during construction. For the purpose of this assessment, the impacts of decommissioning activities are therefore predicted to be no greater than those for construction. In actuality, the release of sediment in the decommissioning phase will be lower than the construction phase as it doesn’t include activities such as seabed drilling and seabed preparation.

3.9.4.41 The impact is predicted to be of local spatial extent, short term duration (for the individual decommissioning activities), intermittent and of high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore considered to be **low**.

Sensitivity of receptor

Marine species

3.9.4.42 The sensitivity of the marine fish and shellfish IEFs can be found in the construction phase assessment (paragraph 3.9.4.12 to paragraph 3.9.4.24), ranging from **low to medium** sensitivity, and these will equally apply in the decommissioning phase.

Diadromous species

3.9.4.43 The sensitivity of the diadromous fish and shellfish IEFs can be found in the construction phase assessment (paragraph 3.9.4.26 to paragraph 3.9.4.27), with **low** sensitivity, and this will equally apply in the decommissioning phase.

Significance of effect

Marine species

3.9.4.44 Overall, the magnitude of the impact is deemed to be low and the sensitivity of most fish and shellfish IEFs is considered to be low. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.4.45 For king and queen scallop and herring, the magnitude of the impact is deemed to be low, and the sensitivity is considered to be medium. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

Diadromous species

3.9.4.46 Overall, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **negligible** significance, which is not significant in EIA terms.

3.9.5 Long term habitat loss

3.9.5.1 The construction, operations and maintenance and decommissioning activities on the generation of the Morgan Generation Assets development may lead to long term habitat loss. The MDS is represented by the installation and presence of foundations, scour protection, cable protection, and cable crossing protection, and is summarised in Table 3.18. While this assessment considers long term habitat loss, in reality the impact will be represented not by a loss of habitat, but rather a change in a sedimentary habitat and replacement with hard artificial substrates (i.e. ‘Physical change to another seabed type’, as defined by MarESA). While the potential habitat loss effects are considered in this section, the potential for colonisation of these hard substrates by fish and shellfish IEFs is considered in section 3.9.7 below.

Construction and operation and maintenance phase

Magnitude of impact

3.9.5.2 The presence of the Morgan Generation Assets infrastructure within the fish and shellfish ecology study area will result in long term habitat loss. The MDS is for up to 1,309,252 m^2 of long-term habitat loss due to the installation of suction bucket four-legged jacket and gravity base foundations for wind turbines and OSPs, associated scour protection, cable protection, and cable crossing protection (Table 3.18). This represents 0.14% of the Morgan Generation Assets boundary.

3.9.5.3 The MDS includes up to 760,452 m^2 of long-term habitat loss due to foundations and associated scour protection. Foundations and associated scour protection will be required for up to all 68 wind turbines and four OSPs in the Morgan Array Area.

3.9.5.4 Cable protection may account for up to 510,000 m^2 of long-term habitat loss. The MDS assumes up to 10% of the inter-array cables and 20% of the interconnector cables would require cable protection with a cable protection width of 10 m. Additionally, cable crossing protection may result in up to 38,800 m^2 of long-term habitat loss. Cable protection may be required for 10 crossings for the inter-array cable, and 10 crossings for the interconnector cables.

3.9.5.5 Long term subtidal habitat loss impacts will occur during the construction phase and will be continuous and irreversible throughout the 35-year operations and maintenance phase.

3.9.5.6 The fish and shellfish ecology study area encompasses areas of high and low intensity spawning ground for herring, although these are located outside of the Morgan Generation Assets, in the area of Douglas Bank within the IoM territorial waters. Further, the substrates within the Morgan Array Area showed limited observations of suitable substrate for herring spawning.

3.9.5.7 Due to the absence of any overlap with mapped or reported herring spawning grounds, and the highly limited extent of substrate suitable for herring spawning, along with the highly localised spatial extent of the impact, it is predicted that this impact will not affect the receptor and the magnitude is therefore considered to be **negligible**.

3.9.5.8 In relation all other fish and shellfish ecology IEFs, the impact is predicted to be of local spatial extent, long term duration, continuous and irreversible during the operations and maintenance phase. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **low**.

Sensitivity of receptor

Marine species

3.9.5.9 Fish and shellfish species that are reliant upon the presence of suitable sediment/habitat for their survival are typically more vulnerable to change depending on the availability of habitat within the wider geographical region. The seabed habitats removed by the installation of infrastructure within the Morgan Array Area will reduce the amount of suitable habitat and available food resources for fish and shellfish species and communities associated with the baseline sediments, however this area represents a low percentage compared with the extensive nature of fish and shellfish habitats (e.g. for spawning, nursery, feeding or overwintering) located within the fish and shellfish ecology study area.

3.9.5.10 As confirmed by the detailed baseline characterisation (see section 3.5.1.2), the fish and shellfish ecology study area coincides with fish spawning and nursery habitats including plaice, sole, lemon sole, herring, sprat, European hake, ling, whiting, cod, haddock *Melanogrammus aeglefinus*, sandeel, horse mackerel *Trachurus trachurus*, mackerel, *Nephrops*, and a range of elasmobranchs (Coull *et al*., 1998; Ellis *et al*., 2012; Aires *et al*., 2014; see Table 3.14 and Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement).

3.9.5.11 The fish species most vulnerable to long-term habitat loss include sandeel and herring, which are demersal spawning species (i.e. eggs are laid on the seabed), as these have specific habitat requirements for spawning (e.g. sandy sediments for sandeel and coarse, gravelly sediments for herring). Demersal-spawning elasmobranchs tend to have low intensity spawning grounds in the fish and shellfish ecology study area (see Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement) which extend well beyond the project boundaries, and thus are unlikely to be significantly impacted by long-term habitat loss. High and low intensity herring spawning habitat is located within the fish and shellfish ecology study area (see section 3.5.2.1). These occur primarily outside the Morgan Generation Assets boundaries and therefore will not be negatively affected directly by long term habitat loss form project infrastructure.

3.9.5.12 Sandeel also have specific habitat requirements throughout their juvenile and adult life history, as well as being demersal spawners, and loss of this specific type of habitat through construction and presence of infrastructure could represent an impact on this species. However, monitoring at Horns Rev I, located off the Danish coast, has indicated that the presence of operational wind farm structures has not led to significant adverse effects on sandeel populations in the long term (van Deurs *et al*., 2012; Stenberg *et al*., 2011). Initial results of a pre- to post-construction monitoring study have reported that in some areas of the Beatrice Offshore Wind Farm, located in the northwest of the North Sea, there was an increase in sandeel abundance (BOWL, 2021a). The findings of a single monitoring study are not able to categorically confirm the conclusion that offshore wind developments are beneficial to sandeel populations; however, it does provide additional evidence that there is no adverse effect on sandeel populations.

3.9.5.13 The fish and shellfish ecology study area also coincides with high intensity sandeel spawning habitat (Ellis *et al*., 2012) as confirmed by benthic site-specific surveys (see Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement for habitat distribution and suitability). The presence of offshore wind farm infrastructure will result in direct impacts on this habitat within the Morgan Generation Assets, though as detailed above the proportion of habitat affected within the Morgan Generation Assets is small, and this area is smaller still in the context of the known sandeel habitats (including spawning and nursery habitats) and the potential sandeel habitats in the fish and shellfish ecology study area.

3.9.5.14 Monitoring at Belgian offshore wind farms has reported that fish assemblages undergo no drastic changes due to the presence of offshore wind farms (Degraer *et al*., 2020). They reported slight, but significant increases in the density of some common soft sediment-associated fish species (common dragonet *Callionymus lyra*, solenette, lesser weever *Echiichthys vipera* and plaice) within the offshore wind farm (Degraer *et al*., 2020). There was also some evidence of increases in numbers of species associated with hard substrates, including crustaceans (including edible crab), sea bass and common squid *Loligo vulgaris* (potentially an indication that foundations were being used for egg deposition; Degraer *et al*., 2020). The author noted that these effects were site specific and therefore may not necessarily be extrapolated to other offshore wind farms, although it is likely that habitats and species in similar conditions will be impacted similarly. More specific to the Irish Sea, the three years post-construction survey of introduced structures in the Walney Extension Wind Farm found the development of mussel and barnacle communities around introduced structures (CMACS, 2014b). This represents a changed species composition compared to the previous sedimentary communities, but this is unlikely to be highly significant in terms of ecosystem function, with only a slight overall reduction in biodiversity noted during post-construction surveys, with a slowly recovering trend towards baseline community diversity noted.

3.9.5.15 The Morgan Array Area also directly overlaps grounds considered important to fishing and spawning of the commercially important queen and king scallop (see Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement for full details on known habitat distribution and suitability). Construction has the potential to directly damage these fishing and spawning grounds, but the potential is known to exist for recovery and increased maturity of the overall population due to decreased fishing pressure following completion of construction, with no significant change in resilience (Raoux *et al*., 2019). Long-term loss of habitat directly around the cables and wind turbine foundations represent only a very small proportion of habitat within the fish and shellfish ecology study area, and so are unlikely to cause significant impacts on the wider scallop populations.

3.9.5.16 *Nephrops* spawning and nursery habitat overlaps with the entirety of the Morgan Array Area, with wider spawning habitats of undetermined intensity throughout the fish and shellfish ecology study area. Long-term habitat loss is predicted to affect a small proportion of this habitat. Levels of impact on *Nephrops* offshore Irish Sea fishing grounds are known to be correlated directly to the intensity and frequency of the disturbance event (Ball *et al*., 2000). As the proportion of the Morgan Generation Assets affected by long term habitat loss is small and the proportion of *Nephrops* habitat available elsewhere in the fish and shellfish ecology study area is high, the overall impact of long-term habitat loss is likely to be low.

3.9.5.17 Most fish and shellfish ecology IEFs in the fish and shellfish ecology study area are deemed to be of low vulnerability, high recoverability and local to national importance. The sensitivity of the receptor is therefore considered to be **low**.

3.9.5.18 King and queen scallop are deemed to be of medium vulnerability, high recoverability, and of regional importance. The sensitivity of the receptor is therefore considered to be **low**.

3.9.5.19 European lobster and *Nephrops* are deemed to be of high vulnerability, medium to high recoverability and of regional importance. The sensitivity of these fish and shellfish IEFs is therefore considered to be **medium**.

3.9.5.20 Sandeel are deemed to be of high vulnerability, high recoverability and of regional importance. The sensitivity of sandeel is therefore considered to be **medium**.

3.9.5.21 Herring are deemed to be of high vulnerability, medium recoverability and of national importance; the sensitivity of herring is therefore considered **medium**.

Diadromous species

3.9.5.22 Diadromous fish species are highly mobile and therefore are generally able to avoid areas subject to long term subtidal habitat loss. Diadromous species that are likely to interact with the fish and shellfish ecology study area are only likely to do so by passing through the area during migrations to and from rivers located on the west coast of England and Wales (e.g. those designated sites with diadromous fish species listed as qualifying features; see Table 3.14 and Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement). The habitats within the fish and shellfish ecology study area are not expected to be particularly important for diadromous fish species and therefore habitat loss during the construction and operations and maintenance phases of the Morgan Generation Assets is unlikely to cause any direct impact to diadromous fish species and would not affect migration to and from rivers.

3.9.5.23 Indirect impacts on diadromous fish species may occur due to impacts on prey species, for example sandeel population impacts affecting food supplies to sea trout. As outlined previously for marine species, the majority of large fish species would be able to avoid potential habitat loss effects due to their greater mobility and would recover into the areas affected following cessation of construction. Sandeel (and other less mobile prey species) would be affected by long term subtidal habitat loss, although recovery of this species is expected to occur quickly as the sediments recover following installation of infrastructure and adults recolonise and also via larval recolonisation of the sandy and gravelly sediments which dominate the fish and shellfish ecology study area. These sediments are known to recover quickly following cable installation (RPS, 2019).

3.9.5.24 Diadromous fish species are deemed to be of low vulnerability, high recoverability and national to international importance. The sensitivity of the receptor is therefore, considered to be **low**.

Significance of effect

Marine species

3.9.5.25 Overall, the magnitude of the impact is deemed to be low, and the sensitivity of most fish IEFs is considered to be low. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.5.26 For king and queen scallop, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.5.27 For European lobster and *Nephrops*, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be medium. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.5.28 For sandeel, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be medium. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.5.29 For herring, the magnitude of the impact is deemed to be negligible, and the sensitivity of the receptor is considered to be medium. The effect will, therefore, be of **negligible** significance, which is not significant in EIA terms. Negligible significance is applied due to the absence of mapped spawning grounds and presence of highly limited substrate suitable for herring spawning within the footprint of long-term habitat loss. This suggests that the area of the Morgan Generation Assets is not important for spawning herring.

Diadromous species

3.9.5.30 Overall, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be low to medium. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

Decommissioning phase

Magnitude of impact

3.9.5.31 Decommissioning will involve leaving the introduced scour protection, cable protection, and cable crossing protection in place, representing up to 1,252,116 m^2 of permanent subtidal habitat loss. Evidence exists to suggest recovery of habitats and species post-decommissioning could occur, based upon removal of all introduced infrastructure, but a precautionary approach of assessing this as permanent habitat loss has been adopted following stakeholder feedback. As such this assessment should be considered conservative.

3.9.5.32 Due to the absence of any overlap with mapped or reported herring spawning grounds, and the highly limited extent of substrate suitable for herring spawning, along with the highly localised spatial extent of the impact, it is predicted that this impact will not affect the receptor and the magnitude is therefore considered to be **negligible**.

3.9.5.33 For all other fish and shellfish ecology IEFs, the impact is predicted to be of local spatial extent, permanent and irreversible. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **low**.

Sensitivity of receptor

Marine species

3.9.5.34 The sensitivity of the marine fish and shellfish IEFs can be found in the construction phase assessment (paragraph 3.9.5.9 to paragraph 3.9.5.20), ranging from **low to medium** sensitivity, and these will equally apply in the decommissioning phase.

Diadromous species

3.9.5.35 The sensitivity of the diadromous fish and shellfish IEFs can be found in the construction phase assessment (paragraph 3.9.4.23 to paragraph 3.9.4.27), with **low** sensitivity, and this will equally apply in the decommissioning phase.

Significance of effect

Marine species

3.9.5.36 Overall, the magnitude of the impact is deemed to be low, and the sensitivity of most fish IEFs is considered to be low. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.5.37 For king and queen scallop, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.5.38 For European lobster and *Nephrops*, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be medium. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.5.39 For sandeel, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be medium. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.5.40 For herring, the magnitude of the impact is deemed to be negligible, and the sensitivity of the receptor is considered to be medium. The effect will, therefore, be of **negligible** significance, which is not significant in EIA terms. Negligible significance is applied due to the absence of mapped spawning grounds and presence of highly limited substrate suitable for herring spawning within the footprint of long-term habitat loss.

Diadromous species

3.9.5.41 Overall, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.6 Electro Magnetic Fields (EMFs) from subsea electrical cabling

3.9.6.1 The operations and maintenance activities on the transmission assets of the Morgan Generation Assets may lead to impacts from EMFs emitted from subsea electrical cabling. The MDS is represented by the presence and operation of inter-array and interconnector cables and is summarised in Table 3.18.

Operations and maintenance phase

Magnitude of impact

3.9.6.2 EMFs comprise both the electrical fields, measured in volts per metre (V/m), and the magnetic fields, measured in microtesla (µT) or milligauss (mG). Background measurements of the magnetic field are approximately 50 µT (i.e. 500 mG) for example in the North Sea and Irish Sea (Tasker *et al.*, 2010; Eirgrid, 2015). It is common practice to block the direct electrical field using conductive sheathing, meaning that the only EMFs that are emitted into the marine environment are the magnetic field and the resultant induced electrical field. It is generally considered impractical to assume that cables can be buried at depths that will reduce the magnitude of the magnetic field, and hence the sediment-sea water interface induced electrical field, to below that at which these fields could be detected by certain marine organisms on or close to the seabed (Gill *et al*., 2005; Gill *et al*., 2009). By burying a cable, the magnetic field at the seabed is reduced due to the distance between the cable and the seabed surface as a result of field decay with distance from the cable (CSA, 2019).

3.9.6.3 A variety of design and installation factors affect EMF levels in the vicinity of the cables. These include current flow, distance between cables, cable insulation, number of conductors, configuration of cable and burial depth. The flow of electricity associated with an alternating current (AC) cable changes direction (as per the frequency of the AC transmission) and creates a constantly varying electric field in the surrounding marine environment (Huang, 2005).

3.9.6.4 The strength of the magnetic field (and consequently, induced electrical fields) decreases rapidly horizontally and vertically with distance from source. A recent study conducted by CSA (2019) found that inter-array and offshore export cables buried between depths of 1 m to 2 m reduces the magnetic field at the seabed surface four-fold. For cables that are unburied and instead protected by thick concrete mattresses or rock berms, the field levels were found to be similar to buried cables.

3.9.6.5 CSA (2019) investigated the link relationship between voltage, current, and burial depth, the results of which are presented in Table 3.28 which shows the magnetic and induced electric field levels expected directly over the undersea power cables and at distance from the cable for varying cable types. Directly above the cable, EMF levels decrease with increased distance from the seafloor to 1 m above the cable, while laterally away from the cable (i.e. at distances greater than 3 m), the magnetic fields at the seafloor and at 1 m above the seafloor are comparable.

Table 3.28: Typical magnetic field levels over AC undersea power cables (buried at target depth of 0.9 to 1.8 m) from offshore wind energy projects (CSA, 2019).

Power cable type	Magnetic field levels (mG)			
	Directly above cable		3 to 7.5 m laterally away from cable	
	1 m above seafloor	At seafloor	1 m above seafloor	At seafloor
Inter-Array	5 to 15	20 to 65	<0.1 to 7	<0.1 to 10
Power cable type	Magnetic field levels (mG)			
	Directly above cable		3 to 7.5 m laterally away from cable	
	1 m above seafloor	At seafloor	1 m above seafloor	At seafloor
Inter-Array	0.1 to 1.2	1.0 to 1.7	0.01 to 0.9	0.01 to 1.1

3.9.6.6 During the operations and maintenance phase of the project there will be up to 390 km of 66 kV to 132 kV inter-array cables, and up to 60 km of 275 kV HVAC interconnector cable (Table 3.18). The minimum burial depth for cables will be 0.5 m, and the operations and maintenance phase are expected to last up to 35 years.

3.9.6.7 The impact is predicted to be of local spatial extent, long term duration, continuous and high reversibility (when the cables are decommissioned). It is predicted that the impact will affect the receptor directly. The magnitude is therefore considered to be **low**.

Sensitivity of receptor

Marine species

3.9.6.8 Fish and shellfish species (particularly elasmobranchs) are able to detect applied or modified magnetic fields. Species for which there is evidence of a response to E and/or B fields include elasmobranchs (shark, skate and ray); plaice (Gill *et al*., 2005; CSA, 2019), and crustaceans such as crab and lobster (Scott *et al*., 2021). It can be inferred that the life functions supported by an electric haptic sense (Caputi *et al*., 2013) may include detection of prey, predators or conspecifics in the local environment (Pedraja *et al*., 2018) to assist with feeding, predator avoidance, and social or reproductive behaviours. Life functions supported by a magnetic sense may include orientation, homing, and navigation to assist with long or short-range migrations or movements (Gill *et al*., 2005; Normandeau *et al*., 2011, Formicki *et al*., 2019).

3.9.6.9 Studies examining the effects of EMFs from AC undersea power cables on fish behaviours have been conducted to determine the thresholds for detection and response to EmFs Table 3.29 provides an up-to-date summary of the scientific studies conducted to assess sensitivity of EMFs on varying fish species.

Table 3.29: Relationship between geomagnetic field detection electro sensitivity, and the ability to detect 50/60-Hz AC fields in common marine fish and shellfish species (adapted from CSA, 2019).

Species group	Detect geomagnetic field	Detect electric field	Evidence from laboratory Studies of 50/60-Hz EMF from AC power cables	Evidence from field studies of AC power cables
Skate	Yes, multiple species (Normandeau *et al.,* 2011)	Yes, multiple species (Normandeau *et al.,* 2011)	No responses expected at 60 Hz (Kempster *et al*., 2013)	No attraction at California AC cable sites operating at up to 914 mG (Love *et al.*, 2016).
Flounder	Potentially, due to observed orientation behaviours (Metcalfe *et al.*, 1993)	Not tested	Not tested	No population-level effects, but some evidence of delayed crossing of cables by species moving across where these cables are laid. It is unclear whether this effect was due to cable EMF or prior sediment disturbance (Vattenfall, 2006).
Tuna and mackerel	Yes, for some species (Walker, 1984)	Not tested (Normandeau *et al.*, 2011)	Not tested	Some evidence of attraction of mackerel to monopile structure, but no effect from cables (Bouma and Lengkeek, 2008).
Lobster and crab	Yes, for some lobster species (Lohmann *et al.*, 1995; Hutchison *et al.,* 2018)	Not tested (Normandeau *et al.*, 2011)	No effect at 800,000 µT (Ueno *et al.,* 1986)	Distribution unaffected by 60 Hz AC cable operating up to 800 mG (Love *et al.*, 2017).

3.9.6.10 Several field studies have observed behaviours of fish and other species around AC submarine cables in the USA (see citations in Table 3.29). Observations at three energized 35- kV AC undersea power cable sites off the coast of California that run from three offshore platforms to shore, which are unburied along much of the route, did not show that fish were repelled by or attracted to the cables (Love *et al*., 2016). A study investigating the effect of EMFs on lesser sandeel larvae spatial distribution found that there was no effect on the larvae (Cresci *et al*., 2022), and a prior study concluded the same for herring (Cresci *et al*., 2020).

3.9.6.11 Elasmobranchs (i.e. shark, skate and ray) are known to be the most electro-receptive of all fish. These species possess specialised electro-receptors which enable them to detect very weak voltage gradients (down to 0.5 µV/m) in the environment naturally emitted from their prey (Gill *et al*., 2005). Both attraction and repulsion reactions to electrical fields have been observed in elasmobranch species. Spurdog, an elasmobranch species known to occur within the fish and shellfish ecology study area, avoided electrical fields at 10 µV/cm (Gill and Taylor, 2001), although it should be noted that this level (i.e. 10 µV/cm is equivalent to 1,000 µV/m) is considerably higher than levels associated with offshore electrical cables. A Collaborative Offshore Wind Research into the Environment (COWRIE)-sponsored mesocosm study demonstrated that the lesser spotted dogfish and thornback ray were able to respond to EMF of the type and intensity associated with subsea cables; the responses of some ray individuals suggested a greater searching effort when the cables were switched on (Gill *et al*., 2009). However, the responses were not predictable and did not always occur (Gill *et al*., 2009). In another study, EMF from 50/60 Hz AC sources appears undetectable in elasmobranchs. Kempster and Colin (2011) have noted the physiological capacity for detection of EMFs in basking shark, known to migrate through the fish and shellfish ecology study area, but no current evidence exists on specific impacts of EMFs of any strength on this species, apart from the likely detection capacity of a standard electrical field benchmark level of 1 V/m (Wilding et al., 2020). More generally, Kempster *et al. (*2013) reported that small shark could not detect EMF produced at 20 Hz and above, and Hart and Collin (2015) found no significant repellent effect of a magnetic field of 14,800 G on shark catch rates, suggesting a low sensitivity to these fields.

3.9.6.12 Crustacea, including lobster and crab, have been shown to demonstrate a response to B fields, with the Caribbean spiny lobster *Panulirus argus* shown to use a magnetic map for navigation (CSA, 2019). EMF exposure has been shown to result in varying egg volumes for edible crab compared to controls. Exposed larvae were significantly smaller, but there were no statistically significant differences in hatched larval numbers, deformities, mortalities, or fitness (Scott, 2019). Exposure to EMFs has also been shown to affect a variety of physiological processes within crustaceans. For example, Lee and Weis demonstrated that EMF exposure affected moulting in fiddler crab (*Uca pugilator* and *Uca pugnax*) (Lee and Weis, 1980). Several studies have also suggested that EMFs affect serotonin regulation which may affect the internal physiology of crustaceans potentially leading to behavioural changes, although such changes have not been reported (Atema and Cobb, 1980; Scrivener, 1971).

3.9.6.13 Crab movement and location inside large cages has been reported to be unaffected by proximity to energized AC undersea power cables off south California and in Puget Sound, indicating crab also were not attracted to or repelled by energized AC undersea power cables that were either buried or unburied (Love *et al*., 2016), and no significant change in distance or speed of travel over time when American lobster *Homarus americanus* were exposed to 53 to 65 μT (Hutchison *et al*., 2020). However, studies on the Dungeness crab and edible crab have reported behavioural changes during exposure to increased EMF and both species showed increased activity when compared to crab that were not exposed (Scott *et al*., 2018; Woodruff *et al*., 2012). Crab may also spend less time buried, which is normally a natural predator avoidance behaviour (Rosaria and Martin, 2010), and some species have been noted not to cross undersea cables (Love *et al*., 2017), potentially reducing habitats available for predation.

3.9.6.14 It is uncertain if other crustaceans including commercially important European lobster and *Nephrops* are able to respond to magnetic fields in this way. Limited research undertaken with the European lobster found no neurological response to magnetic field strengths considerably higher than those expected directly over an average buried power cable (Normandeau *et al*., 2011; Ueno *et al*., 1986). A field study by Hutchison *et al*. (2018) observed the behaviour of American lobster (a magneto-sensitive species) to direct current (DC) and AC fields from a buried cable and found that it did not cause a barrier to movement or migration, as both species were able to freely cross the cable route. However, lobster were observed to make more turns when near the energised cable. Adult lobster have been shown to spend a higher percentage of time within shelter when exposed to EMF. European lobster exposed to EMF have also been found to have a significant decrease in egg volume at later stages of egg development and more larval deformities (Scott, 2020).

3.9.6.15 Scott *et al*. (2020) presents a review of the existing papers on the impact of EMFs on crustacean species. Of the papers reviewed by Scott *et al*. (2020), three studied EMF effects on fauna in the field, the rest were laboratory experiments which directly exposed the target fauna to EMFs (Scott *et al*., 2020). These laboratory experiments, while giving us an indication of crustacean behaviour to EMFs, may be less applicable in the context of subsea cables in the marine environment. Of the field experiments, one demonstrated that lobster have a magnetic compass by tethering lobster inside a magnetic coil (Lohmann *et al*., 1995), one focused on freshwater crayfish and put magnets within the crayfish hideouts (Tański *et al*., 2005), and the last one looked at shore crab at an offshore wind farm and found no adverse impact on the population. The two former papers may not be directly applicable to offshore wind farm subsea cables and the latter found no adverse impact on the population of shore crab from the offshore wind farm (Langhamer *et al*., 2016).

3.9.6.16 Further research by Scott *et al.* (2021) found that physiological and behavioural impacts on edible crab occurred at 500 µT and 1000 µT, causing disruption to the L-Lactate and D-Glucose circadian rhythm and altering Total Haemocyte Count, and also causing attraction to EMF exposed areas and reduced roaming time. However, these physiological and behavioural effects did not occur at 250 µT. Seeing as even in the event of an unburied cable the maximum magnetic field reported was 78.27 µT (Normandeau *et al.*, 2011), it can be assumed that the magnetic fields generated by the Morgan cables will be lower than 250 µT, and therefore will not present any adverse effects on edible crab. Harsanyi *et al*. (2022) noted that chronic exposure to EMF effects could lead to physiological deformities and reduced swimming test rates in lobster and edible crab larvae. However, these deformities were in response to EMF levels of 2,800 µT and therefore are considerably higher than EMF effects expected for buried cables. The report recommends burying of cables in order to reduce any potential impacts associated with high levels of EMF in line with the designed in mitigation outlined in Table 3.19.

3.9.6.17 In summary, the range over which these species can detect electric fields is limited to a scale of metres around electrical cables buried to a target depth of 0.9 to 1.8 m (CSA, 2019). Pelagic species generally swim well above the seafloor and can be expected to rarely be exposed to the EMFs at the lowest levels from AC undersea power cables buried in the seafloor, resulting in impacts that would therefore be localised and transient. Demersal species (e.g. elasmobranchs) that dwell on the bottom, will be closer to the undersea power cables and thus encounter higher EMF levels when near the cable. Demersal species and shellfish are also likely to be exposed for longer periods of time and may be largely constrained in terms of location. However, the rapid decay of the EMFs with horizontal distance (Bochert and Zettler, 2006) (i.e. within metres) minimises the extent of potential impacts. Finally, fish that can detect the Earth's magnetic field are unlikely to be able to detect magnetic fields produced by 50/60Hz AC power cables and therefore these species are unlikely to be affected in the field (CSA, 2019).

3.9.6.18 Most marine fish and shellfish ecology IEFs in the fish and shellfish ecology study area are deemed to be of low vulnerability, high recoverability and local to national importance. The sensitivity of the receptor is therefore considered to be **low**.

3.9.6.19 Decapod crustaceans and elasmobranchs in the fish and shellfish ecology study area are deemed to be of medium vulnerability, high recoverability, and local to national importance. The sensitivity of the receptor is therefore considered to be **low**.

Diadromous species

3.9.6.20 EMFs may also interfere with the navigation of sensitive diadromous species. Species for which there is evidence of a response to E and/or B fields include river lamprey, sea lamprey, European eel, and Atlantic salmon (Gill *et al*., 2005; CSA, 2019). Effects of EMFs surrounding undersea cables on allis shad, twaite shad and sparling are currently poorly researched, with recommendations made to investigate these potential effects in future (Gill, *et al*., 2012; Sinclair *et al*., 2020; noting that shad species are pelagic and therefore unlikely to interact with EMF from installed cables). Lamprey possess specialised ampullary electroreceptors that are sensitive to weak, low frequency electric fields (Bodznick and Northcutt, 1981; Bodznick and Preston, 1983), which are hypothesised to be used for prey-detection, although further research is required in this area (Tricas and Carlston, 2012). Chung-Davidson *et al*. (2008) found that weak electric fields may play a role in the reproduction of sea lamprey and it was suggested that electrical stimuli mediate different behaviours in feeding-stage and spawning-stage individuals. This study (Chung-Davidson *et al*., 2008) showed that migration behaviour of sea lamprey was affected (i.e. adults did not move) when stimulated with electrical fields of intensities of between 2.5 and 100 mV/m, with normal behaviour observed at electrical field intensities higher and lower than this range. It should be noted, however, that these levels are considerably higher than modelled induced electrical fields expected from AC subsea cables (see Table 3.28). There is currently no evidence of lamprey responses to magnetic B fields (Gill and Bartlett, 2010).

3.9.6.21 Atlantic salmon and European eel have both been found to possess magnetic material of a size suitable for magnetoreception, and these species can use the earth’s magnetic field for orientation and direction-finding during migration (Gill and Bartlett, 2010; CSA, 2019). Mark and recapture experiments undertaken at the Nysted operational offshore wind farm showed that eel did cross the offshore export cable (Hvidt *et al*., 2003). Studies on European eel in the Baltic Sea have highlighted some limited effects of subsea cables (Westerberg and Lagenfelt, 2008), with evidence of direct detection of EMFs through the lateral line of this species (Moore and Riley, 2009). The swimming speed during migration was shown to change in the short term (tens of minutes) with exposure to AC electric subsea cables, even though the overall direction remained unaffected (Westerberg and Langenfelt, 2008). The authors concluded that any delaying effect (i.e. on average 40 minutes) would not be likely to influence fitness in a 7,000 km migration, with little to no impact on migratory behaviour noted beyond 500 m from wind farm development infrastructure (Ohman *et al*., 2007). Research in Sweden on the effects of a High Voltage Direct Current (HVDC) cable on the migration patterns of a range of fish species, including salmonids, failed to find any effect (Westerberg *et al*., 2007; Wilhelmsson *et al*., 2010). Research conducted at the Trans Bay cable, a DC undersea cable near San Francisco, California, found that migration success and survival of chinook salmon (*Oncorhynchus tshawytscha*) was not impacted by the cable. However, as with the Hutchison *et al*. (2018) study on lobster, behavioural changes were noted when these fish were near the cable (Kavet *et al*., 2016) with salmon appearing to remain around the cable for longer periods. These studies demonstrate that while DC undersea power cables can result in altered patterns of fish behaviour, these changes are temporary and do not interfere with migration success or population health. As outlined in Table 3.18, the cables proposed for the Morgan Generation Assets are HVAC.

3.9.6.22 Table 3.30 provides a summary of the scientific studies conducted to assess sensitivity to EMFs of varying diadromous fish species.

Table 3.30: Relationship between geomagnetic field detection electro sensitivity, and the ability to detect 50/60-Hz AC fields in diadromous fish species (adapted from CSA, 2019).

Species group	Detect geomagnetic field	Detect electric field	Evidence from laboratory studies of 50/60Hz EMF from AC power cables	Evidence from field studies of AC power cables
American/European Eel	Yes, for multiple species (Normandeau *et al.*, 2011).	Mixed evidence (Normandeau *et al.*, 2011).	No effect of 950 mG magnetic field at 50 Hz on swim behaviour or orientation (Orpwood *et al.,* 2015).	Unburied AC cable did not prevent migration of eel (Westerberg *et al.,* 2007).
Salmon	Yes, for multiple species (Yano *et al.*, 1997, Putman *et al.*, 2014).	Not tested (Normandeau *et al.*, 2011).	No effect of 950 mG magnetic field at 50Hz on swim behaviour (Armstrong *et al.*, 2015).	Not surveyed.

3.9.6.23 Diadromous fish IEFs in the fish and shellfish ecology study area are deemed to be of low vulnerability, high recoverability and national to international importance. The sensitivity of the receptor is therefore, considered to be **low**.

Significance of effect

Marine species

3.9.6.24 Overall, the magnitude of the impact is deemed to be low, and the sensitivity of most fish and shellfish IEFs is considered to be low. This gives rise to an impact significance of negligible or minor adverse. Due to the limited range of EMF impacts, and considering the long term nature of this effect, following a precautionary approach, the effect will therefore be of **minor adverse** significance, which is not significant in EIA terms.

3.9.6.25 The magnitude of impact on decapod crustaceans and elasmobranch IEFs is considered to be low, and the sensitivity is also low. This gives rise to an impact significance of negligible or minor adverse. Due to the limited range of EMF impacts, and considering the long term nature of this effect, following a precautionary approach, the effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

Diadromous species

3.9.6.26 Overall, the magnitude of the impact is deemed to be low, and the sensitivity of diadromous IEFs is considered to be low. This gives rise to an impact significance of negligible or minor adverse. Due to the limited range of EMF impacts, and considering the long term nature of this effect, following a precautionary approach, the effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.7 Introduction and colonisation of hard structures

3.9.7.1 The construction and operations and maintenance activities on the generation assets and rock protection around the transmission assets will lead to colonisation of hard surfaces with consequent effects on fish and shellfish populations. The MDS is represented by the wind turbine foundations, scour protection, cable protection, and cable crossing protection, and is summarised in Table 3.18. These are likely to continue beyond the decommissioning phase of the project if infrastructure is left in situ post decommissioning (discussed in further detail below).

Construction, operations and maintenance and decommissioning phases

Magnitude of impact

3.9.7.2 The MDS is for up to 1,791,198 m^2 of habitat creation due to the installation of suction bucket jacket foundations, associated scour protection and cable protection associated with inter-array cables and interconnector cables as well as their associated crossings in subtidal habitats (Table 3.18). This equates to 0.19% of the Morgan Generation Assets area. In reality, the suction caisson jacket foundations will have a lattice design rather than a solid surface, which would result in a smaller surface area than has been assumed for the MDS. It is expected that the foundations and scour and cable protection will be colonised by epifaunal species already occurring within the area (e.g. tunicates, bryozoans, mussel and barnacles which are typical of temperate seas), which will likely attract increased abundances of demersal and pelagic fish species through predation behaviours.

3.9.7.3 Decommissioning will involve removal of wind turbine foundations and cables, leaving cable and scour protections *in situ* on the seafloor. This equates to up to 1,252,116 m^2 of residual hard substrata after removal of the wind turbine foundations and cabling.

3.9.7.4 A review by Degraer *et al*. (2020) explained the process by which wind turbine foundations are colonised and the vertical zonation of species that can occur. In general biofouling communities on offshore installations are dominated by mussel species, macroalgae, and barnacles near the water surface. This essentially creates a new intertidal zone, with filter feeding arthropods at intermediate depths; and anemones in deeper locations (De Mesel *et al*., 2015). Colonisation by these species will likely represent an increase in biodiversity and a change compared to the situation if no hard substrates were present (Lindeboom *et al*., 2011).

3.9.7.5 The introduction of new hard substrate will represent a shift in the baseline conditions from soft substrate areas (i.e. muds, sands and gravels) to hard substrate in the areas where infrastructure is present. This may produce some potentially beneficial effects, for example the likely increase in biodiversity and individual abundance of reef species and total number of species over time, as observed at the monopile foundations installed at Lysekil research site (a test site for offshore wind-based research, north of Gothenburg, Sweden) (Bender *et al*., 2020). Additionally, the increased structural complexity of the substrate may provide refuge as well as increasing feeding opportunities for larger and more fish and shellfish mobile species (Langhamer and Wilhelmsson, 2009), with an expected increase in ecosystem carrying capacity (Andersson and Ohman, 2010). This effect can also be applied to jacket foundations, wherein a study by Lefaible *et al*. (2019) identified that jacket foundations had higher densities and species richness in closer vicinity to the wind turbine foundations compared to a control and a monopile foundation. A study of gravity base foundations in the Belgian part of the North Sea by Mavraki *et al.* (2020), found that higher food web complexity was associated with zones of high accumulation of organic material, such as soft substrate or scour protection, suggesting potential reef effect benefits from the presence of the hard structures.

3.9.7.6 The reef effect may be enhanced by the deposition of fouling material on the seabed. An investigation conducted at the research platform Forschungsplattformen in Nord- und Ostsee 1 FINO 1 in the southwest German Bight in the North Sea reported that yearly, 878,000 single shell halves from blue mussel (*Mytilus edulis*) sink onto the seabed from the FINO 1 platform, thereby greatly extending the reef effects created by the construction of the offshore platform structure (Krone *et al*., 2013). Removal of marine growth from the regularly licenced wind turbine foundation cleaning and maintenance may also cause debris to fall within the vicinity of the wind turbine foundation. It is likely that seaweed/algal material would disperse into the water column, with heavier material (e.g. mussel) being deposited within 10 m to 15 m of the foundation. This material has the potential to change the prevailing sediment type in the immediate vicinity of the wind turbine foundations, and therefore extending the reef effect. These processes have been noted to increase abundances of reef-related fish species around offshore wind farm structures (Bergström *et al*., 2013).

3.9.7.7 The attraction of fish and shellfish species to installed hard structures is supported by the first year's monitoring from Beatrice offshore wind farm (APEM, 2021) which noted fish and shellfish at the base of foundations although no biological material was recorded on the seabed. Material may be rapidly consumed by organisms or relocated due to tidal currents and further monitoring will be required to clarify if biological material builds up over time (APEM, 2021). Any additional potential effects up the food chain in relation to marine mammals (Volume 2, Chapter 4: Marine mammals of the Environmental Statement) and ornithology (Volume 2, Chapter 5: Offshore ornithology of the Environmental Statement) will be considered in their individual chapters.

3.9.7.8 The impact is predicted to be of local spatial extent, long term duration, continuous and irreversible during the lifetime of the Morgan Generation Assets. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **low**.

Sensitivity of receptor

Marine species

3.9.7.9 Hard substrate habitat created by the introduction of wind turbine foundations and scour/cable protection are likely to be primarily colonised within hours or days after construction by demersal and semi-pelagic fish species (Andersson, 2011), with more complex communities later likely attracted to the developing algal and suspension feeder communities as potential new sources of food (Karlsson *et al*., 2022). Continued colonisation has been seen for a number of years after the initial construction, until a stratified recolonised population is formed (Krone *et al*., 2013), subject to natural seasonal variability, but still representing a significant change from the baseline sedimentary environment (Kerckhof, *et al*., 2010). Feeding opportunities or the prospect of encountering other individuals in the newly introduced heterogenous environment (Langhamer, 2012) may attract fish aggregations from the surrounding areas, which may increase the carrying capacity of the area in the long term (Andersson and Öhman, 2010; Bohnsack, 1989).

3.9.7.10 The dominant natural substrate character of the fish and shellfish ecology study area (largely sandy gravel and gravelly sand) will determine the number of new species found on the introduced vertical hard surface and associated scour protection. When placed on an area of seabed which is already characterised by typically high diversity rocky substrates, few species will be added to the area, but the increase in total hard substrate could sustain higher abundance (Andersson and Öhman, 2010), especially in the case of scour protection, which can up to double the number of crustaceans found near wind turbine foundations compared to wind turbine foundations with no scour protection (Krone *et al*., 2017). Conversely, when placed on a soft seabed, as will occur in this case, most of the colonising fish will be normally associated with rocky (or other hard bottom) habitats, thus the overall diversity of the area may increase (Andersson *et al*., 2009). A new baseline species assemblage will be formed via recolonisation, and the original soft-bottom population will be displaced (Desprez, 2000). This was observed in studies by Leonhard *et al*. (Danish Energy Agency, 2012) at the Horns Rev offshore wind farm, and Bergström *et al*. (2013) at the Lillgrund offshore wind farm, where an increase in fish species associated with reef structures was noted, and similar trends were seen in the Walney Extension three years post-construction colonisation study (CMACS, 2014b).

3.9.7.11 Impacts on demersal fish and shellfish communities are varied, with the original sandy-bottom fish population near the Lillgrund offshore wind farm reported to be displaced by introduced hard substrate communities (Danish Energy Agency, 2012). However, a decrease in soft sediment species is contradictory to findings of Degraer *et al*. (2020) where an increase in density of soft sediment species was seen, although this increase may be related to reduced fishing pressure within the array. These increases may only be site-specific and cannot be extrapolated to applying to all introduced hard structures without further research. However, a recent review (Dunkley and Solandt, 2022) has found that rates of bottom-towed fishing has decreased by 77% in almost all investigated offshore wind farm sites, with associated protection of demersal and pelagic fish and shellfish populations. Further, a meta-analysis by Gill *et al*., (2021) found no evidence of negative impacts from offshore wind farm construction and associated hard structure introduction on a range of demersal and pelagic fish, with potential positive effects in terms of increased biomass and abundance noted for shellfish.

3.9.7.12 The longest monitoring programme conducted to date at the Lillgrund offshore wind farm in the Öresund Strait in south Sweden, showed no overall increase in fish numbers, although redistribution towards the foundations within the offshore wind farm area was noticed for some species (i.e. cod, eel and eelpout; Andersson, 2010). More species were recorded after construction than before, which is consistent with the hypothesis that localised increases in biodiversity may occur following the introduction of hard substrates in a soft sediment environment. Overall, results from earlier studies reported in the scientific literature did not provide robust data (e.g. some were visual observations with no quantitative data) that could be generalised to the effects of artificial structures on fish abundance in offshore wind farm areas (Wilhelmsson *et al*., 2010). More recent papers are, however, beginning to assess population changes and observations of recolonisation in a more quantitative manner (Bouma and Lengkeek, 2012; Krone *et al*., 2013), with hard substrates consistently increasing species richness in the long term, but changing species composition towards a shellfish-dominated hard substrate community, thus having an impact of local ecological function (Coolen, *et al*., 2020).

3.9.7.13 There is some uncertainty as to whether artificial reefs facilitate recruitment in the local population, or whether the effects are simply a result of concentrating biomass from surrounding areas (Inger *et al*., 2009). Linley *et al*. (2007) concluded that finfish species were likely to have a neutral to beneficial likelihood of benefitting, which is supported by evidence demonstrating that abundance of fish can be greater within the vicinity of wind turbine foundations than in the surrounding areas (Wilhelmsson *et al*., 2006a; Inger *et al*., 2009), with increases in species richness noted in some studies (Coolen *et al*., 2020). A number of studies on the effects of vertical structures and offshore wind farm structures on fish and benthic assemblages have been undertaken in the Baltic Sea (Wilhelmsson *et al*., 2006a; 2006b). These studies have shown evidence of increased abundances of small demersal fish species in the vicinity of structures, most likely due to the increase in abundance of epifaunal communities which increase the structural complexity of the habitat (e.g. mussel and barnacles *Cirripedia spp*.).

3.9.7.14 It was speculated that in true marine environments, such as the north Irish Sea, offshore wind farms may enhance local species richness and diversity, with small demersal species such as gobies or sandeel providing prey items for larger, commercially important species including cod (which have been recorded aggregating around vertical steel constructions in the North Sea; Wilhelmsson *et al*., 2006a), and other pelagic species, although only in the direct vicinity of the altered habitats (Andersson, 2010). Monitoring of fish populations in the vicinity of an offshore wind farm off the coast of the Netherlands indicated that the offshore wind farms acted as a refuge for at least part of the cod population (Lindeboom *et al*., 2011; Winter *et al*., 2010). Similarly, horse mackerel, mackerel, herring, and sprat have been found to utilise the new hard substrate for spawning, or predation on the newly developed community (Glarou *et al*., 2020).

3.9.7.15 In contrast, post construction fisheries surveys conducted in line with the Food and Environmental Protection Act (FEPA) licence requirements for the Barrow and North Hoyle offshore wind farms, found no evidence of fish abundance across these sites being affected, either positively or negatively, by the presence of the offshore wind farms (Cefas, 2009; BOWind, 2008). These suggested that any effects, if seen, are likely to be highly localised and while of uncertain duration, the evidence suggests effects are not necessarily adverse, although uncertainty does exist surrounding this issue.

3.9.7.16 It is likely that the greatest potential for beneficial effects exist for crustacean species, such as crab and lobster, due to expansion of their natural habitats (Linley *et al*., 2007) and the creation of additional heterogenous hard substrate refuge areas. Where foundations and scour protection are placed within areas of sandy and coarse gravelly sediments, this will represent novel habitat and new potential sources of food in these areas and could potentially extend the habitat range of shellfish species such as edible crab, which strongly associate with wind farm foundations (Hooper and Austen, 2014). Post-construction monitoring surveys at the Horns Rev offshore wind farm in the North Sea noted that the hard substrates were used as a hatchery or nursery grounds for several species and was particularly successful for edible crab (BioConsult, 2006). They concluded that crustacean larvae and juveniles rapidly invade the hard substrates from the breeding areas (BioConsult, 2006). As both crab and lobster are commercially exploited in the vicinity of the fish and shellfish ecology study area, there is potential for benefits to the fisheries, depending on the materials used in construction of the offshore wind farm.

3.9.7.17 Other shellfish species, such as mussel species, have the potential for great expansion of their normal habitat due to increased hard substrate in areas of sandy habitat. Krone *et al. (*2013) coined the term ‘’Mytilusation’’ to describe this mass biofouling process recorded at a platform in the German Bight, North Sea. It was found that over a three-year period, almost the entire vertical surface of area of the platform piles had been colonised by three key species blue mussel, the amphipod *Jassa spp*. and anthozoans (mainly *Metridium senile*, the plumose anemone). These three species were observed to occur in depth-dependant bands, attracting pelagic fish species such as horse mackerel in large numbers. As discussed above, layers of shell detritus were visible at the base of the foundations due to the mussel populations above, and both velvet swimming crab and edible crab were recorded here, which shows potential benefits to these existing IEF species within the Morgan Array Area.

3.9.7.18 The colonisation of new habitats may also potentially lead to the introduction of INNS, which may have indirect adverse effects on shellfish populations as a result of competition. The site-specific benthic survey around the Morgan Generation Assets identified no INNS as being currently present. However, this dataset is limited and cannot be used to draw conclusions about the entire fish and shellfish ecology study area, with the potential for INNS to currently be present or be introduced during the course of the construction and operations and maintenance phases. There is little evidence of adverse effects on fish and shellfish IEFs resulting from colonisation of other offshore wind farms by INNS. The post construction monitoring report for the Barrow offshore wind farm demonstrated no evidence of INNS on or around the monopiles (EMU, 2008a), and a similar study of the Kentish Flats monopiles only identified slipper limpet *Crepid154ornicatecata* (EMU, 2008b). A study into the spread of INNS by wind farm hard substrate colonisation suggested the risk of this occurring was minor, and requires more research to fully understand, with implementation of precautionary built-in measures recommended to prevent spread where possible (Lasram *et al*., 2019). The impact of INNS on seabed habitats is further discussed and assessed in Volume 2, Chapter 2: Benthic subtidal ecology of the Environmental Statement.

3.9.7.19 Marine fish and shellfish ecology IEFs in the fish and shellfish ecology study area are deemed to be of low vulnerability, and local to national importance (recoverability is not relevant to this impact during the operations and maintenance phase). The sensitivity of the receptor is therefore, considered to be **low**.

Diadromous species

3.9.7.20 Diadromous species that are likely to interact with the fish and shellfish ecology study area are only likely to do so by passing through the area during migrations to and from rivers flowing into the east Irish Sea (i.e. on the west coast of England, southwest coast of Scotland and north coast of Wales), with these sites designated based on the presence of diadromous fish species (see section 3.4.1.3). In most cases, it is expected that diadromous fish are unlikely to utilise the increase in hard substrate within the fish and shellfish ecology study area for feeding or shelter opportunities as they are only likely to be in the vicinity when passing through during migration.

3.9.7.21 However, there is potential for impacts upon diadromous fish species resulting from increased predation by marine mammal species within offshore wind farms. Tagging of harbour seal *Phoca vitulina* and grey seal *Halichoerus grypus* around Dutch and UK windfarms provided significant evidence that the seal species were utilising wind farm sites as foraging habitats (Russell *et al*., 2014), specifically targeting introduced structures such as wind turbine foundations. However, a further study using similar methods concluded that there was no change in behaviour within the wind farm (McConnell *et al*., 2012), so it is not certain exactly to what extent seals utilise offshore wind developments overall. More site-specific data from the north Irish Sea has found that harbour porpoise and grey seal also utilise wind farm areas for feeding (Goold, 2008), suggesting a potential risk of foraging on diadromous species around the infrastructure within the Morgan Array Area. However, due to the small spatial and temporal overlaps between foraging behaviour and diadromous migrations, it is unlikely that this would result in significant increased predation on diadromous species. Research has shown that Atlantic salmon smolts spend little time in the coastal waters, and instead are very active swimmers in coastal waters, making their way to feeding grounds quickly (Gardiner *et al*., 2018a; Gardiner *et al*., 2018a; Newton *et al*., 2017; Newton *et al*., 2019; Newton *et al*., 2021; see Volume 4, Annex 3.1: Fish and shellfish ecology technical report of the Environmental Statement for further detail on Atlantic salmon migration). Due to the evidence that Atlantic salmon tend not to forage in the coastal waters, it is unlikely that they will spend time foraging around wind turbine foundations and therefore are at low risk of impact from increased predation from seals and other predators.

3.9.7.22 Sea trout may be at higher risk of increased predation from seals than Atlantic salmon due to their higher usage of coastal environments. Sea trout are generalist, opportunistic feeders with their diet comprising mainly of fish, crustaceans, polychaetes and surface insects with the proportion of each of these prey categories varying dependent on season (Rikardsen *et al*., 2006; Knutsen *et al*., 2001). Due to the potential for increase in juvenile crustacean species and other shellfish species which are potential prey items from sea trout, it is possible that foraging sea trout may be attracted to the hard substrates introduced by installation of the Morgan Generation Assets. This attraction could in turn lead to increased predation of seal species upon sea trout species. However, there is little evidence at present documenting an increased abundance of sea trout around wind turbine foundations (increases in fish abundance tend to be hard bottom dwelling fish species), therefore the above effect of increased prey items attracting sea trout is only theoretical. Further, the Morgan Array Area is situated in an area of both low and high intensity sandeel spawning, and it is likely that sandeel will make up a considerable proportion of sea trout diet when in the marine environment (Svenning *et* al., 2005; Thorstad *et al.,* 2016*)*. Sandeel species are unlikely to be directly associated with introduced hard structures due to sandy habitat preferences (largely outside the Morgan Array Area). Sea trout may be less likely to be attracted to the increased prey availability colonised on hard substrates, given there is an existing abundance of prey species which are not associated with hard structure communities.

3.9.7.23 The low risk of effects on diadromous fish species extends to the freshwater pearl mussel, which has part of its life stage that is reliant on diadromous fish species including Atlantic salmon and sea trout, and the potential of impact on these species is low.

3.9.7.24 Sea lamprey are parasitic in their marine phase, feeding off larger fish and marine mammals (Hume, 2017). As such it is not expected that they will be particularly attracted to structures associated with offshore wind developments. However, this is not certain, as there is limited information available on the utilisation of the marine environment by sea lamprey.

3.9.7.25 Most diadromous fish species are deemed to be of low vulnerability, high recoverability and national to international importance. The sensitivity of the receptor is therefore, considered to be **low**.

3.9.7.26 Sea trout are deemed to be of medium vulnerability, high recoverability and national importance. The sensitivity of the receptor is therefore, considered to be **low**.

Significance of effect

Marine species

3.9.7.27 Overall, the magnitude of the impact is deemed to be low, and the sensitivity of all fish and shellfish IEFs is considered to be low. This gives rise to an impact significance of negligible or minor adverse. Due to the long term nature of the effect, and following a precautionary approach, the effect will, therefore, be of **minor adverse** significance, at worst, which is not significant in EIA terms.

3.9.7.28 As outlined above, there is potential for beneficial effects to certain fish and shellfish IEFs, although there are uncertainties as to which species in particular would benefit and the significance of this positive effect.

Diadromous species

3.9.7.29 The magnitude of the impact is deemed to be low, and the sensitivity of all diadromous fish species is considered to be low. This gives rise to an impact significance of negligible or minor adverse. Due to the long term nature of the effect, and following a precautionary approach, the effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.8 Disturbance/remobilisation of sediment-bound contaminants

3.9.8.1 The construction, operations and maintenance, and decommissioning activities of the Morgan Generation Assets may lead to disturbance or remobilisation of sediment-bound contaminants such as metals, hydrocarbons, and organic pollutants. The MDS is represented by sandwave clearance, cable installation, cable repair, and any infrastructure removal activities and is summarised in Table 3.18.

- The relevant MarESA pressures and benchmarks used to inform this impact assessment are described here:Transitional elements and organometal contamination: Exposure of marine species or habitat to one or more relevant contaminants via uncontrolled releases or incidental spills. The increase in transition elements levels compared to natural background concentrations are most likely due to their input from land/riverine sources, by air or directly at sea.
- Hydrocarbon and Polycyclic Aromatic Hydrocarbons (PAH) contamination: Exposure of marine species or habitats to one or more relevant hydrocarbon contaminants via uncontrolled releases or incidental spills. Increases in the levels of these compounds are compared with natural background concentrations.
- Synthetic compound contamination: Exposure of marine species or habitats to one or more relevant synthetic contaminants via uncontrolled releases or incidental spills. Increases in the levels of these compounds are compared with natural background concentrations.

Construction and operations and maintenance phase

Magnitude of impact

3.9.8.2 The installation of the Morgan Generation Assets infrastructure will likely lead to remobilisation of sediment-bound contaminants. Sediment samples were collected from 11 stations in the Morgan Array Area and from 13 stations within the Morgan Array Area ZoI. Sediment grab samples were analysed for contaminants including heavy metals, polychlorinated biphenyls (PCBs), organotins, and PAHs. The full results of this sediment chemistry analysis are detailed in Volume 4, Annex 2.1: Benthic ecology technical report of the Environmental Statement. The concentrations of the heavy metals, PAHs and PCBs was compared to the corresponding Cefas Action Levels 1 and 2 (AL1 and AL2) and the Canadian threshold effect level (TEL) and probable effect levels.

3.9.8.3 Concentrations of arsenic marginally exceeded the Cefas AL1 (20 mg/kg) at one station in the Morgan Array Area (ENV23) and two stations in the Morgan Array Area

ZoI but were well below the Cefas AL2. Within the Morgan Array Area, 10 sample stations exceeded the Canadian TEL for arsenic, as did seven sample stations in the Morgan Array Area ZoI; however, all were below the Canadian PEL.

3.9.8.4 The total area that is likely to be disturbed by construction activities, and therefore the potential volume of material disturbed, resulting in the potential release of sediment bound contaminants is set out in section 3.9.2. While the area affected is relatively large, the proportion of this area affected at any one time will only be a fraction of this overall total for the construction phase. The MDS is for the inter-array sandwave clearance; activities are to be undertaken over a 12-month duration within the wider four-year construction programme. Clearance accounts for up to an 80 m wide corridor along 156 km of cable length and to an average depth of 3 m, totalling a spoil volume of up to 5,026,651 m^3. The interconnector cables sandwave clearance activities account for a much smaller total spoil volume of 3,060,814 m^3, based on clearance in a 104 m wide, 5.1 m deep corridor along up to 36 km of interconnector cables. For sandwave clearance associated with OSP foundations, the total spoil volume is 10,149,455 m^3 (247,548 m^3 per location), based on 41 locations supporting the largest suction bucket four-legged jacket foundation with a base diameter of 205 m, to an average depth of 7.5 m.

3.9.8.5 Following disturbance because of construction activities, the majority of re-suspended sediments are expected to be deposited in the immediate vicinity of the works. The release of contaminants from the small proportion of fine sediments is likely to be rapidly dispersed with the tide and currents, and therefore increased bioavailability resulting in significant adverse eco-toxicological effects are not expected.

3.9.8.6 For most IEFs, the impact is predicted to be of local spatial extent, short term duration, intermittent and of high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore considered to be **low**.

3.9.8.7 For sandeel, the impact is predicted to be of local spatial extent, short term duration, intermittent and of high reversibility. It is predicted that the impact will affect the receptor directly, however due to the absence of significant elevations of PAHs, the magnitude is therefore considered to be **negligible**.

Sensitivity of receptor

Marine species

3.9.8.8 The disturbance/remobilisation of sediment-bound contaminants has the potential to affect IEFs primarily within and in the vicinity of the Morgan Generation Assets. Generally, residues in water are less likely to be a long-term concern because of photo-degeneration and dilution to below biological significant concentrations, causing sediment-bound contaminants to be most impactful. Tolerance to heavy metals varies depending on species, and tolerance tends to be low for most groups of IEF species. For example, the capacity of bivalves, such as king and queen scallop, which have limited mobility to avoid this impact, to accumulate heavy metals exceeding background environmental levels, in their tissues is well known, resulting in sub-lethal effects (Aberkali and Trueman, 1985). The only heavy metal of concern within the subtidal area of the Morgan Generation Assets is non-anthropogenically introduced arsenic, which is present in levels lower than those typical of deep-sea sediments (typically 40 µg/g) (Neal *et al.*, 1979). The most common bioavailable organoarsenic compound, arsenobetaine is not reported as having significant toxic impacts on fish and shellfish species if ingested (Neff, 1997), which is already highly unlikely in this situation. As such, the local fish and shellfish communities have developed in an environment of existing low levels of contamination, so any release of contaminants from construction activities is not likely to significantly increase bioavailability beyond natural levels. Suchanek (1993) reviewed the effects of oil on bivalves. Generally, contact with oil causes an increase in energy expenditure and a decrease in feeding rate, resulting in less energy available for growth and reproduction.

3.9.8.9 Studies on PCBs largely demonstrate they are highly toxic and can undergo biomagnification within food webs to have significant impacts on fish species such as sprat and herring (Vuorinen *et al*., 2002, Burreau *et al*., 2006). PCBs are also known to contaminate various shellfish species including scallop (Marsden and Cranford, 2016), as well as edible crab and velvet swimming crab (Bodin *et al*., 2007a). Crustacean species have been found to be able to metabolise PCBs (Bodin *et al*., 2007b), suggesting even low-level PCB contamination will not have a significant impact on these species. Biomagnification within the food web can expose elasmobranchs, including but not limited to basking shark to this contaminant (Boldrocchi *et al*., 2022), with the potential for negative metabolic impacts if exposed for long periods of time (Tiktak *et al*., 2020). However, as there is no PCB concentration above AL1 within the Morgan Generation Assets area, and these species are highly migratory, they are unlikely to be exposed to any short-term remobilisation of very low-level contaminants within the Morgan Generation Assets.

3.9.8.10 The effects of remobilised sediment-bound PAHs are well understood, with significant negative impacts noted on sandeel hatching success and survival (Bunn *et al*., 2000), and a wide literature exists concerning other impacts on the identified marine IEFs. However, as all PAH concentrations were under AL1 and both CSQGs, this impact with have little to no effect on any species present.

3.9.8.11 King and queen scallop are deemed to be of medium vulnerability, high recoverability, and regional importance. The sensitivity of the receptor is therefore considered to be **low**.

3.9.8.12 Sandeel are deemed to be of medium vulnerability to PAHs specifically, medium recoverability, and regional importance. The sensitivity of the receptor is therefore considered to be **medium**.

3.9.8.13 All other fish and shellfish IEFs are deemed to be of low vulnerability, high recoverability, and local to national importance. The sensitivity of the receptor is, therefore, considered to be **low**.

Diadromous species

3.9.8.14 Diadromous species will likely only be present within the fish and shellfish ecology study area when migrating to or from rivers flowing into the east Irish Sea. theThe possibility for temporal and spatial overlap of these species and the very short-term remobilisation of sediment-bound contaminants, which will likely resettle within a small number of tidal cycles, is very low. Also, it is known that many diadromous species are exposed naturally to levels of PCBs, such as in trout (Atuma *et al*., 1993), sea lamprey (Madenjian *et al*., 2013), European eels (Bressa *et al*., 1997), and Atlantic salmon (Zitko, 1974). Similarly, bioaccumulation of heavy organometals has been noted on trout gills (Tkachenko *et al*., 2019), alongside a range of other low levels of natural exposure in other IEF species. Given this acclimation to natural contaminants, with no significant detriments to health or spawning noted at low levels, it is therefore likely that this impact will have little impact on diadromous species during construction.

3.9.8.15 All diadromous IEF species are deemed to be of low vulnerability, high recoverability, and national to international importance. The sensitivity of the receptor is, therefore, considered to be **low**.

Significance of effect

Marine species

3.9.8.16 The magnitude of the impact is deemed to be low, and the sensitivity of king and queen scallop are considered to be low. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.8.17 The magnitude of the impact is deemed to be negligible, and the sensitivity of sandeel is considered to be medium. The effect will, therefore, be of **negligible** significance due to the absence of elevated PAH concentrations, which is not significant in EIA terms.

3.9.8.18 The magnitude of the impact is deemed to be low, and the sensitivity of all other IEFs is considered to be low. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

Diadromous species

3.9.8.19 The magnitude of the impact is deemed to be low, and the sensitivity of diadromous species is considered to be low. The effect will, therefore, be on **minor adverse** significance, which is not significant in EIA terms.

Decommissioning

Magnitude of impact

3.9.8.20 Decommissioning could potentially involve the removal of scour protection or cable protection, or removal of suction caissons using overpressure, which would increase SSC overall in the area, with related remobilisation of sediment-bound contaminants. However, these will be significantly below the amount of sediment remobilised during construction and will thus likely be below AL or CSQG thresholds.

3.9.8.21 The impact is predicted to be of local spatial extent, short term duration, intermittent and high reversibility. It is predicted that the impact will affect the receptor indirectly. The magnitude is therefore considered to be **negligible**.

Sensitivity of receptor

Marine species

3.9.8.22 The sensitivity of the marine fish and shellfish IEFs can be found in the construction phase assessment (paragraph 3.9.8.8 to paragraph 3.9.8.13) with low to medium sensitivity, and these will equally apply in the decommissioning phase.

Diadromous species

3.9.8.23 The sensitivity of the diadromous fish and shellfish IEFs can be found in the construction phase assessment (paragraph 3.9.8.14 to paragraph 3.9.8.15), with low sensitivity, and these will equally apply in the decommissioning phase.

Significance of effect

Marine species

3.9.8.24 The magnitude of the impact is deemed to be negligible, and the sensitivity of king and queen scallop are considered to be low. The effect will, therefore, be of **negligible** significance, which is not significant in EIA terms.

3.9.8.25 The magnitude of the impact is deemed to be negligible, and the sensitivity of sandeel is considered to be medium. The effect will therefore, be of **negligible** significance, which is not significant in EIA terms.

3.9.8.26 The magnitude of the impact is deemed to be negligible, and the sensitivity of all other IEFs is considered to be low. The effect will therefore be of **negligible** significance, which is not significant in EIA terms.

Diadromous species

3.9.8.27 The magnitude of the impact is deemed to be negligible, and the sensitivity of diadromous species is considered to be low. The effect will therefore be of **negligible** significance, which is not significant in EIA terms.

3.9.9 Injury due to increased risk of collision with vessels

3.9.9.1 Guidance provided by National Oceanic and Atmospheric Administration (NOAA) has defined serious injury to basking shark and marine mammals as ‘any injury that will likely result in mortality’ (NMFS, 2005). NMFS clarified its definition of ‘serious injury’ in 2012 and stated their interpretation of the regulatory definition of serious injury as any injury that is ‘more likely than not’ to result in mortality, or any injury that presents a greater than 50% chance of death to the basking shark or marine mammal (NMFS, 2012; Helker *et al*., 2017). Non-serious injury is likely to result in short-term impacts and may also have long-term effects on health and lifespan.

3.9.9.2 Collisions of vessels with basking shark have the potential to result in both fatal and non-fatal injuries (Darling and Keogh, 1994), with these collisions being known to occur relatively frequently (Scott and Gisborne, 2006). The potential therefore exists for collisions with basking shark in any vessel activities throughout the lifetime of the Morgan Generation Assets.

Construction phase

Magnitude of impact

3.9.9.3 Vessel traffic associated with the Morgan Generation Assets has the potential to lead to an increase in vessel movements within the fish and shellfish ecology study area. This increase in vessel movement could lead to an increase in interactions between basking shark and vessels during offshore construction, with vessels travelling at higher speeds (>7 m/s) posing a higher risk because of the potential for a stronger impact (Schoeman *et al*., 2020). Except for CTVs, vessels involved in the construction phase are likely to be travelling considerably slower than this, and all vessels will be required to follow a project offshore EMP. The offshore EMP and embedded Code of Conduct within the Outline plan for rafting birds and marine mammals (Document Reference J15) include instructions for vessel behaviour and vessel operators, including advice to operators to not deliberately approach basking shark and to avoid sudden changes in course or speed. With the Morgan Generation Assets designed in measures in place, the risk of collision is anticipated to be reduced and would only be present for transiting vessels (as opposed to stationary).

3.9.9.4 Vessel traffic associated with the construction activities will result in an increase in vessel movements within the fish and shellfish ecology study area as up to 1,878 return trips by construction vessels may be made throughout the construction phase (Table 3.18). This could lead to an increase in interactions between basking shark and up to 63 construction vessels on site at any one time over the potential four-year construction period. It is likely that these may include 22 main installation and support vessels, eight tug/anchor handlers, four cable lay installation and support vessels, one guard vessel, five survey vessels, seven seabed preparation vessels, 11 CTVs, three scour protection installation vessels and two cable protection installation vessels). A proportion of vessels involved in construction will be relatively small in size (e.g. tugs, vessels carrying ROVs, crew transfer vessels, dive boats, barges and RIBs) and due to good manoeuvrability able to move to avoid basking shark, when detected (Schoeman *et al*., 2020). Larger vessels with lower manoeuvrability may need larger distances to avoid an animal, however they will also be travelling at slower speeds and have more time to react when basking shark are detected. In addition, the sound emissions from vessels involved in the construction phase are likely to deter animals from the potential zone of impact. The vessel movements will be contained within the Morgan Array Area and will follow existing shipping routes to and from the ports.

3.9.9.5 The impact is predicted to be of local spatial extent, medium term duration, intermittent and, whilst the risk will only occur during vessel transits, the effect of collision on sensitive receptors is of medium to low reversibility (depending on the extent of injuries). It is predicted that the impact will affect the receptor directly. With designed-in measures in place the risk of collision will be reduced, however, given the potential for a collision to lead to injury the magnitude is, conservatively, considered to be **low**.

Sensitivity of receptor

3.9.9.6 Basking shark and other large animals are generally able to detect and avoid vessels, however, it is unclear why some individuals do not always move out of the path of an approaching vessel (Schoeman *et al*., 2020). It has been suggested that behaviours such as resting, foraging, nursing, and socialising could distract these animals from detecting the risk posed by vessels (Dukas, 2002), as well as their need to spend time near the surface for feeding (Pirotta *et al*., 2018). There can be consequences to a lack of response to disturbance, in terms of behavioural habituation that can result in decreased wariness of vessel traffic, which has the potential to result in an increased collision risk (Cates *et al*., 2017).

3.9.9.7 There have been 63 reports of vessel collisions with basking shark over a 21-year study period within the vicinity of the Irish Sea (Solandt and Chassion, 2013), although it is possible that mortality from vessel strikes is under-recorded (Van Waerebeek *et al*., 2007). Therefore, any predicted vessel collisions may be an underestimate of the true number within the fish and shellfish ecology study area. This should be considered in the context of the nearby IoM territorial waters, where the designated MNRs have been identified as an area of potential conservation importance for migrating basking sharks (Dolton *et al*., 2020). However, it should be noted that no basking shark were observed during 12 months of aerial surveys of the Morgan Array Area and as such, although they are known to occur in the area, there is no evidence to demonstrate that the Morgan Generation Assets is particularly important for basking shark, therefore reducing the potential for collision risk.

3.9.9.8 Individual basking shark tend to show distressed behaviour and avoidance tendencies when disturbed by vessels (Bloomfield and Solandt, 2008). If physical impact does occur, the injuries can potentially be significant, although long-term monitoring has noted successful healing of wounds from propellor injuries (Speedie *et al*., 2009) and ship collisions (Solandt and Chassion, 2013), with negative impacts only seen after repeated direct exposure to disturbance and damage (Kelly *et al*., 2004). Due to the implementation of an offshore EMP for all vessels, this repeated exposure and damage is unlikely to occur in this case, with any collisions unlikely to be lethal at the speeds most vessels are travelling.

3.9.9.9 Basking shark within the Morgan fish and shellfish ecology study area are deemed to be of low vulnerability, medium recoverability, and of international importance. The sensitivity of the receptor, therefore, is considered to be **medium**.

Significance of effect

3.9.9.10 The magnitude of the impact is deemed to be low, and the sensitivity of basking shark is considered to be medium. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

Operations and maintenance phase

Magnitude of impact

3.9.9.11 Vessel usage during operations and maintenance phase of the Morgan Generation Assets may lead to injury to basking shark due to collision with vessels. Vessel types which will be required during the operations and maintenance phase include those used during routine inspections, repairs and replacement of equipment, major component replacement, painting or other coatings, removal of marine growth, replacement of access ladders, and geophysical surveys (Table 3.18).

3.9.9.12 Any on-site activities will require vessel transit, with up to 16 vessels present at any one time (five CTVs/workboats, three jack-up vessels, three cable repair vessels, four SOV or similar, and one excavator/backhoe dredger), and a maximum licenced 719 vessel movements to and from the site per year, with most (608) of these being CTVs. Over the predicted 35-year lifetime of the Morgan Generation Assets, this could lead to a maximum of approximately 25,165 vessel movements overall, with each representing a collision risk to basking shark. However, implementation of the offshore EMP and any other designed-in measures will limit the risk of these collisions, and the decreased number of vessels on-site at any one time will likely reduce the risk further when compared to the construction activities.

3.9.9.13 The impact is predicted to be of local spatial extent, long term duration, intermittent, and of medium to low reversibility if collision occurs. It is predicted that the impact will affect the receptor directly. With designed-in measures in place, collision risk will be reduced, but the long-term duration of the operations and maintenance activities makes the magnitude of this impact **low**.

Sensitivity of receptor

3.9.9.14 The sensitivity of the basking shark can be found in the construction phase assessment (paragraph 3.9.9.6 to paragraph 3.9.9.10), with **medium** sensitivity, and this will equally apply in the operations and maintenance phase.

Significance of effect

3.9.9.15 The magnitude of the impact is deemed to be low, and the sensitivity of basking shark is considered to be medium. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

Decommissioning phase

Magnitude of impact

3.9.9.16 Vessel movements during the decommissioning phase may potentially lead to collision risks with basking shark. Activities during this phase are expected to be a reversal of the construction phase, with similar or identical vessel numbers and movements as are already covered in the construction assessment.

3.9.9.17 The impact is predicted to be of local spatial extent, medium term duration, intermittent, and of medium to low reversibility if collision occurs. It is predicted that the impact will affect the receptor directly. With designed-in measures in place the risk of collision will be reduced, however, given the potential for a collision to lead to injury the magnitude is, conservatively, considered to be **low**.

Sensitivity of receptor

3.9.9.18 The sensitivity of the basking shark can be found in the construction phase assessment (paragraph 3.9.9.6 to paragraph 3.9.9.10), with **medium** sensitivity, and this will equally apply in the decommissioning phase.

Significance of effect

3.9.9.19 The magnitude of the impact is deemed to be low, and the sensitivity of basking shark is considered to be medium. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.

3.9.10 Future monitoring

3.9.10.1 No fish and shellfish ecology monitoring to test the predictions made within the impact assessment is considered necessary at this stage.

3.10 Cumulative effects assessment methodology

3.10.1 Methodology

3.10.1.1 The CEA takes into account the impact associated with the Morgan Generation Assets and the Morgan and Morecambe Offshore Wind Farms: Transmission Assets together with other projects and plans. The projects and plans selected as relevant to the CEA presented within this chapter are based upon the results of a screening exercise (see Volume 3, Annex 5.1: Cumulative effects screening matrix of the Environmental Statement). Each project has been considered on a case-by-case basis for screening in or out of this chapter's assessment based upon data confidence, effect-receptor pathways and the spatial/temporal scales involved.

3.10.1.2 The fish and shellfish ecology CEA methodology has followed the methodology set out in Volume 1, Chapter 5: EIA methodology of the Environmental Statement. As part of the assessment, all projects and plans considered alongside the Morgan Generation Assets have been allocated into 'tiers' reflecting their current stage within the planning and development process, these are listed below. Broadly, the approach to identifying projects considered in the fish and shellfish ecology CEA is consistent with that taken for subtidal (i.e. screening projects to a range of 50 km for additive effects) and physical processes (i.e. screening projects within two tidal excursions). However, for underwater sound during the construction phase, a larger buffer of 100 km from the Morgan Generation Assets has been used to screen projects to account for the greater zone of influence associated with construction sound (specifically piling).

3.10.1.3 The CEA is presented in a series of tables (one for each potential cumulative impact), and considers the following:

- Scenario 1: Morgan Generation Assets together with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets
- Scenario 2: Morgan Generation Assets together with the Morecambe Offshore Windfarm: Generation Assets and the Morgan and Morecambe Offshore Wind Farms: Transmission Assets
- Scenario 3: Morgan Generation Assets together with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets

3.10.1.4 A tiered approach to the assessment has been adopted, as follows:

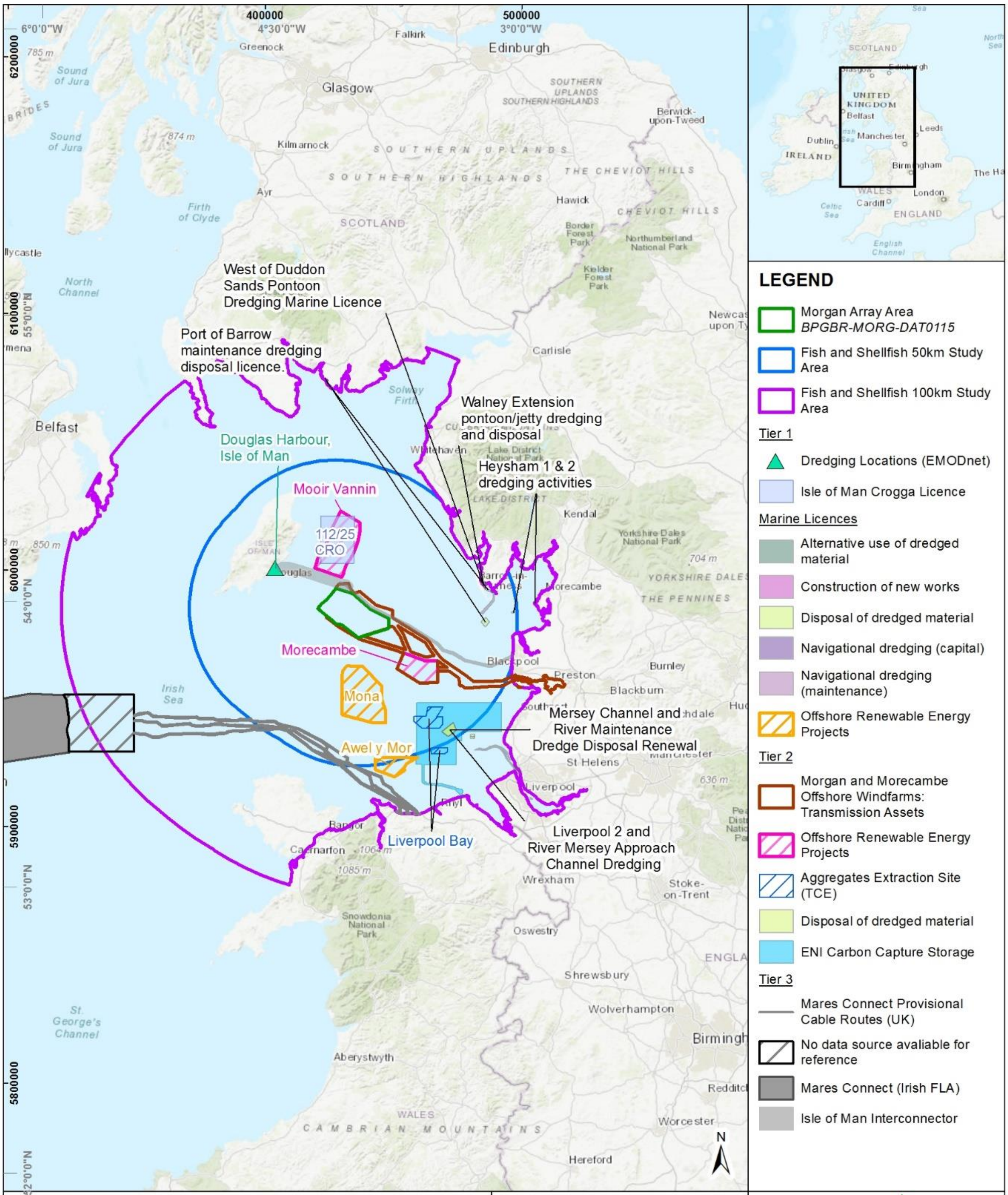
- Tier 1 includes projects, plans and activities at the following stages:
  - Under construction
  - Permitted application
  - Submitted application
  - Those currently operational that were not operational when baseline data were collected.
- Tier 2 includes Tier 1 projects, as well as projects where:
  - Scoping report has been submitted and is in the public domain
- Tier 3 includes Tier 1 and Tier 2 projects, as well as projects where:
  - Scoping report has not been submitted and is not in the public domain
  - Identified in the relevant Development Plan
  - Identified in other plans and programmes.

3.10.1.5 This tiered approach is adopted to provide a clear assessment of the Morgan Generation Assets and Morgan and Morecambe Offshore Wind Farms: Transmission Assets alongside other projects, plans and activities.

3.10.1.6 The specific projects, plans and activities scoped into the CEA, are outlined in Table 3.31 and shown in Figure 3.15.

3.10.1.7 A number of the impacts considered for the Morgan Generation Assets alone, as outlined in Table 3.18 and section 3.9, have not been considered within the CEA due to the localised and temporally restricted nature of these impacts. These impacts include:

- Disturbance/remobilisation of sediment-bound contaminants in all phases
- Temporary habitat loss/disturbance – operations and maintenance phase
- Increase in suspended sediment concentrations and associated deposition – operations and maintenance phase.



Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Data Sources: Client, NRW Survey Application P2578_R6143_Rev1, Departmnet of Housing Local Government and Heritage Forshore Application FS007635, TCE, NRW

Project Name:
MORGAN OFFSHORE WIND PROJECT

0 5 10 20 30 nm
0 5 10 20 30 40 50 60 70 km

Drawing Number:
RPSE-MG-FAS-E004-04

Drawing Title:
OTHER PROJECTS, PLANS AND ACTIVITIES SCREENED INTO THE CUMULATIVE EFFECTS ASSESSMENT

Geodetic Information:
Datum: ETRS 1989
Projection: ETRS 1989 UTM Zone 30N
Scale@160mmx220mm: 1:2,500,000

VER	DATE	DETAILS	BY	CHECK
00	14/11/23	First Issue	MJ	CB
MJ	27/03/24	Revision	MJ	LS

Figure 3.15: Other projects*, plans and activities screened into the cumulative effects assessment.

* The Awel y Môr agreement for lease area extends further to the west than the application boundary presented, however Awel y Môr Offshore Wind Farm Ltd. have decided to develop in the area presented

Table 3.31: List of other projects, plans and activities considered within the CEA.

Project/Plan	Status	Distance from the Morgan Generation Assets (km)	Description of project/plan	Dates of construction (if applicable)	Dates of operation (if applicable)	Overlap with the Morgan Generation Assets
Morgan Generation Assets	**-**	**-**	**-**	**Q1 2026 to Q4 2029**	**Q1 2030 to Q4 2065**	**-**
Tier 1						
Offshore renewables projects						
Mona Offshore Wind Farm	Application Submitted	11.1	1.5 GW (Up to 107 wind turbine foundations)	2028 to 2029	2030 to 2065	The construction, operations and maintenance and decommissioning phases of this project will overlap with the construction, operations and maintenance and decommissioning phases of the Morgan Generation Assets
Awel y Môr Offshore Wind Farm	Application Submitted	46.8	Up to 100MW (48 to 91 wind turbine foundations)	2026 to 2030	2030 to 2055	The construction, operations and maintenance and decommissioning phases of this project will overlap with the construction and operations and maintenance of the Morgan Generation Assets.
Oil and gas						
Isle of Man Crogga Licence (112/25)	Permitted	9.6	Licence for exploratory geotechnical and geophysical surveys as well as exploratory drilling,	n/a	2017 to 2048	The permitted activities associated with this project will overlap with the construction and operations and maintenance phases of the Morgan Generation Assets.

MORGAN OFFSHORE WIND PROJECT: GENERATION ASSETS

Project/Plan	Status	Distance from the Morgan Generation Assets (km)	Description of project/plan	Dates of construction (if applicable)	Dates of operation (if applicable)	Overlap with the Morgan Generation Assets
Dredging activities and dredge disposal sites						
Douglas Harbour Dredging, Isle of Man	Operational	22.7	Dredging to deepen harbour channels and capital dredging in front of the proposed terminal to create a berth pocket.	n/a	2016 to 2031	Dredging and disposal activities associated with this project will overlap with the construction and operations and maintenance phases of the Morgan Generation Assets.
Walney Extension pontoon/jetty dredging and disposal	Operational	35.7	A Marine Licence is being sought for dredging and associated disposal activities for the Walney Extension Offshore Wind Farm operations and maintenance base at the Port of Barrow.	n/a	2019 to 2029	Dredging and disposal activities associated with this project will overlap with the construction phase of the Morgan Generation Assets.
Port of Barrow maintenance dredging disposal licence (MLA/2015/00458/1)	Operational	35.9	Dredging is required to maintain the Port of Barrow and its approach channel at its advertised navigational depth for all vessels entering and leaving the port.	n/a	2016 to 2026	Dredging and disposal activities associated with this project will overlap with the construction phase of the Morgan Generation Assets.
West of Duddon Sands Pontoon Dredging Marine Licence	Operational	39.1	Sedimentation can cause the pontoon edge adjacent to the harbour wall to be raised during spring low tides. The scope of the marine licence application covers dredging which will be required annually based on the current observed rates of accumulation.	n/a	2018 to 2028	The operations and maintenance activities associated with this project will overlap with the construction phase of the Morgan Generation Assets.
Liverpool 2 and River Mersey Approach Channel Dredging	Operational	44.5	Capital dredging in front of the proposed terminal to create a berth pocket.	n/a	2019 to 2028	The operations and maintenance activities associated with this project will

MORGAN OFFSHORE WIND PROJECT: GENERATION ASSETS

Project/Plan	Status	Distance from the Morgan Generation Assets (km)	Description of project/plan	Dates of construction (if applicable)	Dates of operation (if applicable)	Overlap with the Morgan Generation Assets
						overlap with the construction phase of the Morgan Generation Assets.
Mersey channel and river maintenance dredge disposal renewal (MLA/2021/00202)	Operational	44.5	The Mersey Docks and Harbour Company Ltd, as the Harbour Authority for the Port of Liverpool has an obligation to dredge the approaches to Liverpool in order to maintain navigation into the Mersey Estuary for all river users.	n/a	2021 to 2031	Dredging and disposal activities associated with this project will overlap with the construction and operations and maintenance phases of the Morgan Generation Assets.
Heysham 1 and 2 dredging activities	Operational	47.9	Maintenance at cooling water outflows for nuclear power station. Dredging of up to 150,000 m^3 silt and 6,000,000 m^3 sand. Disposal of up to 28,000 m^3 per year.	n/a	2017 to 2027	The operations and maintenance activities associated with this project will overlap with the construction phase of the Morgan Generation Assets.
Tier 2						
Offshore renewables projects						
Mooir Vannin Offshore Windfarm	Pre-application	4.8	Ørsted have signed an agreement for lease to develop a 700 MW (annual output 3,000 GWh) wind farm on the east coast and have undertaken initial surveys since 2016.	2030 to 2032	Operational in 2032 with end date unknown	This project will overlap with the operations and maintenance and decommissioning phases of the Morgan Generation Assets.
Morecambe Offshore Windfarm: Generation Assets	Pre-application	11.2	12 to 24MW (Up to 40 wind turbine foundations)	2026 to 2028	2029 to 2089	The construction, operations and maintenance and decommissioning phases of this project will overlap with the construction, operations and maintenance and

Project/Plan	Status	Distance from the Morgan Generation Assets (km)	Description of project/plan	Dates of construction (if applicable)	Dates of operation (if applicable)	Overlap with the Morgan Generation Assets
						decommissioning phases of the Morgan Generation Assets.
Morgan and Morecambe Offshore Wind Farms: Transmission Assets	Pre- application	0.0	Morgan and Morecambe Offshore Wind Farms: Transmission Assets	2026 to 2028	2029 to 2064	Project construction phase overlaps with Morgan Generation Assets construction phase.
ENI HyNet Carbon Capture and Storage (CCS)	Pre-application (for offshore elements of the project)	31.0	CCS project in the east Irish Sea. Works will include installation of a new Douglas CCS platform and work on the existing Hamilton, Hamilton North and Lennox wellhead platforms.	Unknown	Unknown	This project will overlap with the construction and operations and maintenance phases of the Morgan Generation Assets.
Aggregate and disposal sites						
Liverpool Bay Area 457	Pre-application	34.3	Proposed extraction of 18 million tonnes of aggregate (mainly sand and fine sediment) over 15 years.	n/a	Unknown	Aggregate extraction activities associated with this project will overlap with the construction and operations and maintenance phases of the Morgan Generation Assets.
Tier 3						
Cables and pipelines						
MaresConnect – Wales-Ireland Interconnector Cable	Permitted but not yet implemented	48.2	A proposed 750MW subsea and underground electricity interconnector cable system linking the existing electricity grids in Ireland and Great Britain.	n/a	n/a	This project will overlap with the construction and operations and maintenance phases of the Morgan Generation Assets.
Isle of Man to UK Interconnector Cable 2	Pre-application	Unknown	A new 70 MW to 100 MW HVAC interconnector to be deployed by 2030 between Pulrose substation and	2024-2030	2030 onwards	Project construction phase overlaps with the Morgan Generation Assets construction phase.

MORGAN OFFSHORE WIND PROJECT: GENERATION ASSETS

Project/Plan	Status	Distance from the Morgan Generation Assets (km)	Description of project/plan	Dates of construction (if applicable)	Dates of operation (if applicable)	Overlap with the Morgan Generation Assets
			northwest England Distribution network.			Project operations and maintenance phase overlaps with the Morgan Generation Assets operations and maintenance phase.

3.10.2 Maximum design scenario

3.10.2.1 The MDSs identified in Table 3.32 have been selected as those having the potential to result in the greatest effect on an identified receptor or receptor group. These scenarios have been selected from the Project Design Envelope provided in Volume 1, Chapter 3: Project description of the Environmental Statement as well as the information available on other projects and plans. Effects of greater adverse significance are not predicted to arise should any other development scenario, based on details within the Project Design Envelope (e.g. different wind turbine foundation layout), to that assessed here, be taken forward in the final design scheme.

Table 3.32: Maximum design scenario considered for the assessment of potential cumulative effects on fish and shellfish ecology.

[a] C=construction, O=operations and maintenance, D=decommissioning

Potential cumulative effect	Phase[a]			Maximum Design Scenario	Justification
	C	O	D		
Temporary habitat loss/disturbance	✓	×	×	**Scenario 1** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets. **Scenario 2** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the Morecambe Offshore Windfarm: Generation Assets. **Scenario 3** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the following other projects/plans: **Tier 1** • Offshore Wind Farm projects: – Awel y Môr Offshore Wind Farm construction phase – Mona Offshore Wind Project construction phase. • Dredging projects: – Port of Barrow maintenance dredging disposal licence – Walney Extension pontoon/jetty dredging and disposal – West of Duddon Sands pontoon dredging marine licence – Mersey channel and river maintenance dredge disposal renewal – Douglas Harbour, IoM – Heysham 1 and 2 dredging activities Liverpool 2 and River Mersey approach channel dredging.	These projects all involve activities which will result in temporary habitat disturbance/loss which may coincide with the construction, operations and maintenance, and decommissioning phases for the Morgan Generation Assets contributing to the potential impact upon fish and shellfish IEFs cumulatively with the Morgan Generation Assets.

Potential cumulative effect	Phase[a]			Maximum Design Scenario	Justification
	C	O	D		
				Tier 2 • Tier 1 projects • Offshore renewables: – Morecambe Offshore Windfarm: Generation Assets – ENI HyNet CCS project. • Aggregate extraction activities: – Liverpool Bay area 457 **Tier 3** • Tier 1 and 2 projects • Cables and pipelines: – MaresConnect – Wales-Ireland Interconnector Cable – Isle of Man Interconnector Cable 2.	
	×	×	✓	**Scenario 1** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets. **Scenario 2** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the Morecambe Offshore Windfarm: Generation Assets. **Scenario 3** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the following other projects/plans: **Tier 1** • Offshore wind farm projects: – Mona Offshore Wind Project.	

Potential cumulative effect	Phase[a]			Maximum Design Scenario	Justification
	C	O	D		
				Tier 2 • Tier 1 projects • Offshore wind farm projects: – Morecambe Offshore Windfarm: Generation Assets – Mooir Vannin Offshore Windfarm. **Tier 3** No tier 3 projects are predicted to overlap with the decommissioning phase of the Morgan Generation Assets.	
Underwater sound impacting fish and shellfish receptors	✓	✗	✗	**Scenario 1** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets. **Scenario 2** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the Morecambe Offshore Windfarm: Generation Assets. **Scenario 3** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the following other projects/plans: **Tier 1** • Offshore wind farm projects: – Awel y Môr Offshore Wind Farm – Mona Offshore Wind Project **Tier 2** • Tier 1 projects • Offshore renewables: – Morecambe Offshore Windfarm: Generation Assets	These projects all involve activities which will result in underwater sound which may coincide with the construction phase for the Morgan Generation Assets contributing to the impact upon fish and shellfish IEFs cumulatively with the Morgan Generation Assets. These justifications broadly align with those noted in the CEA of Volume 2, Chapter 2: Benthic subtidal ecology of the Environmental Statement.

Potential cumulative effect	Phase[a] C	O	D	Maximum Design Scenario	Justification
				– ENI HyNet CCS project. **Tier 3** No tier 3 projects are predicted to interact cumulatively with the Morgan Generation Assets for this impact.	
Increased SSCs and associated sediment deposition	✓	×	×	**Scenario 1** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets. **Scenario 2** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the Morecambe Offshore Windfarm: Generation Assets. **Scenario 3** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the following other projects/plans: **Tier 1** • Offshore Wind Farm projects: – Awel y Môr Offshore Wind Farm – Mona Offshore Wind Project • Dredging projects: – Port of Barrow maintenance dredging disposal – Walney Extension pontoon/jetty dredging and disposal – West of Duddon Sands pontoon dredging – Mersey channel and river maintenance dredge disposal – Douglas Harbour, IoM – Heysham 1 and 2 dredging activities – Liverpool 2 and River Mersey approach channel dredging	These projects all involve activities which will result in increased SSC and sediment deposition which may coincide with the construction, operations and maintenance, and decommissioning phases for the Morgan Offshore Wind Project contributing to the impact upon fish and shellfish IEFs cumulatively with the Morgan Offshore Wind Project.

Potential cumulative effect	Phase[a]			Maximum Design Scenario	Justification
	C	O	D		
				• Aggregate extraction activities: – Liverpool Bay Area 457 aggregate extraction. **Tier 2** • Tier 1 projects • Offshore renewables: – Morecambe Offshore Windfarm: Generation Assets **Tier 3** • Tier 1 and 2 projects • Cables and pipelines: – MaresConnect – Wales-Ireland Interconnector Cable. – Isle of Man Interconnector 2	
	✗	✗	✓	**Scenario 1** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets. **Scenario 2** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the Morecambe Offshore Windfarm: Generation Assets. **Scenario 3** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the following other projects/plans: **Tier 1** • Offshore renewables: – Mona Offshore Wind Project	

Potential cumulative effect	Phase[a]			Maximum Design Scenario	Justification
	C	O	D		
				Tier 2 • Tier 1 projects • Offshore renewables: – Morecambe Offshore Windfarm: Generation Assets – Morgan and Morecambe Offshore Wind Farms: Transmission Assets. **Tier 3** No tier 3 projects are predicted have been identified as interacting cumulatively with the Morgan Generation Assets for this impact.	
Long term habitat loss.	✓	✓	✗	**Scenario 1** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets. **Scenario 2** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the Morecambe Offshore Windfarm: Generation Assets. **Scenario 3** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the following other projects/plans: **Tier 1** • Offshore wind farm projects: – Awel y Môr Offshore Wind Farm – Mona Offshore Wind Project • Oil and Gas projects: – Isle of Man Crogga Licence.	These projects will all result in the installation of hard structures on the seabed which will lead to long term habitat loss within the CEA benthic subtidal ecology study area meaning they may also affect habitats that the Morgan Generation Assets will also affect.

Potential cumulative effect	Phase[a]			Maximum Design Scenario	Justification
	C	O	D		
				Tier 2 • Tier 1 projects • Offshore renewables: – Morecambe Offshore Windfarm: Generation Assets – Mooir Vannin Offshore Windfarm – ENI HyNet CCS project. **Tier 3** • Tier 1 and 2 projects • Cables and pipelines: – MaresConnect – Wales-Ireland Interconnector Cable. – Isle of Man Interconnector Cable 2.	
	×	×	✓	**Scenario 1** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets. **Scenario 2** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the Morecambe Offshore Windfarm: Generation Assets. **Scenario 3** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the following other projects/plans: **Tier 1** • Offshore renewables: – Mona Offshore Wind Project.	

Potential cumulative effect	Phase[a]			Maximum Design Scenario	Justification
	C	O	D		
				Tier 2 • Tier 1 projects • Offshore renewables: – Morecambe Offshore Windfarm: Generation Assets – Mooir Vannin Offshore Windfarm – ENI HyNet CCS project. **Tier 3** No tier 3 projects are predicted have been identified as interacting cumulatively with the Morgan Generation Assets for this impact.	
Electromagnetic Fields (EMF) from subsea electrical cabling.	✗	✓	✗	**Scenario 1** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets. **Scenario 2** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the Morecambe Offshore Windfarm: Generation Assets. **Scenario 3** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the following other projects/plans: **Tier 1** • Offshore wind farm projects: – Awel y Môr Offshore Wind Farm – Mona Offshore Wind Project. **Tier 2** • Tier 1 projects	These projects all involve activities which will result in EMF emissions which may coincide with the operations and maintenance phase for the Morgan Generation Assets, contributing to this impact upon fish and shellfish IEFs cumulatively with the Morgan Generation Assets.

Potential cumulative effect	Phase[a]			Maximum Design Scenario	Justification
	C	O	D		
				• Offshore wind farm projects: – Morecambe Offshore Windfarm: Generation Assets – Moor Vannin Offshore Windfarm. **Tier 3** • Tier 1 and 2 projects • Cables/pipelines: – MaresConnect Wales-Ireland Interconnector Cable. – Isle of Man Interconnector 2 construction phase.	
Introduction and colonisation of hard structures	✓	✓	✗	**Scenario 1** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets. **Scenario 2** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the Morecambe Offshore Windfarm: Generation Assets. **Scenario 3** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the following other projects/plans: **Tier 1** • Offshore wind farm projects: – Awel y Môr Offshore Wind Farm – Mona Offshore Wind Project. • Oil and Gas projects: – Isle of Man Crogga Licence.	These projects will all result in the installation of hard structures on the seabed which could be colonised by new communities which may coincide with the construction, operations and maintenance phases for the Morgan Generation Assets, contributing to this impact upon fish and shellfish IEFs cumulatively with the Morgan Generation Assets.

Potential cumulative effect	Phase[a]			Maximum Design Scenario	Justification
	C	O	D		
				Tier 2 • Tier 1 projects • Offshore renewables: – Morecambe Offshore Windfarm: Generation Assets – Mooir Vannin Offshore Windfarm. – ENI HyNet CCS project **Tier 3** • Tier 1 and 2 projects • Cables/pipelines: – MaresConnect – Wales-Ireland Interconnector Cable – Isle of Man Interconnector 2.	
Injury due to increased risk of collision with vessels (basking shark only)	✓	✓	✓	**Scenario 1** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets. **Scenario 2** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the Morecambe Offshore Windfarm: Generation Assets. **Scenario 3** MDS as described for the Morgan Generation Assets (Table 3.18) assessed cumulatively with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the following other projects/plans: **Tier 1** • Offshore Wind Farm projects: – Awel y Môr Offshore Wind Farm – Mona Offshore Wind Farm.	These projects all involve activities which will result in increased vessel traffic that may collide with basking shark, which may coincide with the construction, operations and maintenance, and decommissioning phases for the Morgan Generation Assets, contributing to the impact on this fish IEF cumulatively with the Morgan Generation Assets.

Potential cumulative effect	Phase[a]			Maximum Design Scenario	Justification
	C	O	D		
				• Dredging projects: – Port of Barrow maintenance dredging disposal licence – Walney Extension pontoon/jetty dredging and disposal – West of Duddon Sands pontoon dredging marine licence – Mersey channel and river maintenance dredge disposal renewal – Douglas Harbour, IoM – Heysham 1 and 2 dredging activities – Liverpool 2 and River Mersey approach channel dredging. **Tier 2** • Tier 1 projects • Offshore renewables: – Morecambe Offshore Windfarm: Generation Assets – Mooir Vannin Offshore Windfarm – ENI HyNet CCS project. **Tier 3** • Tier 1 and 2 projects • Cables and pipelines: – MaresConnect – Wales-Ireland Interconnector Cable. – Isle of Man Interconnector 2.	

3.11 Cumulative effects assessment

3.11.1 Overview

3.11.1.1 A description of the significance of cumulative effects upon fish and shellfish ecology receptors arising from each identified impact is given below.

3.11.2 Temporary subtidal habitat loss

3.11.2.1 There is the potential for cumulative temporary habitat loss as a result of construction and decommissioning activities associated with the Morgan Generation Assets and other offshore wind farms (i.e. from cable burial, jack-up activities, anchor placements and seabed preparation), dredging activities; aggregate extraction activities and cables and pipelines (see Table 3.18). For the purposes of this Environmental Statement, this additional impact has been assessed within the cumulative fish and shellfish ecology study area, defined as the area within a 50 km buffer of the Morgan Generation Assets. The 50 km buffer area captures a fair representation of potentially impacted fish and shellfish IEFs within the cumulative fish and shellfish ecology study area in proximity to the Morgan Generation Assets. The potential effects of this impact alone were assessed for this project in section 3.9.2.

3.11.2.2 A summary of cumulative effects assessment for temporary subtidal habitat loss or disturbance is presented in Table 3.34.

Scenario 1

3.11.2.3 Scenario 1 includes the Morgan Generation Assets and the Morgan and Morecambe Offshore Wind Farms: Transmission Assets.

Scenario 2

3.11.2.4 Scenario 2 assesses the scenario 1 projects, plus the Morecambe Offshore Windfarm: Generation Assets.

Scenario 3

3.11.2.5 Scenario 3 assesses the scenario 1 projects, and each of the projects and plans outlined in tiers 1 to 3 below; within scenario 3, the Morecambe Offshore Windfarm: Generation Assets as considered a tier 2 project.

Tier 1

Construction phase

Magnitude of impact

3.11.2.6 Almost all plans/projects/activities screened into the assessment for cumulative effects from temporary habitat loss/disturbance are either on-going activities (i.e. licensed and application aggregate extraction areas) or other offshore wind farms which are consented, submitted or under construction (i.e. tier 1).

3.11.2.7 The predicted cumulative temporary habitat loss and disturbance from each of the tier 1 plans, projects, and activities is presented in Table 3.33 together with a breakdown of the sources of this data from the relevant Environmental Statements, marine licences, and reports, and any assumptions made where necessary information was not presented in these. Table 3.33 shows that for all projects, plans, and activities in the tier 1 assessment, the cumulative temporary habitat loss/disturbance is estimated at up to 201.7 km^2 (including the Morgan Generation Assets and Morgan and Morecambe Offshore Wind Farms: Transmission Assets), where quantification data is available. A summary of the cumulative effects of temporary, subtidal habitat loss is given in Table 3.34.

Table 3.33: Cumulative tier 1 temporary habitat loss for the Morgan Generation Assets along with relevant projects and plans during the construction phase.

Project	Predicted temporary habitat disturbance/loss (km^2)	Component parts of temporary habitat disturbance/loss	Source
Morgan Generation Assets	61.42	See Table 3.18	n/a
Morgan and Morecambe Offshore Wind Farms: Transmission Assets	64.03	Temporary habitat disturbance/loss may result from: • Jack up events • Sandwave clearance and deposition • Cable removal and installation • UXO clearance	Morecambe Offshore Windfarm Ltd and Morgan Offshore Wind Ltd. (2023)
Offshore renewables			
Mona Offshore Wind Project	60.51	Temporary habitat disturbance/loss may result from: • Jack up events • Sandwave clearance and deposition • Cable removal and installation • UXO clearance	Mona Offshore Wind Ltd. (2024)
Awel y Môr Offshore Wind Farm	10.02	Temporary habitat disturbance/loss may result from: • Jack up events • Anchoring • Intertidal horizontal directional drilling (HDD).	RWE (2022)
Dredging activities and dredge disposal sites			
Port of Barrow maintenance dredging disposal licence.	0.01	Temporary habitat disturbance/loss may result from: • Dredging of silt, sand and gravel. The values provided for this project represent the area of the project as no temporary habitat disturbance/loss values were provided.	Associated British Ports (2016)
Walney Extension pontoon/jetty dredging and disposal	0.01	Temporary habitat disturbance/loss may result from: • Material deposition.	Orsted (2018)

Project	Predicted temporary habitat disturbance/loss (km^2)	Component parts of temporary habitat disturbance/loss	Source
Liverpool 2 and River Mersey approach channel dredging	3.71	Temporary habitat disturbance/loss may result from: • Dredging of silt. The values provided for this project represent the area of the project as no temporary habitat disturbance/loss values were provided.	Royal Haskoning (2012)
Mersey channel and river maintenance dredge disposal renewal	0.5	Temporary habitat disturbance/loss may result from: • Dredging of silt and sand.	Royal Haskoning (2018)
Heysham 1 and 2 dredging activities	No quantification provided.	Dredging of the channel outside of the power station by the coolant outflow.	n/a
Douglas Harbour dredging Isle of Man	No quantification provided.	Annual maintenance dredging of the harbour.	n/a
West of Duddon Sands Pontoon Dredging Marine Licence	No quantification provided.	Dredging of the channel leading to the maintenance facility.	n/a
Total	200.21		

Decommissioning Phase

Magnitude of impact

3.11.2.8 Just one tier 1 project has been identified within the cumulative fish and shellfish ecology study area for the decommissioning phase assessment: the Mona Offshore Wind Project. The decommissioning phase of this project is expected to coincide with the decommissioning of the Morgan Generation Assets and Morgan and Morecambe Offshore Wind Farms: Transmission Assets.

3.11.2.9 A summary cumulative effects assessment for temporary subtidal habitat loss or disturbance is presented in Table 3.34.

Tier 2

Construction phase

Magnitude of impact

3.11.2.10 The tier 2 construction phase assessment considers the Morecambe Offshore Wind Farm Generation Assets, the ENI HyNet CCS project and Liverpool Bay Area 457 alongside the Morgan Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets and tier 1 projects. Construction activities for these projects may occur within the same window and therefore there is potential for cumulative effects to arise.

3.11.2.11 A summary cumulative effects assessment for temporary subtidal habitat loss or disturbance is presented in Table 3.34.

Decommissioning phase

Magnitude of impact

3.11.2.12 The tier 2 projects considered for the cumulative decommissioning assessment are the decommissioning phase of the Morecambe Offshore Wind Farm Generation Assets, and the operation and maintenance phase of Mooir Vannin Offshore Windfarm alongside Morgan Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the tier 1 projects.

3.11.2.13 A summary cumulative effects assessment for temporary subtidal habitat loss or disturbance is presented in Table 3.34.

Tier 3

Construction phase

Magnitude of impact

3.11.2.14 Two tier 3 projects have been identified for the construction phase assessment, the MaresConnect Wales-Ireland Interconnector Cable and the Isle of Man Interconnector 2, which are considered alongside the Morgan Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets, tier 1 and tier 2 projects. No specifications for these projects are currently publicly available, including planned construction programmes, therefore only a high-level qualitative assessment has been applied.

3.11.2.15 A summary cumulative effects assessment for temporary subtidal habitat loss or disturbance is presented in Table 3.34.

Decommissioning phase

3.11.2.16 No tier 3 projects were identified with potential for cumulative effects with the decommissioning of the Morgan Generation Assets and Morgan and Morecambe Offshore Wind Farms: Transmission Assets.

Table 3.34: Temporary subtidal habitat loss and disturbance.

	Scenario 1 Morgan Generation Assets + Transmission Assets	Scenario 2: Morgan Generation Assets + Morecambe Offshore Windfarm: Generation Assets + Transmission Assets	Scenario 3: Morgan Generation Assets + Transmission Assets + Tier 1, Tier 2, Tier 3 projects
Construction			
Magnitude of impact	The temporary habitat disturbance/loss predicted to result from Morgan Generation Assets is up to 61.42 km^2, leading to a predicted cumulative temporary habitat loss/disturbance alongside the Transmission Assets (64.03 km^2) during the construction phase of 125.45 km^2; this does not represent a large area compared to the cumulative study area of 11,367.6 km^2. For most fish and shellfish IEFs, the potential cumulative effect is predicted to be of regional spatial extent, medium term duration, intermittent and of high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **low.** For herring the magnitude is considered to be **negligible** due to the lack of overlap with mapped spawning grounds and presence of limited suitable substrates within the Morgan Generation Assets. For sandeel, magnitude is considered **low** due to their widespread spawning and habitation grounds, and the very low proportion of suitable substrata within the area of the Morgan Generation Assets.	Whilst the area of temporary habitat loss and disturbance increases when considering the three projects together, the Morecambe Offshore Windfarm: Generation Assets leads to a very minor increase of 3.46 km^2; increasing the total footprint of temporary habitat loss and disturbance to 128.91 km^2. Magnitudes are consistent with those presented in Scenario 1.	**Tier 1** Cumulative effects of temporary subtidal habitat loss may exist for the Morgan Generation Assets, Transmission Assets, and the projects listed in Table 3.33, to represent a potential cumulative temporary subtidal habitat loss of up to 200.21 km^2. Magnitudes are consistent with those presented in Scenario 1. **Tier 2** Cumulative effects of temporary subtidal habitat loss may exist for the Morgan Generation Assets, Transmission Assets, tier 1 projects, the Morecambe Offshore Windfarm, ENI Hynet CCS and Liverpool Bay Area 457. The abovementioned projects, excluding ENI Hynet CCS, represent a potential cumulative temporary subtidal habitat loss of up to 132.15km^2, as per Scenario 2, plus the 74.75 km^2 of temporary subtidal habitat loss expected from Tier 1 projects (where data is available; total 206.90 km^2). Based on the scale of the project, ENI Hynet CCS is not expected to represent a notable increase in footprint. Magnitudes are therefore consistent with those presented in Scenario 1. **Tier 3** Cumulative effects of temporary subtidal habitat loss may exist for the Morgan

	Scenario 1 **Morgan Generation Assets** **+ Transmission Assets**	**Scenario 2:** **Morgan Generation Assets** **+ Morecambe Offshore Windfarm: Generation Assets** **+ Transmission Assets**	**Scenario 3:** **Morgan Generation Assets + Transmission Assets** **+ Tier 1, Tier 2, Tier 3 projects**
			Generation Assets, Transmission Assets, tier 1 and 2 projects, and the proposed MaresConnect Wales-Ireland Interconnector Cable and Isle of Man Interconnector 2 cable. Insufficient information is available to quantitatively assess the tier 3 projects, however due to these being cable installations, the footprint of temporary habitat loss is not expected to represent a notable increase when compared with the abovementioned projects. Magnitudes are therefore consistent with those presented in Scenario 1.
Sensitivity of receptor	The sensitivity of fish and shellfish IEFs to this impact is described previously for the construction phase of the Morgan Generation Assets alone in paragraph 3.9.2.15 to paragraph 3.9.2.41. Most fish and shellfish ecology IEFs in the fish and shellfish ecology study area are deemed to be of low vulnerability, high recoverability and local to national importance. The sensitivity of the receptor is therefore considered to be **low**. King and queen scallop are deemed to be of medium vulnerability, high recoverability, and of regional importance. The sensitivity of the receptor is therefore considered to be **low.** European lobster and *Nephrops* are deemed to be of high vulnerability, medium to high recoverability and of regional importance. The sensitivity of these fish and shellfish IEFs is therefore considered to be **medium**. Sandeel are deemed to be of high vulnerability (due to their substrate specificity), high recoverability and of regional importance. The sensitivity of sandeel is therefore considered to be **high**. Herring are deemed to be of high vulnerability, medium recoverability and of national importance. The sensitivity of herring to this impact is therefore considered to be **high**. Diadromous fish in the fish and shellfish ecology study area are deemed to be of low vulnerability, high recoverability and national to international value. The sensitivity of the receptor is therefore considered to be **negligible.**		
Significance of effect	Overall, the magnitude of the impact is deemed to be low, and the sensitivity of most fish IEFs is considered to be low. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms. For king and queen scallop, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.		

	Scenario 1 Morgan Generation Assets + Transmission Assets	Scenario 2: Morgan Generation Assets + Morecambe Offshore Windfarm: Generation Assets + Transmission Assets	Scenario 3: Morgan Generation Assets + Transmission Assets + Tier 1, Tier 2, Tier 3 projects
	For European lobster and *Nephrops*, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be medium. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms. For sandeel, the magnitude of the impact is deemed to be low, and the sensitivity of the receptor is considered to be high. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms. For herring, the magnitude of the impact is deemed to be negligible, and the sensitivity of the receptor is considered to be high. The effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms. For diadromous fish IEFs, the magnitude of the impact is low and the sensitivity of the receptor is negligible. This gives rise to an impact significance of negligible or minor adverse. Based upon the low vulnerability to this impact, and the low likelihood of effects to diadromous fish receptors, the effect will therefore be of **negligible** significance, which is not significant in EIA terms.		
Further mitigation and residual significance	Mitigation: None required Residual significance: Negligible to minor adverse		
Decommissioning			
Magnitude of impact	The expected magnitude of temporary habitat loss will be less than the construction phase due to some construction activities not being required (e.g., sandwave clearance). As a precautionary measure, magnitudes are considered consistent with those presented for the construction phase above.	As for Scenario 1, the expected magnitude of temporary habitat loss will be less than the construction phase due to some construction activities not being required (e.g., sandwave clearance). As a precautionary measure, magnitudes are considered consistent with those presented for the construction phase above.	**Tier 1** The decommissioning phase of the Mona Offshore Wind Project may have temporal overlap with the decommissioning of the Morgan Generation Assets and Transmission Assets, with temporary habitat loss considered less that the cumulative footprint for the construction phase, due to not including Awel y Môr (based on the available project lifetime information) and due to some construction activities not being required (e.g., sandwave clearance). As a precautionary measure, magnitudes are considered consistent with those presented for the construction phase above. **Tier 2** Cumulative effects of temporary subtidal habitat loss may exist for the Morgan Generation Assets decommissioning

	Scenario 1 **Morgan Generation Assets** **+ Transmission Assets**	**Scenario 2:** **Morgan Generation Assets** **+ Morecambe Offshore Windfarm: Generation Assets** **+ Transmission Assets**	**Scenario 3:** **Morgan Generation Assets + Transmission Assets** **+ Tier 1, Tier 2, Tier 3 projects**
			alongside the Transmission Assets, tier 1 projects, the Morecambe Offshore Wind Farm and the operation and maintenance phase of Mooir Vannin Offshore Windfarm. Excluding Mooir Vannin, the above mentioned projects are expected to represent a smaller footprint of impact than for the construction phase, due to the absence of some construction activities (e.g. sandwave clearance). Based on the limited information available regarding the technical specifications for Mooir Vannin, the operation and maintenance phase of this project is expected to include cable repair and replacement activities. These activities are expected to contribute only a minor amount of temporary habitat loss, in comparison to the decommissioning works at Morgan Generation Assets and the other tier 2 projects. As a precautionary measure, magnitudes are considered consistent with those presented for the construction phase above. **Tier 3** No tier 3 projects were identified with potential for cumulative effects with the decommissioning of the Morgan Generation Assets.
Sensitivity of receptor	Please refer to the construction phase.		
Significance of effect	Please refer to the construction phase.		
Further mitigation and residual significance	Mitigation: None required		

	Scenario 1 Morgan Generation Assets + Transmission Assets	Scenario 2: Morgan Generation Assets + Morecambe Offshore Windfarm: Generation Assets + Transmission Assets	Scenario 3: Morgan Generation Assets + Transmission Assets + Tier 1, Tier 2, Tier 3 projects
	Residual significance: Negligible to minor adverse		

3.11.3 Underwater sound impacting fish and shellfish receptors

3.11.3.1 There is the potential for cumulative impacts from underwater sound generation as a result of construction phase of the Morgan Generation Assets and other offshore wind farms. For the purposes of this Environmental Statement, this potentially additive impact has been assessed within the cumulative fish and shellfish ecology study area for underwater sound, defined as the area within a 100 km buffer of the Morgan Generation Assets.

3.11.3.2 It is important to note that despite sound producing activities potentially occurring simultaneously, sound levels are not mathematically additive, as described in section 3.9.3. Whilst sound levels would be expected to show an increase, the increase would not represent the two individual sound levels additively, the key potential cumulative effect to consider is the increased area of ensonification. Further, the soundscape is expected to return to near-baseline conditions upon completion of construction activities.

3.11.3.3 Summary of cumulative effects assessments are presented in Table 3.35, outlining the magnitude, sensitivity of receptors and significance of effect within each defined scenario.

Scenario 1

3.11.3.4 Scenario 1 includes the Morgan Generation Assets and the Morgan and Morecambe Offshore Wind Farms: Transmission Assets:

- Morgan and Morecambe Offshore Wind Farms: Transmission Assets (Morecambe Offshore Windfarm Ltd and Morgan Offshore Wind Ltd, 2023)
  - Temporal and spatial overlap with Morgan Generation Assets during construction potentially resulting in a cumulative impact (piling and UXO clearance)
  - Piling: 6 days (single piling) to install 6 monopiles (4 x 16m diameter monopiles at Morgan Offshore Wind Project and 2 x 14m monopiles at Morecambe Offshore Wind Project), with a maximum hammer energy of 5,500 kJ. A maximum of 44 hours of piling is expected under this scenario, although please note that the OSPs and associated foundations considered for the Transmission Assets are also included within the Morgan Generation Assets assessment, therefore the overlap here is somewhat overestimated. Piling will be undertaken over two years of a four-year construction phase
  - Sound modelling: Injury and mortality to ranges of up to 1,050 m for group 1 fish, 4,340 m for group 2, 3 and 4 fish, as static receptors. Ranges are much lower for moving receptors. Behavioural effects expected to a range of up to tens of kilometres from the source, with sound contours overlapping herring and cod spawning habitat. Contours which overlapped herring spawning grounds were evident using both the precautionary 135dB re 1 $\mu Pa^2.s$ SEL_{ss} and more moderate 160dB re 1 µPa SPL_{pk} thresholds. Based on the very short piling duration associated with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets, potential effects to all fish and shellfish receptors were assessed to be not significant.

Scenario 2

3.11.3.5 Scenario 2 assesses the scenario 1 projects, plus the Morecambe Offshore Windfarm: Generation Assets:

- Morecambe Offshore Windfarm: Generation Assets (Morecambe Offshore Windfarm Ltd, 2023)
    - Temporal and spatial overlap with Morgan Generation Assets during construction potentially resulting in a cumulative impact (piling and UXO clearance).
    - Piling: Maximum hammer energy of 5,000 kJ to install up to 42 monopiles (40 x wind turbine foundations and 2 x OSP foundations) or 168 pin piles (based on four pin piles at each of 42 jacket foundations). A maximum of 756 hours of piling is expected based on the pin piling scenario. Piling of foundations will be undertaken within a construction phase of 2.5 years.
    - Sound modelling: Based on a maximum hammer energy of 5,000 kJ, injury and mortality to ranges of up to 1,300 m for group 1 fish, 6,700 m for group 2 fish, and 5,000 m calculated for group 3 and 4 fish as static receptors were modelled. Ranges are much lower for moving receptors. Behavioural effects are expected to a range of up to tens of kilometres from the source, but with no overlap of contours with any mapped herring spawning grounds and no significant effects predicted for the species assessed.

Scenario 3

3.11.3.6 Scenario 3 assesses the scenario 1 projects, and each of the projects and plans outlined in tiers 1 to 3 below; within scenario 3, the Morecambe Offshore Windfarm: Generation Assets as considered a tier 2 project.

Tier 1

Construction phase

Magnitude of impact

3.11.3.7 The projects and activities considered under the tier 1 assessment include the Morgan Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets, and other projects including:

- Awel y Môr Offshore Wind Farm (RWE, 2022)
    - Temporal and spatial overlap with Morgan Generation Assets during construction potentially resulting in a cumulative impact (piling and UXO clearance)
    - Piling: Maximum hammer energy of 5,000 kJ to install up to 50 monopiles over 74 days (single vessel). A maximum of 896 hours of piling is expected under this scenario. Piling will be undertaken a period of three years
    - Sound modelling: Injury and mortality to ranges of up to 1,300 m for group 1 fish, 6,300 m for group 2 fish, and 8,600 m calculated for group 3 fish as static receptors. Ranges are much lower for moving receptors. Behavioural effects are expected to a range of up to tens of kilometres from the source, but with no overlap of contours with any mapped herring spawning grounds and no significant effects predicted for the species assessed.
- Mona Offshore Wind Project Mona Offshore Wind Ltd., (2024)

  - Temporal and spatial overlap with Morgan Generation Assets during construction potentially resulting in a cumulative impact (piling and UXO clearance)
  - Piling: 114 days (single piling) to install 454 pin piles (256 for 64 x four-legged wind turbine foundation jackets, 150 for 10 x gravity base foundations, 48 for 4 x four-legged jacket OSPs), with a maximum hammer energy of 4,400 kJ. A maximum of 106 of piling is expected under this scenario. Piling will be undertaken over two years of a four-year construction phase
  - Sound modelling: Injury and mortality to ranges of up to 556 m for group 1 fish, 3,180 m for group 2, 3 and 4 fish, as static receptors. Ranges are much lower for moving receptors. Behavioural effects are expected to a range of up to tens of kilometres from the source, with sound contours overlapping herring and cod spawning habitat. Contours which overlapped herring spawning grounds were at highly precautionary levels (135dB re 1 µPa^2.s SEL$_{ss}$), with a very minor overlap with low intensity spawning grounds at a more moderate threshold of 160dB re 1 µPa SPL$_{pk}$. On this basis, a precautionary moderate adverse significant effect is predicted for herring. Overlap with cod spawning habitat at a threshold of 160dB re 1 µPa SPL$_{pk}$ represented a very small proportion of spawning habitat available within the wider Irish Sea, therefore effects to cod were considered not significant.

3.11.3.8 Mitigation including soft starts and ramp-up procedures will reduce the risk of injury and mortality to some fish and shellfish receptors. Similar approaches are typically applied for UXO clearance by using a gradual increase in charge size to perform a ramp up.

3.11.3.9 A summary cumulative effects assessment for underwater sound affecting fish and shellfish receptors is presented in Table 3.35.

Tier 2

Construction phase

Magnitude of impact

3.11.3.10 The projects and activities considered under the tier 2 assessment include the Morgan Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets, and the Morecambe Offshore Windfarm: Generation Assets, and the following projects and plans:

- ENI Hynet CCS (ENI, 2021).
  - Potential temporal overlap with Morgan Generation Assets during construction potentially resulting in a cumulative impact (piling and UXO clearance).
  - Piling: Piling is required for installation of a new platform; the duration of this activity is expected to be far shorter than the piling associated with the Morgan Generation Assets and other offshore wind projects considered, thereby representing only a minor increase in the ensonified area, should piling occur at the same time.

3.11.3.11 A summary cumulative effects assessment for underwater sound affecting fish and shellfish receptors is presented in Table 3.35.

Table 3.35: Underwater sound impacting fish and shellfish receptors.

	Scenario 1 Morgan Generation Assets + Transmission Assets	Scenario 2: Morgan Generation Assets + Morecambe Offshore Windfarm: Generation Assets + Transmission Assets	Scenario 3: Morgan Generation Assets + Transmission Assets + Tier 1, Tier 2, Tier 3 projects
Construction			
Magnitude of impact	The magnitude of impact for this scenario represents installation of 454 x pin piles at Morgan Generation Assets with a maximum hammer energy of up to 4,400 kJ, and installation of six monopiles at the Transmission Assets with a maximum hammer energy of 5,500 kJ. The Transmission Assets is expected to represent only a minor and very short-term contribution to the cumulative under water sound levels generated by the Morgan Generation Assets. The potential cumulative effect on most fish and shellfish receptors is predicted to be of regional spatial extent, relatively short-term duration, intermittent and of high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore considered to be **low**. For cod, the cumulative effect is predicted to be of regional spatial extent, relatively short-term duration (with spawning of cod occurring from January to April), intermittent and of high reversibility. It is predicted that the impact will affect the receptor directly. Based on the extent of the area available for cod spawning outside of the modelled impacted zone, the	The magnitude of impact for this scenario represents the projects within Scenario 1, with the addition of the Morecambe Offshore Windfarm: Generation Assets which is based upon a maximum hammer energy is of 5,000 kJ for the installation of 42 monopiles. The magnitude for fish and shellfish receptors is consistent with that presented for Scenario 1 (**low to medium**, negligible outside of the cod and herring spawning periods).	**Tier 1** The magnitude of impact for this scenario represents the projects within Scenarios 1 and 2, with the addition of Awel y Môr and the Mona Offshore Wind Project. Awel y Môr has a maximum hammer energy of up to 5,000 kJ, with up to 50 monopiles being installed. Mona Offshore Wind Project includes pin piling with a maximum hammer energy of 4,400 kJ, to install up to 454 pin piles. The magnitude for most fish and shellfish receptors is consistent with that presented for Scenario 1 (**low**), except for cod and herring. For cod and herring, the cumulative effect is predicted to be of regional spatial extent, short-term duration, intermittent and of high reversibility. It is predicted that the impact will affect the receptor directly. The ensonified area regionally is expected to increase during overlapping construction phases of Morgan Generation Assets, Awel y Môr and Mona Offshore Wind Project, although the effects of overlapping sound contours are not expected to be mathematically additive. This is expected to reduce the proportion of available habitat for cod spawning in the east Irish Sea when compared to the project alone assessment.

	Scenario 1 Morgan Generation Assets + Transmission Assets	Scenario 2: Morgan Generation Assets + Morecambe Offshore Windfarm: Generation Assets + Transmission Assets	Scenario 3: Morgan Generation Assets + Transmission Assets + Tier 1, Tier 2, Tier 3 projects
	magnitude is therefore considered to be **low** during the cod spawning season. Outside of this period, the magnitude in respect of cod is considered **negligible**. For herring, the cumulative effect is predicted to be of regional spatial extent, relatively short-term duration (noting that spawning of Manx herring is reported to consistently occur over three to four weeks from late September; Dickey-Collas *et al.*, 2001), intermittent and of high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore considered to be **medium** during the herring spawning season and **negligible** outside of this period.		For herring the increased area of ensonification has potential to affect herring behaviour over a wider spatial scale, however, due to the proximity of the Morgan Generation Assets to the mapped herring spawning grounds and areas of high aggregated herring larval densities, the project alone is expected to have the greatest effect on this species (see section 3.9.3). The magnitude for cod and for herring is therefore, considered to be **medium.** **Tier 2** The magnitude of impact for this scenario represents the projects within Scenarios 1 and 2, tier 1 projects and ENI Hynet CCS. ENI Hynet CCS includes a small amount of piling for installation of a new platform, therefore is not expected to contribute notably to the soundscape during construction. The magnitude for fish and shellfish receptors is therefore consistent with that presented for tier 1 (**low to medium**). **Tier 3** No tier 3 projects were identified with potential for cumulative effects with the construction of the Morgan Generation Assets.
Sensitivity of receptor	The sensitivity of the fish and shellfish IEFs to this impact is described previously for the construction phase of the Morgan Generation Assets alone in paragraph 3.9.3.18 to paragraph 3.9.3.83. Most fish and shellfish IEFs are deemed to be of low vulnerability, high recoverability and local to international importance. The sensitivity of the receptor is therefore, considered to be **low.**		

	Scenario 1 Morgan Generation Assets + Transmission Assets	Scenario 2: Morgan Generation Assets + Morecambe Offshore Windfarm: Generation Assets + Transmission Assets	Scenario 3: Morgan Generation Assets + Transmission Assets + Tier 1, Tier 2, Tier 3 projects
	Sprat are deemed to be of medium vulnerability, high recoverability and regional importance. The sensitivity of the receptor is therefore, considered to be **medium**. Cod are deemed to be of high vulnerability, medium recoverability in the context of the Irish Sea stock, and regional importance. The sensitivity of the receptor is therefore considered to be **high**. Herring are deemed to be of high vulnerability, high recoverability and national importance, with strong reactions noted to relatively low levels of sound due to their hearing physiology. The sensitivity of the receptor is therefore, considered to be **high**. It should be noted however, that evidence exists to suggest that biological drivers (i.e. those related to spawning) may override such responses to underwater sound, suggesting a potential lower sensitivity when highly motivated to continue or undertake a particular activity (Brown and May Marine, 2009d; Peña *et al.*, 2013). Allis shad and twaite shad are deemed to be of medium vulnerability, high recoverability, and national importance. The sensitivity of the receptor is therefore considered to be **high**.		
Significance of effect	For most fish and shellfish IEFs, the magnitude of the impact is deemed to be low, and the sensitivity is considered low. The effect will therefore be of **minor adverse** significance, which is not significant in EIA terms. For sprat, the magnitude of the impact is deemed to be low, and the sensitivity is considered medium. The effect will be of **minor adverse** significance, which is not significant in EIA terms. For cod, the magnitude of the impact is deemed to be low, and the sensitivity is considered high. The effect will be of **minor adverse** significance, which is not significant in EIA terms, in line with the alone assessment. For herring, the magnitude of the impact is deemed to be medium during the herring spawning period, and the sensitivity of herring is considered to be high. The effect will, therefore, be of **moderate adverse** significance, which is significant in EIA terms, in line with the alone assessment. Outside of the herring spawning period, the magnitude of the impact is negligible, and the sensitivity of the receptor is high. The effect will therefore be of **minor adverse** significance which is not significant in EIA terms. For allis and twaite shad, the magnitude of the impact is low and the sensitivity of the receptor is high. This gives rise to an impact significance of minor or moderate adverse. Due to the short term, intermittent nature of the impact being unlikely to affect migration to or from key rivers, and the lack of direct sound impact on freshwater spawning habitats, the effect will therefore be of **minor adverse** significance, which is not significant in EIA terms.		**Tier 1** For most fish and shellfish IEFs, the magnitude of the impact is deemed to be low, and the sensitivity is considered low. The effect will therefore be of **minor adverse** significance, which is not significant in EIA terms. For sprat, the magnitude of the impact is deemed to be low, and the sensitivity is considered medium. The effect will be of **minor adverse** significance, which is not significant in EIA terms. For cod and herring, the magnitude of the impact is deemed to be medium, and the sensitivity is considered high. The effect will be of **moderate adverse** significance, which is significant in EIA terms. For allis and twaite shad the magnitude of the impact is low and the sensitivity of the receptor is high. Consistent with scenarios 1 and 2, the effect is therefore of **minor**

	Scenario 1 Morgan Generation Assets + Transmission Assets	Scenario 2: Morgan Generation Assets + Morecambe Offshore Windfarm: Generation Assets + Transmission Assets	Scenario 3: Morgan Generation Assets + Transmission Assets + Tier 1, Tier 2, Tier 3 projects
			adverse significance, which is not significant in EIA terms. **Tier 2** Significance of effect for all receptors are consistent with those presented for tier 1. **Tier 3** No tier 3 projects were identified with potential for cumulative effects with the construction of the Morgan Generation Assets.
Further mitigation and residual significance	Mitigation: Post consent, following a refined project design envelope and programme clarity, the Outline underwater sound management strategy (Document Reference J13) will investigate options to manage underwater sound levels (such as NAS, temporal and spatial piling restrictions, piling methods, soft start) in order to reduce the magnitude for the project alone, and minimise the project's contribution to any cumulative effect. The project has prepared an Outline underwater sound management strategy (Document Reference J13) which is secured as a condition of the deemed marine licence(s) within the Draft DCO (Document Reference C1). Residual significance: Minor adverse anticipated.		

3.11.4 Increased SSCs and associated sediment deposition

3.11.4.1 Increased suspended sediment concentrations and associated sediment deposition is expected to occur in relation to the construction and decommissioning phases of the Morgan Generation Assets, which was assessed for project alone in section 3.9.4. Should other activities take place concurrently with the Morgan Generation Assets, there is potential for cumulative increased SSCs.

3.11.4.2 A summary assessment of the cumulative effects of increased SSCs and associated sediment deposition is given in Table 3.36.

Scenario 1

3.11.4.3 Scenario 1 includes the Morgan Generation Assets and the Morgan and Morecambe Offshore Wind Farms: Transmission Assets:

- Morgan and Morecambe Offshore Wind Farms: Transmission Assets
  - Increased SSC and sediment deposition is likely to result from site preparation activities in advance of installation activities including sandwave and debris clearance, drilling for foundation installation and cable installation and burial activities
  - Levels are similar in magnitude to the Morgan Generation Assets and are unlikely to cause any significant cumulative impacts overall
  - Volume of sediment disturbed: sandwave clearance 10,447,489 m^3, foundation installation 72,320 m^3 and cable installation 3,015,000 m^3.

Scenario 2

3.11.4.4 Scenario 2 assesses the scenario 1 projects, plus the Morecambe Offshore Windfarm: Generation Assets:

- Morecambe Offshore Windfarm: Generation Assets
  - Increased SSC and sediment deposition is likely to result from site preparation activities in advance of installation activities including sandwave and debris clearance, drilling for foundation installation and cable installation and burial activities, with potential for sediment plume and deposition overlap during construction activities with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets
  - Volume of sediment disturbed: 1,238,700 m^3.

Scenario 3

3.11.4.5 Scenario 3 assesses the scenario 1 projects, and each of the projects and plans outlined in tiers 1 to 3 below; within scenario 3, the Morecambe Offshore Windfarm: Generation Assets is considered a tier 2 project.

Tier 1

Construction phase

Magnitude of impact

3.11.4.6 The projects and activities considered under the tier 1 assessment include the Morgan Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets, and other projects including:

- Awel y Môr Offshore Wind Farm (RWE, 2022)
  - Construction activities for Awel y Môr Offshore Wind Farm may result in increased suspended sediment concentration; however, these activities would be of limited spatial extent and frequency and are unlikely to interact with sediment plumes from the Morgan Generation Assets.
- Mona Offshore Wind Project (Mona Offshore Wind Ltd., 2024)
  - Increases in SSC and sediment deposition predicted to result from the Mona Offshore Wind Project are similar to those reported for the Morgan Generation Assets. This could potentially result in SSC increases of up to 1,000 mg/l during the sediment disposal immediately adjacent to the sediment release site, although this would be highly localised and would return to background levels within a couple of tidal cycles, with redistribution of deposited material within the existing tidal regime.

3.11.4.7 There is limited publicly available information to quantify any increases in suspended sediments and associated sediment deposition for the dredging projects listed in Table 3.32.

3.11.4.8 A summary assessment of the cumulative effects of increased SSCs and associated sediment deposition is given in Table 3.36.

Decommissioning phase

Magnitude of impact

3.11.4.9 The decommissioning phase of the Mona Offshore Wind Project has the potential to overlap temporally with the decommissioning of the Morgan Generation Assets. The expected magnitude of increased SSC and sediment deposition will be less than the construction phase, although if scour protection, cable protection and the suction caisson foundations were to be removed this would result in an increase in SSC.

3.11.4.10 A summary assessment of the cumulative effects of increased SSCs and associated sediment deposition is given in Table 3.36.

Tier 2

Construction phase

Magnitude of impact

3.11.4.11 The projects and activities considered under the tier 2 assessment include the Morgan Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets, and the Morecambe Offshore Windfarm: Generation Assets.

3.11.4.12 A summary assessment of the cumulative effects of increased SSCs and associated sediment deposition is given in Table 3.36.

Decommissioning phase

Magnitude of impact

3.11.4.13 The decommissioning phase of the Morecambe Offshore Windfarm: Generation Assets, could have the potential to overlap temporally with the decommissioning of the Morgan Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets and tier 1 projects. The expected magnitude of increased SSC and sediment deposition associated with the decommissioning of these projects are expected to be less than the construction phase. This represents a lower number of activities and reduced levels of seabed disturbance, and therefore this is not expected to significantly increase the cumulative impact.

3.11.4.14 A summary assessment of the cumulative effects of increased SSCs and associated sediment deposition is given in Table 3.36.

Tier 3

Construction phase

Magnitude of impact

3.11.4.15 The proposed construction of the MaresConnect Wales-Ireland Interconnector Cable and the Isle of Man Interconnector 2 project have a low potential to overlap with the construction phase of the Morgan Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets, tier 1 and tier projects, with the MaresConnect Interconnector Cable being 48.2 km from the Morgan Generation Assets, and the Isle of Man Interconnector 2 project being a currently unspecified distance from the Transmission Assets. However, the likely jet trenching activities for the laying and burying of the cables for both projects could run concurrently and interaction of SSC plumes on spring tide events may occur. The concentration of suspended sediment will reduce significantly moving further from the activity, with the distance between the projects causing the potential overlap of resultant plumes likely to be negligible.

3.11.4.16 A summary assessment of the cumulative effects of increased SSCs and associated sediment deposition is given in Table 3.36.

Table 3.36: Increased SSCs and associated sediment deposition.

	Scenario 1 Morgan Generation Assets + Transmission Assets	Scenario 2: Morgan Generation Assets + Morecambe Offshore Windfarm: Generation Assets + Transmission Assets	Scenario 3: Morgan Generation Assets + Transmission Assets + Tier 1, Tier 2, Tier 3 projects
Construction			
Magnitude of impact	The Morgan Generation Assets (displacement of up to 20,261,920 m^3 of total spoil volume for sandwave clearance and cable installation) could result in SSC increases of up to 1,000 mg/l during sediment disposal immediately adjacent to the sediment release site. The Transmission Assets anticipates a lower volume of disturbed sediment (13,534,809 m^3). The two projects combined are not expected to significantly increase the magnitude compared to the Morgan Generation Assets alone, with sediment plumes creating the highest turbidity immediately adjacent to the release site and returning to background levels within a few tidal cycles. Deposited sediments are expected to be incorporated into the natural hydrodynamic regime and redistributed over the course of a series of spring tides. The cumulative effect is predicted to be of local spatial extent, short term duration, intermittent and high reversibility. It is predicted that the impact will affect the receptor indirectly. The magnitude is therefore, considered to be **low.**	The Morecambe Offshore Wind Farm Generation Assets represents only a very small increase in the volume of disturbed sediments when compared to the Morgan Generation Assets and Transmission Assets (1,238,700 m^3) and is therefore expected to represent a change in the magnitude presented for Scenario 1. The magnitude is consistent with that presented in Scenario 1.	**Tier 1** Cumulative in SSC may occur for the Morgan Generation Assets, Transmission Assets, the proposed development of Awel y Môr Offshore Wind Farm, and Mona Offshore Wind Farm. Sediment plumes generated at Awel y Môr are expected to be of limited spatial extent and are therefore unlikely to interact with sediment plumes from the Morgan Generation Assets. Sediment plumes from the Mona Offshore Wind Project may interact with those generated by the Morgan Generation Assets, however high levels of SSC are expected to be limited to immediately adjacent to the release point for each project, rapid assimilation into natural tidal cycles. The magnitude is consistent with that presented in Scenario 1. **Tier 2** This scenario is identical to that presented in Scenario 2. The magnitude is consistent with that presented in Scenario 1. **Tier 3** Sediment plumes from the MaresConnect Wales-Ireland Interconnector Cable and

	Scenario 1 Morgan Generation Assets + Transmission Assets	Scenario 2: Morgan Generation Assets + Morecambe Offshore Windfarm: Generation Assets + Transmission Assets	Scenario 3: Morgan Generation Assets + Transmission Assets + Tier 1, Tier 2, Tier 3 projects
			Isle of Man Interconnector 2 project may interact with those generated by Morgan Generation Assets, Transmission Assets, tier 1 and tier 2 projects. It is expected, however, that the SSCs would reduce rapidly with increasing distance from the activity and therefore the potential overlap of resultant plumes would be negligible. The magnitude is consistent with that presented in Scenario 1.
Sensitivity of receptor	The sensitivity of fish and shellfish IEFs to this impact is described previously for the construction phase of the Morgan Generation Assets alone in paragraph 3.9.4.12 to paragraph 3.9.4.27. Most fish and shellfish ecology IEFs are deemed to be of low to medium vulnerability, high recoverability and local to national importance. The sensitivity of these IEFs is therefore considered to be **low**. Based on the sensitivity of herring eggs to the smothering effects of sediment deposition, herring are deemed to be of medium vulnerability, medium recoverability and of national importance, and therefore the sensitivity of this receptor is considered to be **medium**. Queen and king scallop are deemed to be of medium vulnerability, medium recoverability and of national importance; the sensitivity of these receptors is therefore considered **medium**.		
Significance of effect	For most fish and shellfish IEFs, the magnitude of the impact is deemed to be low and the sensitivity is considered to be low. The effect will therefore be of **minor adverse** significance, which is not significant in EIA terms. For king and queen scallop and herring, the magnitude of the impact is deemed to be low, and the sensitivity is considered to be medium. The effect will therefore be of **minor adverse** significance, which is not significant in EIA terms. For diadromous fish the magnitude of impact is deemed to be low and the sensitivity is low. This gives rise to an impact significance of negligible or minor adverse. Based upon diadromous fish typically inhabiting areas of high SSCs (estuarine environments) and the short-term, reversible nature of the impact, the effect is considered to be of **negligible** significance, which is not significant in EIA terms.		
Further mitigation and residual significance	Mitigation: None required Residual significance: Negligible to minor adverse		

	Scenario 1 Morgan Generation Assets + Transmission Assets	Scenario 2: Morgan Generation Assets + Morecambe Offshore Windfarm: Generation Assets + Transmission Assets	Scenario 3: Morgan Generation Assets + Transmission Assets + Tier 1, Tier 2, Tier 3 projects
Decommissioning			
Magnitude of impact	The decommissioning phases of the Morgan Generation Assets could have the potential to overlap temporally with the decommissioning of the Transmission Assets. The sediment disturbance volumes as a result of decommissioning for both projects are expected to be of lower magnitude than for the construction phase due to the absence of drilling and sandwave clearance. The cumulative effect is predicted to be of local spatial extent, short term duration, intermittent and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **low.**	The decommissioning phases of the Morecambe Offshore Windfarm: Generation Assets could have the potential to overlap temporally with the decommissioning of the Transmission Assets and Morgan Generation Assets. The sediment disturbance volumes as a result of decommissioning for both projects are expected to be of lower magnitude than for the construction phase due to the absence of drilling and sandwave clearance. The magnitude is consistent with that presented in Scenario 1.	**Tier 1** The decommissioning of Mona Offshore Wind Farm may overlap with the decommissioning of the Morgan Generation Assets and Transmission Assets. The sediment disturbance volumes as a result of decommissioning for both projects are expected to be of lower magnitude than for the construction phase due to the absence of drilling and sandwave clearance. The magnitude is consistent with that presented in Scenario 1. **Tier 2** This scenario is identical to that presented in Scenario 2. The magnitude is consistent with that presented in Scenario 1. **Tier 3** No tier 3 projects were identified with potential for cumulative effects with the decommissioning of the Morgan Generation Assets and Morgan and Morecambe Offshore Wind Farms: Transmission Assets.
Sensitivity of receptor	Receptor sensitivities are consistent with those presented for the construction phase.		
Significance of effect	Significance of effect for all receptors are consistent with those presented for the construction phase.		
Further mitigation and residual significance	Mitigation: None required Residual significance: Negligible to minor adverse		

3.11.5 Long term habitat loss

3.11.5.1 Long term subtidal habitat loss/habitat alteration within the Morgan Generation Assets will begin during the construction phase as infrastructure is gradually installed and will continue during the operations and maintenance phase when infrastructure is operational. Long term habitat loss will occur directly under all wind turbine and OSP foundation structures (the options of pin piled jacket and gravity base foundations for all structures). The installation of scour protection and cable protection (including at cable crossings), where this is required, will also lead to habitat alteration and a physical change to another seabed type under the scour/cable protection material. Magnitude has been considered for both phases combined as the structures will be placed during construction and remain throughout the operations and maintenance phase. The potential impact of long-term habitat loss persisting after the decommissioning phase has also been considered as the MDS assumes that scour and cable protection will be left *in situ* following decommissioning.

3.11.5.2 Three tier 1 projects (Awel y Môr Offshore Wind Farm, Mona Offshore Wind Farm and the Isle of Man Crogga Licence), four tier 2 projects (Morgan and Morecambe Offshore Wind Farms: Transmission Assets, Morecambe Offshore Wind Farm Generation Assets, ENI HyNet CCS project, and Mooir Vannin Offshore Windfarm) and two tier 3 projects (the MaresConnect Wales-Ireland Interconnector Cable and Isle of Man Interconnector 2 project) have been identified.

3.11.5.3 A summary of the cumulative effects of long-term habitat loss are given in Table 3.37.

Scenario 1

3.11.5.4 Scenario 1 includes the Morgan Generation Assets and the Morgan and Morecambe Offshore Wind Farms: Transmission Assets:

- Morgan and Morecambe Offshore Wind Farms: Transmission Assets (Morecambe Offshore Windfarm Ltd and Morgan Offshore Wind Ltd, 2023)
  - Up to 1.51 km^2 of long term habitat loss due to the presence of foundations, scour protection and cable protection remaining for an operation and maintenance phase of 35 years.

Scenario 2

3.11.5.5 Scenario 2 assesses the scenario 1 projects, plus the Morecambe Offshore Windfarm: Generation Assets:

- Morecambe Offshore Windfarm: Generation Assets (Morecambe Offshore Windfarm Ltd, 2023)
  - Up to 0.5 km^2 of long term habitat loss associated with the presence of foundations, scour protection, cable protection, and cable crossing protection remaining in place throughout the operation and maintenance phase.

Scenario 3

3.11.5.6 Scenario 3 assesses the scenario 1 projects, and each of the projects and plans outlined in tiers 1 to 3 below; within scenario 3, the Morecambe Offshore Windfarm: Generation Assets is considered a tier 2 project.

Tier 1

Construction and operation and maintenance phases

Magnitude of impact

3.11.5.7 Awel y Môr Offshore Wind Farm and Mona Offshore Wind Project have been identified as having potential to result in a cumulative effect alongside the Morgan Generation Assets and Morgan and Morecambe Offshore Wind Farms: Transmission Assets. Compared to the extent of the fish and shellfish ecology study area, these projects represent a relatively small footprint of loss.

- Awel y Môr Offshore Wind Farm (RWE, 2022)
  - Up to 1.7 km^2 of long term habitat loss due to the presence of foundations, scour protection and cable protection remaining for an operation and maintenance phase of 25 years.
- Mona Offshore Wind Project (Mona Offshore Wind Ltd., 2024)
  - Up to 2.19 km^2 of long term habitat loss associated with the presence of foundations, scour protection, cable protection, and cable crossing protection remaining for an operation and maintenance phase of 35 years.
- Isle of Man Crogga Licence
  - No quantification regarding the impact of this activity has been published however based on the nature of the work it is likely that activities such as the installation of a well head and any discharged drill cuttings may result in long term habitat loss (Isle of Man Government, 2021).

3.11.5.8 A summary of the cumulative effects of long-term habitat loss are given in Table 3.37.

Decommissioning phase

Magnitude of impact

3.11.5.9 Awel y Môr Offshore Wind Farm and Mona Offshore Wind Project has been identified as having potential to result in a cumulative effect alongside the Morgan Generation Assets and Morgan and Morecambe Offshore Wind Farms: Transmission Assets. The footprint of permanent habitat loss post-decommissioning for these projects is slightly smaller than for the construction and operation and maintenance phases. Compared to the extent of the fish and shellfish ecology study area, these projects represent a relatively small footprint of loss.

- Awel y Môr Offshore Wind Farm (RWE, 2022)
  - Up to 1.7 km^2 of long term habitat loss due to the presence of foundations, scour protection and cable protection.
- Mona Offshore Wind Project (Mona Offshore Wind Ltd., 2024)
  - Up to 2.14 km^2 of permanent habitat loss associated with the presence of scour and cable protection remaining *in situ* post-decommissioning.

3.11.5.10 A summary of the cumulative effects of long-term habitat loss are given in Table 3.37.

Tier 2

Construction and operation and maintenance phases

Magnitude of impact

3.11.5.11 The projects and activities considered under the tier 2 assessment include the Morgan Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets, the Morecambe Offshore Windfarm: Generation Assets and the other projects and plans listed below. These projects have been identified as having potential to result in a cumulative effect alongside the Morgan Generation Assets and tier 1 projects. Compared to the extent of the fish and shellfish ecology study area, these projects represent a relatively small footprint of loss.

- Mooir Vannin Offshore Windfarm (Ørsted, 2023)
  - No quantifiable information is available within the Scoping Report with regards to the area of long term habitat loss predicted for this project, however habitat loss is expected to be associated with the presence of foundations, scour protection and cable protection, and to persist for the duration of the operation and maintenance phase.
- ENI HyNet CCS project (ENI, 2023)
  - No quantifiable information is publicly available with regards to the area of long term habitat loss predicted for this project, however habitat loss is expected to be associated with the presence of a platform, scour protection, and cable and pipeline protection, and to persist for the duration of the operation and maintenance phase.

3.11.5.12 A summary of the cumulative effects of long-term habitat loss are given in Table 3.37.

Decommissioning phase

Magnitude of impact

3.11.5.13 Morecambe Offshore Windfarm: Generation Assets, Mooir Vannin Offshore Windfarm and the ENI HyNet CCS project have been identified as having potential to result in a cumulative effect alongside the Morgan Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the tier 1 projects. The expected magnitude of long-term habitat loss will be similar to the construction phase, due to the leaving in place of scour protection, and cable protection. Permanent habitat loss will mostly therefore occur due to the presence of these structures. Compared to the extent of the fish and shellfish ecology study area, these projects represent a relatively small footprint of loss.

3.11.5.14 A summary of the cumulative effects of long-term habitat loss are given in Table 3.37.

Tier 3

Construction and operation and maintenance phases

Magnitude of impact

3.11.5.15 The proposed construction of the MaresConnect Wales-Ireland Interconnector Cable and Isle of Man Interconnector 2 projects will potentially overlap with the construction phase and operation and maintenance phases of the Morgan Generation Assets, leading to a potential cumulative impact. Specifically, the installation of electrical cables is likely to involve introduction of cable protection which will represent long term habitat loss. The exact specifications of the cable protection for both projects are not currently known, although the overlap and thus cumulative impact between these, Morgan Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets, tier 1 and 2 projects is expected to be minor to negligible, given the large distance between the projects.

3.11.5.16 A summary of the cumulative effects of long term habitat loss are given in Table 3.37.

Table 3.37: Long term habitat loss.

	Scenario 1 Morgan Generation Assets + Transmission Assets	Scenario 2: Morgan Generation Assets + Morecambe Offshore Windfarm: Generation Assets + Transmission Assets	Scenario 3: Morgan Generation Assets + Transmission Assets + Tier 1, Tier 2, Tier 3 projects
Construction and operation and maintenance			
Magnitude of impact	The installation of infrastructure for both of these projects would result in up to 2.82 km^2 of long term habitat loss through the presence of foundations, scour protection and cable protection. Due to the absence of any overlap with mapped or reported herring spawning grounds, and the highly limited extent of substrate suitable for herring spawning, along with the highly localised spatial extent of the impact, it is predicted that this impact will not affect the receptor and the magnitude is therefore considered to be **negligible**. For all other fish and shellfish IEFs, the impact is predicted to be of local spatial extent, long term duration, continuous and irreversible during the operations and maintenance phase. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **low**.	The installation of infrastructure for these three projects would result in up to 3.32 km2 of long term habitat loss through the presence of foundations, scour protection and cable protection. Magnitudes are consistent with those presented in Scenario 1.	**Tier 1** Cumulative effects of long term habitat loss may exist for the Morgan Generation Assets, Transmission Assets, Awel y Môr Offshore Wind Farm, Mona Offshore Wind Project and Isle of Man Crogga Licence, to represent a potential cumulative long term habitat loss of up to approximately 6.71 km^2 through the presence of foundations, scour protection and cable protection. Magnitudes are consistent with those presented in Scenario 1. **Tier 2** Cumulative effects of long term habitat loss may exist for the Morgan Generation Assets, Transmission Assets, tier 1 projects and the tier 2 Morecambe Offshore Windfarm: Generation Assets, Mooir Vannin Offshore Windfarm, and the ENI HyNet CCS project. There is no information available publicly to quantify the long term habitat loss associated with Mooir Vannin and ENI HyNet CCS, but the Morecambe Offshore Windfarm: Generation Assets will increase the area of long term habitat loss by just 0.5 km2. The ENI HyNet CCS project is expected to represent a small total footprint of habitat loss, and Mooir Vannin is expected to be of a similar scale to Morgan Generation Assets. Collectively the footprint of long term habitat

	Scenario 1 **Morgan Generation Assets** **+ Transmission Assets**	**Scenario 2:** **Morgan Generation Assets** **+ Morecambe Offshore Windfarm: Generation Assets** **+ Transmission Assets**	**Scenario 3:** **Morgan Generation Assets + Transmission Assets** **+ Tier 1, Tier 2, Tier 3 projects**
			loss associated with these projects is considered relatively small in the context of the fish and shellfish ecology study area. Magnitudes are consistent with those presented in Scenario 1. **Tier 3** Cumulative effects of long term habitat loss may exist for the Morgan Generation Assets, tier 1 and 2 projects and the proposed construction of the MaresConnect Wales-Ireland Interconnector Cable and Isle of Man Interconnector 2 projects. No information is available publicly to quantify the footprint of long term habitat loss associated with these tier 3 projects, however due to the nature of cable installation, the area of loss is expected to be relatively small. Magnitudes are consistent with those presented in Scenario 1.
Sensitivity of receptor	The sensitivity of fish and shellfish IEFs to this impact is described previously for the construction phase of the Morgan Generation Assets alone in paragraph 3.9.5.9 to paragraph 3.9.5.24. Most fish and shellfish ecology IEFs in the fish and shellfish ecology study area are deemed to be of low vulnerability, high recoverability and local-national value. The sensitivity of the receptor is therefore, considered to be **low.** King and queen scallop in the fish and shellfish ecology study area are deemed to be of medium vulnerability, high recoverability and regional value. The sensitivity of the receptor is therefore, considered to be **low.** European lobster and *Nephrops* are deemed to be of high vulnerability, medium to high recoverability and regional value. The sensitivity of the receptor is therefore, considered to be **medium.** Sandeel are deemed to be of high vulnerability, high recoverability and regional value. The sensitivity of the receptor is therefore, considered to be **medium.** Herring are deemed to be of high vulnerability, medium recoverability and of national importance; the sensitivity of herring is therefore considered **medium**.		

	Scenario 1 **Morgan Generation Assets** **+ Transmission Assets**	**Scenario 2:** **Morgan Generation Assets** **+ Morecambe Offshore Windfarm: Generation Assets** **+ Transmission Assets**	**Scenario 3:** **Morgan Generation Assets + Transmission Assets** **+ Tier 1, Tier 2, Tier 3 projects**
	Diadromous fish are deemed to be of low vulnerability, high recoverability and national to international value. The sensitivity of the receptor is therefore, considered to be **low.**		
Significance of effect	For most fish and shellfish ecology species IEFs in the fish and shellfish ecology study area, the magnitude of the cumulative impact is deemed to be low and the sensitivity of the receptor is considered to be low. The cumulative effect will therefore be of **minor adverse** significance, which is not significant in EIA terms. For king and queen scallop, the magnitude of the cumulative impact is deemed to be low and the sensitivity of the receptor is considered to be low. The cumulative effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms. For European lobster and *Nephrops*, the magnitude of the cumulative impact is deemed to be low and the sensitivity of the receptor is considered to be medium. The cumulative effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms. For sandeel, the magnitude of the cumulative impact is deemed to be low and the sensitivity of the receptor is considered to be medium. The cumulative effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms. For herring, the magnitude of the cumulative impact is deemed to be negligible and the sensitivity of the receptor is considered to be medium. The cumulative effect will, therefore, be of **negligible** significance, which is not significant in EIA terms. For diadromous fish species, the magnitude of the cumulative impact is deemed to be low and the sensitivity of the receptor is considered to be low. The cumulative effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.		
Further mitigation and residual significance	Mitigation: None required Residual significance: Negligible to minor adverse		
Decommissioning			
Magnitude of impact	The footprint of permanent habitat loss post-decommissioning is expected to be slightly smaller than (but very similar to) the construction and operation and maintenance phases, due to the removal of foundations, but the expectation that scour and cable protection will remain *in situ*. Magnitudes are therefore consistent with those presented in the construction phase.		
Sensitivity of receptor	Please refer to the construction and operation and maintenance phase.		
Significance of effect	Please refer to the construction and operation and maintenance phase.		
Further mitigation and residual significance	Mitigation: None required Residual significance: Negligible to minor adverse		

3.11.6 EMFs from subsea electrical cabling

3.11.6.1 The operation of the subsea cabling laid and buried as part of the Morgan Generation Assets will produce electromagnetic fields, with potential impacts on fish and shellfish receptors within the Morgan Array Area. This could have impacts cumulatively with the operation and maintenance phases of the tier 1 Awel y Môr Offshore Wind Farm and Mona Offshore Wind Farm, the tier 2 Morecambe Offshore Windfarm: Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets, and the Mooir Vannin Offshore Windfarm and the tier 3 MaresConnect Wales-Ireland Interconnector Cable and Isle of Man Interconnector 2 projects. A summary of the cumulative effects of EMFs from subsea electrical cabling is given in Table 3.38.

Scenario 1

3.11.6.2 Scenario 1 includes the Morgan Generation Assets and the Morgan and Morecambe Offshore Wind Farms: Transmission Assets:

- Morgan and Morecambe Offshore Wind Farms: Transmission Assets (Morecambe Offshore Windfarm Ltd and Morgan Offshore Wind Ltd, 2023)
  - Cables: Up to 60 km of 275 kV HVAC interconnector cables and 610 km of 220 kV or 275 kV HVAC export cables
  - The minimum burial depth for cables is planned to be 0.5 m, likely limiting EMFs to the range of metres from the cable.

Scenario 2

3.11.6.3 Scenario 2 assesses the scenario 1 projects, plus the Morecambe Offshore Windfarm: Generation Assets:

- Morecambe Offshore Windfarm: Generation Assets (Morecambe Offshore Windfarm Ltd, 2023)
  - Cables: 110 km of inter-array cables and 10 km of platform link cables, 132 kV AC transmission
  - The minimum burial depth for cables is planned to be 0.5 m, with a target of 1.5 m burial depth, likely limiting EMFs to the range of metres from the cable.

Scenario 3

3.11.6.4 Scenario 3 assesses the scenario 1 projects, and each of the projects and plans outlined in tiers 1 to 3 below; within scenario 3, the Morecambe Offshore Windfarm: Generation Assets is considered a tier 2 project.

Tier 1

Operations and maintenance phase

Magnitude of impact

3.11.6.5 The maximum EMF impacts associated with the tier 1 Awel y Môr Offshore Wind Farm and Mona Offshore Wind Project will originate from the projects' inter-array, interconnector and offshore export cables, which have the potential for creating a cumulative impact with the inter-array and interconnector cables of the Morgan

Generation Assets and the cables associated with the Morgan and Morecambe Offshore Wind Farms: Transmission Assets.

- Awel y Môr Offshore Wind Farm (RWE, 2022)
  - Cables: 145 km of inter-array cables and 81.3 km of export cables
  - The minimum burial depth for cables is planned to be 1 m, likely limiting EMFs to the range of up to 10 m from the cable
- Mona Offshore Wind Project (Mona Offshore Wind Ltd., 2024)
  - Cables: Up to 500 km of 66 kV to 132 kV inter-array cables, 50 km of 275 kV HVAC interconnector cable, and up to 360 km of 275 kV HVAC offshore export cables
  - The minimum burial depth for cables will be 0.5 m, likely limiting EMFs to the range of metres from the cable.

3.11.6.6 A summary of the cumulative effects of EMFs from subsea electrical cabling is given in Table 3.38.

Tier 2

Operations and maintenance phase

Magnitude of impact

3.11.6.7 Potential EMF impacts associated with the tier 2 projects within the cumulative fish and shellfish ecology study area will originate from the inter-array, interconnector, and offshore export cables of the Morecambe Offshore Windfarm: Generation Assets and Moor Vannin Offshore Windfarm. These projects have the potential to generate a cumulative effect alongside the Morgan Generation Assets, the Morgan and Morecambe Offshore Wind Farms: Transmission Assets and tier 1 projects.

- Mooir Vannin Offshore Windfarm (Ørsted, 2023)
  - No quantifiable information is publicly available with regards to the quantity or minimum burial depth of the inter-array and export cables associated with Mooir Vannin
  - Quantities are expected to be similar in scale those associated with Morgan Generation Assets, with the potential for effects up to a range of metres from the cables. Minimal, if any, overlap is predicted with the Morgan Generation Assets and other projects included within the CEA, assuming that cables will be subject to burial or protection of an appropriate thickness.

3.11.6.8 A summary assessment of the cumulative effects of EMFs from subsea electrical cabling is given in Table 3.38.

Tier 3

Operations and maintenance phase

Magnitude of impact

3.11.6.9 The proposed construction of the Isle of Man Interconnector 2 project and operation of the MaresConnect Wales-Ireland Interconnector Cable and will temporally overlap with the construction, and operations and maintenance phase of the Morgan Generation Assets and the Morgan and Morecambe Offshore Wind Farms: Transmission Assets, resulting in a potential cumulative impact. Specifically, both projects are expected to continuously produce EMFs during operation, although exact specifications are not currently publicly available for either project. However, the overall potential cumulative impact is expected to be small and limited to directly around the cables, with very little to no overlap between either project and the Morgan Generation Assets and Morgan and Morecambe Offshore Wind Farms: Transmission Assets.

3.11.6.10 A summary of the cumulative effects of EMFs from subsea electrical cabling is given in Table 3.38.

Table 3.38: EMFs from subsea electrical cabling.

	Scenario 1 **Morgan Generation Assets** **+ Transmission Assets**	**Scenario 2:** **Morgan Generation Assets** **+ Morecambe Offshore Windfarm: Generation Assets** **+ Transmission Assets**	**Scenario 3:** **Morgan Generation Assets + Transmission Assets** **+ Tier 1, Tier 2, Tier 3 projects**
Operations and maintenance			
Magnitude of impact	Effects of EMFs are expected to be limited to a range of just metres from the cables associated with both Morgan Generation Assets and the Transmission Assets. The cumulative effect is predicted to be of local spatial extent, long term duration, continuous and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **low.**	Effects of EMFs are expected to be limited to a range of just metres from the cables associated with Morgan Generation Assets, Morecambe Offshore Windfarm: Generation Assets and the Transmission Assets. The magnitude is consistent with that presented in Scenario 1.	**Tier 1** Effects of EMFs are expected to be limited to a range of just metres from the cables associated with Morgan Generation Assets, Awel y Môr and Mona Offshore Wind Project, representing only a small footprint in the scale of the fish and shellfish ecology study area. The magnitude is consistent with that presented in Scenario 1. **Tier 2** Effects of EMFs are expected to be limited to a range of just metres from the cables associated with Morgan Generation Assets, tier 1 projects, Transmission Assets, Morecambe Offshore Windfarm: Generation Assets and Mooir Vannin Offshore Windfarm, representing only a small footprint in the scale of the fish and shellfish ecology study area, with little potential for overlapping ranges. The magnitude is consistent with that presented in Scenario 1. **Tier 3** Cumulative effects from EMFs from subsea electrical cabling may exist for the Morgan Generation Assets, and the MaresConnect Wales-Ireland Interconnector Cable and the Isle of Man Interconnector 2 projects, though

	Scenario 1 Morgan Generation Assets + Transmission Assets	Scenario 2: Morgan Generation Assets + Morecambe Offshore Windfarm: Generation Assets + Transmission Assets	Scenario 3: Morgan Generation Assets + Transmission Assets + Tier 1, Tier 2, Tier 3 projects
			specifications are not currently publicly available. The magnitude is consistent with that presented in Scenario 1.
Sensitivity of receptor	For most fish and shellfish ecology IEFs in the fish and shellfish ecology study area are deemed to be of low vulnerability, high recoverability and local-national value. The sensitivity of the receptor is therefore, considered to be **low.** Decapod crustaceans and elasmobranchs are deemed to be of medium vulnerability, high recoverability and local to national value. The sensitivity of the receptor is therefore, considered to be **low.** Diadromous fish in the fish and shellfish ecology study area are deemed to be of low vulnerability, high recoverability and national-international value. The sensitivity of the receptor is therefore, considered to be **low.**		
Significance of effect	For most marine fish and shellfish ecology IEFs, the magnitude of the cumulative impact is deemed to be low and the sensitivity of the receptor is considered to be low. The cumulative effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms. For decapod crustaceans and elasmobranchs, the magnitude of the cumulative impact is deemed to be low and the sensitivity of the receptor is considered to be medium. The cumulative effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms. For diadromous fish, the magnitude of the cumulative impact is deemed to be low and the sensitivity of the receptor is considered to be medium. The cumulative effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.		
Further mitigation and residual significance	Mitigation: None required Residual significance: Minor adverse		

3.11.7 Introduction and colonisation of hard structures

3.11.7.1 The introduction of hard structures into areas of predominantly soft sediments has the potential to alter community composition and biodiversity within the cumulative fish and shellfish ecology study area. Colonisation of hard substrates will occur over time, beginning in the construction phase and continuing through the operations and maintenance and decommissioning phases, with this impact assessed alone for the Morgan Generation Assets in section 3.9.7. Cumulative impacts may occur through the introduction of other projects within the cumulative fish and shellfish ecology study area. Specifically, the tier 1 Awel y Môr Offshore Wind Farm, Mona Offshore Wind Project and Isle of Man Crogga Licence, the tier 2 ENI HyNet CCS project, Morecambe Offshore Windfarm: Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets and Mooir Vannin Offshore Windfarm, and the tier 3 MaresConnect Wales-Ireland Interconnector Cable and Isle of Man Interconnector 2 projects represent areas of introduced hard structures, in terms of foundations, scour protection, and cable protection. A summary assessment of the cumulative effects of introduction and colonisation of hard structures is given in Table 3.39.

Scenario 1

3.11.7.2 Scenario 1 includes the Morgan Generation Assets and the Morgan and Morecambe Offshore Wind Farms: Transmission Assets:

- Morgan and Morecambe Offshore Wind Farms: Transmission Assets (Morecambe Offshore Windfarm Ltd and Morgan Offshore Wind Ltd, 2023)
  - Up to 1.51 km^2 of habitat creation due to the presence of foundations, scour protection and cable protection.

Scenario 2

3.11.7.3 Scenario 2 assesses the scenario 1 projects, plus the Morecambe Offshore Windfarm: Generation Assets:

- Morecambe Offshore Windfarm Generation Assets (Morecambe Offshore Windfarm Ltd, 2023)
  - Up to 0.5 km^2 of introduced habitat associated with the presence of foundations, scour protection, cable protection, and cable crossing protection.

Scenario 3

3.11.7.4 Scenario 3 assesses the scenario 1 projects, and each of the projects and plans outlined in tiers 1 to 3 below; within scenario 3, the Morecambe Offshore Windfarm: Generation Assets is considered a tier 2 project.

Tier 1

Construction and operation and maintenance phases

Magnitude of impact

3.11.7.5 Awel y Môr Offshore Wind Farm, Mona Offshore Wind Project and the Isle of Man Crogga Licence have been identified as having potential to result in a cumulative effect alongside the Morgan Generation Assets and Morgan and Morecambe Offshore Wind

Farms: Transmission Assets. Compared to the extent of the fish and shellfish ecology study area, these projects represent a relatively small footprint of habitat creation.

- Awel y Môr Offshore Wind Farm (RWE, 2022)
  - Up to 1.7 km^2 of habitat creation due to the presence of foundations, scour protection and cable protection remaining for an operation and maintenance phase of 25 years
- Mona Offshore Wind Project (Mona Offshore Wind Ltd., 2024)
  - Up to 2.69 km^2 of habitat creation associated with the presence of foundations, scour protection, cable protection, and cable crossing protection
- Isle of Man Crogga Licence
  - No quantification regarding the impact of this activity has been published however based on the nature of the work it is considered that activities such as the installation of a well head and any other subsea infrastructure will result in increased availability of hard substrata for colonisation (Isle of Man Government, 2021).

3.11.7.6 A summary assessment of the cumulative effects of introduction and colonisation of hard structures is given in Table 3.39.

Tier 2

Construction and operations and maintenance phases

Magnitude of impact

3.11.7.7 The Morecambe Offshore Windfarm: Generation Assets, Mooir Vannin Offshore Windfarm and ENI HyNet CCS project will increase the introduced hard structure area available for colonisation, with potential cumulative impacts on the fish and shellfish ecology IEFs within the cumulative fish and shellfish ecology study area alongside Morgan Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the tier 1 projects.

- Mooir Vannin Offshore Windfarm (Ørsted, 2023)
  - No quantifiable information is available within the Scoping Report with regards to the area of habitat creation predicted for this project, however it is expected to be associated with the presence of foundations, scour protection and cable protection
- ENI HyNet CCS project (ENI, 2023)
  - No quantifiable information is publicly available with regards to the area of introduced habitat predicted for this project, however habitat creation is expected to be associated with the presence of a platform, scour protection, and cable and pipeline protection.

3.11.7.8 A summary assessment of the cumulative effects of introduction and colonisation of hard structures is given in Table 3.39.

Tier 3

Construction and operations and maintenance phases

Magnitude of impact

3.11.7.9 The proposed construction of the MaresConnect Wales-Ireland Interconnector Cable and Isle of Man Interconnector 2 projects will likely overlap with the construction phase of the Morgan Generation Assets, leading to a potential cumulative impact alongside the Morgan and Morecambe Offshore Wind Farms: Transmission Assets, tier 1 and tier 2 projects. Specifically, the installation of electrical cables is likely to include introduction of cable protection which will act as potential sites for colonisation by hard substrate communities. Although no exact specifications are publicly available for the areas for potential colonisation, it is expected that the cable protection will only represent a small increase of introduced hard structures proportional to the entire cumulative fish and shellfish ecology study area, and so will have only a minor cumulative impact.

3.11.7.10 A summary assessment of the cumulative effects of introduction and colonisation of hard structures is given in Table 3.39.

Table 3.39: Colonisation of hard structures.

	Scenario 1 **Morgan Generation Assets** **+ Transmission Assets**	**Scenario 2:** **Morgan Generation Assets** **+ Morecambe Offshore Windfarm: Generation Assets** **+ Transmission Assets**	**Scenario 3:** **Morgan Generation Assets + Transmission Assets** **+ Tier 1, Tier 2, Tier 3 projects**
Construction and operation and maintenance			
Magnitude of impact	Morgan Generation Assets and the Transmission Assets represent the introduction of 3.2 km^2 of habitat available for colonisation, in the form of foundations, scour protection and cable protection. This area is small in the context of the cumulative fish and shellfish ecology study area. The cumulative effect for all fish and shellfish IEFs is predicted to be of regional spatial extent, long term duration, continuous and of low reversibility or irreversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **low.**	Morgan Generation Assets, Morecambe Offshore Windfarm: Generation Assets and the Transmission Assets represent the introduction of 3.7 km^2 of habitat available for colonisation, in the form of foundations, scour protection and cable protection. This area is small in the context of the cumulative fish and shellfish ecology study area and represents only a minor increase on Scenario 1. The magnitude is consistent with that presented in Scenario 1.	**Tier 1** Cumulative effects from colonisation of hard structures may exist for the Morgan Generation Assets, Transmission Assets, Awel y Môr, Mona Offshore Wind Project and the Isle of Man Crogga Licence, representing a total MDS of 6.18 km^2. Whilst this does represent an increase in area from the alone assessment for Morgan Generation Assets, this area is still considered just a small proportion of the seabed available within the cumulative fish and shellfish ecology study area. The magnitude is consistent with that presented in Scenario 1. **Tier 2** Cumulative effects from the introduction and colonisation of hard structures may exist for the Morgan Generation Assets, tier 1 projects, Morecambe Offshore Windfarm: Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets, Mooir Vannin Offshore Windfarm and the ENI HyNet CCS project. Except Mooir Vannin and ENI HyNet CCS (due to the absence of available quantitative data), the predicted cumulative area of introduced habitat will be 6.68 km^2, representing on a small increase when compared with tier 1.

	Scenario 1 Morgan Generation Assets + Transmission Assets	Scenario 2: Morgan Generation Assets + Morecambe Offshore Windfarm: Generation Assets + Transmission Assets	Scenario 3: Morgan Generation Assets + Transmission Assets + Tier 1, Tier 2, Tier 3 projects
			The magnitude is consistent with that presented in Scenario 1. **Tier 3** Cumulative effects from colonisation of hard structures may exist for the Morgan Generation Assets, tiers 1 and 2 projects and the proposed construction of the MaresConnect Wales-Ireland Interconnector Cable and Isle of Man Interconnector 2 projects, although no specifications are publicly available for the areas for potential colonisation. The area is however expected to be relatively small for this project. The magnitude is consistent with that presented in Scenario 1.
Sensitivity of receptor	Marine fish and shellfish IEFs are deemed to be of low vulnerability and local to national value and of high recoverability. The sensitivity of the receptor is therefore considered to be **low.** Most diadromous fish in the fish and shellfish ecology study area are deemed to be of low vulnerability, high recoverability and national-international value. The sensitivity of the receptor is therefore considered to be **low.** Sea trout are deemed to be of medium vulnerability, high recoverability, and national value. The sensitivity of the receptor is therefore considered to be **low.**		
Significance of effect	Overall, for all fish and shellfish IEFs the magnitude of the cumulative impact is deemed to be low and the sensitivity of the receptor is considered to be low. This gives rise to an impact significance of negligible or minor adverse. Applying a precautionary approach given the long term nature of this impact, the cumulative effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.		
Further mitigation and residual significance	Mitigation: None required Residual significance: Minor adverse		

3.11.8 Injury due to increased risk of collision with vessels (basking shark only)

3.11.8.1 Increased levels of vessel activity related to the construction, operations and maintenance, and decommissioning phases of the Morgan Generation Assets will likely represent an increased risk of collision with basking shark, with this impact assessed alone in section 3.9.8. This could have cumulative impacts with the vessels involved in activities associated with the tier 1 Awel y Môr Offshore Wind Farm and Mona Offshore Wind project, tier 2 Morecambe Offshore Windfarm: Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets, Mooir Vannin Offshore Windfarm and the ENI HyNet CCS project, and the tier 3 MaresConnect Wales-Ireland Interconnector Cable and Isle of Man Interconnector 2 projects, which will involve increased vessel activity in every phase over their proposed lifetimes.

Scenario 1

3.11.8.2 Scenario 1 includes the Morgan Generation Assets and the Morgan and Morecambe Offshore Wind Farms: Transmission Assets:

- Morgan and Morecambe Offshore Wind Farms: Transmission Assets (Morecambe Offshore Windfarm Ltd and Morgan Offshore Wind Ltd, 2023)
  - Construction: Up to 740 vessel return trips, and up to 70 construction vessels on site at any one time
  - Operation and maintenance: Up to 1,155 vessel return trips per year and up to 19 vessels on site at any one time
  - Decommissioning: Similar numbers of vessel trips and vessels on site are predicted as for the construction phase.

Scenario 2

3.11.8.3 Scenario 2 assesses the scenario 1 projects, plus the Morecambe Offshore Windfarm: Generation Assets:

- Morecambe Offshore Windfarm: Generation Assets (Morecambe Offshore Windfarm Ltd, 2023)
  - Construction: Up to 30 construction vessels on site at any one time
  - Operation and maintenance and decommissioning: Not assessed but assumed to be lower than or similar to that described for construction.

Scenario 3

3.11.8.4 Scenario 3 assesses the scenario 1 projects, and each of the projects and plans outlined in tiers 1 to 3 below; within scenario 3, the Morecambe Offshore Windfarm: Generation Assets is considered a tier 2 project.

Tier 1

All phases

Magnitude of impact

3.11.8.5 The construction and operation and maintenance phases of the Awel y Môr Offshore Wind Farm, and all phases of the Mona Offshore Wind Project are expected to overlap temporally with the Morgan Generation Assets and Morgan and Morecambe Offshore Wind Farms: Transmission Assets, potentially resulting in a cumulative impact.

- Awel y Môr Offshore Wind Farm (RWE, 2022)
  - Construction, operation and maintenance and decommissioning: Increased vessel numbers in the area, but area already supports heavy vessel traffic, therefore the increased vessel numbers are not considered significant
- Mona Offshore Wind Project (Mona Offshore Wind Ltd., 2024)
  - Construction: Up to 2,055 vessel return trips, and up to 86 construction vessels on site at any one time
  - Operation and maintenance: Up to 849 vessel return trips per year and up to 21 vessels on site at any one time
  - Decommissioning: Similar numbers of vessel trips and vessels on site are predicted as for the construction phase.

3.11.8.6 Limited information is available publicly regarding potential vessel activities associated with the relevant dredging projects to this assessment, listed in Table 3.32, therefore these have not been considered quantitatively, however it is acknowledged that these may give rise to a cumulative effect. Due to the scale of these projects, however, compares with the offshore wind projects listed above, the number of additive vessels is expected to be comparatively low, and therefore any cumulative effect would be limited.

3.11.8.7 A summary assessment of the cumulative effects of injury due to increased risk of collision with vessels (for basking shark) is given in Table 3.40.

Tier 2

All phases

Magnitude of impact

3.11.8.8 The Morecambe Offshore Windfarm: Generation Assets, Mooir Vannin Offshore Windfarm and ENI HyNet CCS project will lead to an increase in the level of vessel activity within the cumulative fish and shellfish ecology study area, with potential to lead to cumulative effects alongside Morgan Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets and the tier 1 projects.

3.11.8.9 Limited information is available publicly regarding the Mooir Vannin Offshore Windfarm and ENI HyNet CCS project, therefore quantitative assessment is not possible.

3.11.8.10 Mooir Vannin is expected to be of a similar scale to the Morgan Generation Assets, and therefore a similar level of vessel activity is anticipated, although this project’s construction and operation and maintenance phases are likely to overlap with the Morgan Generation Assets and Morgan and Morecambe Offshore Wind Farms: Transmission Assets operation and maintenance and decommissioning phases, therefore the highest levels of vessel activity (associated with the construction phase) will not occur concurrently.

3.11.8.11 The ENI HyNet CCS project is of a much smaller scale than the Morgan Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets or other large tier 1 and 2 projects, and therefore is expected to represent lower levels of vessel activity, and to provide only a very minor contribution to any cumulative effect.

3.11.8.12 A summary assessment of the cumulative effects of injury due to increased risk of collision with vessels (for basking shark) is given in Table 3.40.

Tier 3

All phases

Magnitude of impact

3.11.8.13 The number of vessels undertaking construction or maintenance activities on the MaresConnect Wales-Ireland Interconnector Cable and the Isle of Man Interconnector 2 projects will overlap temporally with the Morgan Generation Assets, Morgan and Morecambe Offshore Wind Farms: Transmission Assets and tier 1 and 2 projects and may cause a cumulative impact. Specifically, these projects will increase construction vessel numbers, although the total number at any one time is not currently publicly available for either project (vessels involved in maintenance of this project are expected to be minimal). This will represent an increased risk of collision with basking shark but compared to the overall area available for basking shark, the potential spatial area of impact is low and therefore the risk of collision will similarly be low.

3.11.8.14 A summary assessment of the cumulative effects of injury due to increased risk of collision with vessels (for basking shark) is given in Table 3.40.

Table 3.40: Injury due to increased risk of collision with vessels (basking shark).

	Scenario 1 Morgan Generation Assets + Transmission Assets	Scenario 2: Morgan Generation Assets + Morecambe Offshore Windfarm: Generation Assets + Transmission Assets	Scenario 3: Morgan Generation Assets + Transmission Assets + Tier 1, Tier 2, Tier 3 projects
All phases			
Magnitude of impact	Construction: Up to 2,618 vessel movements and 133 vessels on site at any one time for Morgan Generation Assets and the Transmission Assets, against a backdrop of existing heavy vessel traffic. Operation and maintenance: Up to 1,874 vessel movements and 35 vessels on site at any one time. Decommissioning: Vessel activity levels expected to be similar to the construction phase as described above. The cumulative effect is predicted to be of regional spatial extent, long term duration, intermittent and of high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **low.**	Morecambe Offshore Windfarm: Generation Assets represents up to an additional 30 vessels on site at any one time during the construction phase, with no information provided regarding the number of trips predicted, bringing the total vessels during construction for these projects to up to 163, within an area with existing heavy vessel traffic. For subsequent phases, the number of vessels for Morecambe Offshore Windfarm: Generation Assets is expected to be lower or similar to that for the construction phase. The magnitude is consistent with that presented in Scenario 1.	**Tier 1** For the Morgan Generation Assets, Transmission Assets and Mona Offshore Wind Project the total number of vessel movements predicted is 4,673, and the maximum number of vessels on site at one time is 219 during the construction phase. During the operation and maintenance phase the total cumulative number of vessel movements predicted is 2,723, and the cumulative maximum number of vessels on site at one time is 56. Vessel activity levels are expected to be similar to the construction phase as described above during decommissioning. No numbers are available to quantify the impact associated with Awel y Môr, however the project considered the risk of impact to be low, given the extent of baseline heavy vessel traffic in region. The same applies to the tier 1 dredge projects listed in Table 3.32, although any contribution to a cumulative impact by these is expected to be minor. The magnitude is consistent with that presented in Scenario 1. **Tier 2** Cumulative effects from injury due to increased risk of collision with vehicles may exist for basking shark from the Morgan Generation Assets, Transmission Assets, and

	Scenario 1 Morgan Generation Assets + Transmission Assets	Scenario 2: Morgan Generation Assets + Morecambe Offshore Windfarm: Generation Assets + Transmission Assets	Scenario 3: Morgan Generation Assets + Transmission Assets + Tier 1, Tier 2, Tier 3 projects
			Morecambe Offshore Wind Farm Generation Assets (up to 30 construction vessels at any one time), and Morgan and Morecambe Offshore Wind Farms: Transmission Assets (up to 70 construction vessels at any one time), and the ENI HyNet CCS project (vessel numbers not yet quantified). For the Morgan Generation Assets, Transmission Assets, Mona Offshore Wind Project, Morecambe Offshore Windfarm: Generation Assets the cumulative maximum number of vessels on site at one time is 249 during the construction phase, therefore representing only a small increase on tier 1. This increase of 30 vessels attributed to Morecambe Offshore Windfarm: Generation Assets is expected to be lower or similar in subsequent phases. Vessel activity levels for most projects are expected to be similar to the construction phase as described above during decommissioning. No numbers are available to quantify the impact associated with tier 1 Awel y Môr and dredge projects, Mooir Vannin or the ENI HyNet CCS project, however due to the existing baseline of generally heavy vessel traffic in region, the increase is not expected to lead to a significant effect. The magnitude is consistent with that presented in Scenario 1. **Tier 3** Cumulative effects from injury due to increased risk of collision with vessels may

	Scenario 1 Morgan Generation Assets + Transmission Assets	Scenario 2: Morgan Generation Assets + Morecambe Offshore Windfarm: Generation Assets + Transmission Assets	Scenario 3: Morgan Generation Assets + Transmission Assets + Tier 1, Tier 2, Tier 3 projects
			exist for basking shark from the Morgan Generation Assets, Transmission Assets, tier 1 and tier 2 projects with the proposed construction of the MaresConnect Wales-Ireland Interconnector Cable and the Isle of Man Interconnector 2 projects (vessel numbers not yet quantified). However vessel numbers for these tier 3 projects are expected to be lower than those predicted for the large-scale offshore wind projects outlined above, and therefore not contribute to a large increase in the magnitude. The magnitude is consistent with that presented in Scenario 1.
Sensitivity of receptor	The basking shark is deemed to be of low vulnerability, medium recoverability and international value. The sensitivity of the receptor is therefore, considered to be **medium.**		
Significance of effect	Overall, the magnitude of the cumulative impact is deemed to be low and the sensitivity of the receptor is considered to be medium. The cumulative effect will, therefore, be of **minor adverse** significance, which is not significant in EIA terms.		
Further mitigation and residual significance	Mitigation: None required Residual significance: Minor adverse		

3.12 Transboundary effects

3.12.1.1 A screening of transboundary impacts has been carried out and any potential for significant transboundary effects with regard to fish and shellfish ecology from the Morgan Generation Assets upon the interests of other states has been assessed as part of this Environmental Statement. The potential transboundary impacts (assessed within Volume 3, Annex 5.2: Transboundary impacts screening of the Environmental Statement) are summarised below.

3.12.1.2 As set out above, most impacts on fish and shellfish IEF receptors will be restricted to within the Morgan Array Area and the immediate surrounding areas. Exceptions to this are impacts from underwater sound, and the impacts of increased suspended sediment concentrations and associated sediment deposition, which have the potential to extend into IoM waters.

3.12.1.3 Underwater sound impacting fish and shellfish receptors have a magnitude deemed to be low to medium (medium during the herring spawning season), and the sensitivity of the receptors to this impact is considered to range from low to high. Potential effects of underwater sound on fish and shellfish receptors are not predicted to extend beyond UK and IoM waters, as the sound contours which reach Irish waters are below the defined underwater sound impact thresholds.

3.12.1.4 Increased SSCs and associated sediment deposition has a magnitude deemed to be low, and the sensitivity of the receptors is considered to be low to medium, with the significance therefore being negligible to minor adverse. However, the identified tidal excursion and physical processes modelling means that any increased SSC is likely to occur principally in the immediate lee of the infrastructure and diminish rapidly with increased distance to be indistinguishable from background levels at 10 km, before crossing any international boundaries, suggesting this impact is unlikely to have any significant transboundary effect.

3.12.1.5 Based on the above assessment, no significant transboundary effects on fish and shellfish IEFs are predicted because of the Morgan Generation Assets.

3.13 Inter-related effects

3.13.1.1 Inter-relationships are the potential impacts and associated effects of different aspects of the proposal on the same receptor. These are:

- Project lifetime effects: Assessment of the scope for effects that occur throughout more than one phase of the Morgan Generation Assets (construction, operations and maintenance, and decommissioning), to interact to potentially create a more significant effect on a receptor than if just assessed in isolation in these three phases (e.g. subsea sound effects from piling, operational wind turbines, vessels and decommissioning)
- Receptor led effects: Assessment of the scope for all effects to interact, spatially and temporally, to create inter-related effects on a receptor. As an example, all effects on fish and shellfish ecology, such as temporary habitat loss; underwater sound; increased SSCs and sediment deposition; long term habitat loss; EMF from subsea cabling; colonisation of hard structure, and disturbance or remobilisation of sediment-bound contaminants may interact to produce a different, or greater effect on this receptor than when the effects are considered in isolation. Receptor-led effects may be short term, temporary or transient effects, or incorporate longer term effects.

3.13.1.2 A description of the likely interactive effects arising from the Morgan Generation Assets on fish and shellfish ecology is provided in Volume 2, Chapter 15: Inter-related effects of the Environmental Statement.

3.14 Summary of impacts, mitigation measures and monitoring

3.14.1.1 Information on fish and shellfish ecology within the fish and shellfish ecology study area was collected through desktop review, with improved coverage of published literature ensured through stakeholder consultation, and incorporation of site-specific data opportunistically collected during site investigation surveys.

3.14.1.2 Table 3.41 presents a summary of the potential impacts, measures adopted as part of the project and residual effects in respect to fish and shellfish ecology. The impacts assessed include temporary habitat loss/disturbance, underwater sound impacting fish and shellfish receptors, increased SSCs and associated sediment deposition, long term habitat loss, EMFs from subsea electrical cabling, introduction and colonisation of hard structures, remobilisation of sediment bound contaminants and injury to basking shark due to increased risk of collision with vessels. Overall, it is concluded that, aside from underwater sound effects during construction, there will be no significant effects impacting fish and shellfish receptors. During construction, there is potential for the project alone to lead to potentially significant impacts to herring during the herring spawning season from underwater sound associated with piling (moderate adverse significance). It is proposed to manage and reduce the effect of this impact through establishment of an Underwater sound management strategy post-consent as tertiary mitigation (outline provided with the application, Document Reference J13. This strategy establishes a process of investigating options to manage underwater sound levels in consultation with the licensing authority and SNCBs and agreeing, prior to construction of those works which would lead to underwater sound impacts, which mitigation measures will be implemented to reduce impacts such that there will be no residual significant effect. The Underwater sound management strategy is secured as a condition of the deemed marine licence(s) within the Draft DCO (Document Reference C1). Therefore following implementation of this tertiary mitigation measure, there will be **no significant residual effects**.

3.14.1.3 Table 3.42 presents a summary of the potential cumulative impacts, mitigation measures and residual effects. The cumulative impacts assessed include temporary habitat loss/disturbance; underwater sound impacting fish and shellfish receptors; increased SSCs and associated sediment deposition; long term habitat loss; EMF from subsea electrical cabling; colonisation of hard structures, and injury due to increased risk of collision with vessels (basking shark only). Overall, it is concluded that there will be potentially significant cumulative effects from the Morgan Generation Assets alongside other projects and plans to herring and cod during their respective spawning seasons through the impact of underwater sound from piling (moderate adverse significance). Tertiary mitigation proposed for the project alone, based upon post-consent development of an Underwater sound management strategy (outline provided with the application, Document Reference J13), will also reduce any cumulative effect based upon reducing the magnitude of sound generated by the Morgan Generation Assets. The Underwater sound management strategy is secured as a condition of the deemed marine licence(s) within the Draft DCO (Document Reference C1). Contribution to any cumulative effect from underwater sound during piling (and other relevant activities) by the Morgan Generation Assets will therefore not be significant. The assessment of cumulative effects from other plans and projects is based upon the respective MDSs presented in the Environmental Statements for tier 1 projects or PEIR for tier 2 projects. The assessment does not consider any further mitigation or reduced/refined project design envelopes for other tier 1 and/or tier 2 projects that may be implemented post-consent. However, it is understood that if other projects are consented, it is reasonable to assume that they will each implement appropriate measures such that any significant effect is reduced to a non-significant level. Although this assessment cannot conclude based upon this assumption, a significant cumulative impact is considered unlikely for this reason. **No residual significant cumulative effects** are expected to occur.

- **No potential significant transboundary impacts** have been identified in regard to effects of the Morgan Generation Assets.

Table 3.41: Summary of potential environmental effects, mitigation and monitoring.

[a] C=construction, O=operations and maintenance, D=decommissioning

Description of effect	Phase[a]			Measures adopted as part of the project	Magnitude of impact	Sensitivity of the receptor	Significance of effect	Further mitigation	Residual effect	Proposed monitoring
	C	O	D							
Temporary habitat loss/disturbance	✓	✓	✓	Development of, and adherence to, an offshore Environmental Management Plan throughout all phases, and actions to reduce potential for introduction of INNS.	C: Negligible to low O: Negligible to low D: Negligible to low	C: Marine – Low to high Diadromous- Negligible O: Marine – Low to high Diadromous - Negligible D: Marine – Low to high Diadromous - Negligible	C: Marine - Minor adverse Diadromous - Negligible O: Marine – Minor adverse Diadromous - Negligible D: Marine – Minor adverse Diadromous - Negligible	Not required	C: Marine - Minor adverse Diadromous - Negligible O: Marine – Minor adverse Diadromous - Negligible D: Marine – Minor adverse Diadromous - Negligible	None proposed
Underwater sound impacting fish and shellfish receptors	✓	×	×	Implementation of piling soft-start and ramp-up measures. This measure will minimise the risk of injury to some fish species in the immediate vicinity of piling activities, allowing individuals to move away from the area before sound levels reach a level at which injury may occur.	C: Negligible to medium	C: Marine – Low to high Diadromous – Low to high	C: Marine – Minor to moderate adverse Diadromous- Minor adverse	Outline underwater sound management strategy (Document Reference J13)	C: Marine – Minor adverse Diadromous- Minor adverse	None proposed

Description of effect	Phase[a]			Measures adopted as part of the project	Magnitude of impact	Sensitivity of the receptor	Significance of effect	Further mitigation	Residual effect	Proposed monitoring
	C	O	D							
Increased suspended sediment concentrations (SSCs) and associated sediment deposition	✓	✓	✓	Development of, and adherence to, an offshore Environmental Management Plan.	C: Low O: Negligible D: Low	C: Marine – Low to medium Diadromous- Low O: Marine – Low to medium Diadromous - Low D: Marine – Low to medium Diadromous - Low	C: Marine – Minor adverse Diadromous - Negligible O: Marine – Negligible or minor adverse Diadromous - Negligible D: Marine – Minor adverse Diadromous - Negligible	Not required	C: Marine – Minor adverse Diadromous - Negligible O: Marine – Negligible or minor adverse Diadromous - Negligible D: Marine – Minor adverse Diadromous - Negligible	None proposed
Long term habitat loss	✓	✓	✓	Development of, and adherence to, an offshore Environmental Management Plan throughout all phases; actions to reduce potential for introduction of INNS, and development and adherence to a CSIP.	C: Negligible to low O: Negligible to low D: Negligible to low	C: Marine – Low to medium Diadromous - Low O: Marine – Low to medium Diadromous - Low D: Marine – Low to medium Diadromous - Low	C: Marine – Negligible to minor adverse Diadromous – Minor adverse O: Marine – Negligible to minor adverse Diadromous – Minor adverse D: Marine – Negligible to minor adverse Diadromous – Minor adverse	Not required	C: Marine – Negligible to minor adverse Diadromous – Minor adverse O: Marine – Negligible to minor adverse Diadromous – Minor adverse D: Marine – Negligible to minor adverse Diadromous – Minor adverse	None proposed

Description of effect	Phase[a]			Measures adopted as part of the project	Magnitude of impact	Sensitivity of the receptor	Significance of effect	Further mitigation	Residual effect	Proposed monitoring
	C	O	D							
Electromagnetic Fields (EMF) from subsea electrical cabling	×	✓	×	Development and adherence to a CSIP. All electrical cables will be buried to depths of at least 0.5m as informed by a Cable Burial Risk Assessment (CBRA). While burial of cables will not reduce the strength of EMF, it does increase the distance between cables and fish and shellfish receptors, thereby potentially reducing the effect on those receptors.	O: Low	O: Marine – Low Diadromous - Low	O: Marine – Minor adverse Diadromous – Minor adverse	Not required	O: Marine – Minor adverse Diadromous – Minor adverse	None proposed
Introduction and colonisation of hard structures	✓	✓	✓	Development of, and adherence to, an offshore Environmental Management Plan throughout all phases, and actions to reduce potential for introduction of INNS.	C: Low O: Low D: Low	C: Marine – Low Diadromous - Low O: Marine – Low Diadromous - Low D: Marine – Low Diadromous - Low	C: Marine –Minor adverse Diadromous – Minor adverse O: Marine – Minor adverse Diadromous – Minor adverse D: Marine – Minor adverse Diadromous – Minor adverse	Not required	C: Marine – Minor adverse Diadromous – Minor adverse O: Marine – Minor adverse Diadromous – Minor adverse D: Marine – Minor adverse Diadromous – Minor adverse	None proposed

Description of effect	Phase[a]			Measures adopted as part of the project	Magnitude of impact	Sensitivity of the receptor	Significance of effect	Further mitigation	Residual effect	Proposed monitoring
	C	O	D							
Remobilisation of sediment bound contaminants	✓	✓	✓	Development of, and adherence to, an offshore Environmental Management Plan.	C: Negligible to low O: Negligible to low D: Negligible	C: Marine – Low to medium Diadromous - Low O: Marine – Low to medium Diadromous – Low D: Marine – Low to medium Diadromous – Low	C: Marine – Negligible to minor adverse Diadromous – Minor adverse O: Marine – Negligible to minor adverse Diadromous – Minor adverse D: Marine – Negligible Diadromous – Negligible	Not required	C: Marine – Negligible to minor adverse Diadromous – Minor adverse O: Marine – Negligible to minor adverse Diadromous – Minor adverse D: Marine – Negligible Diadromous – Negligible	None proposed
Injury due to increased risk of collision with vessels	✓	✓	✓	An offshore Environmental Management Plan will be issued to all Project vessel operators, requiring them to: • Not deliberately approach basking shark • Keep vessel speed to a minimum; and • Avoid abrupt changes in course or speed should basking shark approach the vessel.	C: Low O: Low D: Low	C: Marine – Medium O: Marine – Medium D: Marine - Medium	C: Marine – Minor adverse O: Marine – Minor adverse D: Marine – Minor adverse	Not required	C: Marine – Minor adverse O: Marine – Minor adverse D: Marine – Minor adverse	None proposed

Description of effect	Phase[a]			Measures adopted as part of the project	Magnitude of impact	Sensitivity of the receptor	Significance of effect	Further mitigation	Residual effect	Proposed monitoring
	C	O	D							
				The offshore Environmental Management Plan will be adhered to at all times.						

Table 3.42: Summary of potential cumulative environmental effects, mitigation and monitoring.

[a] C=construction, O=operations and maintenance, D=decommissioning

Description of effect	Phase[a]			Measures adopted as part of the project	Magnitude of impact	Sensitivity of the receptor	Significance of effect	Further mitigation	Residual effect	Proposed monitoring
	C	O	D							
Scenario 1										
Temporary habitat loss/disturbance	✓	×	✓	Development of, and adherence to, an offshore Environmental Management Plan.	C: Negligible to low D: negligible to low	C: Marine – Low to high Diadromous- Negligible D: Marine – Low to high Diadromous - Negligible	C: Marine - Minor adverse Diadromous - Negligible D: Marine – Minor adverse Diadromous - Negligible	Not required	C: Marine - Minor adverse Diadromous - Negligible D: Marine – Minor adverse Diadromous - Negligible	None proposed
Underwater sound impacting fish and shellfish receptors	✓	×	×	Implementation of piling soft-start and ramp-up measures. This measure will minimise the risk of injury to fish species in the immediate vicinity of piling activities, allowing individuals to move away from the area before sound levels reach a level at which injury may occur.	C: Marine - Negligible to medium Diadromous - Low	C: Marine – Low to high Diadromous – Low to high	C: Marine – Minor to moderate adverse Diadromous- Minor adverse	Outline underwater sound management strategy (Document Reference J13)	C: Marine – Minor adverse Diadromous- Minor adverse	None proposed

Description of effect	Phase[a]			Measures adopted as part of the project	Magnitude of impact	Sensitivity of the receptor	Significance of effect	Further mitigation	Residual effect	Proposed monitoring
	C	O	D							
Increased suspended sediment concentrations (SSCs) and associated sediment deposition	✓	×	✓	Development of, and adherence to, an offshore Environmental Management Plan.	C: Low D: Low	C: Marine – Low to medium Diadromous - Low D: Marine – Low to medium Diadromous - Low	C: Marine – Minor adverse Diadromous - Negligible D: Marine – Minor adverse Diadromous - Negligible	Not required	C: Marine – Minor adverse Diadromous - Negligible D: Marine – Minor adverse Diadromous - Negligible	None proposed
Long term habitat loss	✓	✓	✓	Development of, and adherence to, an offshore Environmental Management Plan throughout all phases; actions to reduce potential for introduction of INNS, and development and adherence to a CSIP.	C: Negligible to low O: Negligible to low D: Negligible to low	C: Marine – Low to medium Diadromous - Low O: Marine – Low to medium Diadromous - Low D: Marine – Low to medium Diadromous - Low	C: Marine – Negligible to minor adverse Diadromous – Minor adverse O: Marine – Negligible to minor adverse Diadromous – Minor adverse D: Marine – Negligible to minor adverse Diadromous – Minor adverse	Not required	C: Marine – negligible to minor adverse Diadromous – Minor adverse O: Marine – Negligible to minor adverse Diadromous – Negligible to minor adverse D: Marine – Negligible to minor adverse Diadromous – Minor adverse	None proposed

Description of effect	Phase[a]			Measures adopted as part of the project	Magnitude of impact	Sensitivity of the receptor	Significance of effect	Further mitigation	Residual effect	Proposed monitoring
	C	O	D							
Electromagnetic Fields (EMF) from subsea electrical cabling	×	✓	×	Development and adherence to a CSIP. All electrical cables will be buried to depths of at least 0.5m as informed by a CBRA. While burial of cables will not reduce the strength of EMF, it does increase the distance between cables and fish and shellfish receptors, thereby potentially reducing the effect on those receptors.	O: Low	O: Marine – Low Diadromous - Low	O: Marine – Minor adverse Diadromous – Minor adverse	Not required	O: Marine – Minor adverse Diadromous – Minor adverse	None proposed
Introduction and colonisation of hard structures	✓	✓	×	Development of, and adherence to, an offshore Environmental Management Plan, and actions to reduce potential for introduction of INNS.	C: Low O: Low	C: Marine – Low Diadromous - Low O: Marine – Low Diadromous - Low	C: Marine – Minor adverse Diadromous – Minor adverse O: Marine – Minor adverse Diadromous – Minor adverse	Not required	C: Marine – Minor adverse Diadromous – Minor adverse O: Marine – Minor adverse Diadromous – Minor adverse	None proposed

Description of effect	Phase[a]			Measures adopted as part of the project	Magnitude of impact	Sensitivity of the receptor	Significance of effect	Further mitigation	Residual effect	Proposed monitoring
	C	O	D							
Injury due to increased risk of collision with vessels	✓	✓	✓	An offshore Environmental Management Plan will be issued to all Project vessel operators, requiring them to: • Not deliberately approach basking shark • Keep vessel speed to a minimum; and • Avoid abrupt changes in course or speed should basking shark approach the vessel. The offshore Environmental Management Plan will be adhered to at all times.	C: Low O: Low D: Low	C: Marine – Medium O: Marine – Medium D: Marine - Medium	C: Marine – Minor adverse O: Marine – Minor adverse D: Marine – Minor adverse	Not required	C: Marine – Minor adverse O: Marine – Minor adverse D: Marine – Minor adverse	None proposed
Scenario 2										
Temporary habitat loss/disturbance	✓	×	✓	Development of, and adherence to, an offshore Environmental Management Plan.	C: Negligible to low D: negligible to low	C: Marine – Low to high Diadromous- Negligible D: Marine – Low to high Diadromous - Negligible	C: Marine - Minor adverse Diadromous - Negligible D: Marine – Minor adverse Diadromous - Negligible	Not required	C: Marine - Minor adverse Diadromous - Negligible D: Marine – Minor adverse Diadromous - Negligible	None proposed

Description of effect	Phase[a]			Measures adopted as part of the project	Magnitude of impact	Sensitivity of the receptor	Significance of effect	Further mitigation	Residual effect	Proposed monitoring
	C	O	D							
Underwater sound impacting fish and shellfish receptors	✓	×	×	Implementation of piling soft-start and ramp-up measures. This measure will minimise the risk of injury to fish species in the immediate vicinity of piling activities, allowing individuals to move away from the area before sound levels reach a level at which injury may occur.	C: Marine - Negligible to medium Diadromous - Low	C: Marine – Low to high Diadromous – Low to high	C: Marine – Minor to moderate adverse Diadromous- Minor adverse	Outline underwater sound management strategy (Document Reference J13)	C: Marine – Minor adverse Diadromous- Minor adverse	None proposed
Increased suspended sediment concentrations (SSCs) and associated sediment deposition	✓	×	✓	Development of, and adherence to, an offshore Environmental Management Plan.	C: Low D: Low	C: Marine – Low to medium Diadromous - Low D: Marine – Low to medium Diadromous - Low	C: Marine – Minor adverse Diadromous - Negligible D: Marine – Minor adverse Diadromous - Negligible	Not required	C: Marine – Minor adverse Diadromous - Negligible D: Marine – Minor adverse Diadromous - Negligible	None proposed

Description of effect	Phase[a]			Measures adopted as part of the project	Magnitude of impact	Sensitivity of the receptor	Significance of effect	Further mitigation	Residual effect	Proposed monitoring
	C	O	D							
Long term habitat loss	✓	✓	✓	Development of, and adherence to, an offshore Environmental Management Plan throughout all phases; actions to reduce potential for introduction of INNS, and development and adherence to a CSIP.	C: Negligible to low O: Negligible to low D: Negligible to low	C: Marine – Low to medium Diadromous - Low O: Marine – Low to medium Diadromous - Low D: Marine – Low to medium Diadromous - Low	C: Marine – Negligible to minor adverse Diadromous – Minor adverse O: Marine – Negligible to minor adverse Diadromous – Minor adverse D: Marine – Negligible to minor adverse Diadromous – Minor adverse	Not required	C: Marine – negligible to minor adverse Diadromous – Minor adverse O: Marine – Negligible to minor adverse Diadromous – Negligible to minor adverse D: Marine – Negligible to minor adverse Diadromous – Minor adverse	None proposed
Electromagnetic Fields (EMF) from subsea electrical cabling	×	✓	×	Development and adherence to a CSIP. All electrical cables will be buried to depths of at least 0.5m as informed by a CBRA. While burial of cables will not reduce the strength of EMF, it does increase the distance between cables and fish and shellfish receptors, thereby potentially reducing the effect on those receptors.	O: Low	O: Marine – Low Diadromous - Low	O: Marine – Minor adverse Diadromous – Minor adverse	Not required	O: Marine – Minor adverse Diadromous – Minor adverse	None proposed

Description of effect	Phase[a]			Measures adopted as part of the project	Magnitude of impact	Sensitivity of the receptor	Significance of effect	Further mitigation	Residual effect	Proposed monitoring
	C	O	D							
Introduction and colonisation of hard structures	✓	✓	×	Development of, and adherence to, an offshore Environmental Management Plan, and actions to reduce potential for introduction of INNS.	C: Low O: Low	C: Marine – Low Diadromous - Low O: Marine – Low Diadromous - Low	C: Marine – Minor adverse Diadromous – Minor adverse O: Marine – Minor adverse Diadromous – Minor adverse	Not required	C: Marine – Minor adverse Diadromous – Minor adverse O: Marine – Minor adverse Diadromous – Minor adverse	None proposed
Injury due to increased risk of collision with vessels	✓	✓	✓	An offshore Environmental Management Plan will be issued to all Project vessel operators, requiring them to: • Not deliberately approach basking shark • Keep vessel speed to a minimum; and • Avoid abrupt changes in course or speed should basking shark approach the vessel. The offshore Environmental Management Plan will be adhered to at all times.	C: Low O: Low D: Low	C: Marine – Medium O: Marine – Medium D: Marine - Medium	C: Marine – Minor adverse O: Marine – Minor adverse D: Marine – Minor adverse	Not required	C: Marine – Minor adverse O: Marine – Minor adverse D: Marine – Minor adverse	None proposed
Scenario 3										

Description of effect	Phase[a]			Measures adopted as part of the project	Magnitude of impact	Sensitivity of the receptor	Significance of effect	Further mitigation	Residual effect	Proposed monitoring
	C	O	D							
Temporary habitat loss/disturbance	✓	✓	✓	Development of, and adherence to, an offshore Environmental Management Plan.	C: Negligible to low D: negligible to low	C: Marine – Low to high Diadromous- Negligible D: Marine – Low to high Diadromous - Negligible	C: Marine - Minor adverse Diadromous - Negligible D: Marine – Minor adverse Diadromous - Negligible	Not required	C: Marine - Minor adverse Diadromous - Negligible D: Marine – Minor adverse Diadromous - Negligible	None proposed
Underwater sound impacting fish and shellfish receptors	✓	×	×	Implementation of piling soft-start and ramp-up measures. This measure will minimise the risk of injury to fish species in the immediate vicinity of piling activities, allowing individuals to move away from the area before sound levels reach a level at which injury may occur.	C: Marine - Negligible to medium Diadromous - Low	C: Marine – Low to high Diadromous – Low to high	C: Marine – Minor to moderate adverse Diadromous- Minor adverse	Outline underwater sound management strategy (Document Reference J13)	C: Marine – Minor adverse Diadromous- Minor adverse	None proposed
Increased suspended sediment concentrations (SSCs) and associated sediment deposition	✓	✓	✓	Development of, and adherence to, an offshore Environmental Management Plan.	C: Low D: Low	C: Marine – Low to medium Diadromous - Low D: Marine – Low to medium Diadromous - Low	C: Marine – Minor adverse Diadromous - Negligible D: Marine – Minor adverse Diadromous - Negligible	Not required	C: Marine – Minor adverse Diadromous - Negligible D: Marine – Minor adverse Diadromous - Negligible	None proposed

Description of effect	Phase[a]			Measures adopted as part of the project	Magnitude of impact	Sensitivity of the receptor	Significance of effect	Further mitigation	Residual effect	Proposed monitoring
	C	O	D							
Long term habitat loss	✓	✓	✓	Development of, and adherence to, an offshore Environmental Management Plan throughout all phases; actions to reduce potential for introduction of INNS, and development and adherence to a CSIP.	C: Negligible to low O: Negligible to low D: Negligible to low	C: Marine – Low to medium Diadromous - Low O: Marine – Low to medium Diadromous - Low D: Marine – Low to medium Diadromous - Low	C: Marine – Negligible to minor adverse Diadromous – Minor adverse O: Marine – Negligible to minor adverse Diadromous – Minor adverse D: Marine – Negligible to minor adverse Diadromous – Minor adverse	Not required	C: Marine – negligible to minor adverse Diadromous – Minor adverse O: Marine – Negligible to minor adverse Diadromous – Negligible to minor adverse D: Marine – Negligible to minor adverse Diadromous – Minor adverse	None proposed
Electromagnetic Fields (EMF) from subsea electrical cabling	×	✓	×	Development and adherence to a CSIP. All electrical cables will be buried to depths of at least 0.5m as informed by a CBRA. While burial of cables will not reduce the strength of EMF, it does increase the distance between cables and fish and shellfish receptors, thereby potentially reducing the effect on those receptors.	O: Low	O: Marine – Low Diadromous - Low	O: Marine – Minor adverse Diadromous – Minor adverse	Not required	O: Marine – Minor adverse Diadromous – Minor adverse	None proposed

Description of effect	Phase[a]			Measures adopted as part of the project	Magnitude of impact	Sensitivity of the receptor	Significance of effect	Further mitigation	Residual effect	Proposed monitoring
	C	O	D							
Introduction and colonisation of hard structures	✓	✓	✓	Development of, and adherence to, an offshore Environmental Management Plan, and actions to reduce potential for introduction of INNS.	C: Low O: Low	C: Marine – Low Diadromous - Low O: Marine – Low Diadromous - Low	C: Marine – Minor adverse Diadromous – Minor adverse O: Marine – Minor adverse Diadromous – Minor adverse	Not required	C: Marine – Minor adverse Diadromous – Minor adverse O: Marine – Minor adverse Diadromous – Minor adverse	None proposed
Injury due to increased risk of collision with vessels	✓	✓	✓	An offshore Environmental Management Plan will be issued to all Project vessel operators, requiring them to: • Not deliberately approach basking shark • Keep vessel speed to a minimum; and • Avoid abrupt changes in course or speed should basking shark approach the vessel. The offshore Environmental Management Plan will be adhered to at all times.	C: Low O: Low D: Low	C: Marine – Medium O: Marine – Medium D: Marine - Medium	C: Marine – Minor adverse O: Marine – Minor adverse D: Marine – Minor adverse	Not required	C: Marine – Minor adverse O: Marine – Minor adverse D: Marine – Minor adverse	None proposed

3.15 References

Acolas, M.L., Anras, M.L.B., Veron, V., Jourdan, H., Sabatie, M.R., Bagliniere, J.L. (2004). An assessment of the upstream migration and reproductive behaviour of allis shad (*Alosa alosa* L.) using acoustic tracking. ICES Journal of Marine Science, 61(8), 1291-1304. Available: https://doi.org/10.1016/j.icesjms.2004.07.023. Accessed October 2023.

Agnalt, A.L., Kristiansen, T.S. and Jorstad, K.E. (2007). Growth, Reproductive Cycle and Movement of Berried European Lobsters (*Homarus gammarus*) in a Local Stock off Southwestern Norway. ICES Journal of Marine Sciences, 64, 288-97.

Aires, C., González-Irusta, J.M., Watret, R. (2014). Updating Fisheries Sensitivity Maps in British Waters. Scottish Marine and Freshwater Science Vol 5 No 10. Edinburgh: Scottish Government, 88pp. DOI: 10.7489/1555-1.

Andersson, M.H. (2011). Offshore Wind Farms - Ecological Effects of Noise and Habitat Alteration on Fish. PhD Thesis, Department of Zoology, Stockholm University.

Andersson, M.H., Berggren, B., Wilhelmsson, D., and Öhman, M.C. (2009). Epibenthic Colonization of Concrete and Steel Pilings in a Cold-Temperate Embayment: A Field Experiment. Helgoland Marine Research, 63, 249–60.

Andersson, M.H., and Öhman, M. (2010). Fish and sessile assemblages associated with wind-turbine constructions in the Baltic Sea. Marine and Freshwater Research, 61, 642-50.

APEM (2021). Beatrice Offshore Wind Farm: Post Construction Benthic Monitoring Method Statement. Available at: [redacted] Accessed October 2023.

Appleby, J., and Scarratt, D.J. (1989). Physical effects of suspended solids on marine and estuarine fish and shellfish, with special reference to ocean dumping: a literature review. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1681.

Armstrong, J.D., Hunter, D.C., Fryer, R.J., Rycroft, P., and Orpwood, J.E. (2015). Behavioural responses of Atlantic salmon to mains frequency magnetic fields. Scottish Marine and Freshwater Science 6(9).

Atema, J., and Cobb, J. S. (1980). Social behaviour in the biology and management of lobsters 409–450.

Bagocius, D. (2015). Piling underwater sound impact on migrating salmon fishing during Lithuanian LNG terminal construction (Curonian Lagoon, Eastern Baltic Sea Coast). Marine Pollution Bulletin, 92(1-2), 45-51. Available: [redacted] Accessed September 2023.

Ball, B.J., Fox, G., and Munday, B.W. (2000). Long- and short-term consequences of a *Nephrops* trawl fishery on the benthos and environment of the Irish Sea. ICES Journal of Marine Science, 57(5), 1315-20 Available: [redacted] Accessed July 2023.

Barker, J., Davies, J., Goralczyk, M., Patel, S., O'Connor, J., Evans, J., Sharp, R., Gollock, M., Wood, F.R., Rosindell, J., Bartlett, C., Garner, B.J., Jones, D., Quigley, D., and Wray, B. (2022). The distribution, ecology and predicted habitat use of the Critically Endangered angel shark (*Squatina squatina*) in coastal waters of Wales and the central Irish Sea. Journal of Fish Biology, 101(3), pp. 640-58. Available:[redacted]. Accessed October 2023.

Barnes M. D. (2017). Guidance on EIS and NIS Preparation for Offshore Renewable Energy Projects, Report for the Environmental Working Group of the Offshore Renewable Energy Steering Group and the Department of Communications, Climate Action and Environment, Dublin: Department of Communications, Climate Action and Environment.

Bender, A., Langhammer, O., and Sundberg, J. (2020). Colonisation of wave power foundations by mobile mega- and macrofauna – a 12 year study. Marine Environmental Research, 161, 105053. Available: [redacted] Accessed September 2023.

Bentley J.W., Serpetti N., Fox C.J., Heymans J.J. and Reid D.G. (2020). Retrospective analysis of the influence of environmental drivers on commercial stocks and fishing opportunities in the Irish Sea. Fish and Oceanography, 295, 415–435.

Bergström, L., Sundqvist, F., and Bergström, U. (2013). Effects of an offshore wind farm on temporal and spatial patterns in the demersal fish community. Marine Ecology Progress Series 485, 11pp.

Berli, B.I., Gilbert, M.J.H., Ralph, A.L., Tierney, K.B., and Burkhardt-Holm, P. (2014). Acute exposure to a common suspended sediment affects the swimming performance and physiology of juvenile salmonids. Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology, 176, 1-10. Available: [redacted]. Accessed July 2023.

BioConsult (2006). Hydroacoustic Monitoring of Fish Communities at Offshore Wind Farms, Horns Rev Offshore Wind Farm, Annual Report 2005.

Birklund, J., and Wijsman, J. W. M. (2005). Aggregate Extraction: A Review on the Effects on Ecological Functions. Report Z3297/10 SAWDPIT Fith Framework Project no EVK3-CT-2001-00056. Available: [redacted]Accessed: October 2023.

Bisson, P.A., and Bilby, R.E. (1982). Avoidance of Suspended Sediment by Juvenile Coho Salmon. North American Journal of Fisheries Management, 2(4), 371-4. Available: [redacted] Accessed July 2023.

Bloomfield, A., and Solandt, J.L. (2008). The Marine Conservation Society Basking Shark Watch 20-year report. Marine Conservation Society, Report. Available: [redacted] Accessed: August 2023.

Bloor, I., Emmerson, J., Lambden, C. and Kaiser, M. J. (2017). The Isle of Man Annual Fisheries Science Report for 2017. Bangor University, Fisheries & Conservation report No. 71.

Bloor, I.S.M., Emmerson, J. and Jenkins, S.R. (2019). Assessment of Queen Scallop stock status for the Isle of Man territorial sea 2019/2020. SFAG Report No. 1, 18pp.

Bloor, I., Coleman, M. and Jenkins, S. (2022). Isle of Man King Scallop 2022 Stock Survey Report. Bangor University Sustainable Fisheries and Aquaculture Group, Fisheries Report, 47 pages.

Bochert, R., and Zettler, M.L. (2006). Effect of Electromagnetic Fields on Marine Organisms. In: Köller, J., Köppel, J., and Peters, W. (eds) Offshore Wind Energy. Springer, Berlin, Heidelberg, 223-34. Available: [redacted]. Accessed June 2023.

Bodznick, D., and Northcutt, R.G. (1981). Electroreception in Lampreys: Evidence that the Earliest Vertebrates were Electroreceptive. Science, 212, 465-67.

Bodznick, D., and Preston, D.G. (1983). Physiological Characterization of Electroreceptors in the Lampreys. *Ichthyomyzon uniscuspis* and *Petromyzon marinus*. Journal of Comparative Physiology 152, 209-17.

Bohnsack, J. A. (1989). Are High Densities of Fishes at Artificial Reefs the Result of Habitat Limitation or Behavioural Preference? B. Mar. Sci., 44(2), 631-45.

Bolle, L.J., de Jong, C., Blom, E., Wessels, P., van Damme, C., and Winter, H. (2014). Effect of pile-driving sound on the survival of fish larvae (Report No. C182/14). Report by IMARES - Wageningen UR.

Bolle, L.J., de Jong, C.A.F., Bierman, S.M., van Beek, P.J.G., Wessels, P.W., Blom, E., van Damme, C.J.G., Winter, H.V., and Dekeling, R.P.A. (2016). Effect of Pile-Driving Sounds on the Survival of

Larval Fish. In: Popper, A., and Hawkins, A. (eds) The Effects of Noise on Aquatic Life II. Advances in Experimental Medicine and Biology, 875, 91-100. Available: [redacted] Accessed September 2023.

Boubee, J.A.T., Dean, T.L., West, D.W., and Barrier, R.F.G. (1996). Avoidance of suspended sediment by the juvenile migratory stage of six New Zealand native fish species. New Zealand Journal of Marine and Freshwater Research, 31(1), 61-9. Available: https://doi.org/10.1080/00288330.1997.9516745. Accessed June 2023.

Bouma, S. and Lengkeek, W. (2008). Benthic communities on hard substrates within the first Dutch offshore wind farm (OWEZ). Algae 2011.

Bouma, S., and Lengkeek, W. (2012). Benthic communities on hard substrates of the offshore wind farm Egmond aan Zee (OWEZ). Noordzeewind, report number: OWEZ_R_266_T1_20120206_hard_substrate.

Bowers, D.G., Boudjelas, S., and Harker, G.E.L. (2010). The distribution of fine suspended sediments in the surface waters of the Irish Sea and its relation to tidal stirring. International Journal of Remote Sensing, 19(14), 2789-805. Available: DOI: 10.1080/014311698214514. Accessed June 2023.

BOWind (2008). Barrow Offshore Wind Farm Post Construction Monitoring Report. First annual report. 15 January 2008, 60pp.

BOWL (2021a). Beatrice Offshore Wind Farm Post-Construction Sandeel Survey–Technical Report.

BOWL (2021b). Beatrice Offshore Wind Farm Post-Construction Cod Spawning Survey – Technical Report.

Boyle, G., and New, P (2018). ORJIP Impacts from Piling on Fish at Offshore Wind Sites: Collating Population Information, Gap Analysis and Appraisal of Mitigation Options. Final report – June 2018. The Carbon Trust. United Kingdom. 247 pp.

Brand, A.R. (1991). Scallop ecology: Distributions and behaviour. In Scallops: biology, ecology and aquaculture (ed. S.E. Shumway), pp. 517-584. Amsterdam: Elsevier.

Brown and May Marine Ltd (2009a). Walney Offshore Wind Farm Pre-Construction Fish Survey.

Brown and May Marine Ltd (2009b). Ormonde Offshore Wind Farm Pre-Construction Juvenile & Adult Fish Survey. Spring 2009.

Brown and May Marine Ltd (2009c). Ormonde Offshore Wind Farm Pre-Construction Juvenile & Adult Fish Survey. Autumn 2009.

Brown and May Marine Ltd. (2009d). Gunfleet Sands Offshore Wind Farm Herring Spawning Survey 2009. Available at: [redacted]. Accessed June 2023.

Brown and May Marine Ltd (2011a). Burbo Bank Extension Offshore wind farm: Adult and Juvenile Fish Characterisation Survey, 13th to 17th May 2011.

Brown and May Marine Ltd (2011b). Burbo Bank Extension Offshore wind farm: Adult and Juvenile Fish Characterisation Survey, 7th to 11th September 2011.

Brown and May Marine Ltd (2012a). Ormonde Offshore Wind Farm, Adult and Juvenile Fish and Epi-benthic Post-Construction Survey (Autumn). Marine Data Exchange. Available: [redacted] Accessed November 2023.

Brown and May Marine Ltd (2012b). Ormonde Offshore Wind Farm, Adult and Juvenile Fish and Epi-benthic Post-Construction Survey. Marine Data Exchange. Available: [redacted]

[redacted] Accessed November 2023.

Brown and May Marine Ltd (2014). Ormonde Offshore Wind Farm, Adult and Juvenile Fish and Epi-benthic Post-Construction Survey. Marine Data Exchange. Available: [redacted]. Accessed November 2023.

Budelmann, B.U. (1992). Hearing in Crustacea. The Evolutionary Biology of Hearing, 131-9. Available: DOI: 10.1007/978-1-4612-2784-7_9. Accessed June 2023.

Campanella, F., and van der Kooij, J. (2021). Spawning and nursery grounds of forage fish in Welsh and surroundings waters. Cefas Project Report for RSPB, 65 pp.

Campbell, A., and Stasko, A. B. (1985). Movements of tagged American lobster, *Homarus americanus*, off southwestern Nova Scotia. Canadian Journal of Fisheries and Aquatic Sciences, 42, 229–38.

Caputi, A.A., Aguilera, P.A., Pereira, A.C., and Rodrigues-Cattaneo, A. (2013). On the haptic nature of the active electric sense of fish. Brain Research, 1536, 27-43. Available: https://doi.org/10.1016/j.brainres.2013.05.028. Accessed July 2023.

Carroll, A.G., Przeslawski, R., Duncan, A., Gunning, M., and Bruce, B. (2017). A critical review of the potential impacts of marine seismic surveys on fish & invertebrates. Marine Pollution Bulletin, 114(1), 9-24. Available: [redacted] Accessed November 2023.

Carter, M.C. (2008). *Aequipecten opercularis* Queen scallop. In Tyler-Walters H. and Hiscock K. Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available: [redacted]. Accessed July 2023.

Casper, B.M., Halvorsen, M.B., and Popper, A.N. (2012). Are Sharks Even Bothered by a Noisy Environment? In: Popper, A.N., Hawkins, A. (eds) The Effects of Noise on Aquatic Life. Advances in Experimental Medicine and Biology, 730, 93-7. Available: [redacted] Accessed July 2023.

Cates, K., DeMaster, D. P., Brownell, R. L. Jr, Silber, G., Gende, S., et al. (2017). Strategic Plan to Mitigate the Impacts of Ship Strikes on Cetacean Populations: 2017-2020. IWC Strategic Plan to Mitigate Ship Strikes. Jersey: International Whaling Commission.

Cefas (2009). Strategic Review of Offshore Wind Farm Monitoring Data Associated with FEPA Licence Conditions. Project ME1117. July 2009.

Cefas (2016). Monthly averages of non-algal SPM (doi:10.14466/CefasDataHub.31).

Celtic Array Ltd. (2013). Round 3 Irish Sea Zone Rhiannon Wind Farm Limited. Preliminary Environmental Information in support of Section 42 of the Planning Act 2008 – October 2012.

Chiasson, A.G. (2011). The effects of suspended sediment on rainbow smelt (*Osmerus mordax*): A laboratory investigation. Canadian Journal of Zoology, 71(12), 2419-24. Available: DOI:10.1139/z93-337. Accessed July 2023.

Christian, J.R., Mathieu, A., Thomson, D.H., White, D., and Buchanan, R.A. (2003). Effect of Seismic Energy on Snow Crab (*Chionoecetes opilio*). Prepared for National Energy Board, Calgary, AB., File No. CAL-1-00364 (2003), 50pp.

Chung-Davidson., Y., Bryan, M.B., Teeter, J., Bedore, C.N., and Li, W. (2008). Neuroendocrine and Behavioural Responses to Weak Electric Fields in Adult Sea Lampreys (*Petromyzon marinus*). Hormones and Behaviour, 54(1), 34-40.

[redacted] [redacted] Accessed October 2023.

CIEEM (2019). Guidelines for Ecological Impact Assessment in the UK and Ireland. Terrestrial, Freshwater, Coastal and Marine, September 2018, Version 1.1 – Updated September 2019.

CMACS Ltd (2010). Autumn Fish Trawl Surveys 2010. Report to Celtic Array Ltd. Report reference: R3-D-EV-075-0070-000000-008. January 2011.

CMACS (2012). Walney Offshore Wind Farm Year 1 post-construction benthic monitoring technical survey report (2012 survey). Report to Walney Offshore Wind Farms (UK) Ltd/DONG Energy. July 2012.

CMACS (2014a). Walney Offshore Wind Farm Year 3 post-construction benthic monitoring technical survey report (2014 survey). Report to Walney Offshore Wind Farms (UK) Ltd/DONG Energy. December 2014.

CMACS (2014b). Walney I&II Offshore Wind Farms post-construction turbine foundation colonisation report (2014 survey). Report to Walney (UK) Offshore Wind Farms Ltd.

Comeau, M., and Savoie, F. (2002). Movement of American lobster (*Homarus americanus*) in the southwestern Gulf of St Lawrence. Fishery Bulletin US, 100, 181–92.

Coolen, J.W.P., van der Weide, B., Cuperus, J., Blomberg, M., Van Moorsel, G.W.N.M., Faasse, M.A., Bos, O.G., Degraer, S., and Lindeboom, H.J. (2020). Benthic biodiversity on old platforms, young wind farms, and rocky reefs. ICES Journal of Marine Science, 77(3), 1250-65. Available: [redacted] October 2023.

Cooper, K. and Martinez, R. (2017). OneBenthic M-Test Tool. Cefas. Available: [redacted]. Accessed October 2023.

Corten, A. (1999). The reappearance of spawning herring on Aberdeen Bank (North Sea) in 1983 and its relationship to environmental conditions. Canadian Journal of Fisheries and Aquatic Sciences, 56, 2051-2061.

Cotton, P.A., Sims, D.W., Fanshawe, S., and Chadwick, M. (2005). The effects of climate variability on zooplankton and basking shark (Cetorhinus maximus) relative abundance off southwest Britain. Fisheries Oceanography, 14(2), 151-155.

Coull, K.A., Johnstone, R, and Rogers, S.I. (1998). Fisheries Sensitivity Maps in British Waters. UKOOA Ltd: Aberdeen.

Cresci, A., Allan, B.J.M., Shema, S.D., Skiftesvik, A.B., and Browman, H.I. (2020). Orientation behaviour and swimming speed of Atlantic herring larvae (*Clupea harengus*) in situ and in laboratory exposures to rotated artificial magnetic fields. J. Exp. Mar. Biol. Ecol., 526, 151358. Available: [redacted] Accessed October 2023.

Cresci, A., Perrichon, P., Durif, C.M., Sørhus, E., Johnsen, E., Bjelland, R., Larsen, T., Skiftesvik, A.B. and Browman, H.I., (2022). Magnetic fields generated by the DC cables of offshore wind farms have no effect on spatial distribution or swimming behaviour of lesser sandeel larvae (*Ammodytes marinus*). Marine Environmental Research, 176, 105609.

CSA Ocean Sciences Inc. and Exponent (2019). Evaluation of Potential EMF Effects on Fish Species of Commercial or Recreational Fishing Importance in Southern New England. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Headquarters, Sterling, VA. OCS Study BOEM 2019-049, 59pp.

Danish Energy Agency (2012). Danish Offshore Wind. Key Environmental Issues - a Follow-up. The Environmental Group: The Danish Energy Agency, The Danish Nature Agency, DONG Energy and Vattenfall.

Darling, J.D., and Keogh, K.E. (1994). Observations of basking sharks, *Cetorhinus maximus*, in Clayoquot Sound. BC. Canadian Field-Naturalist 108(2), 199-210.

Day, R.D., McCauley, R., Fitzgibbon, Q.P., and Semmens, J.M. (2016). Assessing the impact of marine seismic surveys on southeast Australian scallop and lobster fisheries. Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, October. CC BY 3.0.

De Mesel I., Kerckhof F., Norro A., Rumes B., Degraer S. (2015). Succession and seasonal dynamics of the epifauna community on offshore wind farm foundations and their role as stepping stones for non-indigenous species. Hydrobiologia, 756: 37–50.

Defra (2023). Biodiversity Net Gain – Government response and summary of responses to consultation. Available: https://www.gov.uk/government/consultations/consultation-on-biodiversity-net-gain-regulations-and-implementation/outcome/government-response-and-summary-of-responses. Accessed October 2023.

Department of Energy Security and Net Zero (2023a). Overarching National Policy Statements for Energy (NPS EN-1). Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1147380/NPS_EN-1.pdf. Accessed November 2023.

Department of Energy Security and Net Zero (2023b). National Policy Statement for Renewable Energy Infrastructure (NPS EN-3). Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1147382/NPS_EN-3.pdf. Accessed November 2023.

Degraer, S., Carey, D., Coolen, J., Hutchison, Z., Kerchof, F., Rumes, B., and Vanaverbeke, J. (2020). Offshore Wind Farm Artificial Reefs Affect Ecosystem Structure and Functioning: A Synthesis. Oceanography, 33(4), 48-57.

Delargy, A., (2019). Quantitative Methods for Producing Evidence to Support Sustainable King Scallop Management. Bangor University (United Kingdom).

de Pontual, H., Lalire, M., Fablet, R., Laspougeas, C., Garren, F., Martin, S., Drogou, M. and Woillez, M. (2019). New insights into behavioural ecology of European seabass off the West Coast of France: implications at local and population scales. ICES Journal of Marine Sciences. 76 (2): 501-515.

De Soto. A., Delorme, N., Atkins, J., Howard, S., Williams, J., and Johnson, M. (2013). Anthropogenic noise causes body malformations and delays development in marine larvae. Sci. Reproduction, 3 (2013), 2831.

Desprez, M. (2000). Physical and biological impact of marine aggregate extraction along the French coast of the eastern English Channel: short and long-term post-dredging restoration. ICES Journal of Marine Science 57, 1428-38.

DFO, (2004). Potential impacts of seismic energy on snow crab. DFO Can Sci Advis Sec. Habitat Status Report 2004/003, 2.

Dickey-Collas, M., Nash, R.D.M., and Brown, J. (2001). The location of spawning of Irish Sea Herring (*Clupea harengus*). Journal of the Marine Biological Association of the UK, 81(04), 713-14. Available: DOI:10.1017/S0025315401004489. Accessed October 2023.

Dignan, S.P., Bloor, I.S.M, Murray, L.G., and Kaiser, M.J. (2014). Predicted impacts of proposed management measures in the Isle of Man queen scallop (*Aequipecten opercularis*) fishery to be introduced in the 2015 fishing season. Fisheries and Conservation Report No. 40, Bangor University, pp.11.

Doherty, P.D., Baxter, J.M., Gell, F.R., Godley, B.J., Graham, R.T., Hall, G., Hall, J., Hawkes, L.A., Henderson, S.M., Johnson, L., and Speedie, C. (2017). Long-term satellite tracking reveals variable seasonal migration strategies of basking sharks in the north-east Atlantic. Scientific reports, 7, 428-37.

Doksaeter, L., Handegard, N., Good, O., Kvadsheim, P., and Nordlund, N. (2012). Behaviour of captive herring exposed to naval sonar transmissions (1.0-1.6 kHz) throughout a yearly cycle. The Journal of the Acoustical Society of America, 131(2), 1632-42. Available: DOI:10.1121/1.3675944. Accessed November 2023.

Dolton, H.R., Gell, F.R., Hall, J., Hawkes, L.A., and Witt, M.J. (2020). Assessing the importance of Isle of Man waters for the basking short *Cetorhinus maximus*. Endangered Species Register, 41, 209-223. Available: DOI: [redacted]. Accessed October 2023.

Degraer, S., Carey, D., Coolen, J., Hutchison, Z., Kerchof, F., Rumes, B., and Vanaverbeke, J. (2020). Offshore Wind Farm Artificial Reefs Affect Ecosystem Structure and Functioning: A Synthesis. Oceanography, 33(4), 48-57.

Drinkwater, K.F. (2005). The response of Atlantic cod (Gadus morhua) to future climate change. ICES Journal of Marine Science, 62(7), 1327-37. Available: [redacted] Accessed October 2023.

Dukas, R. (2002). Behavioural and ecological consequences of limited attention. Philos. T. R. Soc. B. 357, 1539–47. Available: doi: 10.1098/rstb.2002.10063. Accessed September 2023.

Duncan P.F. and Emmerson J. (2018). Commercial Fisheries & Sea Angling. In: Manx Marine Environmental Assessment (2nd Ed.). Isle of Man Government. 71 pp.

Dunkley, F., and Solandt, J.L. (2022). Windfarms, fishing, and benthic recovery: Overlaps, risks and opportunities. Marine Policy, 145, 105262. Available: [redacted] Accessed November 2023.

Edmonds, N.J., Firmin, C.J., Goldsmith, D., Faulkner, R.C., and Wood, D.T. (2016). A review of crustacean sensitivity to high amplitude underwater sound: Data needs for effective risk assessment in relation to UK commercial species. Marine Pollution Bulletin, 108(1–2), 5-11.

EGS (2011). Lynn and Inner Dowsing Offshore Wind Farms Post-Construction Survey Works Phase 2 – Benthic Ecology Survey Centrica Contract No. CREL/C/400012, Final Report, 184pp.

Eirgrid Group (2015). North-South 400 kV Interconnection Development Environmental Impact Statement Volume 3B, Available at: [redacted] Accessed: October 2023.

Ellis, J.R., Milligan, S.P., Readdy, L., Taylor, N., and Brown, M.J. (2012). Spawning and nursery grounds of selected fish species in UK waters. Sci. Ser. Tech. Rep., Cefas Lowestoft, 147 m 56pp.

Ellis, J.R., Pawson, M.G., and Shackley, S.E. (1996). The comparative feeding ecology of six species of shark and four species of skate (Elasmobranchii) in the North-east Atlantic. Journal of the Marine Biological Association of the United Kingdom, 76, 89-106.

EMU (2004). Subsea Cable Decommissioning – A Limited Environmental Appraisal. Report commissioned by British Telecommunications plc, Cable and Wireless and AT&T, Report no. 04/J/01/06/0648/0415, available from UKCPC.

EMU (2008a). Barrow Offshore Wind Farm Monopile Ecological Survey. Report No 08/J/1/03/1321/0825. Report prepared on behalf of Narrow Offshore Wind Ltd. December 2008.

EMU (2008b). Kentish Flats Offshore Wind Farm Turbine Foundation Faunal Colonisation Diving Survey. Report No 08/J/1/03/1034/0839. Prepared on behalf of Kentish Flats Ltd. November 2008.

ENI (2023). HyNet North West Liverpool Bay CCS Ltd HyNet Carbon Dioxide Transportation and Storage Project. Offshore EIA Scoping Report.

FAO, (2009). *Dicentrarchus labrax*. In: Cultured aquatic species fact sheets. Available online: [redacted] Accessed: March 2023.

Fewtrell, J.L., and McCauley, R.D. (2012). Impact of air gun noise on the behaviour of marine fish and squid. Marine Pollution Bulletin, 64(5), 984-93. Available: [redacted] Accessed November 2023.

Filiciotto, F., Vazzana, M., Celi, M., Maccarrone, V., Ceraulo, M., Buffa, G., Arizza, V., de Vincenzi, G., Rosario, G., Mazzola, S., and Buscaino, G. (2016). Underwater sound from boats: Measurement of its influence on the behaviour and biochemistry of the common prawn (*Palaemon serratus*, Pennant 1777). Journal of Experimental Marine Biology and Ecology, 478. Available: 10.1016/j.jembe.2016.01.014. Accessed June 2023.

Foden, J., Rogers, S.I., and Jones, A.P. (2009). Recovery rates of UK seabed habitats after cessation of aggregate extraction. Marine Ecology Progress Series, 390, 15-26. Available: doi: 10.3354/meps08169. Accessed June 2023.

Formicki, K., Korzelecka-Orkisz, A., and Tansk, A. (2019). Magnetoreception in fish. Journal of Fish Biology, 95(1), 73-91. Available: [redacted]. Accessed October 2023.

Gardiner, R., Main, R., Kynoch, R., Gilbey, J., and Davies, I. (2018a). A needle in the haystack? Seeking salmon smolt migration routes off the Scottish east coast using surface trawling and genetic assignment. Poster presentation to the MASTS Annual Science Meeting 31 October – 2 November 2018.

Gardiner, R., Main, R., Davies, I., Kynoch, R., Gilbey, J., Adams, C., and Newton M. (2018b). Recent investigations into the marine migration of salmon smolts in the context of marine renewable development. Conference Presentation. Environmental Interactions of Marine Renewables (EIMR) Conference, Kirkwall, 24-26 April 2018.

Gardline Limited (2023). Morgan and Morecambe Offshore Wind Farms Integrated Survey – Environmental Baseline Survey Report Ref 11781.

Gill, A.B., and Taylor. H. (2001). The Potential of Electromagnetic Fields Generated by Cabling between Offshore Wind Turbines upon Elasmobranch Fishes. Report for the Countryside Council for Wales, CCW Science report No. 488, 60pp.

Gill, A. B., Gloyne-Phillips, I., Neal, K. J., and Kimber, J. A. (2005). The Potential Effects of Electromagnetic Fields Generated by Sub-Sea Power Cables Associated with Offshore Wind Farm Developments on Electrically and Magnetically Sensitive Marine Organisms – A Review. COWRIE 1.5 Electromagnetic Fields Review.

Gill, A.B., Huang, Y., Gloyne-Philips, I., Metcalfe, J., Quayle, V., Spencer, J., and Wearmouth, V. (2009). COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2: EMF-Sensitive Fish Response to EM Emissions from Sub-Sea Electricity Cables of the Type used by the Offshore Renewable Energy Industry. COWRIE-EMF-1-06.

Gill, A.B., and Bartlett, M. (2010). Literature review on the potential effects of electromagnetic fields and subsea noise from marine renewable energy developments on Atlantic salmon, sea trout and European eel. Scottish Natural Heritage Commissioned Report No.401.

Gill, A.B., Bartlett, M., and Thomsen, F. (2012). Potential interactions between diadromous fishes of UK conservation importance and the electromagnetic fields and subsea noise from marine renewable energy developments. Journal of Fish Biology, 81, 664-695. Available: doi:10.1111/j.1095-8649.2012.03374.x. Accessed October 2023.

Gill, A., Bremner, J., Blake, S., Fierens, L., Mynott, F., and Vanstaen, K. (2021). Effects of offshore wind farm construction and operation on commercial finish and commercial shellfish stocks and fisheries – Systematic evaluation of the literature. Cefas Project Report for Orsted Energy, 115pp.

Glarou, M., Zrust, M., and Svendsen, J.C. (2020). Using Artificial-Reef Knowledge to Enhance the Ecological Function of Offshore Wind Turbine Foundations: Implications for Fish Abundance and Diversity. Journal of Marine Science and Engineering, 8(5). Available: 10.3390/jmse8050332. Accessed October 2023.

Goold, J. (2008). Seasonal and spatial patterns of harbour porpoise and grey seal at a UK offshore wind farm site. Proceedings of the ASCOBANS/ECS workshop, Offshore Wind Farms and Marine Mammals: Impacts and Metholdologies for Assessing Impacts, Special publication series no.49, 32-6.

Gregory, R.S., and Levings, C.D. (1998). Turbidity reduces predation on migration juvenile Pacific salmon. Transactions of the American Fisheries Society, 127, 275-85.

Halvorsen, M. B., B. M. Casper., C. M. Woodley, T. J. Carlson and A. N. Popper. (2011). Predicting and mitigating hydroacoustic impacts on fish from pile installations. NCHRP Research Results Digest 363, Project 25-28, National Cooperative Highway Research Program, Transportation Research Board, National Academy of Sciences, Washington, D.C.

Halvorsen, M. B., B. M. Casper, C. M. Woodley, T. J. Carlson and A. N. Popper. (2012). Threshold for onset of injury in Chinook salmon from exposure to impulsive pile driving sounds. PLoS ONE 7: e38968.

Harding, H., Bruintjes, R., Radford, A. N., and Simpson, S. D. (2016). Measurement of Hearing in the Atlantic salmon (*Salmo salar*) using Auditory Evoked Potentials, and effects of Pile Driving Playback on salmon Behaviour and Physiology. Marine Scotland Science; Scottish Marine and Freshwater Science, 7, 46–7.

Harsanyi, P., Scott, K., Easton, B.A., de la Cruz Ortiz, G., Chapman, E.C., Piper, A.J., Rochas, C.M., and Lyndon, A.R. (2022). The Effects of Anthropogenic Electromagnetic Fields (EMF) on the Early Development of Two Commercially Important Crustaceans, European Lobster, *Homarus gammarus* (L.) and Edible Crab, *Cancer pagurus* (L.). Journal of Marine Science and Engineering, 10(5), p.564.

Hart, N.S., and Collin, S.P. (2015). Sharks senses and shark repellents. Integrative Zoology, 10 (1), 38-64. Available: DOI [redacted]. Accessed June 2023.

Hawkins, A.D. (2009). The impact of pile driving upon fish. 5th International Conference on Bioacoustics 2009, Proceedings of the Institute of Acoustics.

Hawkins, A.D., and Popper, A.N. (2016). A sound approach to assessing the impact of underwater sound on marine fishes and invertebrates. ICES Journal of Marine Science, 74(3), 635-51.

Hawkins, A.D., and Popper, A.N. (2014). Assessing the Impact of Underwater Sounds on Fishes and Other Forms of Marine Life. Acoustics Today, 10(2), 30-41.

Hawkins, A. D., Roberts L., and Cheesman, S. (2014). Responses of free-living coastal pelagic fish to impulsive sounds, J. Acoust. Soc. Am., 135, PP3101-3116.

Helker, V. T., M. M. Muto, K. Savage, S. Teerlink, L. A. Jemison, K. Wilkinson, and J. Jannot. (2017). Human-caused mortality and injury of NMFS-managed Alaska marine mammal stocks, 2011-2015. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-354,112 p.

Hendrick, V.J., Hutchison, Z.L., and Last, K.S. (2016). Sediment Burial Intolerance of Marine Macroinvertebrates. PLOS ONE, 26901775. Available: [redacted]. Accessed May 2023.

Hiddink, J.G., Jennings, S., Sciberras, M., Szostek, C.L., Hughes, K.M., Ellis, N., Rijnsdorp, A.D., McConnaughey, R.A., Mazor, T., Hilborn, R., Collie, J.S., Pitcher, C.R., Amoroso, R.O., Parma, A.M., Suuronen, P., and Kaiser, M.J. (2017). Global analysis of depletion and recovery of seabed biota after bottom trawling disturbance. PNAS, 114(21), 8301-6, available: https://doi.org/10.1073/pnas.1618858114. Accessed October 2023.

Holland, G. J., Greenstreet, S. P. R., Gibb, I. M., Fraser, H. M., and Robertson, M. R., (2005). Identifying Sandeel *Ammodytes marinus* Sediment Habitat Preferences in the Marine Environment. Mar. Ecol. Prog. Ser., 303, 269-82.

Hooper, T., and Austen, M. (2014). The co-location of offshore windfarms and decapod fisheries in the UK: Constraints and opportunities. Marine Policy, 43, 295-300. Available: [redacted]. Accessed May 2023.

Howe, V.L., Gell, F.R., and Hanley, L.J. (2018). Subtidal Ecology. In: Manx Marine Environmental Assessment (2nd Ed). Isle of Man Government, 48pp.

Howell, T.R.W., and Fraser, D.I., (1984). Observations on the dispersal and mortality of the scallop *Pecten maximus* (L.). ICES Council Meeting Papers, 35.

Huang, Y. (2005). Electromagnetic Simulations of 135- kV Three phase Submarine Power Cables. Centre for Marine and Coastal Studies, Ltd. Prepared for Sweden Offshore.

Hume, J. (2017). A review of the geographic distribution, status and conservation of Scotland’s lampreys. The Glasgow Naturalist. Volume 26, Part 4.

Hutchison, Z.L., Sigray, P., He, H., Gill, A.B., King, J., and Gibson, C. (2018). Electromagnetic Field (EMF) Impacts on Elasmobranch (shark, rays, and skates) and American Lobster Movement and Migration from Direct Current Cables. Sterling (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2018-003.

Hutchison, Z.L., Gill, A.B., Sigray, P., He, H., and King, J.W. (2020). Anthropogenic electromagnetic fields (EMF) influence the behaviour of bottom-dwelling marine species. Scientific Reports, 10(4219). Available: [redacted]. Accessed October 2023.

Hvidt, C.B., Bech, M., and Klaustrup, M. (2003). Monitoring programme-status report 2003. Fish at the cable trace. Nysted offshore wind farm at Rødsand. Bioconsult.

ICES (2005). ICES-FishMap – Sprat. Species Factsheet. Available online: [redacted] Accessed: January 2024.

ICES (2006). Report of the Herring Assessment Working Group South of 620 N (HAWG), 14 - 23 March, ICES Headquarters. ICES CM 2006/ACFM:20. 647pp.

ICES (2018a). Celtic Seas ecoregion – Fisheries overview, including mixed-fisheries considerations. Available:[redacted]. Accessed October 2023.

ICES (2018b). Thornback ray (*Raja clavata*) in divisions 7.a, 7.f–g (Irish Sea, Bristol Channel, Celtic Sea North). ICES Advice on fishing opportunities, catch, and effort - Celtic Seas Ecoregion. Available: [redacted]. Accessed October 2023.

ICES (2019a). Scallop Assessment Working Group (WGSCALLOP). ICES Scientific Reports. 2:111. 57 pp. Available: [redacted] Accessed April 2023.

ICES (2019b). Scallop Assessment Working Group (WGSCALLOP). ICES Scientific Reports. 2:111. 57 pp. Available: [redacted]. Accessed April 2023.

ICES. (2020). Scallop Assessment Working Group (WGSCALLOP). ICES Scientific Reports, 2(111), 57pp. Available: [redacted] Accessed October 2023.

ICES (2021). International Bottom Trawl Survey Working Group (IBTSWG). ICES Scientific Reports, 3(69), 201pp. Available: [redacted]Accessed October 2023.

ICES (2022a). Working Group on Surveys on Ichthyoplankton in the North Sea and adjacent Seas (WGSINS; outputs from 2021 meeting) ICES Scientific Reports. 4:27. 47pp.

ICES (2022b). Fish trawl surveys. Biotic data in fish trawl surveys (DATRAS). 2012 to 2022 data from NIGFS. Available online: [redacted] Accessed October 2023.

IEMA (2016). Environmental Impact Assessment. Guide to Delivering Quality Development. Available: [redacted] Accessed October 2023.

IEMA (2017). Delivering Proportionate EIA, A Collaborative Strategy for Enhancing UK Environmental Impact Assessment Practice. Available: [redacted] Accessed November 2023.

Inger, R., Attril, M.J., Bearhop, S., Broderick, A.C., Grecian, W.J., Hodgson, D.J., Mills, C., Sheehan, E., Votier, S.C., Witt, M.J., and Godley, B.J. (2009). Marine Renewable Energy: Potential Benefits to Biodiversity? An Urgent Call for Research. Journal of Applied Ecology, 46, 1145-53.

International Council for the Exploration of the Sea (ICES) (2021). Celtic Seas Ecoregion: Fisheries overview, including mixed-fisheries considerations, 30th November 2021. Available: FisheriesOverview_CelticSeas_2021.pdf (ices.dk) Accessed October 2023.

Isle of Man Government (2018). Manx Marine Nature Reserves Byelaw 1 2018. Statutory Document 2018/0186, available: Manx Marine Nature Reserves Byelaws 2018 (SD 2018-0186). InforMEA. Accessed 05 July 2022.

Isle of Man Government (2021). A Long-Term Management Plan for the Isle of Man King Scallop Fishery. Fisheries Division, Department of Environment, Food and Agriculture, Policy No. SF/LTMP/SCALLOP/1.0. Available: [redacted] Accessed: November 2023.

Jarv, L., Aps, R., Raid, T., and Jarvik, A. (2015). The impact of activities of the Port of Sillamäe, Gulf of Finland (Baltic Sea), on the adjacent fish communities in 2002–2014. 16th International Congress of the International Maritime Association of the Mediterranean, Conference Paper.

Jennings, S. and Pawson, M.G. (1992). The origin and recruitment of bass, *Dicentrarchus labrax*, larvae to nursery areas. Journal of the Marine Biological Association of the UK. 72: 199-212.

Jensen, H., Kristensen, P.S., and Hoffmann, E. (2004). Sandeels in the wind farm area at Horns Reef. Report to ELSAM, August 2004. Danish Institute for Fisheries Research, Charlottenlund.

Jensen, H., Rindorf, A., Wright, P.J., and Mosegaard, H. (2010). Inferring the location and scale of mixing between habitat areas of lesser sandeel through information from the fishery. ICES Journal of Marine Science, 68 (1), 42pp.

Jerko, H., Turunen-Rise, I., Enger, P.S., and Sand, O. (1989). Hearing in the eel (*Anguilla anguilla*). Journal of Comparative Physiology, 165, 455-9. Available: https://doi.org/10.1007/BF00611234. Accessed October 2023.

Jezequel, Y., Cones, S., Jensen, F.H., Brewer, H., Collins, J., and Mooney, T.A. (2022). Pile driving repeatedly impacts the giant scallop (*Placopecten magellanicus*). Scientific Reports, 12(1), 15380. Available: doi: 10.1038/s41598-022-19838-6. Accessed October 2023.

JNCC (2010a). Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise. August 2010. Joint Nature Conservation Committee, Aberdeen, UK.

JNCC (2010b). JNCC guidelines for minimising the risk of injury to marine mammals from using explosives. Joint Nature Conservation Committee, Aberdeen, UK.

JNCC. (2017). JNCC guidelines for minimising the risk of injury to marine mammals from geophysical surveys. Joint Nature Conservation Committee, Aberdeen, UK.

JNCC (2019). JNCC MPA Mapper. Online map resource, Available: https://jncc.gov.uk/mpa-mapper/. Accessed: October 2023.

Judd, A. (2012). Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects. Report by Centre for Environment Fisheries and Aquaculture Science (CEFAS).

Kaiser, M.J., Hormbrey, S., Booth, J.R., Hinz, H., and Hiddink, J.G. (2018). Recovery linked to life history of sessile epifauna following exclusion of towed mobile fishing gear. Journal of Applied Ecology, 55(3), 1060-70, available: [redacted]. Accessed: October 2023.

Karlsson, R., Tivefalth, M., Duranovic, I., Martinsson, S., Kjolhamar, A., and Murvoll, K.M. (2022). Artificial hard-substrate colonisation in the offshore Hywind Scotland Pilot Park. Wind Energy Science, 7, pp. 801-814. Available: [redacted] Accessed November 2023.

Kavet, R., Wyman, M.T., and A.P. Klimley. (2016). Modelling magnetic fields from a dc power cable buried beneath San Francisco Bay based on empirical measurements. PLoS One 11(2):e0148543.

Kelly. C, Glegg, G.A., and Speedie, C.D. (2004). Management of marine wildlife disturbance. Ocean & Coastal Management, 47, 1-19.

Kempster, R., and Colin, S. (2011) Electrosensory pore distribution and feeding in the basking shark *Cetorhinus maximus* (Lamniformes: Cetorhinidae). Aquatic Biology, 12, 33-36. Available: [redacted]. Accessed October 2023.

Kempster, R.M., Hart, N.S., and Collin, S.P. (2013). Survival of the Stillest: Predator Avoidance in Shark Embryos. PLoS ONE 8(1), e52551.

Kerckhof, F. (2010). Early development of the subtidal marine biofouling on a concrete offshore windmill foundation on the Thornton Bank (southern North Sea): first monitoring results. Underwater Technology, 29, 137-149.

Kiorbe, T., Frantsen, E., Jensen, C.S., and Sorensen, G. (1981). Effects of suspended sediment on development and hatching of herring (*Clupea harengus*) eggs. Estuarine, Coastal and Shelf Science, 13(1), 107-11. Available: [redacted] Accessed October 2023.

Kjelland, M.E., Woodley, C.M., Swannack, T.M., and Smith, D.L. (2015). A review of the potential effects of suspended sediment on fishes: potential dredging-related physiological, behavioral, and transgenerational implications. Environment Systems and Decisions. 35, 334-50.

Knutsen, J., Knutsen, H., Gjøsæter, J., and Jonsson, B. (2001). Food of anadromous brown trout at sea. Journal of Fish Biology, 59, 533 – 543. Available: 10.1111/j.1095-8649.2001.tb02359.x. Accessed June 2023.

Krone, R., Dederer, G., Kanstinger, P., Kramer, P., Schneider, C., and Schmalenbach, I. (2017). Mobile demersal megafauna at common offshore wind turbine foundations in the German Bight (North Sea) two years after deployment - increased production rate of *Cancer pagurus*. Marine Environmental Research, 123, 53-61. Available: [redacted] Accessed July 2023.

Krone, R. Gutowa, L. Joschko, TJ., and Schröder, A. (2013). Epifauna dynamics at an offshore foundation Implications of future wind power farming in the North Sea. Marine Environmental Research, 85, 1-12.

Lagardère J.P., and Spérandio, M. (1981). Influence du niveau sonore de bruit ambiant sur la croissance de la crevett *Crangon crangon*. Resultats préliminaires Aquaculture, 24, 77-90.

Langhamer, O. and Wilhelmsson, D. (2009). Colonisation of fish and crabs of wave energy foundations and the effects of manufactured holes - a field experiment. Marine environmental research, 68 4, 151-7.

Langhamer, O. (2012). Artificial Reef Effect in relation to Offshore Renewable Energy Conversion: State of the Art. The Scientific World Journal, Article ID 386713, 8pp. Available: [redacted]. Accessed July 2023.

Langhamer, O., Holand, H., and Rosenqvist, G. (2016). Effects of an Offshore Wind Farm (OWF) on the common shore crab *Carcinus maenas*: Tagging pilot experiments in the Lillgrund Offshore Wind Farm (Sweden). PLoS One, 11, 1–17.

Lambert, G.I., Jennings, S., Kaiser, M.J., Davies, T.W., and Hiddink, J.G. (2014). Quantifying recovery rates and resilience of seabed habitats impacted by bottom fishing. Journal of Applied Ecology, 51(5), 1326-36. Available: [redacted]. Accessed October 2023.

Laming, S.R., Jenkins, S.R., and McCarthy, I.D. (2013). Repeatability of escape response performance in the queen scallop, *Aequipecten opercularis*. Journal of Experimental Biology, 216(17), 3264-72, available:[redacted]. Accessed: October 2023.

Lasram, F.B.R., Bourgougnon, N., Yolanda, D.A., Gillet, P., Le Loc'h, F., Masse, C., Nexer, M., Lejart, M., Quillien, N., and Taormina, B. (2019). Does the colonisation of offshore renewable energy farms facilitate the introduction and spread of non-indigenous species? COM3T Bulletin no. 2, 52(16), 7pp., reference: 52036030.

Last, K.S., Hendrick, V.J., Beveridge, C.M., and Davies, A.J. (2011). Measuring the effects of suspended particulate matter and smother on the behaviour, growth and survival of key species found in areas associated with aggregate dredging. Marine Aggregate Levy Sustainability Fund, Project MEPF 08/P76.

Latto P.L., Reach I.S., Alexander D., Armstrong S., Backstrom J., Beagley E., Murphy K., Piper R., and Seiderer L.J., (2013). Screening Spatial Interactions between Marine Aggregate Application Areas and Sandeel Habitat. A Method Statement produced for BMAPA.

Lawson, J.M., Pollom, R.A., Gordon, C.A., Barker, J., Meyers, E.K.M., Zidowitz, H., Ellis, J.R., Bartoli, A., Morey, G., Fowler, S.L., Alvarado, D.J., Fordham, S.V., Sharp, R., Hood, A.R., and Dulvy, N.K. (2019). Extinction risk and conservation of critically endangered angel sharks in the Eastern Atlantic and Mediterranean Sea. ICES Journal of Marine Science, 77(1), pp. 12-29. Available: [redacted] Accessed October 2023.

Lee, P.H. and Weis, J.S. (1980). Effects of magnetic fields on regeneration in fiddler crabs. Biology Bulletin, 159, 681–691.

Lincoln, H., Robins, P.E., Wilmes S-B., Pérez-Mayol, S., Moore, A., Simpson, S., Goward-Brown, A., Heney, C., Malham, S., Morales-Nin, B., Hold, N. and McCarthy I.D. (2024). Predicting potential spawning areas of European bass, *Dicentrarchus labrax*, in the Irish and Celtic seas. Fisheries Research. 270 (2024): 106884.

Lindeboom, H.J., Kouwenhoven, H.J., Bergman, M.J.N., Bouma, S., Brasseur, S., Daan, R., Fijn, R.C. de Haan, D., Dirksen, S., van Hal, R., Hille Ris Lambers, R., ter Hofstede, R., Krijgsveld, K.L., Leopold, M., and Scheidat, M. (2011). Short-term ecological effects of an offshore wind farm in the Dutch coastal zone; a compilation. Environmental Research Letters, 6, 035101, 13pp.

Lefaible, N., L. Colson, U. Braeckman, and T. Moens. (2019). Evaluation of turbine-related impacts on macrobenthic communities within two offshore wind farms during the operational phase. Pp 47–

64 in Environmental Impacts of Offshore Wind Farms in the Belgian Part of the North Sea: Marking a Decade of Monitoring, Research and Innovation.

Linley, E.A.S., Wilding, T.A., Black, K., Hawkins, A.J.S., and Mangi S. (2007). Review of the Reef Effects of Offshore Wind Farm Structures and their Potential for Enhancement and Mitigation. Report from PML Applications Ltd and the Scottish Association for Marine Science to the Department for Business, Enterprise and Regulatory Reform (BERR), Contract No: RFCA/005/0029P.

Lohmann, K.J., Pentcheff, N.D., Nevitt, G.A., Stetten, G.D., Zimmer-Faust, R.K., Jarrard, H.E., and Boles, L.C. (1995). Magnetic orientation of spiny lobsters in the ocean: experiments with undersea coil systems. Journal of Experimental Biology 198(2), 041-2,048.

Love, M.S., Nishimoto, M.M., Clark, S., and Bull, A.S. (2016). Renewable Energy in situ Power Cable Observation. U.S. Department of the Interior, Bureau of Ocean Energy Management, Pacific OCS Region, Camarillo, CA. OCS Study 2016-008, 86pp.

Love, M.S., Nishimoto, M.M., Clark, S., McCrea, M., and Bull, A.S. (2017). Assessing potential impacts of energized submarine power cables on crab harvests. Continental Shelf Research, 151(1), 23-29. Available: [redacted] Accessed October 2023.

MacDonald, D.S., Little, M., Eno, N.C., and Hiscock, K. (1996). Disturbance of benthic species by fishing activities: a sensitivity index. Aquatic Conservation Marine and Freshwater Ecosystems, 6(4), 257-68. Available: [redacted] Accessed October 2023.

Mackenzie, C.L., Ormondroyd, G.A., Curling, S.F., Ball, R.J., Whiteley, N.M., and Malham, S.K. (2014). Ocean Warming, More than Acidification, Reduces Shell Strength in a Commercial Shellfish Species during Food Limitation. PLoSONE. Available: [redacted] Accessed October 2023.

Manx Whale and Dolphin Watch (2023). Basking Sharks sightings data. Accessed: July 2023, Available: [redacted] Accessed October 2023.

MarineSpace Ltd, ABPmer Ltd, ERM Ltd, Fugro EMU Ltd and Marine Ecological Surveys Ltd, (2013). Environmental Effect Pathways between Marine Aggregate Application Areas and Sandeel Habitat: Regional Cumulative Impact Assessments. A report for BMAPA.

Marshall, C., and Wilson, E. (2008). *Pecten maximus*. Great scallop. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme. Plymouth: Marine Biological Association of the United Kingdom. Available: [redacted]. Accessed September 2023.

Mavraki, O., De Mesel, I., Degraer, S., Moens, T., and Vanaverbeke, J. (2020). Resource niches of co-occurring invertebrate species at an offshore wind turbine indicate a substantial degree of trophic plasticity. Frontiers in Marine Science, 7(379), 17pp. Available: 10.3389/fmars.2020.00379. Accessed October 2023.

McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M.N., Penrose, J.D., Prince, R.I.T., Adhitya, A., Murdoch, J., and McCabe, K. (2000). Marine Seismic Surveys – A Study of Environmental Implications. Appea Journal, 692-707.

Mann, D.A., Lu, Z., Hastings, M.C., and Popper, A.N. (1998). Detection of ultrasonic tones and simulated dolphin echolocation clicks by a teleost fish, the American shad (*Alosa sapidissima*). The Journal of the Acoustical Society of America, 104(562). Available: [redacted]. Accessed November 2023.

Mann, D.A., Higgs, D., Tavolga, W., Souza, M.J., and Popper, A.N. (2001). Ultrasound detection by clupeiform fishes. The Journal of the Acoustical Society of America, 109, 3048–54.

Manx Whale and Dolphin Watch (2023). Basking Sharks sightings data. Accessed: July 2023, Available: [redacted]. Accessed October 2023.

MarLIN (2021). Marine Evidence based Sensitivity Assessment (MarESA) Available at: MarLIN - The Marine Life Information Network - Marine Evidence based Sensitivity Assessment (MarESA). Accessed November 2023.

McConnell, B., Lonergan, M., and Dietz, R. (2012). Interactions between seals and offshore wind farms. The Crown Estate, 41pp., ISBN: 978-1-906410-34-6.

McKinstry, C., Carlson, T., and Brown, R (2007). Derivation of a mortal injury metric for studies of rapid decompression of depth-acclimated physostomous fish Final Report of the Pacific Northwest Laboratory, 17080.

Messieh, S.N., Wildish, D.J., and Peterson, R.H. (1981). Possible impact from dredging and soil disposal on the Miramichi Bay herring fishery. Canadian Technical Report for Fisheries and Aquatic Sciences, 1008, 33pp.

Metcalfe, J.D., Holford, B.H., and Arnold, G.P. (1993). Orientation of plaice (*Pleuronectes platessa*) in the open sea – evidence for the use of external directional clues. Marine Biology 117, 559-66.

Mickle, M.F., Miehls, S.M., Johnson, N.S., and Higgs, D.M. (2019). Hearing capabilities and behavioural response of sea lamprey (*Petromyzon marinus*) to low-frequency sounds. Canadian Journal of Fisheries and Aquatic Sciences, 76(9), 1541-8. Available: [redacted]. Accessed October 2023.

Minchin, D. (1992). Biological observations on young scallops, *Pecten maximus*. Journal of the Marine Biological Association of the United Kingdom, 72(4), 801-19.

Mona Offshore Wind Ltd (2024). Mona Offshore Wind Project Environmental Statement. Available at: https://infrastructure.planninginspectorate.gov.uk/projects/wales/mona-offshore-wind-farm/?ipcsection=docs&stage=app&filter1=Environmental+Statement

Moore, A.B., Bater, R., Lincoln, H., Robins, P., Simpson, S.J., Brewin, J., Cann, R., Chapman, T., Delargy, A., Heney, C. Jones, M., Southworth, L., Spencer, J., Hold, N. and McCarthy, I.D. (2021). Bass and ray ecology in Liverpool Bay. Bangor University Sustainable Fisheries and Aquaculture Group. Fisheries Report 3.1. 68pp.

Moore, A., and Riley, W.D. (2009). Magnetic particles associated with the lateral line of the European eel *Anguilla anguilla*. Journal of Fish Biology, 74, 1629-34.

Morecambe Offshore Windfarm Ltd. (2023). Chapter 10: Fish and Shellfish Ecology. Morecambe Offshore Windfarm Generation Assets PEIR. Available at: [redacted] Accessed April 2023.

Morgan Offshore Wind Limited (2023). Morgan Offshore Wind Project Generation Assets PEIR. Volume 4, Annex 8.1: Fish and shellfish ecology technical report.

Moriarty, M., Greenstreet, S., Dransfeld, L., Shepard, S., Trenkel, V., and Reid, D. (2015). Variation in the abundance distribution of skate and ray species in the Celtic Seas. Presentation to Fisheries Society of the British Isles Annual Symposium 30th July, Plymouth University, UK.

MarineSpace Ltd, ABPmer Ltd, ERM Ltd, Fugro EMU Ltd and Marine Ecological Surveys Ltd, (2013). Environmental Effect Pathways between Marine Aggregate Application Areas and Sandeel Habitat: Regional Cumulative Impact Assessments. A report for BMAPA.

Morley, E.L., Jones, G., and Radford, A.N. (2013). The importance of invertebrates when considering the impacts of anthropogenic noise. Proc. R. Soc. B, 281.

Morrison, F., Harvey, E., Franze, and Menden-Deuer, S. (2019). Storm-Induced Predator-Prey Decoupling Promotes Springtime Accumulation of North Atlantic Phytoplankton. Frontiers in Marine

Science, Marine Ecosystem Ecology. Available: https://doi.org/10.3389/fmars.2019.00608. Accessed October 2023.

MMO (2021). North West Inshore and North West Offshore Marine Plan, June 2021.

Mueller-Blenkle, C., Mcgregor, P., Gill, A.B., Andersson, M., Metcalfe, J., Bendall, V., Sigray, P., Wood, D., and Thomsen, F. (2010). Effects of pile-driving noise on the behaviour of marine fish. Published by Cefas on behalf of COWRIE Ltd.

Murray, L.G., Hinz, H. and Kaiser, M.J. (2009). Annual Marine Fisheries Research Report to DAFF 2007/2008. Fisheries & Conservation report, Bangor University 8.

Narita, D., Rehdanz, K., and Tol, R.S.J. (2012). Economic costs of ocean acidification: a look into the impacts on global shellfish production. Climatic Change, 113, 1049-63. Available: https://doi.org/10.1007/s10584-011-0383-3. Accessed October 2023.

National Biodiversity Network (NBN) Atlas. (2019). Available: NBN Atlas - UK's largest collection of biodiversity information. Accessed October 2023.

Natural England and Defra (2022). Offshore Wind Marine Environmental Assessments: Best Practice Advice for Evidence and Data Standards. Available by contacting NEOffshoreWindStrategicSolutions@naturalengland.org.uk. Accessed September 2023.

Neal, K.J. and Wilson, E. (2008). *Cancer pagurus* Edible crab. In Tyler-Walters, H. and Hiscock, K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available: [redacted] Accessed August 2023.

Nedwell, J., Turnpenny, A., Lovell, J.M., and Edwards, B. (2006). An investigation into the effects of underwater piling noise on salmonids. The Journal of the Acoustical Society of America, 120(5,1) 2550-4, DOI:10.1121/1.2335573.

Newell, R.C. Seiderer, L.J. and Hitchcock, D.R. (1998). The impact of dredging works in coastal waters: A review of the sensitivity to disturbance and subsequent recovery of biological resources on the seabed. Oceanography and Marine Biology, 36, 127-78.

Newton, M., Main, R. and Adams, C. (2017). Atlantic Salmon *Salmo salar* smolt movements in the Cromarty and Moray Firths, Scotland. LF000005-REP-1854, March 2017.

Newton, M. Honkanen, H. Lothian, A. and Adams, C (2019). The Moray Firth Tracking Project – Marine Migrations of Atlantic Salmon (*Salmo salar*) Smolts. Proceedings of the 2019 SAMARCH Project: International Salmonid Coastal and Marine Telemetry Workshop.

Newton, M., Barry, J., Lothian, A., Main, R. A., Honkanen, H., McKelvey, S. A., Thompson, P., Davies, I., Brockie, N., Stephen, A., O'Hara Murray, R., Gardiner, R., Campbell, L., Stainer, P., and Adams, C. (2021). Counterintuitive active directional swimming behaviour by Atlantic salmon during seaward migration in the coastal zone. ICES Journal of Marine Science, 78(5), 1730–1743. [redacted] Accessed October 2023.

NMFS (2005). 'Scoping Report for NMFS EIS for the National Acoustic Guidelines on Marine Mammals'. National Marine Fisheries Service.

NMFS (2012). National Marine Fisheries Service Policy Directive 02-238. Process for Distinguishing Serious from Non-Serious Injury of Marine Mammals.

Normandeau (Normandeau Associates, Inc.), Exponent Inc., Tricas, T. and Gill, A. (2011). Effects of EMFs from Undersea Power Cables on Elasmobranchs and Other Marine Species. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement, Pacific OCS Region, Camarillo, CA.OCS Study BOEMCSARE 2011-09. Available: [redacted] . Accessed August 2023.

Olbert, A.I., Dabrowski, T., Nash, S., and Hartnett, M. (2012). Regional modelling of the 21st century climate changes in the Irish Sea. Continental Shelf Research, 41, 48-60. Available: https://doi.org/10.1016/j.csr.2012.04.003. Accessed August 2023.

Ohman, M.C., Sigray, P., and Westerberg, H. (2007). Offshore windmills and the effects of electromagnetic fields on fish. Ambio, 36, 630-3.

O'Neill, R.1, Ó Maoiléidigh, N., McGinnity, P. and Culloty, S. (2018). The novel use of pop-off satellite tags (PSATs) to investigate the migratory behaviour of European sea bass *Dicentrarchus labrax* (L., 1758) in the Celtic Sea area. Journal of Fish Biology. 92 (5): 1404-1421.

Orpwood, J.E., Fryer, R.J., Rycroft, P., and Armstrong, J.D. (2015). Effects of AC magnetic fields (MFs) on swimming activity in European eels *Anguilla anguilla*. Scottish Marine and Freshwater Science 6(8), 1-22.

Ørsted (2018) Walney Extension Pontoon/Jetty Dredging and Disposal Supporting Environmental Information, Available: View application and documents - MCMS (marinemanagement.org.uk). Accessed February 2024.

Ørsted. (2023). Mooir Vannin Offshore Wind Farm. Scoping Report. Available: [redacted] Accessed November 2023.

OSPAR (2008). OSPAR Guidance on Environmental Considerations for Offshore Wind Farm Development. OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic, Report reference number 2008-3, available: [redacted]. Accessed: October 2023.

Parry, G.D., Heislers, S., Werner, G.F., Asplin, M.D., and Gason, A. (2002). Assessment of Environmental Effects of Seismic Testing on Scallop Fisheries in Bass Strait. Marine and Freshwater Resources Institute, Report Number 50, Marine and Freshwater Resources Institute: Queenscliff.

Parry, G.D., and Gason, A. (2006). The effect of seismic surveys on catch rates of rock lobsters in western Victoria, Australia Fish. Res., 79, 272-84.

Pawson, M.G., Pickett, G.D., Leballeur, J., Brown, M. and Fritsch, M. (2007). Migrations, fishery interactions, and management units of sea bass (*Dicentrarchus labrax*) in Northwest Europe. ICES Journal of Marine Science. 64: 332-345.

Payne, J.F., Andrews, C.A., Fancey, L.L., Cook, A.L., and Christian, J.R., (2007). Pilot study on the effects of seismic air gun noise on lobster (*Homarus americanus*). Canadian Technical Report of Fisheries and Aquatic Sciences No.2712, V + 46.

Pearson W.H., Skalski, J.R., Skulkin, S.D., and Malme, C.I. (1994). Effects of seismic energy releases on the survival and development of zoeal larvae of Dungeness crab (*Cancer magister*). Mar. Environ. Res., 38, 93-113.

Pedraja, F., Hofmann, V., Lucas, K.M., Young, C., Engelmann, J., and Lewis, J.E. (2018). Motion parallax in electric sensing. Proceedings of the National Academy of Sciences, 115(3), 573-7. Available: [redacted]. Accessed June 2023.

Peña, H., Handegard, N.O., and Ona, E. (2013). Feeding herring schools do not react to seismic air gun surveys. ICES Journal of Marine Science, 70(6), 1174-80, [redacted]. Accessed October 2023.

Phua, C. van den Akker, S. Baretta, M., and van Dalfsen, J. (2002). Ecological Effects of Sand Extraction in the North Sea. The North Sea Foundation.

Piper, A.T., White, P.R., Wright, R.M., Leighton, T.G., and Kemp, P.S. (2019). Response of seaward-migrating European eel (*Anguilla anguilla*) to an infrasound deterrent. Ecological Engineering, 127, 480-6. Available: [redacted]. Accessed June 2023.

Pirotta, V., Grech, A., Jonsen, I.D., Laurance, W.F., and Harcourt, R.G. (2018). Consequences of global shipping traffic for marine giants. Frontiers in Ecology and the Environment, 17(1), pp. 39-47. Available: [redacted] Accessed August 2023.

Planning Inspectorate (2018). Advice Note Nine: Rochdale Envelope. Version 3.

Planning Inspectorate (2019). Advice Note Seventeen: Cumulative effects assessment relevant to nationally significant infrastructure projects. Version 2.

Planning Inspectorate (2020a). Advice Note Seven: Environmental Impact Assessment: Process, Preliminary Environmental Information and Environmental Statements. Version 7.

Planning Inspectorate (2020b). Advice Note Twelve: Transboundary Impacts and Process. Version 6.

Platcha, D.T.T., and Popper, A.N. (2003). Evasive responses of American shad (*Alosa sapidissima*) to ultrasonic stimuli. Acoustic Research Letters Online, 4(25). Available: https://doi.org/10.1121/1.1558376. Accessed October 2023.

Popper, A.N., Hawkins, A.D., Fay, R.R., Mann, D., Bartol, S., Carlson, T., Coombs, S., Ellison, W.T., Gentry, R., Halvorsen, M.B., Lokkeborg, S., Rogers, P., Southall, B.L., Zeddies, D.G., and Tavolga, W.N. (2014). ASA S3/SC1.4 TR-2014 Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI. Springer and ASA Press, Cham, Switzerland.

Popper, A.N. and Hoxter, B. (1987). Sensory and non-sensory ciliated cells in the ear of the sea lamprey, *Petromyzon marinus*. Brain, Behavior and Evolution, 30, 43-61.

Popper, A.N. (2005). A review of hearing by sturgeon and lamprey. Report to US Army Corps of Engineers, Portland District.

Popper, A.N., Salmon, M., and Horch, K.W. (2001). Acoustic detection and communication by decapod crustaceans. Journal of Comparative Physiology A, 187 (2): 83-9.

Raoux, A., Lassalle, G., Pezy, J.P., Tecchio, S., Safi, G., Ernande, B., Maze, C., Le Loc'h, F., Lequesne, J., Girardin, V., Daubin, J.C., and Niquil, N. (2019). Measuring sensitivity of two OSPAR indicators for a coastal food web model under offshore wind farm construction. Ecological Indicators, 96(1), 728-38. Available: [redacted] Accessed October 2023.

Reach I.S., Latto P., Alexander D., Armstrong S., Backstrom J., Beagley E., Murphy K., Piper R. and Seiderer L.J. (2013). Screening Spatial Interactions between Marine Aggregate Application Areas and Atlantic Herring Potential Spawning Areas. A Method Statement produced for BMAPA.

RenewableUK (2013). Cumulative Impact Assessment Guidelines – Guiding Principles for Cumulative Impacts Assessment in Offshore Wind Farms. CIEEM report, available: [redacted] Accessed October 2023.

Rikardsen, A.H., Amundsen, P.A., Knudsen, R., and Sandring, S. (2006). Seasonal marine feeding and body condition of sea trout (*Salmo trutta*) at its northern distribution. ICES Journal of Marine Science, 63(3), 466–75.

Roach, M., Cohen, M., Forster, R., Revill, A. S., and Johnson, M. (2018). The effects of temporary exclusion of activity due to wind farm construction on a lobster (*Homarus gammarus*) fishery suggests a potential management approach. – ICES Journal of Marine Science, 75, 1416–26.

Roberts, L., Cheesman, S., Elliott, M., and Breithaupt, T. (2016). Sensitivity of *Pagurus bernhardus* (L.) to substrate-borne vibration and anthropogenic noise. Journal of Experimental Marine Biology and Ecology, 474, 185-94.

Rosaria, J.C., and Martin, E.R. (2010). Behavioural changes in freshwater crab, *Barytelphusa cunicularis* after exposure to low frequency electromagnetic fields. World J. Fish Mar. Sci., 2, 487-94

Rowley, A.F., Cross, M.E., Culloty, S.C., Lynch, S.A., Mackenzie, C.L., Morgan, E., O'Riordan, R.M., Robins, P.E., Smith, A.L., Thrupp, T.J., Vogan, C.L., Wootton, E.C., and Malham, S.K. (2014). The potential impact of climate change on the infectious diseases of commercially important shellfish populations in the Irish Sea - a review. ICES Journal of Marine Science, 71(4), 741-59. Available: [redacted]. Accessed October 2023.

RPS (2019). Review of Cable installation, protection, migration and habitat recoverability, The Crown Estate, Rev03.

Russell, D.J.F., Brasseur, S.M.J.M., Thompson, D., Hastie, G.D., Janik, V.M., Aarts, G., McClintock, B.T., Matthiopoulos, J., Moss, S.E.W., and McConnell, B. (2014). Marine mammals trace anthropogenic structures at sea. Current Biology, 24, R638–R639.

RWE (2022). Awel y Môr Offshore Wind Farm Preliminary Environmental Information Report Volume 2, Chapter 7: Marine Mammals. Environmental Statement chapter.

Sabatini, M., and Hill, J.M. (2008). *Nephrops norvegicus* Norway lobster. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available: [redacted]. Accessed: September 2023.

Sand, O., Enger, P.S., Karlsen, H.E., Knudsen, F., and Kvernstuen, T. (2000). Avoidance Responses to Infrasound in Downstream Migrating European Silver Eels, *Anguilla anguilla*. Environmental Biology of Fishes, 57, 327-36. Available: [redacted] Accessed October 2023.

Schmidt, M., Philipp, E.E.R., and Abele, D. (2008). Size and age-dependent changes of escape response to predator attack in the Queen scallop Aequipecten opercularis. Marine Biology Research, 4(6), p. 442-450, available: [redacted]. Accessed: October 2023.

Schoeman, R.P., Patterson-Abrolat, C., Plon, S. (2020). A Global Review of Vessel Collisions with Marine Animals. Frontiers in Marine Science, Marine Conservation and Sustainability Review. Available: [redacted] Accessed October 2023.

Scott, K. (2019). Understanding the biology of two commercially important crustaceans in relation to fisheries and anthropogenic impacts. (Heriot-Watt University).

Scott, K., Piper, A.J.R., Chapman, E.C.N., and Rochas, C.M.V. (2020). Review of the effects of underwater sound, vibration and electromagnetic fields on crustaceans. Seafish Report.

Scott, K., Harsanyi, P., Easton, B.A.A., Piper, A.J.R., Rochas, C.M.V., and Lyndon, A.R. (2021). Exposure to Electromagnetic Fields (EMF) from Submarine Power Cables Can Trigger Strength-Dependent Behavioural and Physiological Responses in Edible Crab, *Cancer pagurus* (L.). J. Mar. Sci. Eng. 2021, 9, 776. Available: [redacted] Accessed October 2023.

Scott, W., and Gisborne, B. (2006). Basking Sharks: The Slaughter of BC's Gentle Giants. Vancouver, New Star Books. 88pp.

Scrivener, J.C. (1971). Agonistic behaviour of the American lobster, *Homarus americanus*. (University of Victoria).

Serpetti, N., Benjamins, S., Brain, S., Collu, M., Harvey, B.J., Heymans, J.J., Hughes, A.D., Risch, D., Rosinski, S., Waggitt, J.J., and Wilson, B. (2021). Modelling Small Scale Impacts of Multi-Purpose Platforms: An Ecosystem Approach. Frontiers in Marine Science, Sec. Marine Ecosystem Ecology. Available: [redacted] Accessed May 2022.

Shark Trust (2022). Basking Shark Project – Hotspots and Sightings. Online report, Available: [redacted]. Accessed: October 2023.

Sigray, P., and Andersson, M. (2011). Particle Motion Measured at an Operation Wind Turbine in Relation to Hearing Sensitivity in Fish. The Journal of the Acoustical Society of America, 130, 200-7.

Sigray, P., Andersson, M., Andre, M., Azzellino, A., Borsani, J.F., Bou, M., Castellote, M., Ceyrac, L., Dellong, D., Folegot, T., Hedgeland, D., Juretzek, C., Klauson, A., Leaper, R., Le Courtois, F., Liebschner, A., Maglio, A., Mueller, A., Norro, A., Novellino, A., Outinen, O., Popit, A., Prospathopoulos, A., Thomsen, F., Tougaard, J., Vakadin, P., Weilgart, L. (2023). Setting EU Threshold Values for impulsive underwater sound. Technical Group on Underwater Noise (TG NOISE), MSFD Common Implementation Strategy. Edited by Jean-Noel Druon, Georg Hanke and Maud Casier, Publications Offshore of the European Union, Luxembourg, doi:10.2760/60215, JRC133477.

Simpson, S.D., Purser, J., and Radford, A.N. (2014). Anthropogenic noise compromises antipredator behaviour in European eels. Global Change Biology, 21(2), 586-93. Available: https://doi.org/10.1111/gcb.12685. Accessed November 2023.

Sinclair, R., Lacey, C., Tyler-Walters, H., Sparling, C., and Tillin, H.M. (2020). Developing FeAST for mobile marine species. Scottish Natural Heritage Research Report No. 1175.

Skold, M., Goransson, P., Jonsson, P., Bastardie, F., Blomqvist, M., Agrenius, S., Hiddink, J.G., Nilsson, H.C., and Bartolino, V. (2018). Effects of chronic bottom trawling on soft-seafloor macrofauna in the Kattegat. Marine Ecology Progress Series, 586, 41-55. Available: DOI: https://doi.org/10.3354/meps12434. Accessed November 2023.

Solan, M., Hauton, C., Godbold, J.A., Wood, C.L., Leighton, T.G., and White, P. (2016). Anthropogenic sources of underwater sound can modify how sediment-dwelling invertebrates mediate ecosystem properties. Scientific Reports, 6, 20540.

Solandt, J-L., and Chassin, E. (2013). Marine Conservation Society Basking Shark Watch Overview of data from 2009 to 2013. Ross on Wye, UK: Marine Conservation Society, 6pp.

Soudijn, F.H., van Kooten, T., Slabbekoorn, H., and de Roos, A.M. (2020). Population-level effects of acoustic disturbance in Atlantic cod: a size-structured analysis based on energy budgets. Proceedings of the Royal Society of Biological Sciences, 287(1929). Available: [redacted]. Accessed November 2023.

Speedie, C.D., Johnson, L.A., and Witt, M.J. (2009). Basking Shark Hotspots on the West Coast of Scotland: Key sites, threats and implications for conservation of the species. Scottish Natural Heritage, Inverness, Scotland, Commissioned Report No.339, 59pp. Available: [redacted] Accessed August 2023.

Speiser, D.I., and Johnsen, S. (2008). Scallops visually respond to the size and speed of virtual particles. Journal of Experimental Biology 211, 2066-70.

Stanley, J.A., Radford, C.A., and Jeffs, A.G. (2012). Effects of Underwater sound on Larval settlement. In: Popper, A.N., and Hawkins, A. (eds) The Effects of Noise on Aquatic Life. Advances in Experimental Medicine and Biology, vol 730. Springer, New York, NY. Available: [redacted]Accessed August 2023.

Stanley, D.R., and Wilson, C.A. (1991). Factors affecting the abundance of selected fishes near oil and gas platforms in the Northern Gulf of Mexico. Fishery Bulletin, 89, 149-59.

Stenberg, C., Deurs, M.V., Støttrup, J., Mosegaard, H., Grome, T., Dinesen, G.E., Christensen, A., Jensen, H., Kaspersen, M., Berg, C.W., Leonhard, S.B., Skov, H., Pedersen, J., Hvidt, C.B., Klaustrup, M., Leonhard, S.B. (Ed.), Stenberg, C. (Ed.), and Støttrup, J. (Ed.) (2011). Effect of the Horns Rev 1 Offshore Wind Farm on Fish Communities, Follow-up Seven Years after Construction. DTU Aqua, DTU Aqua Report No. 246.

Svenning, M., Borgstrøm, R., Dehli, T.O., Moen, G., Barett, R., Pedersen, T., and Vader, W. (2005). The impact of marine fish predation on Atlantic salmon smolts (*Salmo salar*) in the Tana Estuary, North Norway, in the presence of an alternative prey, lesser sandeel (*Ammodytes marinus*). Fisheries Research. Available: 10.1016/j.fishres.2005.06.015. Accessed June 2023.

Szostek, C.L., Davies, A.J., and Hinz, H. (2013). Effects of elevated levels of suspended particulate matter and burial on juvenile king scallops *Pecten maximus*. Marine Ecology Progress Series, 474, 155-65. Available: DOI: [redacted]. Accessed June 2023.

Tański, A., Formicki, K., Śmietana, P., Sadowski, M., and Winnicki, A. (2005). Sheltering behaviour of spinycheek crayfish (*Orconectes limosus*) in the presence of an artificial magnetic field. Bull. Fr. La Pech. La Piscic. 376–377, 787–793.

Tasker, M., Amundin, M., Andre, M., Hawkins, A.D., Lang, W., Merck, T., Scholik-Schlomer, A., Teilmann, J., Thomsen, F., Werner, S., and Zakharia, M. (2010). Managing underwater sound in European waters: implementing the Marine Strategy Framework Directive. Advances in Experiment Medicine and Biology, 730, 583-5, doi: 10.1007/978-1-4419-7311-5_132.

Thorstad, E. Todd, C., Uglem, I., Bjørn, P., Gargan, P., Vollset, K., Halttunen, E., Kålås, S., Berg, M., and Finstad, B. (2016). Marine life of the sea trout. Marine Biology, 163.

The Planning Inspectorate (2022). Advice Note ten, Habitat Regulations Assessment relevant to Nationally Significant Infrastructure Projects. Version 9. Available: https://infrastructure.planninginspectorate.gov.uk/legislation-and-advice/advice-notes/advice-note-ten/. Accessed November 2023.

Tricas, T.C. and Carlson, B.A. (2012). Electroreceptors and magnetoreceptors. In: Cell Physiology Source Book: Essentials of Membrane Biophysics (N. Sperlakis, ed.), 4th ed. Academic Press, San Diego, 705-725.

Tyler-Walters, H., Tillin, H.M., d'Avack, E.A.S., Perry, F., and Stamp, T. (2023). Marine Evidence-based Sensitivity Assessment (MarESA) – Guidance Manual. Marine Life Information Network (MarLIN). Marine Biological Association of the UK, Plymouth, p. 170, available: [redacted] accessed: October 2023.

Ueno, S., Lövsund, P., and Öberg, P.Å. (1986). Effect of time-varying magnetic fields on the action potential in lobster giant axon. Medical and Biological Engineering and Computing 24(5), 521-526.

van Deurs, M., Grome, T.M., Kaspersen, M., Jensen, H., Stenberg, C., Sørensen, T.K., Støttrup, J., Warnar, T., and Mosegaar, H. (2012). Short and Long Term Effects of an Offshore Wind Farm on Three Species of Sandeel and their Sand Habitat. Marine Ecology Progress Series, 458, 169-180.

Van Hal, R., Griffioen, A.B. and van Keeken, O.A. (2017). Changes in fish communities on a small spatial scale, an effect of increased habitat complexity by an offshore wind farm. Marine Environmental Research. 126, 26–36.

Van Waerebeek, K., Baker, A.N., Félix, F., Gedamke, J., Iniguez, M., Sanino, G.P., et al. (2007). Vessel collisions with small cetaceans worldwide and with large whales in the Southern Hemisphere, an initial assessment. Lat. Am. J. Aquat. Mamm. 6, 43–69. doi: 10.5597/lajam00109.

Vandendriessche, S., Derweduwen, J. and Hostens, K. (2015). Equivocal effects of offshore wind farms in Belgium on soft substrate epibenthos and fish assemblages. Hydrobiologia. 756, 19–35.

Vattenfall, A., and Skov-og. N. (2006). Danish offshore wind-Key environmental issues (No. NEI-DK-4787). DONG Energy.

Wahlberg, M. and Westerberg, H. (2005). Hearing in fish and their reactions to sounds from offshore wind farms. Marine Ecology Progress Series. 288, 295–309.

Wale, M.A., Simpson, S.D., and Radford, A.N. (2013). Size-dependent physiological responses of shore crabs to single and repeated playback of ship noise. Biology Letters, 9(2), https://doi.org/10.1098/rsbl.2012.1194.

Wale, M.A., Briers, R.A., Hartl, M.G.J., Bryson, D., and Diele, K. (2019). From DNA to ecological performance: Effects of anthropogenic noise on a reef-building mussel. Science of the Total Environment, 689, 126-132, 10.1016/j.scitotenv.2019.06.380.

Walker, M.M. (1984). Learned magnetic field discrimination in yellowfin tuna, *Thunnus lbacares*. Journal of Comparative Physiology A: Neuroethology, Sensory, Neural, and Behavioral Physiology 155(5), 673-9.

Westerberg, H., Langenfelt, I., Andersson, I., Wahlberg, M., and Sparrevik, E. (2007). Inverkan på fisk och fiske av SwePol Link - Fiskundersökningar 1999-2006 (in Swedish). Swedish Fisheries Agency.

Westerberg, H., and Langenfelt, I., (2008). Sub-sea power cables and the migration behaviour of the European eel. Fisheries Management and Ecology, 15, 369-75.

White, M., Gaffney, S., Bowers, D.G., and Bowyer, P. (2003). Interannual Variability in Irish Sea Turbidity and Relation to Wind Strength. Biology and Environment: Proceedings of the Royal Irish Academy, 10B(2), .83-90. Available: [redacted]. Accessed September 2023.

Wilber, D., and Clarke, D.G. (2001). Biological Effects of Suspended Sediments: A Review of Suspended Sediment Impacts on Fish and Shellfish With Relation to Dredging Activities in Estuaries. North American Journal of Fisheries Management, 21(4), 855-75, DOI:10.1577/1548-8675(2001)021<0855:BEOSSA>2.0.CO;2.

Wilding, C.M., Wilson, C.M., and Tyler-Walters, H. (2020). *Cetorhinus maximus* Basking shark. In Tyler-Walters H. Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available: [redacted] Accessed September 2023.

Wilhelmsson, D., Malm, T. and Ohman, M.C. (2006a). The Influence of Offshore Wind Power on Demersal Fish. ICES Journal of Marine Science 63, 775-84.

Wilhelmsson, D., Yahya, S.A.S. and Ohman, M.C. (2006b). Effects of high-relief structures on cold temperate fish assemblages: A field experiment. Marine Biology Research, 2006; 2, 136-47.

Wilhelmsson, D., Malm, T., Thompson, R., Tchou, J., Sarantakos, G., McCormick, N., Luitjens, S., Gullström, M., Patterson Edwards, J.K., Amir, O. and Dubi, A. (2010). Greening Blue Energy: Identifying and Managing the Biodiversity Risks and Opportunities of Offshore Renewable Energy. Edited by Gland, Switzerland: IUCN. 102pp.

Williams, R. Wright, A.J., Ashe, E., Blight, L.K., Bruintjes, R., Canessa, R., Clark, C.W., Cullis-Suskui, S., Dakin, D.T., Erbe, C., Hammonds, P.S., Merchant, N.D., O'Hara, P.D., Purser, J., Radford, A.N., Simpson, S.D., Thomas, L., and Wale, M.D. (2015). Impacts of anthropogenic noise on marine life: publication patterns, new discoveries, and future directions in research and management. Ocean Coast. Manag., 115, 17-24.

Winter H.V., Aarts, G., and Van Keeken, O.A. (2010). Residence time and behaviour of sole and cod in the Offshore Wind Farm Egmond aan Zee (OWEZ) IMARES, Wageningen YR Report number: C038/10, 50pp.

Woodruff, D.L., Ward, J.A., Schultz, I.R., Cullinan, V.I., and Marshall, K.E. (2012). Effects of Electromagnetic Fields on Fish and Invertebrates Task 2.1.3: Effects on Aquatic Organisms Fiscal Year 2011 Progress Report. US Department of Energy.

Wright, P.J., Jensen, H., and Tuck, I. (2000). The influence of sediment type on the distribution of the lesser sandeel, *Ammodytes marinus*. Journal of Sea Research 44, 243-256.

Wright, A.J., and Cosentino, A.M. (2015). JNCC guidelines for minimising the risk of injury and disturbance to marine mammals from seismic surveys: We can do better. Marine Pollution Bulletin, 100(1), 231-9, [redacted]

Zhou, W., Xu, X., Tu, X., and Chen, Y. (2016). Preliminary exploration for effects of sound stimulus on the movement behavior of *Litopenaeus vannamei*. in 2016 IEEE/OES China Ocean Acoustics Symposium, COA 2016 4–9 (IEEE, 2016). doi:10.1109/COA.2016.7535775.