The Sizewell C Project

6.3 Volume 2 Main Development Site

Chapter 22 Marine Ecology and Fisheries

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22. Marine Ecology and Fisheries

22.1 Introduction

22.1.1 This chapter of **Volume 2** of the **Environmental Statement (ES)** presents an assessment of the Marine Ecology and Fisheries effects arising from the construction and operation of the Sizewell C power station at the main development site (referred to throughout this volume as 'the proposed development'). This includes an assessment of potential impacts, the significance of effects, the requirements for mitigation and the residual effects.

22.1.2 Detailed descriptions of the site, the proposed development and the different phases of development are provided in **Chapters 1** to **4** of this volume of the **ES**. A description of the anticipated activities for the decommissioning of the Sizewell C power station, including a summary of the types of environmental effects likely to occur is provided in **Chapter 5** of this volume. A glossary of terms and list of abbreviations used in this chapter is provided in **Volume 1, Appendix 1A** of the **ES**.

22.1.3 The Marine Ecology and Fisheries **ES** assessments form part of the wider marine discipline assessment and are informed by the results presented in previous **ES** chapters including:

- Coastal geomorphology and hydrodynamics in **Chapter 20** of this volume.
- Marine water quality and sediment in **Chapter 21** of this volume.

22.1.4 Marine Ecology and Fisheries assessments are contextualised against the baseline conditions at the main development site and wider southern North Sea area. These characterisation reports are presented in the following technical appendices of this chapter:

- Phytoplankton characterisation. BEEMS Technical Report TR346. **Appendix 22A** of this volume.
- Zooplankton characterisation. BEEMS Technical Report TR315. **Appendix 22B** of this volume.
- Benthic ecology characterisation. BEEMS Technical Report TR348. **Appendix 22C** of this volume.

- Fish characterisation. BEEMS Technical Report TR345. **Appendix 22D** of this volume.

- Marine mammal characterisation. BEEMS Technical Report TR324. **Appendix 22E** of this volume.

- Commercial and recreational fisheries characterisation. BEEMS Technical Report TR123. **Appendix 22F** of this volume.

22.1.5 Impacts of the proposed development have been identified and assessed in detail in a series of technical reports that form appendices to the **ES**. Impact assessments are considered in relation to the baseline environmental conditions to determine the potential for effects from the proposed development and to ascertain if effects would be significant. The primary Technical Reports that inform the assessments presented within this chapter form appendices for the Sizewell C DCO submission and include:

- Sizewell Coastal Geomorphology and Hydrodynamics: Synthesis for Environmental Impact Assessment (MSR1/4). BEEMS Technical Report TR311. **Appendix 20A** of this volume;

- Sizewell Marine Sediment Quality. BEEMS Technical Report TR305. **Appendix 21D** of this volume;

- Sizewell C- Marine Water and Sediment Quality Synthesis (MSR2/6). BEEMS Technical Report TR306. **Appendix 21E** of this volume;

- Sizewell C - H1 Assessment. BEEMS Technical Report TR193. **Appendix 21F** of this volume;

- Sizewell Entrainment Predictions. BEEMS Technical Report TR318. **Appendix 22G** of this volume;

- Modelling the effect of Sizewell C entrainment on the phytoplankton of Sizewell Bay. BEEMS Technical Report TR385. **Appendix 22H** of this volume;

- Sizewell C - Impingement predictions based upon specific cooling water system design. BEEMS Technical Report TR406. **Appendix 22I** of this volume;

- Modelling of sediment dispersion of dredge material from Sizewell C construction and operation. BEEMS Technical Report TR480. **Appendix 22J** of this volume; and

- Underwater noise effects assessment at Sizewell C. BEEMS Technical Report TR312. **Appendix 22L** of this volume.

22.1.6 Following consultation on the 2019 SZC Co. Stage 3 Preliminary Environmental Information (PEI) (Ref. 22.1) and through engagement with statutory bodies through the Marine Technical Forum , a final Scoping Report for the marine ecology and fisheries assessment was produced **Appendix 22M** of this volume. The marine ecology and fisheries Scoping Report identified the impacts with the potential to cause significant effects on different receptor groups which require further assessment in the **ES**. Furthermore, the report scoped out with appropriate justification, activities where the potential to cause impacts exist but the magnitude of the impact is considered negligible and therefore, would not warrant further investigation. Comments received from the statutory stakeholders have been addressed in the second edition of the marine ecology and fisheries final Scoping Report, which is appended to the **ES**:

- Sizewell C- Marine Ecology and Fisheries Final Scoping Report. British Eneregy Estuarine and Marine Studies (BEEMS) Technical Report TR490. **Appendix 22M** of this volume.

a) Marine ecology and fisheries assessment structure

22.1.7 The Marine Ecology and Fisheries **ES** chapter follows the structure of technical chapters maintained throughout the **ES**, as explained in **Volume 1, Chapter 6**. Assessment methodologies conform to those detailed in the updated 2019 SZC Co. EIA Scoping Report (Ref. 22.2) included within **Volume 1, Appendix 6A** of the **ES**.

22.1.8 Following consultation feedback on the original 2014 SZC Co. EIA Scoping Report (Ref. 22.3), the marine ecology and fisheries assessment has been split up by receptor groups, as follows:

- Plankton.

- Benthic Ecology.

- Fish Ecology.

- Marine Mammals.
- Indirect and Food Web Effects.
- Fisheries.

22.1.9 Receptor specific assessments allow technical specialists and consultees the opportunity to review ecological receptors in self-contained sections of the **ES**. To aid this process, detailed summaries of receptor baseline conditions for each receptor group are provided in the relevant section allowing the assessments to be stand-alone.

22.1.10 A cumulative effects assessment (CEA) for marine ecology and fisheries receptors is provided in **Volume 10, Chapter 4** of the **ES**.

22.1.11 Assessments are based on the components of the proposed development and consider construction and operational impacts of each component. The development components considered in the marine ecology and fisheries assessments presented within this chapter during construction and operation of the proposed development comprise of:

- the coastal defence features;
- the beach landing facility (BLF);
- the cooling water infrastructure (intakes and outfalls);
- the fish return and recovery (FRR) system, and;
- the combined drainage outfall (CDO).

22.1.12 Activities associated with each development component have been identified and the relevant pressures with the potential to affect receptors are assessed. The intention of this structure is to allow rapid identification of the potential for effects for any given development component on receptors of interest. A description of the anticipated activities for the decommissioning of the Sizewell C power station, including a summary of the types of environmental effects likely to occur is provided in **Volume 2 Chapter 5** of the **ES**.

22.1.13 Works above the mean high water mark are not directly referred to in this chapter. These include (but are not limited to) works associated with the

Sizewell B relocated facilities proposals and the off-site developments considered in this volume of the **ES**.

22.2 Legislation, policy and guidance

22.2.1 **Volume 1, Chapter 3** of the **ES** identifies and describes legislation and policy relevance to the assessment of the likely significant effects of the Sizewell C Project. Legislation, policy and guidance of specific relevance to the assessment of marine ecology and fisheries impacts is presented in **Volume 1, Appendix 6R** of the **ES**.

22.2.2 This section lists the specific legislation, policy and guidance of relevance to the marine ecology and fisheries assessment that is further described in **Volume 1, Appendix 6R** of the **ES**.

a) International

22.2.3 The following international legislation and conventions are relevant to the marine ecology assessment, as described in **Volume 1, Appendix 6R** of the **ES**.

- Directive 92/43/ECC on the Conservation of natural habitats and of wild fauna and flora (the Habitats Directive).
- Directive 2009/147/EC on the conservation of wild birds (the Birds Directive).
- Ramsar Convention.
- The Oslo and Paris convention for the protection of the marine environment of the north-east Atlantic (OSPAR).
- The Bonn Convention on the Conservation of Migratory Species of Wild Animals.
- The Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas.
- The Bern Convention of the Conservation of Wildlife and Natural Habitats 1979.
- The Convention on Biological Diversity 1992.

- Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy (the Water Framework Directive).

- Directive 2008/56/EC on establishing a framework for community action in the field of marine environmental policy (the Marine Strategy Framework Directive).

22.2.4 Furthermore, the following international legislation and policies are relevant to the fisheries assessment, as described in **Volume 1, Appendix 6R** of the **ES:**

- European Union Common Fisheries Policy 2009, and;

- EU directives and regulations listed in the Marine Management Organisation's (MMO) 'Blue Book'.

b) National

i. Legislation

22.2.5 The following national legislation are relevant to the marine ecology and fisheries assessments, as described in **Volume 1, Appendix 6R** of the **ES:**

- The Water Environment (Water Framework Directive) (England and Wales) Regulations 2003.

- Wildlife and Countryside Act 1981.

- Countryside and Rights of Way Act 2000.

- Natural Environment and Rural Communities Act 2006.

- Marine and Coastal Access Act 2009.

- Conservation of Habitats and Species Regulations 2017.

- Salmon and Freshwater Fisheries Act 1975.

- Registration of Buyers and Sellers and Designation of Fish Auctions and Site Regulations.

22.2.6 Furthermore, the management of inshore fisheries in Suffolk falls mainly within the remit of the Eastern Inshore Fisheries and Conservation Authority and is governed by Eastern Inshore Fisheries and Conservation Authority byelaws. The Environment Agency is responsible for management of fisheries upstream of any river beyond the highest point to which ordinary tides flow, beyond the road bridges on the A12 at Lowestoft, the A12 across the River Blyth, the B1069 across the River Alde, the A1152 across the River Deben, and the A137 across the River Orwell, and in freshwaters. The Environment Agency is also responsible for sea trout and eel fisheries out to the 6nm limit (although, in effect, the Eastern Inshore Fisheries and Conservation Authority manages the coastal sea trout fishery).

ii. Policy

22.2.7 As stated in **Volume 1, Chapter 3** of the **ES**, the Overarching National Policy Statement (NPS) for Energy (NPS EN-1) (Ref. 22.4) when combined with the NPS for Nuclear Power Generation (NPS EN-6) (Ref. 22.5) provides the primary basis for decisions on applications for nuclear power generation developments. In addition, whilst the development consent for the proposed development would be determined in accordance with NPS EN-1 and EN-6, the application must also have regard to the UK Marine Policy Statement (MPS) 2011 (Ref. 22.6). The requirements of NPS EN-1, EN-6 and the MPS relevant to the marine ecology and fisheries assessment, and where these have been addressed within this **ES** are set out in **Volume 1, Appendix 6R** of the **ES**.

c) Regional

22.2.8 The following regional policies are relevant to the marine ecology and fisheries assessment, as described in **Volume 1, Appendix 6R** of the **ES:**

- East Inshore Marine Plan;
- Anglian River Basin District (RBD) Eel Management Plan; and
- Suffolk Shoreline Management Plan.

d) Local

22.2.9 The following local policies are relevant to the marine ecology assessment, as described in **Volume 1, Appendix 6R** of the **ES**:

- Suffolk Coastal District Local Plan July 2013 – policy SP13 lists the assessment of ecological impacts on nearby designated sites as a local issue to be considered by the Council in the Local Impact Report if an application for the Sizewell C power station is submitted.

e) Guidance

22.2.10 This chapter draws on a range of guidance documents including but not limited to assessment methodologies, chemical standards, underwater noise assessment threshold and mitigation guidelines and cooling water infrastructure best practice guidance. Standards and guidelines applied are detailed in the relevant sections and technical appendices.

22.2.11 The following guidance documents have been referred to within the marine ecology and fisheries assessment methodology, as described in **Volume 1, Appendix 6R** of the **ES**:

- Chartered Institute of Ecology Environmental Management (CIEEM) Guidelines for ecological impact assessment in Britain and Ireland: Terrestrial, Freshwater, Coastal and Marine (Ref. 22.7).
- Cefas (2004) Offshore Wind farms: Guidance note for Environmental Impact Assessment in respect of FEPA and CPA requirements (Ref. 22.8).
- The potential effects of the proposed development were identified by applying an activities-pressures matrix following the approach outlined in the Healthy and Biologically Diverse Seas Evidence Group (Ref. 22.9).

22.3 Methodology

a) Scope of the assessment

22.3.1 The **ES** assessment method that has been applied for the Sizewell C Project is detailed in **Volume 1**, **Chapter 6** of the **ES**. The full method of assessment for marine ecology and fisheries that has been applied for the proposed development is included in **Volume 1, Appendix 6R** of the **ES**.

22.3.2 This section provides specific details of the marine ecology and fisheries methodology applied to the assessment of the proposed development to provide appropriate context for the assessments that follow.

22.3.3 The scope of assessment considers the impacts of the construction and operational phases of the proposed development. Commissioning considerations, primarily relating to discharges during cold flush testing of the reactors, are considered as part of the construction assessment.

22.3.4 A high-level description of the anticipated activities for the decommissioning of the Sizewell C power station, including a summary of the types of environmental effects likely to occur is provided in **Chapter 5** of this volume. As discussed in **Chapter 5**, for the decommissioning of the proposed development, it is necessary to obtain prior consent from the Office for Nuclear Regulation (ONR) and undertake a separate EIA at the time of submission. Therefore, a further assessment of decommissioning will be made based on the available technology, methods of decommissioning, and baseline environmental conditions at the time, following a process of consultation.

22.3.5 The potential effects of the proposed development were identified by applying an activities-pressures matrix following the approach outlined in the Healthy and Biologically Diverse Seas Evidence Group (Ref. 22.9). The initial step reviewed the construction and operational elements of each development component to determine the site-specific list of activities. The full list of activities for each development component was cross tabulated with the OSPAR Intercessional Correspondence Group on Cumulative Effects (ICG-C) list of pressures (Ref. 22.10). The OSPAR ICG-C list of pressures were applied to allow a consistent recognisable and defined list of pressures for assessment purposes.

22.3.6 Pressures fall within the overarching themes of:

- Hydrological changes.
- Pollution and other chemical changes from sediment resuspension or discharges.
- Physical loss.
- Physical damage.
- Other physical damage (e.g. noise and light).
- Biological pressures.

22.3.7 Assessments pertaining to radiological considerations of the proposed development are detailed in **Volume 2 Chapter 25** of the **ES.**

22.3.8 Each overarching pressure theme has a number of specific pressures that were cross tabulated with the development activities. Cross tabulation allowed a formal means to scope out activities with no pressure pathways and identify potential activity-pressure pathways on a given receptor. The

Marine Ecology and Fisheries Scoping Report, provided in **Appendix 22M** of the **ES**, identifies the impacts with the potential to cause significant effects on different receptor groups which require further assessment in the **ES**.

22.3.9 The scope of this assessment has also been established through a formal EIA scoping process undertaken with the Planning Inspectorate (PINS). A request for an EIA scoping opinion was initially issued to PINS in 2014, with an updated request issued in 2019 found in **Volume 1, Appendix 6A** of the **ES**.

22.3.10 Comments raised in the EIA scoping opinion received in 2014 and 2019 have been taken into account in the development of the assessment methodology. These are detailed in **Volume 1**, **Appendices 6A** to **6C** of the **ES**.

b) Consultation

22.3.11 The scope of the assessment has also been informed by ongoing consultation and engagement with statutory consultees throughout the design and assessment process. To facilitate engagement with statutory stakeholders on the marine assessments, the Sizewell C Marine Technical Forum (MTF) was established on 26 March 2014.

22.3.12 The Marine Technical Forum has an independent chair, supported by a technical secretariat supplied by SZC Co. together with nominated technical representatives from Natural England, the Environment Agency and the Marine Management Organisation (MMO), together with consultants working on their behalf. The Eastern Inshore Fisheries and Conservation Authority, Suffolk Country Council and the Royal Society for the Protection of Birds (RSPB) have also been in attendance at marine ecology and fisheries Marine Technical Forum meetings as participating guests.

22.3.13 The key aim of the Marine Technical Forum is to provide a means whereby the nature of the marine monitoring at Sizewell and the results and their outcomes can be readily discussed. Agreement or consensus between SZC Co. and the statutory environmental bodies, and clarity on any points of difference is sought. The Marine Technical Forum aims to seek a common view whilst respecting the independence of the statutory environmental bodies so that relevant advice to SZC Co. may be distilled, and that statutory environmental bodies' consultations and decision making may be best informed.

22.3.14 In advance of the Sizewell C DCO, the Sizewell C Marine Technical Forum has sought to develop a shared understanding of the status and sufficiency of the marine studies advanced by SZC Co., the assessments of the Sizewell C Project impact based upon these studies and the proposed means of mitigation, in order both to facilitate advice given by its members to the PINS and inform their own procedures.

22.3.15 Since November 2018, the Marine Technical Forum has convened on four occasions for marine ecology and fisheries discussions alone. The meetings have focused on the following areas:

- 1st November 2018: Presentations of evidence in support of the Stage 3 PEI.
- 1st – 2nd May 2019: Presentations of assessments for all receptors and updates to underwater noise and dredge modelling assessments.
- 18th June 2019: Focussed session on impingement and entrainment assessments.
- 18th December 2019: Sizewell B visit to observe impingement monitoring followed by presentations on updates to impingement and entrainment assessments and *Sabellaria spinulosa* at the site.

c) Study area

22.3.16 The geographical extent of the marine ecology study area was determined by the potential zone of influence (ZOI) of the proposed development.

22.3.17 The Greater Sizewell Bay (GSB) forms the initial reference area for marine assessment purposes. The GSB extends from Blyth Piers in the north to the Coralline Crag outcrops near Thorpeness in the south and this is provided in **Figure 20.1** of **Chapter 20** of this volume. The seaward boundary extends to the eastern flank of the Sizewell-Dunwich Bank, to include the spatial extent of the proposed cooling water infrastructure. The landward limit is delineated by the mean high water springs (MHWS) tidal mark.

22.3.18 The GSB is an open coastal system and water exchanges between the bay and the rest of the southern North Sea. The spatial extent of potential impacts from the proposed development are therefore dependent on the tidal regime and the transmission and persistence of the pressure[1]. The ZOI has been informed by the largest-scale potential impacts associated with the proposed development, which include:

[1] Pressures are the mechanism through which an impact may occur. Pressures include chemical or physical changes in the environment, such as chemical discharges or underwater noise. The transmission and persistence of pressures along with features of the physical environment, such as bathymetry and tidal flows influence the ZOI.

- Results from underwater noise modelling during construction activities (impact piling, dredging, drilling);
- Results from suspended sediment plume modelling associated with dredging and drilling activities; and
- Thermal plume modelling of the in-combination impacts of Sizewell B and Sizewell C cooling water discharges (applying the 2ºC mean excess temperature contour at the seabed).

22.3.19 The consultation process identified the need to consider receptor specific effects beyond the ZOI, particularly for highly mobile species. Effects on marine ecological receptors are dependent on the distribution, mobility and ecology of the species being considered relative to the impact. Therefore, assessments determine the receptor-specific spatial scale within the 'Impact Magnitude' narrative.

22.3.20 The boundary of the study area for commercial fisheries was determined to be the International Council for the Exploration of the Sea (ICES) rectangles accounting for the local fishery (ICES rectangle 33F1) and the regional context (ICES rectangles 32F1, 32F2, 33F2, 34F1 and 34F2). The boundary of the study area for recreational angling from beaches and boats was ICES rectangle 33F1. The location of ICES rectangles relative to the proposed development, including spawning and nursery ground information for selected species is presented in **Figures 22.11** to **22.14**.

22.3.21 Some assessment, such an impingement and entrainment require effects to be considered at the scale of the stock or population, provided in

22.3.22

22.3.23 **Table** 22.110; **Section 22.8c)** in this chapter. Given the wide geographic scale of some fish stock assessment units and the potential for other developments with similar activities to act cumulatively on same fish stocks, a dedicated cumulative effects assessment (CEA) has been completed. The effects of entrainment and impingement from the development of new nuclear builds (NNBs) on fish stocks with overlapping geographic ranges has been assessed in **Volume 10 Chapter 4** of the **ES.**

d) Designated sites within the study area

22.3.24 A number of statutory and non-statutory designated sites are located within the ZOI of the proposed development.

22.3.25 The proposed development has the potential to affect ecological sites designated as being of European or International Importance for nature conservation. Consequently, a **Shadow Habitats Regulations Assessment** (**HRA**) (Doc Ref. 5.10) is submitted to the PINS with the Sizewell C DCO application. The **Shadow HRA** (Doc Ref. 5.10) details the likely significant effects on the designated features of European Sites including SPAs, SACs and Ramsar sites within the ZOI of the proposed development (Doc Ref. 5.10).

22.3.26 In conjunction with the **Shadow HRA** (Doc Ref. 5.10) this chapter considers the specific marine components (below MHWS) of designated European Sites. During scoping, details of which can be found in **Appendix 22M** of this volume, potential marine impacts of the proposed development on Sites of Special Scientific Interest (SSSIs) and Country Wildlife Sites were also considered. The results of the scoping exercise are available in the Edition 2 of the Marine Ecology and Fisheries Final Scoping Report provided in **Appendix 22M** of this volume.

22.3.27 Direct effects on marine ornithological receptors and vegetated shingle (annual vegetation of drift lines) are considered in an EIA context within Terrestrial Ecology and Ornithology **Chapter 14** of this volume. Indirect effects on designated features, including effects on prey species or effects on supporting habitat, are considered herein and within Coastal Geomorphology and Hydrodynamics **Chapter 20** of this volume**,** as appropriate. A scoping exercise identified the statutory and non-statutory sites with marine features relevant to marine ecology and fisheries, provided in **Appendix 22M** of the **ES**. **Table 22.1** provides a summary of the sites considered within this chapter and provides a means of signposting where assessments on receptors beyond the scope of this chapter are provided.

22.3.28 Food web effects and indirect effects on designated features mediated through changes in the abundance and distribution of marine prey species are considered within this chapter.

Table 22.1: Assessment signpost for statutory and non-statutory designated sites with marine features.

Site and location	Description of site features with marine components	How and where is the feature assessed in the ES?
Minsmere to Walberswick SPA and Ramsar site. **Located adjacent to the north-east boundary of the main development site.**	The site consists of a mosaic of marshes, dykes, reedbeds, brackish lagoons, mudflats, shingle and driftlines. The SPA is designated for breeding, wintering and passage bird populations of European importance, including breeding populations of marsh harrier (*Circus aeruginosus*), bittern (*Botaurus stellaris*), avocet (*Recurvirostra avosetta*) and little tern (*Sterna albifrons*). The Ramsar site supports a diverse range of wetland bird species in nationally important numbers.	Changes to coastal process and mitigation measures that could have a bearing on the SPA are considered in Geomorphology and Hydrodynamics **Chapter 20** of this volume, including narrative of potential future shorelines scenarios. Potential effects on marine ornithological receptors are considered in Terrestrial Ecology and Ornithology **Chapter 14** of this volume. Likely significant effects on designated bird species are assessed as part of the **Shadow HRA** (Doc Ref. 5.10). This chapter considers the following issues: – The potential for chemical discharges to impact the wetland habitats through direct intersection, overtopping or percolation through the dune systems. – Potential changes in the availability of marine prey species of designated birds due to avoidance behaviours (e.g. underwater noise) or mortality (e.g. impingement). – The potential for thermal/chemical discharges to disrupt migratory pathways of glass eels into the Minsmere sluice (prey item for bitterns).
Minsmere to Walberswick Heaths and Marshes SAC Located adjacent to the north-east boundary of the main development site.	The site is designated for ‘annual vegetation of drift lines’. Species include sea sandwort (*Honckenya peploides*) and sea beet *Beta vulgaris* ssp. *maritima*.	The potential for chemical discharges to impact the wetland habitats through direct intersecion, overtopping or perculation through the dune sytems is considered herein. Changes to coastal process and mitigation measures that could have a bearing on the SAC are considered in Geomorphology and

Site and location	Description of site features with marine components	How and where is the feature assessed in the ES?
		Hydrodynamics **Chapter 20** of this volume, including narrative of potential future shorelines scenarios. Annual vegetation of drift lines is assessed in Terrestrial Ecology and Ornithology, **Chapter 14** of this volume.
Minsmere to Walberswick Heaths and Marshes SSSI. Adjacent to the north of the main development site.	This SSSI contains a complex series of habitats, notably mudflats, shingle beach, reedbeds, heathland and grazing marsh. These habitats combine to create an area of exceptional scientific interest that supports a diverse breeding and wintering bird assemblage and a diverse range of invertebrates.	The potential for chemical discharges to impact the wetland habitats through direct intersecion, overtopping or perculation through the dune sytems is considered herein. Annual vegetation of drift lines is assessed in Terrestrial Ecology and Ornithology, **Chapter 14** of this volume. Changes to coastal process and mitigation measures that could have a bearing on the SSSI are considered in Geomorphology and Hydrodynamics **Chapter 20** of this volume, including narrative of potential future shorelines scenarios.
Alde-Ore Estuary SPA and Ramsar site. Approximately 5km south of the main development site.	The Alde-Ore Estuary is identified as a Ramsar site for its diverse and nationally important wetland bird species, and as an SPA because it supports bird populations of European importance, including breeding populations of avocet, little tern and sandwich tern (*Sterna sandvicensis*), and over-wintering ruff (*Philomachus pugnax*). The site also supports important migratory populations of lesser black-backed gull (*Larus fuscus*) during the breeding season and redshank (*Tringa tetanus*) during the winter. The site also supports a seabird assemblage of international importance (including little tern, sandwich tern, lesser black-backed gull, black headed gull (*Larus ridibundus*) & herring gull (*Larus argentatus*).	This chapter considers the following issues: – Potential for chemical discharges to intersect the wetlands within the mouth of the Alde-Ore Estuary at ecologically relevant levels. – Potential changes in the availability of marine prey species of designated birds due to avoidance behaviours or mortality. Likely significant effects on designated bird species is assessed as part of the **Shadow HRA** (Doc Ref. 5.10). Potential effects on marine ornithological receptors are considered in Terrestrial Ecology and Ornithology **Chapter 14** of this volume.
Outer Thames Estuary SPA Includes the area of	The Outer Thames Estuary SPA qualifies by supporting populations of European importance of wintering red-throated diver (*Gavia stellata*).	This chapter considers potential changes in the availability of marine prey species of designated birds due to avoidance behaviours or

Site and location	Description of site features with marine components	How and where is the feature assessed in the ES?
open sea adjacent to the main development site.	The site also protects foraging areas for little tern and common tern during the breeding season enhancing the protection already afforded to their feeding and nesting areas in the adjacent coastal SPAs (including the Minsmere to Walberswick SPA).	mortality associated with impacts including but not limited to underwater nosie entrapment and/or thermal/chemical discharges. Likely significant effects on designated bird species is assessed as part of the **Shadow HRA** (Doc Ref. 5.10).
Orfordness-Shingle Street SAC. Approximately 8km south of the main development site.	The habitats that are a primary reason for selection of this site are 'coastal lagoons', 'annual vegetation of drift lines' and 'perennial vegetation of stony banks'. The coastal lagoons are not a marine feature as they occur landward of highest astronomical tide, and form part of the percolation lagoon features on the east coast.	The potential for chemical discharges to impact the wetland habitats through direct intersecion, overtopping or perculation through the dune sytems is considered herein.
Southern North Sea SAC Includes the area of open sea adjacent to the main development site.	The Southern North Sea SAC is designated for the Annex II species harbour porpoise (*Phocoena phocoena*) for both Winter and Summer seasons. The area supports approximately17.5% of th e UK North Sea Management Unit (MU) population.	Harbour porpoise are a key species. Direct effects on porpoise, and indirect effects on prey species will be considered further.
Orford Inshore MCZ. Offshore, approximately 16km south-east of the main development site and 14km from the Alde Ore estuary	The site is composed of subtidal mixed sediments that form important nursery and spawning grounds for some species of fish, including Dover sole, lemon sole and sandeels. Burrowing anemones, sea cucumbers, urchins, starfish and nationally important shark species are found at the site. The area is an important foraging area for seabirds. Harbour porpoise pass through the site. The protected features at the site are 'subtidal mixed sediments'.	The proposed development is not considered to have any effect on the management objectives of the protected features at the site as it is situated beyond the ZOI for development impacts. However, the mixed sediments provide nursery and spawning grounds for fish. The potential for the proposed development to affect fish species utilising the MCZ, primarily through entrapment, is considered.
Humber Estuary SAC. Approximately 220km north of the main development site.	The site is designated for the Annex II species grey seal (*Halichoerus grypus*).	Whilst the SAC is located well beyond the ZOI of the proposed development, grey seals are highly mobile species and individuals from the Humber Estuary SAC may transit past the site or utilise the area for foraging.

Site and location	Description of site features with marine components	How and where is the feature assessed in the ES?
		Grey seals are a key species for the the Marine Ecology and Fisheries **ES**. Direct effects on seals, and indirect effects on prey species will be considered further.
Leiston to Aldeburgh SSSI Approximately 1km south of the main development site.	This SSSI contains a rich mosaic of habitats, including acid grassland, heath, scrub, woodland, fen, open water and vegetated shingle. There is a gradual transition between the vegetated shingle of the strandline community and the shingle heath resulting from increasing stability and distance from tidal influence.	Changes to coastal process and mitigation measures that could have a bearing on the SSSI are considered in Geomorphology and Hydrodynamics **Chapter 20** of this volume. Annual vegetation of drift lines is assessed in Terrestrial Ecology and Ornithology, **Chapter 14** of this volume. Features are above MHWS and no further assessment is made in this chapter.
Suffolk Shingle Beaches Country Wildlife Sites.	The Country Wildlife Site forms part of the east coast vegetated shingle matrix and supports coastal sand and shingle habitats, a diverse assemblage of invertebrate species is found at the coastal site.	Changes to coastal process and mitigation measures that could have a bearing on the Country Wildlife Sites are considered in Geomorphology and Hydrodynamics **Chapter 20** of this volume. Annual vegetation of drift lines is assessed in Terrestrial Ecology and Ornithology, **Chapter 14** of this volume. Features are above MHWS and no further assessment is made in this chapter.

e) Assessment scenarios

22.3.29 Marine Ecology and Fisheries ES assessment scenarios consider the construction, commissioning and operational phases of the proposed development.

22.3.30 The construction period is expected to last between nine and 12 years. For assessment purposes, construction Year 1 is taken to be 2022. The primary construction phase is between 2022 and 2033. The station is assumed to be fully operational by 2034, Unit 1 may become operational by 2033.

22.3.31 There are five phases to the main construction period:

- Phase 1: Site establishment and preparation for earthworks.
- Phase 2: Main earthworks.
- Phase 3: Main civil works.
- Phase 4: Mechanical and Engineering fit out, instrumentation and commissioning.
- Phase 5: Removal of temporary facilities and restoration.

22.3.32 Details of construction activities during each phase are set out in **Chapter 4** of this volume.

22.3.33 The marine components relevant to each phase are briefly summarised in this section. An understanding of the construction sequence is required in order to assess in-combination effects within the Sizewell C Project (inter-relationships).

22.3.34 During Phase 1, the work will commence to construct the Beach Landing Facility (BLF) and the northern coastal defence that supports the BLF haul road. Capital dredging would be required to create a navigable channel and planar surface for barges to come aground at the BLF. The capital dredge would be followed by smaller volume maintenance dredges. Dredging activities are considered in detail in **Section 22.3.i)** of this chapter.

22.3.35 The Combined Drainage Outfall (CDO) system would be constructed to allow construction discharges into the GSB.

22.3.36 Phase 2 would involve the primary earthworks including the excavation the made ground at the power station platform area, within the cut-off area. During Phase 2 maximum dewatering scenarios are anticipated.

22.3.37 The construction of the power station and ancillary infrastructure would occur in Phase 3. The accommodation campus would be in full use and associated discharges of treated sewage are assessed. Permanent infrastructure relevant to the marine environment includes:

- construction of the cooling water intake and outfall tunnels;
- insertion of the intake and outfall headworks including capital dredging[2] and drilling of vertical connecting shafts;
- installation of cooling water structures and main pump house, and;
- construction of the hard-coastal defence feature (HCDF).

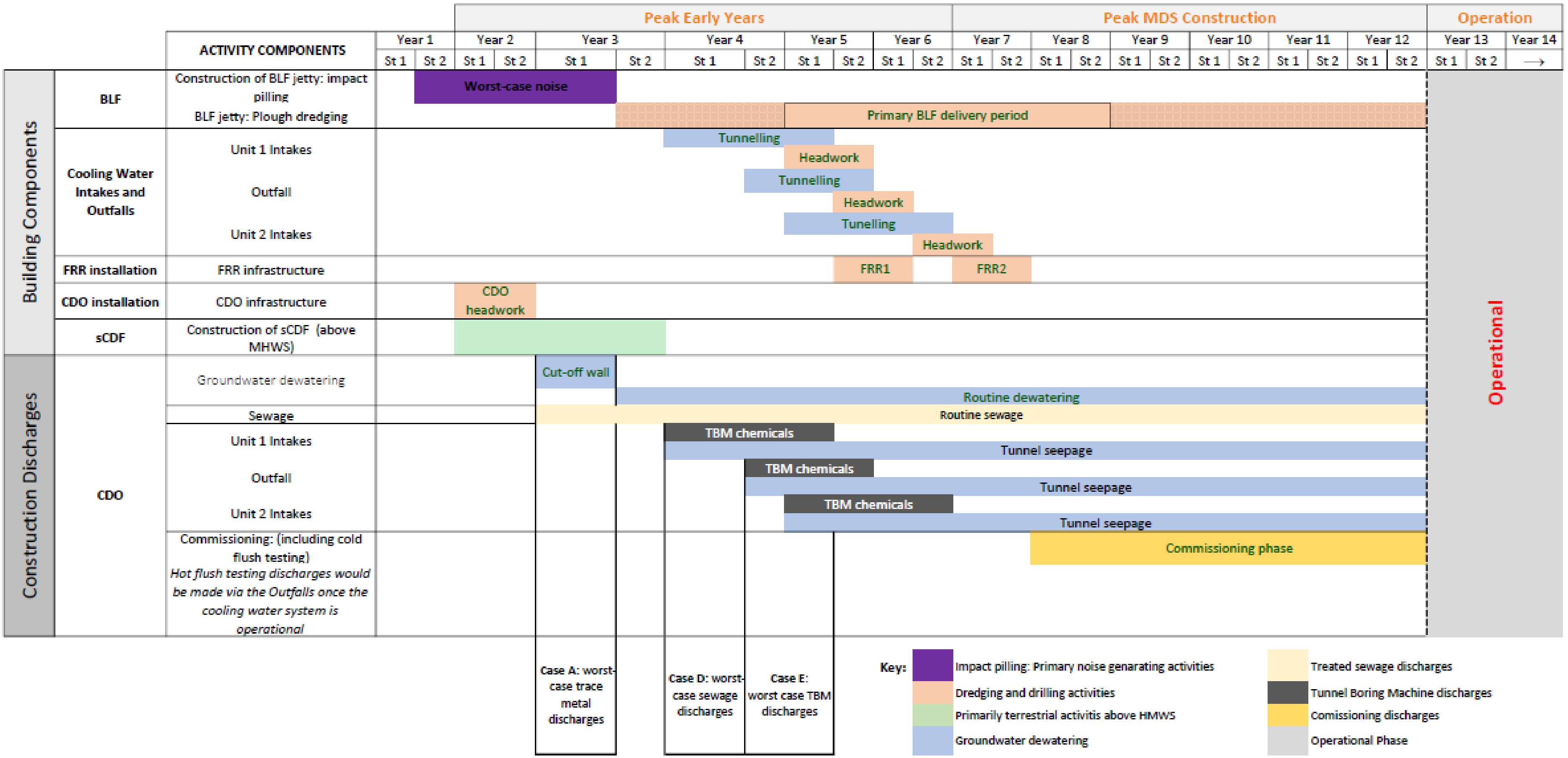
22.3.38 In Phase 4, building works including the cooling water infrastructure and the two reactors would be completed and engineering of the main power station would begin. Completion of reactor Unit 1 and Unit 2 is expected to be separated by 12 months.

22.3.39 During commissioning, the power station will be tested including flushing of the cooling water system (CWS). Discharges would be via the CDO during cold flush testing. Discharges from hot functional testing would be via the cooling water discharge once completed.

22.3.40 An indicative timeline is presented in **Plate 22.1** and is applied as a starting point for assessments purposes.

[2] Dredging activities are considered in detail in **Section 22.3.i)** of this chapter.

Plate 22.1: Indicative development timeline for assessment scenarios.



f) Assessment criteria: marine ecology

22.3.41 As described in **Volume 1**, **Chapter 6**, the **ES** methodology considers whether impacts of the proposed development would have an effect on resources or receptors. Assessments broadly consider the value of a receptor, the magnitude of impacts relative to baseline conditions and the sensitivity of the receptor to the predicted impact. These criteria are used to classify effects and their significance.

22.3.42 Marine ecology methods apply an Ecological Impact Assessment (EcIA) based approach to assess the potential effects of the proposed development on marine ecology receptors (Ref. 22.7).

22.3.43 The term marine ecology *receptor* primarily applies to species and habitats. Functional traits, diversity indices or species groups may be assessed as receptor proxies, where appropriate.

i. Receptor Value

22.3.44 Baseline characterisations of the study area identified important receptors for assessment purposes. Receptors were selected for assessment based on socio-economic, conservation or ecological value. Common and abundant taxa were also selected for assessment in the ES. As such receptor value determines the species that will be assessed and may be applied to determining the significance of an ecological effect on a given receptor. For example, an effect may be considered in relation to the conservation objectives of a designated species.

22.3.45 The value of marine ecological receptors has been uncoupled from sensitivity. This allows sensitivity assessments to be undertaken for a given impact independently of value.

22.3.46 The highest scoring value for ecological, socio-economic and/or conservation importance determines the overall value of a receptor (**Table 22.2)**. Receptors with very low value would not be included as key taxa during baseline characterisations and are therefore scoped out of the ES assessments.

Table 22.2: Marine ecology receptor value.

Value	General description for assigning value
High	• High ecological value (other ecosystem features dependent on it). • International conservation value such as designated feature of a SAC, SPA, Ramsar sites, or SSSIs.

Value	General description for assigning value
	• Species "of principle importance for the purpose of conserving biodiversity" listed in Section 41 (England) of the Natural Environment and Rural Communities (NERC) Act 2006. • National/international socio-economic value.
Medium	• Moderate ecological value (e.g. abundant/common and/or another feature partially depends on it). • National conservation value such as designated features of regional or county importance, such as Country Widlife Sitess, Conservation Areas. • Moderate national/regional socio-economic value (e.g. commercial fishery).
Low	• Low ecological value (e.g. not selected as an abundant/common taxa and/or limited connection to other ecosystem features) • Regional/local conservation value such as local nature reserves. • Local socio-economic value (e.g. artisanal fishery).
Very Low.	• Receptor neither common nor abundant locally and no functional dependencies. • Receptors with no conservation designation. • No immediate socio-economic value.

ii. Impact magnitude

22.3.47 Impact magnitude primarily considers the spatial extent of the impact, the duration of the impact and the amount of change (beneficial or adverse) relative to baseline conditions. Additional factors such as frequency, timing and reversibility are taken into consideration and reported where appropriate as these factors can contribute towards the sensitivity of a receptor to an impact (Ref. 22.7).

22.3.48 The predicted amount of change for a given impact is assessed in relation to regulatory thresholds or standardised pressure benchmarks, for example, Environmental Quality Standards (EQS). In the absence of established standards, applied thresholds based on a 'weight of evidence approach' and pressure benchmarks proposed in Marine Evidence-based Sensitivity Assessments (Ref. 22.11) are used to inform impact magnitude. Pressure benchmarks provide a basis for assessing the sensitivity of a given receptor to the site-specific impacts relative to recognised standards. However, it should be noted that benchmarks are not universally applicable and site-specific factors at Sizewell may require further scrutiny.

22.3.49 Benchmark thresholds are applied to trigger further ecological investigation and do not necessarily infer sensitivity of all receptor groups.

22.3.50 The duration of the impact is considered in relation to pressure benchmarks and construction timelines. The construction phase is anticipated to last approximately 9 to 12 years, impacts during the construction phase are considered short (< 1 year) to medium-term (1-12 years), whilst impacts that occur (or persist) for longer durations are considered long-term. Pressure benchmarks often consider changes over the course of a year, therefore impacts under one year are considered low duration. It should be noted that sensitivity assessments (described in the following section) take into consideration the ecology of the species of concern relative to the duration/frequency of impacts.

22.3.51 Impact magnitude is assessed on a four-point scale; Very Low, Low, Medium, and High (**Table 22.3**).

22.3.52 Generic descriptions help with assigning impact magnitude. However, it should be noted that expert judgement is required when determining the weight of each of the factors involved in the overall assessment of impact magnitude. Within each receptor assessment, pertinent information required for assigning impact magnitude is provided.

Table 22.3: Marine ecology descriptions of impact magnitude.

Impact Magnitude	Generic description	Spatial Extent	Amount of Change	Duration
High	Large-scale, measurable changes which are typically permanent or of long-duration over most of the study area and potentially beyond.	Changes occur across much of the area of interest and possibly beyond (e.g. 1,000s of hectares, ha).	Clear, measurable changes beyond natural variation and exceeds site-specific pressure benchmark.	Long-term or even permanent, more than 12 years.
Medium	Medium-scale measurable changes over much of the study area. Impacts are typically not permanent or permanent impacts are small scale.	Changes occur across a moderate proportion of the area of interest (e.g. 100s of ha).	Measurable changes beyond natural variation.	Medium-term temporary impacts, one to 12 years.
Low	Noticeable but small-scale change over a partial area. Impacts are typically short-term.	A partial spatial area is exposed to changes (e.g. 10s of ha).	Measurable change within range of natural variation.	Short-term temporary, less than a year.
Very Low.	Very small-scale or barely discernible changes, over a small area. Impacts are short-lived.	Very small extent is exposed to changes (e.g. 1ha).	Change possible but intangible from natural variation.	Very short term, e.g. spring-neap cycle or less.

iii. Sensitivity

22.3.53 Sensitivity assessments determine the resistance of a receptor to a pressure and the ability to recover following the cessation of the pressure, termed resilience. Within the context of the ES, sensitivity assessments are completed relative to the site-specific magnitude of impacts predicted during construction and operational phases of the development.

22.3.54 Sensitivity is assessed on a four-point scale: Not Sensitive, Low, Medium, and High. A general guide for sensitivity assessment is provided in **Table 22.4**.

Table 22.4: Guidance for marine ecology sensitivity criteria.

Sensitivity	General description for assigning sensitivity
High	Little or no capacity for resistance, limited or prolonged recovery.
Medium	Low capacity for resistance, low capacity for resiliance (e.g. after 10 years).
Low	Moderate resistance to the pressure, moderate capability for resiliance (e.g. after 5 years).
Not Sensitive.	High capacity for resistance, high capacity for resiliance (e.g. after 1 year).

22.3.55 Resistance and resilience descriptors follow the general approach described in **Volume 1**, **Chapter 6** of the **ES** but are further informed by the Marine Evidence-based Sensitivity Assessment approach for benthic (Ref. 22.11) and highly mobile (Ref. 22.12) receptors.

22.3.56 The resistance of an ecological receptor is assessed against the predicted impact magnitude. Resistance is considered using the following criteria:

- **None:** A severe decline in the extent, density or abundance of the habitat or species due to mortality or displacement.
- **Low**: A significant decline in the extent, density or abundance of the habitat or species due to mortality or displacement.
- **Medium:** A moderate decline in the extent, density or abundance of the habitat or species due to mortality or displacement.
- **High:** No or very minor changes in the extent, density or abundance of the habitat or species. Physiological and behavioural changes in metabolism, reproductive rates, feeding rates and foraging effort may occur but not at the detriment of the population.

22.3.57 The resilience of a receptor is assessed in terms of its ability to recover once the pressure is removed and the environment returns to pre-impact conditions. A number of receptor specific factors are considered in the assessment of resilience, these include:

- the lifespan and age of maturity of the receptor;
- factors affecting fecundity, reproductive success and/or larval mortality;
- dispersal and recruitment patterns; and
- population dynamics including natural mortality.

22.3.58 Recovery implies that a species or habitat has returned to pre-impacted habitat conditions or populations levels with structure and functioning maintained. It does not necessarily mean that all the species within the community have returned to pre-impacted levels.

22.3.59 Resilience following pressures causing behavioural avoidance / displacement are based on evidence for the time it takes a receptor to return to an impacted area once the pressure ceases. However, behavioural responses in highly mobile species (fish and marine mammals) can cause considerable population declines due to temporary displacement and should be given greater weight in assessing sensitivity (Ref. 22.12).

22.3.60 The **ES** considers the potential indirect food web effects associated with such responses.

iv. Effects and significance

22.3.61 The aim of the EcIA process is to determine the occurrence of ecological effects and the potential significance of such effects caused by the proposed development. A final cross tabulation of the magnitude of impacts and sensitivity of the receptors provides a guideline for the classification of effects (**Table 22.5**). The tabulation is treated as a guideline and expert judgement must be applied once all the factors of the assessment have been considered and reported.

Table 22.5: Classification of effects based on sensitivity of receptors and magnitude of impact.

Impact magnitude	Sensitivity of receptor			
	Not sensitive.	**Low**	**Medium**	**High**
Very Low.	Negligible	Negligible	Minor	Minor
Low	Negligible	Minor	Minor	Moderate
Medium	Minor	Minor	Moderate	Major
High	Minor	Moderate	Major	Major

22.3.62 The generic definitions of effects for marine ecology receptors are shown in **Table 22.6.**

Table 22.6: Generic definitions of effects to marine ecology receptors.

Effect	General description for assigning effects
Major	Very large or large changes in ecological receptors which may alter the structure or function of the overall marine ecosystem. Effects, both adverse and beneficial, that are likely to be important considerations at an international or national level because they contribute to achieving international/national objectives or are likely to result in exceedance of statutory objectives and/or breaches of legislation.
Moderate	Intermediate changes in ecological receptors that are likely to be important and could cause subtle changes in other ecosystem features.
Minor	Small change in ecological receptors with limited discernible effects on other ecosystem features. These effects may be raised as local issues but are unlikely to be instrumental in the decision-making process.
Negligible	No discernible change in the ecological features. An effect that is likely to have a negligible or no influence, irrespective of other effects.

22.3.63 Following the classification of an effect as presented in **Table 22.6,** a clear statement is made as to whether the effect is 'significant' or 'not significant'. Identification of significant effects is central to the EcIA process and reporting of such effects is required to allow decision markers to be adequately informed of the beneficial or adverse ecological effects of the proposed development. As a general rule, major and moderate effects are considered to be significant and minor and negligible effects are considered to be not significant. However, professional judgement is also applied where appropriate.

22.3.64 Receptor value may influence the judgement of the significance of effect. For example, a minor effect to a designated species which contravenes conservation objectives may be considered significant. A significant effect has implications for the biodiversity conservation objectives for important ecological features or for biodiversity in general. Additionally, an effect may be deemed significant if the structure or functioning of a defined site, habitat or ecosystem is adversely affected (Ref. 22.7).

g) Assessment criteria: fisheries

22.3.65 Effects on fisheries consider the sensitivity of the specific fishery to development impacts during the construction and operational phase of the proposed development. Assessments are based on the fishing gear groups defined (e.g. potting, driftnetting, trawling) and recreational fishing.

22.3.66 The commercial or recreational value of the fishery is determined from the commercial and recreational fisheries baseline characterisation, provided in **Appendix 22F** of this volume and is based on the value definitions defined in **Table 22.2**.

22.3.67 The magnitude of predicted impacts is considered on an individual fishery basis and defined spatially and temporally. Assessments consider whether an impact is temporary or permanent. Magnitude is largely a function of the fishery dependence on the area under consideration for the proposed development. **Table 22.7** provides the descriptors of impact magnitude for fisheries receptors.

22.3.68 The duration of impacts associated with construction are short term to medium term, occurring over the nine to 12 years estimated for construction. Impacts associated with operation are potentially long term, occurring over the operational lifetime of the proposed development. The timing of specific fisheries varies seasonally, and it is therefore not possible to standardise the definition of duration of effects across the receptor groups.

22.3.69 The sensitivity of each fishery receptor is scored based on limitations of operating in different fishing grounds and an ability of fishers to work more than one gear type. Descriptions of fisheries sensitivity are provided in **Table 22.8**.

22.3.70 The assessment of effects and significance follow the same approach as in **Table 22.6**.

Table 22.7: Definitions of impact magnitude for fisheries assessments.

Impact Magnitude	Generic description
High	A high proportion of the available fishing area and/or a high proportion of a commercial species (by weight or landing value) from the study area is impacted. Changes to fishing activity are long-term or permanent.

Impact Magnitude	Generic description
Medium	A moderate proportion of the available fishing area and/or a moderate proportion of a commercial species (by weight or landing value) from the study area is impacted. Changes to fishing activity is temporary but recovery within a reasonable timescale is not possible.
Low	A minor proportion of the available fishing area and/or a minor proportion of a commercial species (by weight or landing value) from the study area is impacted. The change is temporary and recovery is possible within a reasonable timescale.
Very Low.	Little or no history of specific fishing activity in the areas under consideration; and / or the change is temporary and recovery is rapid.

Table 22.8: Descriptions of sensitivity for fisheries assessments.

Sensitivity	Description
High	Restricted operational range and low ability to exploit other areas and low capability to utilise other gear types. High level of dependence on the fishing area allowing limited spatial tolerance. Limited ability to recovery losses from exploiting alternative fishing grounds.
Medium	Moderate operational range allowing access to other areas and/or moderate capability to utilise other gear types. Fishing in alternative areas may only partially recovers of losses.
Low	Large operational range allowing access to other areas and/or capability to utilise different gear types. Fishing in alternative areas allows high recoverability of losses.
Very Low.	Extensive operational range and/or fishing method versatility. Able to target several fisheries.

h) Assessment methodology

22.3.71 The assessment of construction and operational phase impact on marine receptors is based on a wide range of evidence sources specific to the proposed development including existing data, onshore and offshore surveys, modelling and a comprehensive programme of stakeholder engagement over a decade preceding the **ES**. Sizewell C Project-specific impact assessments consider changes in coastal processes, changes in water and/ or sediment quality, introduction of noise, and cooling water abstraction resulting in impingement and entrainment pathways.

22.3.72 The specific details of the topic methodologies for determining impacts are detailed within the relevant technical appendices, provided in **Section 22.1** of this chapter.

22.3.73 Water and sediment quality assessment methodologies are summarised in **Chapter 21** of this volume and include:

- Regulatory standards and thresholds for assessments (for sediments, nutrient, dissolved oxygen, microbial and chemical effects).
- Approaches to chemical discharge screening.
- Discharge model selection[3] and parametrisation.

i) Assumptions of the assessments

22.3.74 Large scale infrastructure projects are inherently complex in their design and a degree of engineering flexibility is required as not all design details can be specified at the time of assessment. Accordingly, the 'Rochdale Envelope' principle is applied, whereby the worst-case design scenario is assessed. This approach ensures, as far as reasonably practicable, that the assessment encompasses the full range of design possibilities. Where there is uncertainty in the engineering design a description of the potential differences for different options is provided.

22.3.75 The assessments are based on baseline information and engineering designs at the time of Sizewell C DCO submission. **Volume 2**, **Chapter 2** of the **ES** provides a description of the main development site. **Volume 2 Chapters 3** and **4** of the **ES** provide a description of the construction and commissioning, and operational phases of the development, respectively. Detailed assumptions underpinning assessments are described within relevant technical reports and summarised herein. Here a summary of the key engineering assumptions for marine ecology assessments for each development component is summarised.

i. Beach landing facility

22.3.76 The BLF would be used to receive large deliveries, including abnormal indivisible loads (AILs) to Sizewell C by barge. Barges would be loaded at a transhipment port and on approach to the BLF the barge would be assisted by tugs and moor at the end of the BLF at high water. As the water level drops, the barge would ground. Large deliveries would then be transported to site along the BLF access road. The BLF would facilitate occasional AIL

[3] Discharge modelling primarily applied CORMIX and General Estuarine Transport Models. CORMIX is a US EPA supported mixing zone model. General Estuarine Transport Model is a validated three-dimensional hydrodynamic model with an inbuilt passive tracer to represent relevant substances in the discharge. Further details are available in **Chapter 21** of this volume.

deliveries during the operational life of the station, approximately every 5-10 years.

22.3.77 The BLF would consist of a piled platform, fenders and ramp and mooring dolphins. Piles would start on the shore above intertidal and extend down to the shallow subtidal. One pair of BLF piles is close to the low tide mark, and three pairs are seaward of low tide. Two fenders would be piled at the seaward end of the BLF and two mooring dolphins would be positioned at approximately 66m and 128m from MHWS. For assessment purposes piles are assumed to be approximately 1m in diameter and the fender/dolphin piles would be 1.5m in diameter. A total of 12 piles would be installed within the marine environment below MHWS with the deepest pile located in a water depth of -3.38m Ordnance Datum Newlyn (ODN).

Construction of the beach landing facility

22.3.78 Constructions of the BLF would involve landward sections being piled by a terrestrial piling machine. Marine piles and dolphins could be installed from a jack-up barge or from a piling rig mounted on the BLF road as it extends seawards.

Piling

22.3.79 Impact piling is the assumed piling method the 12 marine piles required for the BLF. Indicative piling specifications for assessment purposes are:

- Maximum hammer energy of 90kJ.
- Strike rate of 46 strikes per minute.
- Each pile would require approximately 1,500 hammer blows to install (lasting approximately 33 minutes).
- A maximum of 5 piles would be installed in any 24-hour period (the timeframe for cumulative noise assessments).

22.3.80 An additional 200kJ hammer energy option, with the same total number of hammer blows to represent a precautionary scenario and to envelope potential engineering options is assessed, this can be found in **Appendix 22L** of the **ES**. It is envisaged that a 20-minute soft start would be implemented (either through an increase in hammer energy or strike rate), resulting in a total piling time of ca. 53 minutes per pile.

ii. Cooling water infrastructure

Construction

22.3.81 Offshore cooling water infrastructure consists of two subterranean intake tunnels and one outfall tunnel. Tunnels would be excavated by tunnel boring machines (TBMs) from land. The TBM heads would be left at the end of each tunnel run, approximately 30m under the seabed.

Tunnelling spoil and chemical discharges

22.3.82 The specific TBM method to be used is dependent on the underlying geology and is still to be confirmed.

22.3.83 Based on current understanding a TBM slurry method is the most likely method. Spoil from the cutting face would be transported to a temporary stockpile for onward management. Groundwater would be generated from digging the galleries allowing access to the tunnels. During the transport and processing of spoil material, groundwater and potentially residual TBM chemicals would be produced in wastewater that would be transported landward and treated appropriately. To encompass worst-case water quality scenarios, assessments assume discharges of wastewater from the CDO.

22.3.84 Bentonite, a clay mineral regularly used in construction and offshore drilling operations, may be applied at the cutter face. A bentonite recovery system would be utilised to minimise the potential for release. Bentonite is considered to pose minor risks to the environment as it is included on the OSPAR list of substances that pose little or no risk to the environment. However, the potential for discharges of bentonite from the CDO to affect SSC is considered. Tunnelling would be approximately 30m below the seabed and the excavated pressure (if required) would either be slightly above ambient, therefore, the potential for 'frac-out' is incredibly small and not considered further.

22.3.85 To envelope alternative tunnelling methods, assessments considered the use of indicative ground conditioning TBM chemicals (sometimes used at the cutter head to optimise efficiency). The exact ground conditioning chemicals (and their chemical constituents) are dependent upon the conditions encountered on site and cannot be precisely specified in advance of drilling trials by the tunnelling contractor. Whilst a slurry method is the most likely tunnelling option, representative chemicals from those applied for Hinkley Point C assessments are considered to most accurately envelope potential tunnelling options at this stage. These include the anti- clogging agent BASF Rheosoil 143 and the soil conditioning additive CLB F5 M. The potential worst-case tunnelling scenario would occur when two cooling water tunnels are being bored simultaneously (Case E; **Plate 22.1**).

22.3.86 A description of the tunnelling chemicals assessment is provided in **Chapter 21** of this volume.

Cooling water headworks

22.3.87 Each tunnel would terminate in two concrete headworks. Prior to the installation of the headworks small scale capital dredging would remove surficial sediments to expose underlying bedrock. Dredging is anticipated to be by cutter suction dredger with local disposal.

22.3.88 Following dredging, the bedrock would undergo ground preparation and a gravel bed would be installed below the proposed headwork, which would be lowered into position. Piles may be required to achieve seismic qualification for some of the headworks. Piles would be installed by drilling, rather than percussive methods to reduce the incidence of underwater noise.

22.3.89 Vertical connection shafts would be drilled with the headwork *in-situ* to connect the headworks to the subterranean tunnels. Drilling would occur through the centre of the headworks, and the spoil deposited within the dredge footprint.

22.3.90 After the headworks are installed and scour protection placed *in-situ* (where required), soft-sediment would be back-filled.

Operation

22.3.91 During operation, the Sizewell C intakes would abstract seawater at an average rate of ca. 132m^3/s (two x 66m^3/s for each intake tunnel) during standard operating procedures. A maximum of 8.6% of the total cooling water flow would supply the essential and auxiliary cooling water systems and the remaining 91.4% (120m^3/s) would supply the main CWS.

22.3.92 An additional scenario was assessed during normal operation of Sizewell B and maintenance of Sizewell C, whereby two of the four pumps are not operating but the two reactors remain running at full power. Such circumstances are unlikely but would result in approximately half the cooling water abstraction rate with the same level of thermal energy applied. Therefore, excess temperatures could potentially rise from 11.6°C to 23.2°C (Ref. 22.13). Modelling has demonstrated that a warmer thermal plume loses heat faster to the atmosphere resulting in less heat being mixed down into the water column resulting in smaller areas of thermal standards exceedance, therefore, normal operating scenarios are considered worst-case, this can be found in **Appendix 21E** of **Volume 2** of the **ES**.

22.3.93 Abstracted water for the CWS would arrive at the forebay at the end of each intake tunnel. Abstracted water would pass over four drum screens for the condenser cooling and over two band screens (and the drum screens) for essential and auxiliary cooling. The proposed approach is for filtration screens to be fitted with a 10mm mesh to remove fish and larger organisms. Fish recovery and return (FRR) systems would return impinged biota back to the sea.

22.3.94 EDF Energy's operational policy for its existing UK fleet is to continuously dose during the growing season to achieve a total residual oxidant (TRO) dose of 0.2mg/l in critical sections (essential cooling water systems for the nuclear island and the turbine hall, and the condensers)[4]. Chlorination would be applied after the drum screens and FRR systems would not be chlorinated thereby preventing exposure of impinged biota to chlorine.

22.3.95 The TRO discharge concentration from the CW systems at the outfall would be 0.15mg/l. To represent the worst-case scenario water quality modelling considers the impacts of 0.15mg/l TRO released at the outfalls at a maximum discharge of 132m^3/s

22.3.96 To reduce the annual duration of chlorinated discharges, seasonal chlorination would be applied, involving chlorination during the period of the year when water temperatures exceed 10ºC. However, spot-chlorination may be required to protect critical plant outside these periods. By 2030, predicted water temperatures at the Sizewell C intakes would exceed 10ºC from the beginning of May until the start of December, this information is provided in **Appendix 21E** of this volume. The potential exists for future climate change to extend the period of the year seawater temperatures exceed 10ºC, and by proxy, the seasonal duration of chlorination. The influence of climate change on the seasonal chlorination strategy is considered further within this chapter and as part of the Sizewell C Project wide In-Combination Climate Impact (ICCI) assessment in **Chapter 26** of this volume.

22.3.97 The lowest volume of water abstracted under normal operating conditions would be approximately 116m^3/s. Water quality assessments for discharged contaminants are based on this discharge rate as it represents the worst-case initial dilution scenario for standard operation of the power station, this information is provided in **Appendix 21E** of Volume 2 of the **ES**.

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[4] Anti-biofouling measures are critical to the safe operation of coastal power stations and requires the prevention of settlement and growth as opposed to killing settled organisms. EDF Energy maintains a fleet wide policy on the choice of anti-biofouling measures and has periodically examined alternative products and approaches but has not found any that offer an improved risk profile than chlorination.

Refuelling and maintenance outages

22.3.98 During the 60-year operational life, each reactor unit would undergo refuelling and maintenance shutdowns ('outages') at approximately 18-month intervals. The duration of these outages would vary according to the maintenance and inspections required but would typically be up to two months.

iii. Fish recovery and return system

Construction

22.3.99 Two FRR systems would be constructed, one for each reactor. The FRR tunnels (approximately 0.65m internal diameter) would be drilled beneath the seabed with arisings transported to landward for disposal.

22.3.100 Prior to installation of the FRR outfall headworks, overlying soft sediment in the shallow subtidal (<6m) would be removed by dredging, probably by a Cutter Suction dredger, with spoil disposed locally within a licensed disposal site. The FRR outfall headwork would comprise a concrete block approximately 3m long, 4.5m high, and 3m wide buried 2m into the sediment.

22.3.101 The proposed position for the FRR outfalls is ca. 475m from the forebays on the seaward flank of the outer longshore bar in water depths of 5.5-6m below ODN.

22.3.102 The exact position of the headworks will depend on constructability with the **Works Plan** (Doc Ref. 2.3) allowing a 25m radius for deviation for all headworks. Indicative positions of the FRR headworks for assessment purposes are assumed to be:

- FRR 1 head: Easting 647980, Northing 264000 -5.6m ODN.
- FRR 2 head: Easting 647980, Northing 264300 -6.0m ODN.

22.3.103 Value engineering has suggested moving the location of FRR 2 outfall further south by ca 46m as this would shorten the length of the tunnel slightly and move it away from close proximity to the CDO. Such a move would also have the benefit of slightly reducing transit times for fish. The modelling of environmental impacts from dead and moribund fish being discharged from the FRR is not sensitive to such a small southerly movement in the discharge point given the large scale of the system and the environmental impact assessment is considered robust for either location of FRR 2.

Operation

22.3.104 Abstracted water would be transported along the intake tunnels to the station forebays where drum and band screens would impinge larger biota, including fish and crustaceans. Impinged biota would be washed off the screens and returned to the GSB via the FRR tunnel and headworks. Transit times along the 475m tunnel to the FRR outfalls would take approximately 13 minutes for a passive object at a discharge at a rate of 0.3m^3/s (Ref. 22.14)

22.3.105 The proposed drum screen mesh size for Sizewell C is 10mm allowing a direct comparison with the current mesh size employed at Sizewell B. In the best practice guide for screening for intakes and outfalls Turnpenny and O'Keeffe (2005) recommend *"mesh size should be as small as is practical, and of no more than 6 mm aperture"* (Ref. 22.15). However, Turnpenny *et al.,* (2010) acknowledge that at coastal sites a 6mm mesh may lead to the risk of ctenophore blockage during Summer months. Sizewell B experiences large numbers of ctenophores at certain times of the year and these more readily distort under drum screen conditions and squeeze through a 10mm mesh screen (Ref. 22.16). A 10mm screen is considered appropriate for Sizewell C.

22.3.106 The specific design details of the FRR system would largely replicate the Hinkley Point C FRR design, take into consideration the design best practice guidance (Ref. 22.15), and comply with Marine Licence conditions, including;

- The pressure of the wash water jets to remove fish.
- The geometry of the fish collection hoppers.
- Flushing rates.
- Optimising return lines and gullies by smoothing and grouting to reduce damage and avoiding sharp bends.

22.3.107 Hydraulic assessments have determined that an Archimedes screw would not be required.

iv. Combined drainage outfall

Construction and construction phase function of the combined drainage outfall

22.3.108 The CDO would be constructed early in the construction phase and act as the site discharge outfall. Prior to CDO completion, station effluents would be reused where possible or tankered offsite for managed disposal.

22.3.109 The CDO would discharge tertiary treated sewage, dewatered groundwater, surface run-off, tunnelling wastewater and commissioning discharges. This information can be found in **Chapter 21** of this volume. A Water Discharge Activity (WDA) Environmental Permit will be required prior to any discharges.

22.3.110 The exact position of the CDO headwork will depend on constructability. For assessment purposes the CDO headwork is assumed to be located at 647980 E, 264340 N on the seaward flank of the outer longshore bar, approximately 400m from the HCDF, in water depths of ca. -6.2m ODN. The location limits the potential for discharges to interact with the coastline.

22.3.111 The CDO tunnel would be drilled beneath the seabed with arisings transported to landward for disposal, with no marine impact pathway. The tunnels would be connected to a concrete outfall structure anticipated to be of similar dimensions to the FRR headworks.

22.3.112 Prior to installation of the CDO outfall headwork, overlying soft sediment in the shallow subtidal (ca. -6m ODN) would be removed probably by a cutter suction dredger with spoil disposed locally within a licensed disposal site.

Commissioning

22.3.113 The CDO would act as a discharge point during the cold flush commissioning phase of the proposed development, this information is provided in **Chapter 3** of this volume.

22.3.114 The complete commissioning process for each unit would last for about 24 months and a 12-month gap is anticipated between the completion of the two reactor units. Cold-flush commissioning discharges from Unit 1 and Unit 2 are unlikely to overlap but a Rochdale Envelope approach was applied to represent the worst-case scenario whereby cold flush commissioning discharges for both Units from the CDO occurred simultaneously. This represents a highly precautionary assessment. A second (most likely) assessment assumes cold-flush testing discharges from Unit 2 are released via the CDO, whilst Unit 1 is operational. This represents a potential worst-case scenario for fish and other biota discharged from the FRR associated with Unit 1, approximately 340m south of the CDO.

22.3.115 Hot functional testing takes place before fuelling the reactor, once the cooling water infrastructure is operational. The effluent produced during hot functional testing would be diluted within the CWS before being discharged via the outfall tunnel.

22.3.116 Further details are available in Marine Water Quality and Sediments, provided in **Chapter 21** of this volume.

Operational

22.3.117 There is no operational function anticipated for the CDO.

v. Summary of dredging and drilling activities for assessment

22.3.118 In the UK dredging and disposal is a licensable activity managed by the MMO under the Marine and Coastal Access Act 2009. Disposal activities must reference a designated disposal site.

22.3.119 A summary of the dredge and drilling activities for each development component is provided in **Table 22.9**. Local disposal is the intended option for capital dredging activities associated with offshore infrastructure.

22.3.120 A disposal site characterisation report, provided in **Appendix 22K** of this volume, has been prepared to detail:

- The need for a new disposal site.
- The characteristics of the material to be disposed.
- The disposal site characteristics.
- The assessment of potential impacts.

22.3.121 A standard Marine Licence condition for dredging and drilling activities is the need to monitor sediment contamination levels to ensure dredge/drill material is deemed acceptable for the proposed disposal route. Samples must have been collected within three years of dredging/drilling activities and analysed in an MMO accredited laboratory. Assessments of impacts from sediment contaminants are based on vibrocores samples collected across the site. Further monitoring will be completed in accordance with licence conditions. It is anticipated that this material would be acceptable for disposal at sea, this information is provided in **Appendix 22K** of this volume.

22.3.122 Capital dredging and disposal would be one-off activitiers, probably undertaken with a cutter suction dredger disposing of sediment at the surface via a pipe extended up to 500m from the dredge site. Maintenance dredging (for the BLF approaches) would be required regularly during construction and would likely be undertaken by a plough dredge. Plough dredging does not require a disposal licence. The impact of SSC plumes and sedimentation from dredging activities has been modelled in BEEMS Technical Report TR480, provided in **Appendix 22J** of this volume. Indicative dredge areas applied for assessment purposes, sediment plume characteristics and changes in sedimentation as a result of dredging activities are provided in **Table 22.10** and **Table 22.11**.

22.3.123 Resuspension of pollutants and nutrients from contaminated sediments has the potential to influence ecological receptors. The sandy nature of the sediments within the GSB, their low organic content and contamination levels present a low risk of contaminant or nutrient release to the water column, provided in **Section 22.4** of this chapter. No further assessments on contaminants or nutrient release from sediments are made. Direct effects of increased SSC and sedimentation rates are considered in detail for each receptor.

22.3.124 The northern cooling intakes (Unit 2) and the outfalls would be located in soft sediment environments. Geological interpretation of the overlying sediment indicates sediment thickness varies between tens of centimetres to more than two metres in these areas. The southern intakes associated with Unit 1 would be positioned on exposed Coralline Crag deposits, with no or minimal overlying sediment. Precautionary assessments of dredge volumes for plume modelling assumed overlying sediments of 6m deep at all sites.

Table 22.9: Summary of dredging and drilling activities and disposal routes.

Development component	Dredge/drill type and frequency	Anticipated dredge method	Disposal option
Navigational dredging for the BLF.	1. **Capital dredge:** The first instance of dredging for the BLF would be a small-scale capital dredge.. 2. **Maintenance dredge:** Infilling of the navigation channel and berthing area would necessitate maintenance dredging to ensure access. The volume and frequency of maintenance dredging would depend on infilling rates and the tolerance of the vessels. Assessments assume maintenance dredging of 10% the initial capital volume to occur at approximately monthly intervals during the campaign period (approximately 31st March to 31st October). **3.** **Preparatory maintenance dredging:** Each season during the construction period (or following large infilling episodes following storm events), increased maintenance dredging would be required equating to the initial capital dredge volume.	Plough dredger.	Plough dredging pushes and agitates the sediment, which is redistributed by tidal processes. Spoil is not extracted and a disposal licence is not required for this activity
Installation of CDO headwork.	**Capital dredge:** Small scale capital dredging would be required required to connect the headwork to the tunnel and bury it within the sediment. Dredging would be a single event.	Cutter suction dredger.	Local disposal in accordance with the marine licence deemed as part of the DCO.
Installation of FRR headworks.	**Capital dredge:** Small scale capital dredging would be required to connect the headworks to the tunnels and bury them within the sediment. Dredging would occur once for each structure.	Cutter suction dredger.	Local disposal in accordance with the marine licence deemed as part of the DCO.
Installation of Cooling water intake and outfall headworks.	**Capital dredge:** Capital dredging would be required to remove the surficial sediments enabling each of the cooling water headworks (2 outfalls and 4 intakes) to be installed on the underlying bedrock.	Cutter suction dredger.	Local disposal in accordance with the marine licence deemed as part of the DCO.
Drilling for vertical shafts connecting	**Drilling:** Vertical connection shafts would be drilled through the centre of the cooling water headworks in-situ to connect them to the subterranean cooling water tunnels.	Reverse circulation drilling.	The release of fine drill cutting is assumed to be in the surface layers as this represents the worst-case plume scenario. Drill arisings would

Development component	Dredge/drill type and frequency	Anticipated dredge method	Disposal option
cooling water tunnels with the headworks.			settle locally wiwthin the dredge footprint or disperse depending on the particle size. Local disposal in accordance with the marine licence deemed as part of the DCO.

Table 22.10: Dredging and drilling activities associated with the proposed development. It should be noted that area and volume estimates are indicative and used in assessment purposes to envelope anticipated activities.

Component	Dredge/drilling method and proposed disposal route	Dredge volume and surface area	Duration and frequency	Sediment characteristics	Assessed further in the ES
BLF	Plough dredging, with sediment redistributed by the tide.	4,600m^3 9,068m^2	Capital dredging expected to take 2.1 days (if continous) per year. Maintenance dredging (10% volume) expected monthly.	100% fine to medium sand (63µm-210µm).	Yes
CDO	Cutter suction dredger with local disposal via a down tide pipe.	1,845m^3 1,320m^2	Single dredge event for the CDO head. Dredging expected to take 9.5 hours.	95% fine to medium sand (63µm-210µm). 5% fines (<63µm).	Yes
Cooling water syustem intakes*[2] (all four).	Cutter suction dredger with local disposal via a down tide pipe.	69,600m^3 20,150m^2	Single dredge event anticipated for each of the four CWS intake heads. Dredging expected to take 34 hours in total (8.5 hours per head).	75% fine to medium sand (63µm-210µm). 20% medium to coarse sand (210µm-420µm). 5% fines (<63µm).	Yes
	Drilling with arisings released at drill site.	3,016m^3 201m^2	Continuous drilling lasting 120 hours (30 hours per head).	50% of drill arisings expected to form spoil heap.	The SSC plume would be indiscernible from background conditions – Not assessed.

Component	Dredge/drilling method and proposed disposal route	Dredge volume and surface area	Duration and frequency	Sediment characteristics	Assessed further in the ES
				50% expected to be fines (<63µm).	A localised spoil heap would form (primarily in the dredge footprint), wider sedimentation rates would be minimal. The impact of the spoil heap is assessed.
CWS outfalls (two).	Cutter suction dredger with local disposal via a down tide pipe.	23,500m³ 7,442m²	Single dredge event anticipated for each of the two CWS outfall heads. Dredging expected to take 14 hours in total (7 hours per head).	60% fine to medium sand (63µm-210µm). 10% medium to coarse sand (210µm-420µm). 30% fines (<63µm).	Yes
	Drilling with arisings released at drill site.	1,908m³ 127m²	Continuous drilling lasting 60 hours (30 hours per head).	Same as drilling for CWS intakes.	As for drilling for CWS intakes.
FRR outfalls	Cutter suction dredger with local disposal via a down tide pipe.	3,690m³ 2,640m²	Single dredge event for each of the two FRR outfall heads. Dredging expected to take 19 hours in total (9.5 hours per head).	Same as dredging for CDO.	Yes

Table 22.11: Substrate removal, suspended sediment plumes and changes in sedimentation rates associated with dredging activities for the proposed development. It should be noted that area and volume estimates are indicative and used in assessment purposes to envelope anticipated activities.

Component	Removal of substratum*.			Changes in SSC (maximum instantaneous plume): spatial extent and amount of change.			Siltation rate changes.	
	Spatial extent.	Amount of change.	Duration and frequency.	Depth average.	Surface water.	Persistence	Spatial extent & amount of change.	Persistence.
BLF – initial dredging.	0.91ha	>0.5m	2.1 days x one event per year.	188ha (>50mg/l) 83ha (100mg/l) 6ha (1,000mg/l)	248ha (>50mg/l) 108ha (100mg/l) 7ha (1,000mg/l)	Return to background levels within several days.	6ha (>20mm) 3ha (>50mm) 1ha (>300mm)	0ha >50mm after 15 days (3ha remains >20mm).
BLF – maintenance dredging.	0.91ha	>0.5m	5 hours x monthly events per campaign.	62ha (>50mg/l) 28ha (100mg/l) 1ha (1,000mg/l)	59ha (>50mg/l) 17ha (100mg/l) 1ha (1,000mg/l)	Return to background levels within several days.	0ha (>20mm)	0ha >10mm after 15 days.
CDO	0.13ha	>0.5m	<24 hours x one event.	91ha (>50mg/l) 28ha (100mg/l) 1ha (1,000mg/l)	152ha (>50mg/l) 89ha (100mg/l) 1ha (1,000mg/l)	Return to background levels within several days.	1ha (>20mm) 0ha (>50mm)	0ha > 20mm after 15 days.
CWS intakes.	2.02ha total (four heads)	>0.5m	<24 hours x four events.	932ha (>50mg/l) 373ha (100mg/l) 14ha (1,000mg/l)	553ha (>50mg/l) 291ha (100mg/l) 34ha (1,000mg/l)	Return to background levels within several days.	106ha (>20mm) 7ha (>50mm) 2ha (>300mm) per head.	0ha >5mm after 15 days.
CWS outfalls.	0.74ha total (two heads).	>0.5m	<24 hours x two events.	(enveloped within intake assessment).	(enveloped within intake assessment).	(enveloped within intake assessment).	40ha (>20mm) 4ha (>50mm) 1ha (>300mm)	….

Component	Removal of substratum*.			Changes in SSC (maximum instantaneous plume): spatial extent and amount of change.			Siltation rate changes.	
	Spatial extent.	Amount of change.	Duration and frequency.	Depth average.	Surface water.	Persistence	Spatial extent & amount of change.	Persistence.
							per head.	
FRR outfalls.	0.26ha total (two heads).	>0.5m	<24 hours x two events.	91ha (>50mg/l) 28ha (100mg/l) 1ha (1,000mg/l)	152ha (>50mg/l) 89ha (100mg/l) 1ha (1,000mg/l)	Return to background levels within several days.	1ha (>20mm) 0ha (>50mm) per head.	0ha >20mm after 15 days.

*For the BLF, the navigational channel is reprofiled by dredging and sediments are dispersed by currents rather than locally disposed.

vi. Unexploded ordnance clearance

22.3.125 To date unexploded ordnance (UXO) have not been identified on site. Should a UXO be identified a full assessment would be completed including preparation of a dedicated marine mammal mitigation protocol and shadow HRA for consultation. The most appropriate mitigation measures for UXO would be discussed with regulators and statutory nature conservation bodies to maintain the integrity of the Southern North Sea SAC in accordance with the conservation objectives (Ref. 22.17). The location and size of the UXO in relation to site-specific factors such as proximity to existing nuclear infrastructure, sensitive habitats and geomorphic features would, in part, determine the suite of mitigation measures available, which as a minimum would adhere to the Joint Nature Conservation Committee guidelines for minimising the risk of disturbance and injury to marine mammals whilst using explosives (Ref. 22.18). Alternative disposal methods or relocation would be considered as well as appropriate mitigation measures including deployment of marine mammal observers (MMOs), acoustic deterrent devices, and potentially, smaller scare charges or bubble curtains where possible to minimise the potential for death or injury.

22.3.126 Pre-GI surveys identified no UXOs in the immediate vicinity of the cooling water infrastructure. Given that UXOs have not been confirmed on site, the appropriate mitigation/management scenarios cannot be confirmed, therefore a hypothetical assessment representing the worst-case scenario is considered for fish, provided in **Section 22.8b** of this chapter, and marine mammal receptors, provided in **Section 22.9b.** An EPS licence may be required for detonation of UXOs.

j) Limitations

22.3.127 The following general limitations have been identified:

- Assessments of effects on marine receptors are dependent on the baseline conditions. Where high levels of natural variation in population size, distribution and/or extent occur, the potential to determine effects is reduced because the signal (effect) may be lost within natural variation. Predicted effect sizes in relation to natural variation are discussed within the assessment for each receptor.

- Sensitivity assessments are reliant on the availability of evidence regarding specific receptors physiology and ecology in similar environmental conditions/impact magnitudes. Where specific information is lacking, representative taxa or scenarios are considered. In cases of limited evidence, a precautionary assessment using expert judgement is applied.

22.4 Baseline environment

22.4.1 The main development site on the Suffolk coast is adjacent to the GSB, which is an open embayment within the southern North Sea. This section provides a summary of the physical and chemical baseline conditions at the site against which impact assessments are made. Further details regarding the physical and chemical characteristics of the site are provided in the Sizewell Coastal Geomorphology and Hydrodynamics Synthesis, provided in **Appendix 20A** of this volume, and the Marine Water and Sediment Quality Synthesis, provided in **Appendix 21E** of the same volume.

22.4.2 Information on ecological receptor baselines including the spatio-temporal monitoring implemented to characterise baseline and selection processes for identifying key taxa is provided in each receptor assessment section. This section provides a summary of the key taxa for consideration in the ES and the designated sites with the potential to be influenced by the proposed development.

a) Physical environment

i. Hydrodynamics

22.4.3 The tidal currents off the Sizewell coast are semi-diurnal and are highly rectilinear with a north – south orientation. Spring tide velocities are approximately 1.2m/s (peak). Tidal currents reduce close to shore to approximately 0.2m/s (peak) within 50m of the coast.

22.4.4 Water movement is dominated by tidal currents that flow south for most of the rising (flood) tide peaking at a velocity of 1.14m/s seaward of Sizewell Bank and flow north for most of the falling (ebb) tide (peak velocity of 1.08m/s). The strong tides and generally shallow bathymetry combine so that the water column is well mixed throughout the year.

22.4.5 Tidal ranges increase in the south of the area. To the north at Lowestoft, Spring tidal range is 1.9m, Sizewell is typified by a tidal range of 2.2m whereas a range of 3.5m occurs at Felixstowe.

22.4.6 Data generated from a wave recorder buoy deployed approximately 4km offshore from the Sizewell Bank in 18m of water showed that the offshore wave climate is bidirectional. The most frequent waves propagate from north-east (23%), south (20%) and south-eastly (15%) directions. The largest waves propagate from the north, which is associated with the greatest fetch (ca. 3,000km). South-easterly waves are mostly generated by winds and have a much shorter fetch (up to 150km) and are typically smaller. For the decade from 2008-2018, wave heights recorded by the buoy greater than 1.5m occurred for <8% of the record and originated from east-north-east and the south, this information is found in **Appendix 20A** in this volume.

ii. Temperature

22.4.7 Seawater temperature trends at Sizewell follow a seasonal cycle with Winter minimum temperatures of approximately 4ºC occuring in February. Temperatures rise throughout the Spring and peak in Summer with temperatures in August reaching a maximum of 20ºC in 2014, this information is provided in **Appendix 22A**[5] of this volume.

22.4.8 Long-term temperature records from Lowestoft, Southwold and Sizewell A and B Power stations span >50 years. Yearly average temperatures were derived from years 1963-2013 with complete sets of monthly values at locations in the Suffolk coastal waterbody. The 98th percentile temperature for the five year period from 2009-2013 is 19.4°C. Baseline temperature records focus on the year thermal modelling was simulated (2009). The effects of climatic warming have been incorporated into assessments, allowing thermal discharges and entrainment temperatures to be considered until the end of the century.

iii. Salinity

22.4.9 Salinity at Sizewell follows an annual trend with lowest values observed in Winter months. The mean annual salinity is 33.3 whilst the 5th percentile Winter salinity is 31.7.

iv. Suspended sediment

22.4.10 Sediment suspended levels in sea water off Sizewell are a result of natural processes but can be influenced by anthropogenic activities. The suspended sediment concentration (SSC) is depth dependent, highly seasonal, and varies throughout the tidal cycle due to processes of deposition and resuspension. The SSC environment is an important factor determining ecological processes.

22.4.11 A MiniLander deployed at the seabed 500m offshore the proposed development recorded daily minimum, mean and maximum SSCs provided in **Table 22.12**. High levels of SSC are driven by both high wave energy events and peak spring tidal currents. Minimum observations are observed when neap tides coincide with low wave energy. The difference between daily maximum and minimum suspended load is approximately 300mg/l at 1m above the seabed and 500mg/l at 0.3m above the seabed.

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[5] Sea water temperatures are a factor determining biological growth and thereby the seasonal chlorination strategy of critical plant. The seasonal chlorination strategy and the potential for climate change to modify the period of chlorination is considered in detail in **Appendix 21E** and **Sections 22.5c** and **Section 22.6**, of this chapter.

Table 22.12: Seabed SSC 500m off the Sizewell C coast.

SSC statistic	SSC at 0.3m above the seabed (mg/l)	SSC at 1m above the seabed (mg/l)
Daily minimum	26	17
Daily mean	103 – 161	72 – 105
Daily maximum	357 – 609	266 – 459

22.4.12 Between November 2018 and February 2019, optical backscatter sensors were mounted on two seabed landers deployed seaward of the Sizewell-Dunwich Bank at the proposed cooling water intake head locations. The mean SSC was 452mg/l and 513mg/l at the northern and southerly positions, respectively. In both locations maximum SSC exceeded 2,000mg/l provided in **Table 22.13**. The offshore SSC environment is higher than the inshore waters landwards of the Sizewell-Dunwich Bank. Variations in SSC were driven by tidal currents and wave energy conditions, with peak SSC observed during high wave energy conditions and low water slack tide. This was attributed to the deposition of material from wave generated sediment plumes residing in the overlying water mass. Low SSC was observed during low wave energy conditions during neap tide periods provided in **Appendix 20A** of this volume.

Table 22.13: Offshore suspended sediment concentration (mg/l) at 1.4m above the seabed at the location of the proposed cooling water intakes.

SSC statistic	Northern intake location (SZ1)	Southern Intake location (SZ2)
Minimum	105	100
Maximum	2,246	2,131
Mean	452	513
Standard Deviation	221	278

22.4.13 Further sampling landward of the Sizewell-Dunwich Bank established seasonal variation in SSC at 1m above the seabed, near the existing Sizewell B outfall provided in **Table 22.14**.

Table 22.14: Inshore SSC 1m above the seabed.

Date	SSC at 1m above the seabed (mg/l)
April to August (2010/11)	15 – 144
September to February (2010/11)	9 – 426
July 2016	8.7 – 68.4
August 2016	7.2– 38.4
September 2016	5.2 – 17.0

22.4.14 Suspended particulate matter data has been collected from the MODIS (Moderate Resolution Imaging Spectroradiometer) satellite database and show average suspended particulate matter values at Sizewell between April and August of 31mg/l and average monthly maximum values of 80mg/l. Between September and March mean suspended particulate matter values of 73mg/l were recorded in the surface waters with average monthly maximum values of 180mg/l, this information is provided in **Appendix 20A** of this volume.

22.4.15 Suspended matter is an important driver for ecological functioning of coastal systems. The WFD dissolved inorganic nitrogen (DIN) standards for coastal waterbodies account for turbidity within the system as phytoplankton are less able to utilise nutrients in turbid systems. DIN standards are based on the annual mean concentration of suspended particulate matter (Ref. 22.19). Based on the satellite data, the surface waters at Sizewell are classed as *'intermediate turbidity'* (10-100mg/l), as provided in **Appendix 21E** of this volume.

v. Ambient noise

22.4.16 The variability in ambient noise levels at Sizewell was established by deploying long-term passive acoustic recorders adjacent to Sizewell B over a two-year period (September 2011 and September 2013) providing 481 days of ambient noise recordings.

22.4.17 The ambient soundscape is characterised by operational noise from the Sizewell B, surf noise, and noise from passing fishing vessels. The tonal noise from Sizewell B has a frequency of 50Hz with harmonics (and sub-harmonics) at multiples of this frequency.

22.4.18 Representative ambient noise levels for the site were derived from the recordings in 1/3-octave bands and give a broader indication of the spread of ambient noise across the frequency spectrum. The median 1/3-octave spectrum corresponds to a broadband (0.1-1kHz) Sound Pressure Level (SPL) of 101 dB re 1 µPa, provided in **Appendix 22L** of this volume.

b) Chemical environment

i. Water quality

Nutrients

22.4.19 The availability of inorganic nutrients plays an important role in modulating phytoplankton populations. Nitrate and phosphate are the primary limiting nutrients, although silicate is also important for diatoms, which dominate the phytoplankton off Sizewell.

22.4.20 Inshore waters off Sizewell have higher nutrient concentrations than offshore. The highest nitrate and silicate concentrations occurred between January and March with concentrations of 30µmol/l and 15µmol/l, respectively. Concentrations of nitrates were the lowest (5µmol/l) in July and Augustwith low values for silicates also seen from May through to August. All nutrients (nitrate, silicate and phosphate) in all three datasets showed similar trends with a decrease in concentration in the Summer and Autumn months and peak concentrations in the Winter and Spring months. Variations of phosphates were associated with the variations of suspended matter, as provided in **Appendix 22A** of this volume.

22.4.21 In the southern North Sea, during the Winter months, low surface irradiance and rapid attenuation of photons within the water column cause strong light limitation. Growth of phytoplankton is stimulated in Spring when nutrients are available, temperature increases and light is no longer limiting, as provided in **Appendix 22A** of this volume. At Sizewell, a Combined Phytoplankton and Macroalgae model determined that light limitation is the primary factor limiting growth until mid-May, at which point nutrients start to become limiting. Initially phosphate is the primary limiting factor, however, this is very short-term, and the system enters a period of nitrate limitation until August when light limitation reoccurs as the primary limiting factor controlling phytoplankton growth, this is provided in **Appendix 22H** of this volume.

22.4.22 Nutrient inputs from agricultural activities and sewage discharges are a concern due to the potential to enhance growth of macroalage and phytoplankton and if biomass reaches excessive levels oxygen depletion can occur. The WFD, sets DIN thresholds for the classification of waterbodies. Because more turbid waters limit light penetration and the photosynthetic depth, higher DIN thresholds are applied as turbidity increases and photosynthesis is limited.

22.4.23 The WFD classifies waterbodies based on the 99th percentile Winter DIN concentration in relation to the turbidity of the waterbody. DIN concentrations of 30.36µmol/l are within the *'good'* classification for waterbodies of intermediate turbidity (i.e. Sizewell). It should be noted that the WFD Suffolk

Coastal transitional and coastal (TraC) waterbody at large is classified as '*moderate'* potential for DIN during Cycle 2 (2013-2016) (Ref. 22.20).

22.4.24 A **WFD compliance assessment** (Doc Ref. 8.14) has been submitted as part of the DCO application. Water quality effects on food webs and designated features of European Marine Sites are considered within this chapter and in the **Shadow HRA** (Doc Ref. 5.10), respectively.

Un-ionised ammonia

22.4.25 Ammonia is a commonly occurring pollutant that enters waterbodies from diffuse and point sources from sewage effluents, industrial and agricultural activities and decomposition of organic matter. Ammonia exists in the toxic un-ionised phase (NH_3) and as ionised ammonium (NH_4^+). The relative proportion of each form depends on the temperature, salinity and pH of the water, with higher temperature and pH favouring ammonia, and higher salinity favouring ammonium (Ref. 22.21).

22.4.26 The EQS for un-ionised ammonia is 21µg/l as an annual mean concentration. The mean background concentration of total ammonia (NH_4-N) in the Sizewell region is 11.4µg/l, the equivalent un-ionised ammonia concentration for average conditions (salinity, pH temperature) would be 0.2µg/l NH_3-N which is below EQS concentrations. The 95th percentile concentration is 26.3µg/l NH_4-N would be equivalent to a 95th percentile un-ionised ammonia concentration of 0.5µg/l NH_3-N, provided in **Appendix 21E** of this volume.

Dissolved oxygen

22.4.27 Dissolved oxygen concentrations are an important factor governing the functioning of ecological communities. Dissolved oxygen can be influenced by the physical environment and biological processes. For example, increases in water temperature reduce the solubility of dissolved oxygen and therefore an important consideration for thermal discharges from power stations.

22.4.28 Monitoring of dissolved oxygen levels at Sizewell has shown levels range between 7 and 11mg/l. Minimum Summer dissolved oxygen values were recorded in July 2015 (6.96 -7.04mg/l) but remained well above the WFD threshold for 'high' (5.7mg/l), provided in **Appendix 21E** of this volume.

ii. Sediment quality

22.4.29 Sediment characteristics including particle size and contaminant loading are important criteria for the assessment of development activities with the potential to disturb or resuspend sediments. Such activities include dredging and drilling. Details of sediment quality in relation to dredging and drilling activities are provided in the disposal site characterisation report, found in

Appendix 22K of this volume, for the marine licence application (to be "deemed" within the Sizewell C DCO as opposed to a separate application).

22.4.30 This section summarises the current baseline sediment quality information for the GSB that was applied for initial assessment purposes, further details are available in BEEMS Technical Report TR305, provided in **Appendix 21D** and **Appendix 22K** that are both provided in this volume. In 2015 a geotechnical survey collected vibrocores samples across the Sizewell site corresponding to areas where proposed marine infrastructure installations would occur (an additional geotechnical Ground Investigation survey was completed in August 2019 but results are not yet available). Samples from 2015 were analysed for chemical and heavy metal contaminants including:

- Heavy metals and insecticides – Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Zinc, DDT and Dieldrin.
- Organotin– Monobutyl-tin, Dibutyl-tin, Tributyl-tin.
- Organic and chlorinated compounds – Polyaromatic hydrocarbons (PAHs), Total Hydrocarbon Content and Polychlorinated biphenyls (PCBs).
- Radionuclides (five core sample).
- Particle size analysis.

22.4.31 Radionuclide sampling shows that concentrations in marine sediments at Sizewell are low (with many values below the limit of detection) and consistent with routine local radionuclide monitoring by the Environment Agency.

22.4.32 There are no statutory thresholds to assess the quality of marine sediment in the UK. Cefas Action Levels are used as part of a 'weight of evidence' approach to assessing the contaminant loading in dredged material and its suitability for disposal to sea. The general guidance for Cefas Action Levels is as follows:

- Below Cefas Action Level 1 - Contaminant levels in dredged material are generally considered of no environmental concern.
- Between Cefas Action Level 1 and Cefas Action Level 2 - Contaminant levels in dredged material require further consideration before a licensing decision can be made.

- Above Cefas Action Level 2 - Contaminant levels in dredged material is generally considered unsuitable for sea disposal.

22.4.33 In addition to Cefas Action Levels, evidence can be drawn from the Interim Canadian Sediment Quality Guidelines. Although not specific to the UK, the guidelines are commonly used to assess sediment quality. The guidelines provide threshold effect levels and probable effect levels. The guidance for Interim Canadian Sediment Quality Guidelines is as follows:

- Below threshold effect levels - Minimal effect range within which adverse effects rarely occur.

- Between threshold effect levels and probable effect levels - Possible effect range within which adverse effects occasionally occur.

- Above probabale effect levels - Probable effect range within which adverse effects frequently occur.

22.4.34 The sediment samples collected at Sizewell indicate that organotin and some heavy metals were below Cefas Action Level 1 and pose no environmental concern. Nickel and Chromium exceeded Cefas Action Level 1 but the highest concentrations reported were less than 25% of Cefas Action Level 2 concentrations and below Interim Canadian Sediment Quality Guidelines probable effect levels concentrations. Arsenic exceeded Cefas Action Level 1 concentrations in six of the samples at different locations and depth profiles. Two samples from the inshore areas (VC18 and VC30) at a sediment depth of 2-2.2m and 5-5.2m showed the highest levels of arsenic, close to, but not exceeding the Cefas Action Level 2 of 100mg/kg (measurements of 84.7mg/kg and 91.5mg/kg). High levels of arsenic have been reported in the region under similar studies (for example see Galloper Wind Farm 2015 (Ref. 22.22). The elevated levels of arsenic at location VC18 and VC30 are not associated with any other elevated contaminants of anthropogenic origin and are found only sub-surface, and as such are considered to be representative of the natural geology and not anthropogenic contamination.

22.4.35 PCBs and organotin were below detection levels in most samples and where detected were considerably below the respective Action Level 1 levels.

22.4.36 Polyaromatic hydrocarbons and total hydrocarbon content exceeded Cefas Action Level 1 for some determinants (no Cefas Action Level 2 exists for hydrocarbons). Elevated levels above the probable effect levels for dimethyl naphthalenes occurred in eleven samples. All other determinants were below probable effect levels limits. A further method to examine polyaromatic hydrocarbons in marine sediments involves comparing levels of grouped polyaromatic hydrocarbons (based on their origin and effects characteristics) with published effects ranges. Effect ranges typically used for assessment include the 'effect range low' and the 'effect range medium'[6]. Effects on biota at concentrations below the effect range low are rarely observed, however at levels above the effective range medium effects are generally or always observed. All values for the sediment samples were below the relative effective range medium values and all except two samples were below the effective range medium values. Samples VC10 (surface) and VC24 (surface) marginally exceed the effect range low for low molecular weight polyaromatic hydrocarbons (levels of 725ng/g and 793ng/g respectively). However, these exceedances are marginal and the effect range low should be considered a low point on a continuum of possible effects, furthermore these two locations represent the highest proportions of fines in the surface sediments and therefore can be expected to adsorb relatively higher levels of organic compounds compared to coarser sediments.

22.4.37 Particle size analysis indicated that most of the samples consisted of sandy material with low organic carbon (OC) content (0.08 – 0.1 OC % inshore and 0.58 – 0.82 % further offshore).

22.4.38 The sediments are therefore considered to be uncontaminated and interpretation of the 2015 samples indicates that the sediment to be dredged should be considered acceptable for disposal at sea. It is noted that the acceptability of material for dredging and disposal will require a contemporary assessment at the time of dredging including, where required, interpretation of new sediment samples, provided in **Appendix 22K** of this volume.

c) Key taxa at Sizewell

22.4.39 The EcIA completed for the **ES** considers marine ecology receptors and resources in the following groups:

- Plankton.
- Benthic ecology.
- Fish.

[6] The effect range low and effect range medium values for summed low molecular weight and high molecular weight polyaromatic hydrocarbons are given in (Ref. 22.534) as; 552ng/g (effect range low) and 3,160ng/g (effect range medium) for low molecular weight and 1,700ng/g (effect range low) and 9,600 (effect range medium) for high molecular weight.

- Marine mammals.
- Commercial and recreational fisheries.

22.4.40 Within each receptor group key taxa have been identified based on the ecological, conservation and/or socio-economic value, provided in **Section 22.3c**. This section provides a baseline summary of the key taxa. A full baseline characterisation is provided within each receptor assessment.

22.4.41 Direct effects on marine ornithological receptors are considered in an **ES** context within the Terrestrial Ecology and Ornithology assessment, provided in **Volume 2, Chapter 14** of the **ES**. Indirect effects on marine ornithological receptors, including effects on prey species or effects on supporting habitat, are considered herein and within Coastal Geomorphology and Hydrodynamics, this is set out in **Volume 2, Chapter 20** of the **ES**.

i. Plankton

22.4.42 The plankton baseline in the coastal waters adjacent to the proposed development was characterised in **Appendix 22B** of this volume, for zooplankton, and **Appendix 22A** of this volume, for phytoplankton. A detailed summary of the sampling methods, selection of the key taxa and key taxa baselines is provided in **Section 22.6b** of this chapter.

Phytoplankton

22.4.43 In turbid coastal waters benthic primary productivity is limited and carbon acquired by free-floating single celled algae (phytoplankton) supports food webs. The variable conditions in coastal waters are reflected in irregular patterns in phytoplankton population sizes, which vary greatly over space and time. At Sizewell, the phytoplankton “Spring bloom” occurs in May when light availability increases and available nutrients allow biomass (as indicated by chlorophyll *a*) to peak. The phytoplankton community is dominated by diatoms (2-500µm) throughout the year, with microflagellates (2-20µm) becoming more abundant from mid-Summer to Autumn. Dinoflagellates are present at lower abundances.

22.4.44 Phytoplankton are ecologically important in maintaining coastal food webs. Whilst phytoplankton do not have direct conservation designation the food webs they support contain designated species.

Zooplankton

22.4.45 The abundance of zooplankton[7] in the GSB follows a seasonal cycle with lower abundances observed in the Winter and peak abundance occurring in May. The species present are representative of the southern North Sea. Zooplankton play an important ecological role in marine food webs providing a flow of energy from phytoplankton to higher trophic levels. No zooplankton species present in the GSB has direct conservation designations.

22.4.46 Approximately 30 taxonomic groups of zooplankton have been identified as characteristic of the GSB based on their abundance and commonality in samples. Four key taxonomic groups have been selected for consideration in the assessment of potential effects of the proposed development: mysids, copepods, amphipods and gelatinous zooplankton. These taxonomic groups are distributed widely across the survey area and have variable, seasonally high abundance. The key zooplankton groups are consistent with the primary zooplankton groups entrained at Sizewell B.

ii. Benthic communities

22.4.47 The benthic fauna of the GSB area has been characterised based on data collected from a series of inshore and offshore surveys conducted between 2008 and 2017. The benthic ecology baseline was characterised in **Appendix 22C** of this volume. A detailed summary of the sampling methods, selection of the key taxa and key taxa baselines is provided in **Section 22.7b** of this chapter.

Intertidal communities

22.4.48 The intertidal habitats within the GSB are predominantly comprised of coarse sediment with ephemeral sand veneers harbouring sediment-dwelling organisms. The beaches of the area are not considered particularly diverse compared with other intertidal beaches in Europe[8]. Intertidal surveys of the area show little evidence of spatially distinct assemblages and no benthic species known to be present have a related conservation importance. Designated coastal vegetated shingle habitats are considered in the Terrestrial Ecology and Ornithology **Volume 2, Chapter 14** of the **ES**.

[7] Zooplankton are a diverse range of animals that spend all or part of their life suspended or weakly swimming in the water column. Zooplankton include invertebrates that spend their whole life-cycle in the plankton, the early life stages (eggs and larvae) of benthic invertebrates and fish (ichthyoplankton).

[8] Over 90% of the macrobenthic faunal abundance on intertidal beaches is comprised of flatworms (Turbellaria), juvenile amphipod shrimps, ribbon worms (nemerteans), and juvenile mussels (*Mytilus edulis*).

Subtidal communities and habitats

22.4.49 Subtidal infauna and epifauna communities are common in a regional context as they are part of a larger community distributed across the south of the North Sea 'infralittoral region', corresponding to the subtidal areas within 50m depth.

22.4.50 One benthic community (infauna and epifauna) spans most of the GSB. Twenty key taxa, belonging to the taxonomic groupings (molluscs, crabs and lobsters, shrimps and prawns, polychaetes and echinoderms) recorded during subtidal surveys have been identified as potentially important in terms of their ecological, conservation and socio-economic value. One species of conservation importance was observed in benthic surveys: the lagoon sand shrimp, *Gammarus insensibilis* (listed in Section 41 of the NERC Act 2006) is typically associated with fine sediments of saline lagoons but was observed in the subtidal zone in low abundance in June 2010.

22.4.51 Two habitats have been identified for their potential conservation and ecological importance in the GSB. Coralline Crag is an outcropping hard substrate habitat and locally unusual amongst the sands and gravels of the GSB provided in **Figure 22.4**. Surveys on the Coralline Crag indicate the presence of *Sabellaria spinulosa* reef formations. When in reef aggregations, *S. spinulosa* is protected under Section 41 of the NERC Act (2006) as an Annex I habitat under the EU Habitats Directive (1992) (but only within Special Areas of Conservation (SACs) designated for habitat protection). *Sabellaria spinulosa* reefs within the GSB are not located inside a SAC designated for the feature. Seasonally high abundance of benthic taxa following recruitment events on the Sizewell-Dunwich Bank, as provided in **Figure 22.4**, suggests the sandbank may provide feeding grounds for higher trophic levels (fish, seals, seabirds). Except for the occurrence of *G. insensibilis* in low densities in June 2010, no species of conservation importance are known to occur on the sandbank. *Gammarus insensibilis* is a lagoon specialist and is designated for protection within lagoons, not the habitat in which it was found within the GSB. Sensitive habitats are considered within this chapter and as part of the and **Shadow HRA** (Doc Ref. 5.10) and **WFD compliance assessment** (Doc Ref. 8.14).

iii. Fish

22.4.52 The fish of the GSB area have been characterised based on data collected during the following surveys:

- from impingement sampling at Sizewell B (2009-2017);
- demersal fishing surveys (2008-2012);

- a pelagic fish survey in 2015;
- River Blyth smelt surveys in 2016,
- glass eel surveys;
- stock assessments; and,
- characterisation of the ichthyoplankton within the GSB was been gained from zooplankton surveys in 2008-2012 and 2014-2017 and entrainment sampling at Sizewell B (2010-11).

22.4.53 A total of 88 fish taxa were identified during surveys in the GSB area. An exercise to identify key taxa based on socio-economic value and conservation/ecological importance resulted in the identification of 24 key fish taxa in the GSB. The key taxa assessed in the EcIA consist of marine fish (demersal/bentho-pelagic and pelagic) and migratory fish.

22.4.54 Many of the species recorded in the GSB area form part of a larger population or stock that may encompass an ICES (The International Council for the Exploration of the Seas) region, the southern North Sea, or the whole of the North Sea. Impingement predictions are assessed against ICES derived spawning stock biomasses where such data exist, which represents international best practice. However, assessment of effects from developmental impacts must consider the relevant assessment scale and local effects have also been considered in **Appendix 22I** of this volume. Where appropriate, assessments may involve a hierarchical approach considering both the population/stock scale and localised effects.

22.4.55 Some of the fish taxa are also prey items for designated birds and marine mammals occurring in proximity to the GSB. Assessments consider the functional linkage between fish as a prey species and the potential for indirect (food web) effects. Potential indirect effect on designated features are considered further in the **Shadow HRA** (Doc Ref. 5.10).

22.4.56 The fish of the GSB were characterised in **Appendix 22D** of this volume, a detailed summary of the sampling methods, selection of the key taxa and key taxa baselines is provided in **Section 22.8b** of this chapter.

Marine fish

22.4.57 Marine fish in the GSB encompass a diversity of demersal fish, such as Dover sole, thornback ray and tope which live on or near the seabed. Some species also occur in the mid-water column and forage on fauna on the seabed or within the water column (bentho-pelagic). The most commonly occurring demersal species in offshore surveys were; Dover sole, whiting, gobies, dab, flounder and thornback ray.

22.4.58 Pelagic fish such as sprat typically occur in the water column and near the surface, forming schools that forage on plankton, other fish and fauna. Six pelagic species were recorded during the coastal surveys including; Atlantic herring, European sprat, anchovy, mackerel, horse mackerel (scad) and pilchard, with sprat being the most abundant.

22.4.59 Sizewell B impingement data indicates that the five most abundant inshore fish species, accounting for 90% of individuals impinged, were sprat, herring, whiting, European seabass, and sand goby.

22.4.60 Spawning grounds for Dover sole and plaice intersect the GSB. Nursery grounds of Dover sole, plaice, whiting, cod, seabass, thornback ray, herring, sprat and mackerel also occur within the GSB.

Migratory fish

22.4.61 Migratory fish undertake migrations between freshwater and seawater in order to reproduce and forage. Key migratory fish taxa for the assessment encompass the following species:

- European smelt.
- European eel.
- Twaite shad.
- Allis shad.
- River lamprey.
- Sea lamprey.
- Salmonids (sea trout and salmon).

22.4.62 All migratory species are considered as key taxa in the assessment. With the exception of the catadromous European eel, the migratory species are anadromous meaning they migrate from the marine environment to freshwater waters to breed. The migratory fish occur in the estuarine, coastal and marine environment and, depending on the life history strategy, may be present as juveniles or adults.

Ichthyoplankton

22.4.63 Evidence for the presence and abundance of early life stages (eggs and larvae) of fish (ichthyoplankton) has been drawn from the 1-year Sizewell B Comprehensive Entrainment Monitoring Programme (CEMP), and zooplankton surveys in 2008-2012 and 2014-2017, provided in **Appendix 22B** of this volume. A total of 51 taxa of fish eggs and larvae were identified from the zooplankton surveys in 2008-2012 and 2014-2017, provided in **Appendix 22B** of this volume. Higher abundances of fish eggs and larvae were generally found in June-July. Over the 2010-11 CEMP surveys, 23 fish taxa were recorded as present, as either eggs, larvae, and/or small juveniles. The species present are those expected for the southern North Sea.

iv. Marine mammals

22.4.64 The marine mammal baseline in the coastal waters adjacent to the proposed development was characterised in **Appendix 22E** of this volume. A detailed summary of the key taxa and their baseline is provided in **Section 22.4** in this chapter.

22.4.65 Three species of marine mammals are known to regularly occur in the Great Sizewell Bay (GSB). These are one cetacean species: harbour porpoise (*Phocoena phocoena*), and two pinniped species: harbour (or common) seal (*Phoca vitulina)* and grey seal (*Halichoerus grypus*).

22.4.66 The proposed development area is situated within the Southern North Sea Special Area of Conversation (SAC). The SAC is designated solely for the purpose of aiding the management of harbour porpoise and is of high importance to harbour porpoise in both the Summer and Winter months. The proposed development is within the Winter area of the SAC.

v. Commercial and recreational fisheries

22.4.67 The fisheries baseline in the coastal waters adjacent to the proposed development was characterised in **Appendix 22F** of this volume, a detailed summary of fisheries baselines and key taxa is provided in **Section 22.11b** in this chapter.

Commercial fisheries

22.4.68 Commercial fishing activity is informed by landings data submitted to the MMO by commercial fishing vessels. Commercial landings are partitioned into ICES statistical rectangles. ICES rectangle 33F1 is located off the Suffolk coast and covers an area from Lowestoft in the north to Orford in the south, thereby encompassing the GSB. Landings figures are based on data obtained from the MMO for ICES rectangle 33F1 for the year 2017. An additional data request to the MMO gathered fisheries data based on landings to the ports of Lowestoft, Pakefield/Kessingland, Southwold, Dunwich, Sizewell, Aldeburgh/River Alde, Orford, and Felixstowe Ferry/Orwell Estuary. This data was compared with the 33F1 data from the same year, provided in **Appendix 22F** of the same volume. UK sea fisheries annual statistics for the year 2018 were published in September 2019 and not available at the time of assessments.

22.4.69 During 2017, 58 vessels operated near the GSB area; most of these were less than 10m in length. Most of the catches were landed into Lowestoft, Aldeburgh, Orford, and Southwold, along with minor landings to Sizewell beach and Great Yarmouth. The larger vessels predominantly landed into Lowestoft, with minor landings to West Mersea, Wells-next-the-Sea and Ipswich.

22.4.70 Commercial landings from 33F1 in 2017 were 375t, with a first sale value of £579,500. Four species contributed over 90% of the total commercial landings by weight[9]. These included: whelk (*Buccinum undatum*), herring, thornback ray, and sole. Due to market value, the species that contribute over 90% to landings by value[10] differ slightly and included: whelk, seabass, sole, lobster, thornback ray, and herring.

22.4.71 Commercial fisheries gear types and fishing methods target different species and are likely to have varying sensitivity to potential development impacts. The primary gear types used within the area are:

- potting;
- netting (drift net and gill net combined);
- long-liners; and
- otter trawlers.

Recreational Fisheries

22.4.72 Information on recreational angling is available from the Angling 2013, 2016 and 2017 surveys, and radiological habits surveys of people living in the Sizewell area and from records of observed shore and boat anglers from the Eastern Inshore Fisheries and Conservation Authority. Additional data on shore angling participation were available from images of the Sizewell beach

[9] 90% of commercial landings by weight: whelks (74.5%), herring (8.3%), thornback rays (5.0%), and sole (2.6%).
[10] 90% of commercial landings by value: whelk (48.1%), seabass (14.2%), sole (11.9%), lobster (9.8%), thornback ray (5.3%), and herring (2.8%).

adjacent to the proposed development obtained from cameras mounted on the turbine hall of the decommissioned Sizewell A between 2015 and 2017. These data sources show that recreational angling from the shore is popular throughout the survey area, provided in **Appendix 22F** of this volume.

22.4.73 Seabass is a popular target for shore anglers fishing in East Anglia, as are cod, mackerel and smooth-hound. Off the Suffolk coast, shore anglers target cod, whiting, seabass, dab, and sole, whilst boat anglers catch the same species as well as mackerel and thornback ray. At Sizewell and Dunwich beaches angling is quiet from December to March, with dab, flounder, whiting and rockling being caught in the deeper water. However, by May, anglers take good catches of cod, and sole. Seabass, smooth-hound and dab are taken in June. The best beach-fishing is from July to November, when seabass, whiting, dab, flounder and rockling are caught by day and large sole and seabass at also taken at night. Cod are taken at night from October onwards.

22.4.74 Estimates of the number of beach and boat angler visits to the Sizewell area in 2009/10 are available from the Eastern Inshore Fisheries and Conservation Authority, based on the experience of the local fishery officer and discussions with local angling clubs. An estimated 23,500 shore-based visits were made to the beaches of the Eastern Inshore Fisheries and Conservation Authority area; almost half (10,900) were in the area of Dunwich – Orford Island (which encompasses Sizewell). However, none of the 18,000 boat-based visits to the Eastern Inshore Fisheries and Conservation Authority area were thought to occur in the Dunwich – Orford Island area. These figures are based on the best judgement of the Eastern IFCA fishery officers and there are large uncertainties around the estimates given.

22.4.75 An estimated 20 charter vessels operated from the various ports in the study area in 2014. Between November and April, the locations fished tended to be within 5nm of the coast, whereas from May onwards, the charter boats venture farther offshore on sandbanks and wrecks, sometimes up to 30nm from the coast.

22.4.76 Valuing the recreational fishery is extremely difficult due to the paucity of data. There are no comprehensive studies of sea angling participation, catches or economics for the eastern region of the UK. National surveys have generated estimates of participation, catches, economic impacts, and social benefits, but do not have the sampling effort needed to provide estimates for Sizewell.

22.4.77 The **ES** considers both the commercial fisheries, grouped by gear type, and recreational anglers, grouped by beach and boat-based anglers, as receptors for direct effects of the proposed development. In addition, the potential for indirect effects on commercially exploited species or recreationally targeted species on the fishery is considered. Key commercially and recreationally important taxa for the purpose of the ES are:

- Dover sole.
- European plaice.
- Whiting.
- Atlantic code.
- European seabass.
- Atlantic herring.
- Thornback ray.
- Common whelk.
- European lobster.
- Brown crab.

22.5 Environmental design and mitigation

22.5.1 This section summarises the environmental design elements of each of the development components that are important considerations for assessment purposes. **Volume 2**, **Chapter 2** of the **ES,** provides a description of the permanent development. **Volume 2, Chapters 3** and **4** of the **ES,** provide a description of the construction and commissioning, and operational, phases of the proposed development.

22.5.2 Primary and tertiary mitigation measures have been identified through the iterative EIA process and have been incorporated into the design and construction planning of the proposed development.

22.5.3 Primary mitigation is often referred to as 'embedded mitigation' and includes modifications to the location or design of the development made during the pre-application phase that are an inherent part of the Sizewell C Project, become a fundamental part of the design for which consent is sought, and do not require additional action to be taken.

22.5.4 Tertiary mitigation measures are legislative requirements and/or standard sectoral practices and will be implemented irrespective of the EIA assessment.

22.5.5 The assessment of effects assumes that these mitigation measures are in place. They are identified in **Chapters 3** and **4** of this volume.

22.5.6 Primary and tertiary mitigation measures are summarised in this section so that it is clear where and why these measures have been included, and the way in which they have contributed to the management and reduction of environmental effects. In some instances where it is possible to make an assessment with and without embedded mitigation assessments include both scenarios with the intention to demonstrate the effectiveness of mitigation measures in reducing environmental effects. An example of this approach is the assessment of fish impingement with and without the fish recovery and return (FRR) systems.

22.5.7 To provide context for the subsequent assessments a brief summary of the development activities and assumptions is provided.

a) Coastal defence feature

22.5.8 The coastal defence features for the proposed development would consist of both a hard-coastal defence feature (HCDF) and soft coastal defence feature (SCDF) made of beach grade sediments. If ongoing shoreline retreat progresses, depleting the SCDF, mitigation would be used to maintain the shingle beach and longshore shingle transport corridor, provided in **Section 20.14** of **Chapter 20** of this volume. Coastal squeeze would not occur until the SCDF were depleted and the supra-tidal shingle habitat began to narrow. Beach maintenance activities, especially beach recharge, may reduce the effects of coastal squeeze[11].

22.5.9 The coastal defence features have several embedded mitigation features:

- Sediments used to construct the SCDF would be delivered to the site rather than reprofiling the beach, resulting in a volumetric increase in the back-beach area delaying erosion processes and the potential for coastal squeeze against the HCDF. Beach grade sediments used in landscaping would be vegetated. As they erode under natural storm events, the SCDF would locally slow the rate of shoreline retreat. The

[11] Design and maintenance of the SCDF is discussed in **Appendix 20A**. In summary, the SCDF would be maintained for as long as mitigation was active. The strategy is consistent with the *Hold The Line* SMP, however, the scenario of potential loss of beach at the frontage of the proposed development exists due to coastal squeeze, and is assessed for intertidal receptors herein. Supra littoral habitats including coastal vegetated shingle, is considered in Terrestrial Ecology and Ornithology **Chapter 14** of this volume.

location, behind the active beach, would result in the gradual release of sediment when storms erode its seaward face. Mitigation would be implemented to maintain the SCDF as provided in **Volume 2, Chapter 20** of the **ES.**

- The HCDF would be located landward of the SCDF and have a rock armour core dressed in a shingle/sand/soil matrix to facilitate vegetation colonisation which, like the SCDF, would stabilise the sediment.

- The HCDF positioning is as far as practical away from the shore (eastern flank) to increase its duration as a terrestrial feature.

b) Beach landing facility

22.5.10 The BLF would be a transmissive structure with few narrow diameter piles and a minimal effect on waves, sediment transport and the adjacent beach. The primary embedded mitigation is the small number of piles in the shallow subtidal, compared to alternative jetty options. Underwater noise propagates more efficiently in deep water as such the small size of the BLF in shallow waters reduces sound propagation. This is primary mitigation.

22.5.11 As detailed in the **Code of Construction Practice (CoCP)** (Doc Ref. 8.11) any coatings or treatments applied to the BLF or other infrastructure must be suitable for use in the marine environment in accordance with best environmental practice (e.g. Guidance for Pollution Prevention)[12] or undergo appropriate assessment at the time in accordance with the marine licence conditions. This is tertiary mitigation.

22.5.12 Piling activities associated with the installation of the 12 marine piles will conform to best environmental practice in accordance with Joint Nature Conservation Committee guidelines (Ref. 22.23) to mitigate effects on marine mammals. A marine mammal mitigation protocol will be submitted as part of the Sziewell DCO Application, provided in **Appendix 22N** of this volume. This is tertiary mitigation.

22.5.13 Plough dredging would be used to create a planar surface for the barges to come aground at the BLF. Plough dredging moves and agitates the sediment, which is then redistributed by tidal processes. Sediment is not removed with the vast majority remaining within the same sediment cell. A description on dredging activities associated with each development component is described in **Section 22.3.i** in this chapter. This is primary mitigation.

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[12] Whilst Guidance for Pollution Prevention are no longer in effect they continue to be considered as best practice.

i. Vessel traffic and pollution

22.5.14 A number of tertiary mitigation measures would be implemented to mitigate potential effects of vessel traffic on marine ecology receptors at the site. These measures are detailed in the **CoCP** (Doc Ref. 8.11). In summary the mitigation includes;

- The potential for chemical and oil spills whilst recognised will be mitigated by compliance with IMO regulations.
- The potential for invasive non-native species (INNS) to be introduced during ballast water activities will be managed by compliance with the IMO Ballast Water Management Convention (adopted in 2004).
- Waste management procedures outlined in site waste management plans.
- Artificial lighting on the BLF and moored vessels would introduce light into the marine environment. Mitigation measures as part of the site Lighting Management Plan aims to minimise light spill into the adjacent environment.

c) Cooling water infrastructure

i. Construction

22.5.15 A tunnel boring machine (TBM) slurry method is the most likely scenario for tunnelling. Spoil from the cutting face would be transported to a temporary stockpile for onward management. This is primary mitigation as it avoids damage to the seabed from the alternative of a 'cut and fill' method.

22.5.16 Groundwater would be generated from digging the galleries allowing access to the tunnels. To encompass worst-case water quality scenarios, assessments assume discharges of wastewater from the CDO. Effects from discharges from the CDO would be mitigated by treatment with a siltbuster or similar technology to minimise sediment inputs (primary mitigation).

ii. Cooling water headworks

22.5.17 The optimal location of the outfall heads was investigated using validated hydrodynamic in consultation with the Environment Agency to ensure compliance with Environment Agency guidelines to reduce environmental impacts of the thermal plume as well as to minimise recirculation of heated water at the Sizewell B intakes.

22.5.18 Embedded (primary) mitigation measures of the design of the intake and outfall headworks includes:

- The intakes and outfalls of the cooling water infrastructure would be located east of the Sizewell-Dunwich Bank approximately 3km offshore in deep water, thereby allowing greater dilution of cooling water discharges and reducing potential intersections with the shore.
- The intakes would be fitted with low-velocity side-entry (LVSE) headworks designed to minimise water velocities across the face. Details of the hydrodynamics associated with the LVSE headworks are provided in (Ref. 22.24).
- The long axis of the intakes would be positioned parallel to the current in a north-south orientation. Intake slits would be positioned on the side of the headworks perpendicular to the tidal flow. This reduces both vertical currents, which fish are susceptible to, and reduces the probability of fish being forced into the intakes by tidal currents.
- Coarse bar screens at the intakes would prevent seals and marine debris from entering the CWS.
- The outfall headworks are designed to funnel thermally buoyant discharges away from the seabed thereby minimising effects on benthic receptors.
- The offshore location of the CW intakes of the proposed development relative to the FRR systems means the potential for re-impingement of fish is negligible.

22.5.19 Seismic qualification will be required for some of the headworks and depending on the ground conditions would be achieved through the installation of piles. Piles would be installed by drilling, rather than percussive methods to reduce the incidence of underwater noise.

iii. Operation

22.5.20 Chlorination of critical plant would be applied after the drum screens, meaning the FRR would not be chlorinated. This primary mitigation prevents exposure of impinged biota to chlorine.

22.5.21 To reduce the annual duration of chlorinated discharges, seasonal chlorination would be applied (tertiary mitigation). However, spot-chlorination may be required to protect critical plant outside these periods.

d) Fish recovery and return system

22.5.22 The FRR is a key element of embedded mitigation, allowing robust species of fish and invertebrates to be impinged prior to being returned to the sea thereby reducing mortality, see **Appendix 22I** of this volume. Dead and moribund biota are also returned to sea via the FRRs, ensuring that biomass is not lost from the system.

i. Construction

22.5.23 A number of primary mitigation measure feature ion the construction of the FRRs. The small diameter FRR tunnels (approximately 0.65m internal diameter) would be drilled beneath the seabed with arisings transported to landward for disposal. No marine impacts would arise apart, potentially, from a very small (non-significant) release of bentonite upon breakthrough to the sea. Primary mitigation would be to utilise a bentonite recovery system at the cutter face to reduce the potential for release.

22.5.24 The northerly position of the two FRR outfalls is designed to be closely aligned with the forebays of each reactor, minimising the required tunnel length and hence the time taken for fish to be returned to the marine environment. The optimal easterly position has been determined by several interacting factors, including:

- The depth of the water at the point of discharge. Water depths must be sufficient at all stages of the tide to reduce predation by surface feeding birds.
- Avoidance of mobile geomorphic features. The two nearshore bars at Sizewell are important to sand transport and move naturally in response to the prevailing wave climate. The bars must be cleared to avoid burial of the system. The outfalls) have been positioned on the seaward flank of the outer longshore bar, where bed level fluctuations are less, due to lower rates of transport. This location minimises the effects of the structures on geomorphology to localised scour only.
- Minimising transit time of impinged biota.
- Avoiding the Sizewell B nearfield discharge plume. The Sizewell B outfall is positioned 150m offshore (from mean water level on the beachface). A short FRR tunnel would, therefore, release fish into the Sizewell B discharge plume on the ebb tide (which would have elevated temperature and contain TRO throughout year).

- Minimising the risk of fish re-impingement into Sizewell B. The Sizewell B intake is 600m offshore and there is a risk that, on the flood tide, some of the fish discharged from the FRR outfall could be re-abstracted at the Sizewell B intake.

ii. Operation

22.5.25 The use of a dedicated FRR for each EPR™ avoids the need for a complex junction system with associated increase in transit times. Elevations and tidal heights allow direct discharge without the need for an Archimedes screw (necessary in the Hinkley Point C design), thus minimising the ‘handling’ of impinged fish and crustaceans. This is primary mitigation.

22.5.26 The FRR wash water would not be chlorinated, therefore, impinged biota would not be subjected to TRO exposure (primary mitigation).

e) Combined drainage outfall

i. Construction phase function of the combined drainage outfall

22.5.27 In accordance with the **CoCP** (Doc Ref. 8.11), discharges from the CDO would be treated with oil separators to minimise potential hydrocarbon contamination from mobile or fixed plant operations and a siltbuster or similar technology to reduce sediment loading (primary mitigation). Discharges would be subject to a WDA Environmental Permit and any conditions therein.

22.5.28 The location of the CDO, approximately 400m offshore from the HCDF, limits the potential for discharges to interact with the coastline (primary mitigation).

ii. Commissioning function of the combined drainage outfall

22.5.29 Chemicals used during the cold testing commissioning phase would be directed to storage and/or treatment tanks as appropriate prior to controlled release via the CDO. This embedded mitigation would allow the managed release of commissioning effluent to achieve environmentally acceptable standards. Discharges would be subject to a WDA Environmental Permit and any conditions therein.

22.6 Plankton assessment

a) Introduction

22.6.1 The section applies the methodology outlined in **Section 22.3** of this chapter, to determine the potential for significant effects arising from the construction and operational phases of the proposed development on plankton receptors.

22.6.2 The magnitude of the environmental impacts prior to any additional (secondary) mitigation assumes the primary and tertiary measures detailed in **Section 22.5** of this chapter, are in place. Where secondary mitigation or monitoring is deemed appropriate to minimise any adverse effects, assessments are considered further as a residual effect, provided in **Section 22.13** of this chapter.

22.6.3 The plankton baseline is described, and forms the basis against which to determine the effects. Effects, both beneficial and adverse consider the sensitivity of plankton receptors to the specific impact magnitude arising from activities associated with the proposed development.

b) Plankton baseline environment

22.6.4 This section presents a description of the baseline community characteristics for phytoplankton and zooplankton within the footprint of the proposed development and in the surrounding area.

22.6.5 Full characterisation reports for phytoplankton can be found in **Appendix 22A** and zooplankton in **Appendix 22B,** both of this volume.

i. Zone of Influence

22.6.6 Plankton have limited mobility. Many species can migrate vertically within the water column but are predominantly passively transported within tidal flows. The lack of spatial fidelity of these taxa has a bearing on the ZoI in relation to the potential impacts of the proposed development.

22.6.7 In the well mixed, tidally dominated waters off Sizewell the ZoI for plankton would be intrinsically linked to tidal flows. Given the open nature of the coastline, the system is non-delineated and mixes with the wider southern North Sea. Furthermore, the tidal volume is dependent on the state of the tide at the location of the impact, for example there are reduced flows inside of the Sizewell-Dunwich Bank compared with areas beyond the bank, provided in **Section 22.4** of this chapter. Therefore, construction discharges from the CDO, for example, would have a different ZOI in comparison to operational discharges from the offshore cooling water outfalls.

22.6.8 To determine the effects of entrainment of Sizewell B and the proposed development operating together on phytoplankton populations, BEEMS Technical Report TR385, provided in **Appendix 22H** of this volume, determined the approximate volume of water within the influence of the power station during a tidal cycle. Based upon a current meter (S2) deployed near the proposed Sizewell C intake locations, a progressive vector diagram method indicated that the north – south excursion is approximately 15.9 km, and 1.4km east – west during spring tides. The trajectory of the tide flows both north and south, thus the tidal volume represents a body of water 31.8km long and approximately 2.8km wide.

22.6.9 The total area of the tidal flow was estimated to be 9,670ha. With an average depth of approximately 12.5m, the total volume of water was estimated to be $1209.7x10^6m^3$.

22.6.10 As described, the location of the impact, state of the tide and even the method applied to calculate the tidal flows has a bearing on the ZOI, provided in **Appendix 21E** of this volume. Accordingly, where appropriate, assessments consider the volume of water impacted.

ii. Current baseline

Phytoplankton

22.6.11 In turbid coastal waters, benthic primary productivity is limited and carbon acquired by free-floating single celled algae (phytoplankton) support food webs.

22.6.12 Phytoplankton growth is controlled by light for photosynthesis, nutrients for cell production, and temperature which determines overall metabolic status. Environmental conditions are more variable in coastal waters than in the open sea, reflected in more variable primary production cycles. Top-down control by filter-feeders and grazing zooplankton are also important factors determining the standing stock of phytoplankton.

22.6.13 The seasonal cycle of phytoplankton standing stocks at Sizewell can be characterised as follows:

- **Winter** - Nutrient availability is high but phytoplankton biomass is limited in a sediment dominated system with low light and low water temperatures.

- **Spring** – Sediment loading decreases and temperature and light availability increase. Phytoplankton are able to utilise the nutrients which have accumulated during the Winter. Phytoplankton biomass increases quickly until a peak is reached in late May (the “Spring bloom”), at which point essential nutrients become limiting, even in the relatively nutrient-rich coastal waters. During the Spring bloom, chlorophyll *a* can reach 10µg/l around Sizewell with mean cell abundance peaking at $2x10^6$ cells/l. Following the peak in biomass, reductions in nutrient availability and grazing cause reductions in the standing stock.

- **Summer / Autumn** – Phytoplankton populations persist and grazing by zooplanton recycles nutrients. Late Summer storms can increase recycling of nutrients but also lead to increases in turbidity. A secondary bloom may occur if sufficient light is available before biomass declines towards Winter.

22.6.14 Data to inform the phytoplankton baseline has been compiled from surveys undertaken as part of the BEEMS monitoring programme in 2012 and 2014, the Environment Agency WFD data from the Sizewell area, from the Cefas West Gabbard site and information from remote sensing of the wider region, provided in **Appendix 22A** of this volume.

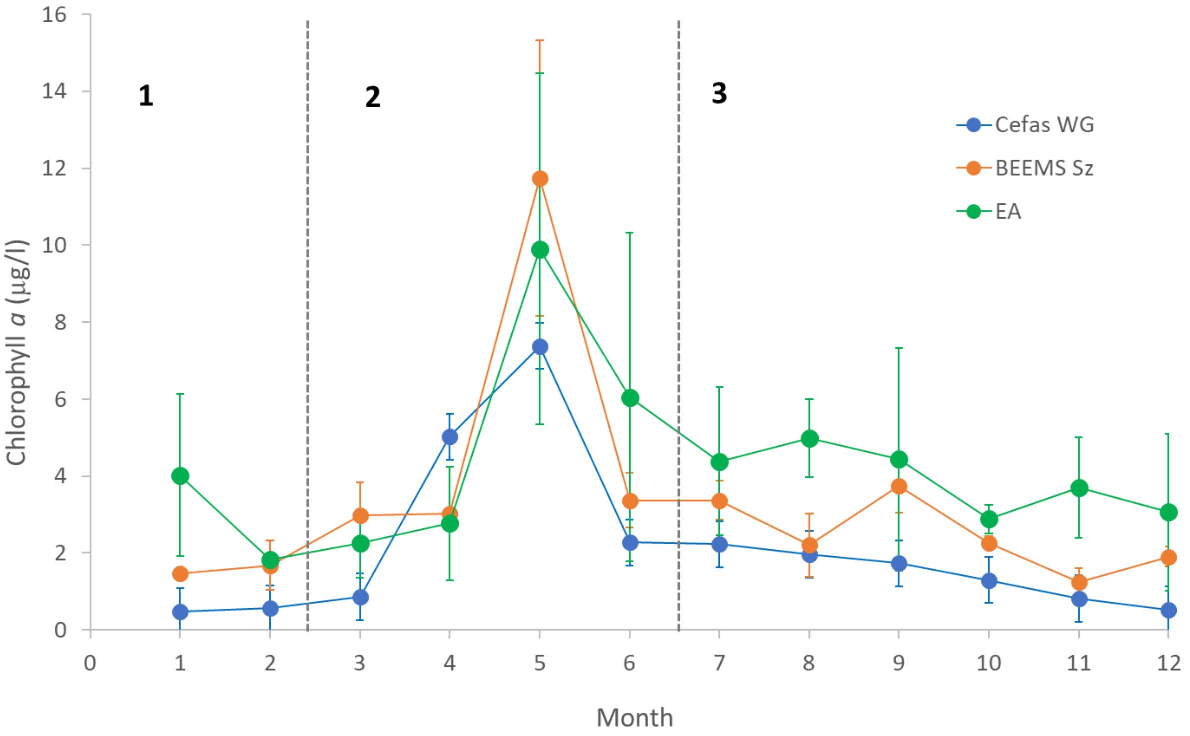
22.6.15 To determine the temporal and spatial variability in phytoplankton communities within the GSB, Additional monthly surveys were completed as part of the BEEMS monitoring programme between March 2014 and January 2017 (Ref. 22.25). These surveys included sampling sites at the location of the current Sizewell B intakes, the Sizewell B outfalls and the proposed location of the Sizewell C cooling water infrastructure. A references site (SZ3), 5.8km to the north of Sizewell was also sampled and provided in **Figure 22.1**.

22.6.16 Phytoplankton cell numbers and biomass (chlorophyll *a*) are highest during the “Spring bloom” in May. A seasonal succession occurs in community composition; however, the system is heavily dominated by diatoms (2-500µm) year-round. Diatom relative abundance peaks at >99% in May and June and dips to 54% in September. Microflagellates (2-20µm) become more abundant in mid-Summer to Autumn. Dinoflagellates were present but typically accounted for less than 13% of the community composition during their peak abundance in August and September.

22.6.17 No detectable differences in phytoplankton taxon distribution were observed between sampling sites within the Greater Sizewell Bay, and the community is representative of the wider region (represented by the Suffolk EA and Cefas West Gabbard data).

22.6.18 A large degree of interannual variation in chlorophyll *a* biomass and abundance has been observed for all sites (**Plate 22.2**). The EA dataset has the longest temporal span from 1992 to 2013 and show chlorophyll *a* peaks at 9.9µg/l (± 4.6 standard deviation) in May. Mean monthly chlorophyll *a* concentration varies by 42% of the mean between years, whilst annual chlorophyll *a* values vary by 45% of the mean, provided in **Appendix 22H** of this volume. Predicted effects from the proposed development will be given in context with the high natural variation.

Plate 22.2: Monthly mean (± standard deviation) of chlorophyll a at the West Gabbard mooring site between 2008 and 2014 (Cefas WG), BEEMS Sizewell surveys 2012 and 2014 (BEEMS Sz) and EA monitoring sites between 1992 and 2013 (EA). The three-stage seasonal succession is illustrated.



Phytoplankton at Sizewell in relation to the WFD plankton tool

22.6.19 Data from March 2014-January 2017 from the reference site and the Sizewell B intakes were used to determine the status of the phytoplankton community by applying the WFD phytoplankton assessment tool.

22.6.20 The phytoplankton tool combines the following metrics:

- chlorophyll *a* (µg/l as a 90th percentile) during the growing season (March to October, inclusive);
- elevated counts; and,
- seasonal succession.

22.6.21 The reference site scored an overall classification of '*good'* status, whilst the Sizewell B intake site was classified as *'high'* status (on the lower threshold of good/high cut-off). The results were broadly consistent with the wider WFD phytoplankton classification of '*good'* within the Suffolk Coastal waterbody. The results are presented in BEEMS Technical Report TR476 (Ref. 22.26). A **WFD Compliance Assessment** (Doc Ref. 8.14) has been submitted as part of the DCO application.

Value of key phytoplankton taxa

22.6.22 The phytoplankton communities observed at Sizewell are broadly consistent with the wider geographic area. Phytoplankton do not have direct conservation designation, however, the food webs they support contain designated species.

22.6.23 Phytoplankton have ecological value due to their role as primary producers and support coastal food webs. Characteristic taxa that account for at least 10% of the total abundance in plankton dataset include microflagellates and the diatoms:

- Chain forming diatoms.
- *Paralia sulcata*.
- Chaetoceros.
- Skeletonema.
- Raphiated pennate diatoms.
- Thalassiosira sp.
- *Asterionellopsis glacialis* (highly abundant in 2016).

22.6.24 The microflagellate *Phaeocystis* sp., which has the potential to cause foam and unsightly / disruptive blooms was observed. Some species of *Pseudo-nitzschia* diatoms produce the neurotoxin domoic acid that can cause amnesic shellfish poisoning. Whilst the *Pseudo-nitzschia* genus has been observed in EA datasets and BEEMS monitoring programmes, the presence of harmful species has not been confirmed. Whilst phytoplankton have limited direct socio-ecomonic value, *Phaeocystis* sp*.* blooms and the potential for toxic species could represent local socio-economic considerations to fisheries, recreational beach users and the power station.

22.6.25 Phytoplankton have very rapid generation times and small-scale impacts are likely to be indiscernible in relation to high spatial and temporal heterogeneity in abundance and biomass. Perturbations at the population level, in terms of phytoplankton community structure or biomass have the potential to disrupt food webs.

22.6.26 The overall value of phytoplankton is considered as medium.

22.6.27 Assessments of the potential effects on phytoplankton consider population parameters such as community composition, biomass and abundance. Where evidence is available, differential effects on the microflagellate and diatom components of the community is presented.

Zooplankton

22.6.28 Zooplankton include the early life stages of fish (ichthyoplankton) and benthic organisms as well as invertebrates that are planktonic throughout their life cycle (holoplankton). Zooplankton feed on phytoplankton, detritus and other smaller zooplankton and form an important food source for higher trophic levels. Zooplankton are a core component of marine ecosystems.

22.6.29 The zooplankton community has been characterised for the marine waters adjacent to the proposed development. Ichthyoplankton sampling began in 2008 and invertebrate zooplankton collection and analysis commenced in June 2009.

22.6.30 Ichthyoplankton and benthic larvae are assessed as part of the life history stage assessments in the fish, provided in **Section 22.8** of this chapter and benthic ecology, provided in **Section 22.7** of this chapter of the ES.

22.6.31 This chapter considers only the holoplankton component of the zooplankton community. The community has been characterised based on data acquired during BEEMS zooplankton surveys between 2009 and 2012, provided in **Appendix 22B** of this volume, and in 2014-2017 (Ref. 22.25). Entrainment monitoring at Sizewell B during 2011 is also used to inform the zooplankton baseline, provided in **Appendix 22G** of this volume.

22.6.32 Surveys between 2009 and 2012 sampled zooplankton from a wide geographic area within the GSB tidal excursion. Sampling primarily took place from February to July. A Gulf VII high-speed plankton sampler fitted with a 270µm mesh net was towed at 3-4.5 knots to sample the larger size fraction zooplankton. From 2010, an additional fine mesh 'PUP' sampler'PUP' fitted with 80µm mesh was used to collect smaller zooplankton specimens. The zooplankton components from the Gulf and 'PUP' samples were kept separate and are described in terms of the larger size fraction zooplankton component and the smaller size fraction zooplankton component.

22.6.33 Data on the spatial and temporal variability in zooplankton abundance and community composition was collected during the period of highest zooplankton biomass. In 2011, the survey area was extended to encompass the extent of the full thermal discharge plume modelled for Sizewell C. This resulted in 39 survey stations, provided in **Figure 22.2**. **Table 22.15** shows the temporal coverage and number of sample stations each month.

Table 22.15: Temporal coverage of zooplankton surveys between 2009 and 2017. Numbers indicate sampling stations, SZ represents sampling completed at the Sizewell B intakes and outfalls and the proposed locations of the Sizewell C cooling water infrastructure.

Month	2009	2010	2011	2012	2014	2015	2016	2017
January	-	-	-	-	-	SZ	SZ	SZ
February	-	24	39	-	-	SZ	SZ	-
March	-	25	39	-	SZ	SZ	SZ	-
April	-	25	39	6	SZ	SZ	SZ	-
May	-	25	39	20	SZ	SZ	SZ	-
June	25	25	39	44	SZ	SZ	SZ	-
July	-	-	-	40	SZ	SZ	SZ	-
August	-	-	-	-	SZ	SZ	SZ	-
September	-	-	-	-	SZ	SZ	SZ	-
October	-	-	-	-	SZ	SZ	SZ	-
November	-	-	-	-	SZ	SZ	SZ	-
December	-	-	-	-	SZ	SZ	SZ	-

22.6.34 Of the larger size fraction zooplankton, characteristic taxa[13] include mysids, ctenophores, gammarid amphipods, polychaete larvae, cumaceans, jellyfish, decapods, nematodes, isopods and krill.

22.6.35 Additional monthly sampling was undertaken between March 2014 and January 2017 to gain a greater understanding of the full seasonal cycle of the zooplankton (Ref. 22.25). A peak in chaetognath abundance from September to November each year was identified when they form a characteristic component of the plankton community.

22.6.36 In both data sets, mysids were both the most common and abundant group. In the 2009-2012 data set mysids were identified in 97% of samples and accounted for nearly 77% of the total abundance of the larger size fraction zooplankton individuals analysed. Mysids identified at Sizewell include *Schistomysis sp.* (primarily *S. spiritus, Siriella sp.*), and *Mesopodopsis sp*. Mysids peak in abundance off Sizewell in May-June. At the sampling station

[13] A taxon was considered ecologically relevant if it accounted for >1% of the total abundance (abundant) or was present in at least 5% of samples (common).

corresponding to the proposed location of the Sizewell C cooling water infrastructure, mysid abundance in May (2014-2017 data) was 41.5 individuals / m^3 (standard deviation (s.d.) ± 29.7). During the same month, 181.1 (± 207.4) individuals / m^3 occurred at the Sizewell B intakes, whilst 471.4 (± 268.1) individuals / m^3 were found at the Sizewell B outfalls. The high variation in the data sets indicates a high degree of interannual and spatial variability in mysid abundance. The data also indicates higher abundance in the waters within the Sizewell-Dunwich Bank and potentially aggregations of mysids near the Sizewell B cooling water outfalls.

22.6.37 Ctenophores were the second most common and abundant group occurring in 59% of the samples and accounting for over 10% of the total abundance in the February to July data set between 2009 and 2012. The species observed off Sizewell primarily included *Pleurobrachia pileus* (sea gooseberry) and *Beroe cucumis.* At the Sizewell C sampling station ctenophore abundance peaked in July at 6.4 (± 8.3) individuals / m^3 (2014-2017 data). Inshore of the Sizewell-Dunwich Bank, ctenophores peaked at 4.2 (± 6.4) individuals / m^3 at the Sizewell B intake sampling location in July. Jellyfish also occur in the plankton off Sizewell and include unidentified medusae, the crystal jellyfish (*Aequorea victoria*), the compass jellyfish (*Chrysaora hysoscella*) and the moon jellyfish (*Aurelia aurita*). Abundance is low throughout most of the year but increases in August and September. At the Sizewell C sampling location a September peak of 4.2 (± 3.5) individuals / m^3 was observed between 2014-2017.

22.6.38 Amphipods, primarily of the family Gammaridae, were present throughout much of the year in the Sizewell surveys. Amphipods are typically benthic or epibenthic making periodic excursions into the water column. The shallow water depths and tidal currents account for the commonality of gammarids in plankton surveys, where they occurred in nearly 43% of the samples and accounted for nearly 1% of the total individuals (2009-2012 data). Amphipod abundance peaked in July at the Sizewell C sampling station at 0.3 (± 0.4) individuals / m^3.

22.6.39 The smaller size fraction zooplankton represented by far the most numerically abundant zooplankton group. The peak abundance for most taxa occurs in May. A total of 60 taxonomic groups were identified in the 2014-2017 surveys. The smaller size fraction zooplankton was characterised by invertebrate eggs, foraminifers, copepods (juveniles and adults), bivalves, polychaetes, bryozoans, appendicularians, rotifers, gastropod larvae, echinoderms, gelatinous zooplankton, cirripedia (barnacle) larvae, nematodes, arachnids (sea mites)[14], and protozoans.

22.6.40 Copepods are a highly diverse group of holoplankton. Copepods were ever-present in zooplankton samples and accounted for over 28% of the total abundance of the smaller size fraction zooplankton (2009-2012 data). Copepods include harpacticoids, cyclopoids and the numerically dominant calanoid orders. *Acartia* spp and *Temora longicornis* are the most dominant calanoid copepod taxa. Other taxa include *Paracalanus* spp., *Pseudocalanus* spp., *Centropages* spp., and larger *Calanus* spp. which was also present in the larger size fraction samples. The abundance of copepods increases from April and remains high through to September. Large spatial and temporal variation in copepod abundance occurs. Peak numbers of 28,352 (± 24,160) and 29,708 (± 31,117) adult individuals / m^3 were recorded at the Sizewell B intake and outfall sampling locations, respectively in July. At the offshore Sizewell C sampling location, July peak abundances of adult copepods reached 24,225 (± 21,924) adult individuals / m^3 (2014-2017 data). Over the Winter period copepod numbers reduce to under 1,000 adult individuals / m^3.

Zooplankton entrainment

22.6.41 Comprehensive Entrainment Monitoring Programme (CEMP) surveys at Sizewell B determined the zooplankton taxa entrained in the cooling water flow. Pumped water samples were taken from the Sizewell B forebay for a year from 2010 to 2011. Zooplankton were entrained in all months of the year, but only in low numbers in January through to March, with March being the minimum. Peak zooplankton entrainment occurred in May and then declined gradually through the Summer and Autumn.

22.6.42 Forty-nine invertebrate zooplankton taxa were encountered in the Sizewell B cooling water. Based on scaled numbers an estimated 294.5×10^9 individual invertebrate zooplankton are entrained annually. Copepods made up over 72% of the total zooplankton entrained with the *Centropages, Temora,* and *Acartia* the most commonly observed. Bentho-pelagic taxa (mainly gammarids 8.7% and mysids 3.4%) and benthic taxa and their larvae (mostly barnacles 3.4%) comprised a further 18.0 % (**Table 22.16**).

[14] Sea spiders of the class pycnogonida (not the same as the land spiders belonging to the class arachnida) were also observed but at low abundance (**Appendix 22B**).

Table 22.16: Proportion of invertebrate zooplankton taxa entrained at Sizewell B.

Functional group.	% of total	Cumulative %
Copepods	72.07	72.07
Bentho-pelagic taxa (mainly gammarids and mysids)	13.44	85.51
Primarily benthic taxa and their larvae	4.54	90.05
Invertebrate eggs	2.48	92.53
Foraminifera	2.46	94.99
Gelatinous plankton	1.25	96.24
Tunicates	0.12	96.36
Nematodes	0.06	96.42
Non-determinate taxa	2.88	99.3
Other non-key taxa	0.71	100

Value of key zooplankton taxa

22.6.43 Over 120 zooplankton taxonomic groups have been identified in the characterisation reports. The characteristic taxa observed at Sizewell are largely consistent with data from the Continuous Plankton Recorder and are typical of the species found in the wider southern North Sea.

22.6.44 None of the holoplankton have direct conservation value. Key zooplankton taxa for EcIA have been selected based on ecological importance and potential socio-economic importance. None of the invertebrate zooplankton taxa have direct commercial value.

22.6.45 Based on the *in-situ* sampling programmes and CEMP, the key zooplankton taxa for assessment purposed include:

- mysids;
- amphipods;
- gelatinous zooplankton; and
- copepods.

22.6.46 These species are common and abundant in the coastal waters off Sizewell and are considered to be ecologically important components of the food web. Gelatinous zooplankton are both abundant and important for the EIA due to their potential socio-economic importance. Gelatinous zooplankton are an important consideration for power plants (Ref. 22.27), due to their gelatinous nature and propensity for populations to expand exponentially (i.e. to form “blooms”) and have the potential to cause blockages of the cooling water intake filters of power stations, which in severe cases can lead to station shutdown (Ref. 22.28).

22.6.47 The selected taxonomic groupings provide an initial starting point for the assessment of impacts of activities associated with the proposed development. These taxa may be applied as proxies for the wider zooplankton community as they are relatively well studied allowing a pragmatic approach to evidence-based sensitivity assessments for a range of development impacts. The value of these species and justification for their inclusion is provided in **Table 22.17**.

Table 22.17: Key representative zooplankton taxa for consideration during Ecological Impact Assessments.

Taxonomic grouping.	Selection process.	Value
Mysids	Bentho-pelgic mysids are the most common and abundant component of the larger size fraction zooplankton. Mysids are selected based on their ecological value.	Changes in the population level have the potential for food web perturbations as mysids form part of the diet of many species. However, natural variability in abundance is high. Value is assessed as *Medium.*
Gelatinous zooplankton.	Gelatinous zooplankton include ctenophores and jellyfish and are both common and seasonally abundant off Sizewell. Gelatinous zooplankton are selected based on their socio-economic and ecological value.	Changes in the population level of gelatinous zooplankton has the potential to affect predator-prey interactions. Impacts with the potential to increase gelatinous zooplankton abundance could also have potential socio-economic implications. Value is assessed as *Medium.*
Amphipods	Amphipods, primarily Gammarids were commonly encountered in zooplankton surveys and were abundant during the CEMP. Gammarids are typically benthic or epibenthic making periodic excursions into the water column where they are preyed upon by fish. Amphipods are selected based on their ecological value.	Changes in the population level have the potential for food web perturbations as amphipods form part of the diet of many species. However, natural variability in abundance is high. Value is assessed as *Medium.*
Copepods	Copepods represent a diverse group of zooplankton and for	Copepods represent an important trophic link betwen phytoplankton

Taxonomic grouping.	Selection process.	Value
	assessment purposes include benthic (harpacticoid) and pelagic species. Copepods are common and abundant in samples of the smaller size fraction zooplankton and accounted for 72% of the total zooplankton entrained at Sizewell B.	and small zooplankton and higher trophic levels. Copepods are prey items for a wide variety of species. Changes in the the copepod community has the potential for food web effects. Copepods have high abundance and natural variability. Value is assessed as *Medium.*

iii. Future baseline

22.6.48 The current baseline is considered appropriate for the duration of the construction and commissioning phases.

22.6.49 The effects of operational impacts on plankton receptors will be considered against well-established current baselines, but the operational design life of the proposed development (60-years) means that some impacts must be considered in relation to potential shifts in future baselines due to climate change.

22.6.50 The plankton future baseline in this section is primarily taken from the Marine Climate Change Impacts Partnership, the most comprehensive reviews of climate change impacts on the UK marine environment. The 2013 Marine Climate Change Impacts Partnership review on plankton (Ref. 22.29) states that there have been changes in plankton ecosystems in the last few decades, particularly related to sea surface temperature, stratification and salinity changes.

22.6.51 The following sections first summarises the Marine Climate Change Impacts Partnership findings of relevance to the GSB plankton ecosystem before the key implications of climate change for assessment purposes are identified.

Sea temperature rises

22.6.52 The southern North Sea, which is shallower with a faster warming rate than other areas of the UK, has seen cold water plankton species decline. Warmer water species have replaced some of the colder water species although they remain less abundant.

22.6.53 There has been an overall increase in gelatinous zooplankton in the North Sea since the 1980s (Ref. 22.29). UK waters have seen an increase in diversity for dinoflagellates and copepods, in particular. For example, there are two species of North Atlantic Calanus copepods, *C. helgolandicus* and *C. finmarchicus*, which illustrate how warming temperatures are affecting distribution. In the past few decades, the warmer-affinity *C. helgolandichus* has been replacing the colder-affinity *C. finmarchicus* in the North Sea. Lindley and Batten (2002) reported data collected in the continuous plankton recorder survey of long-term changes in zooplankton in four, regularly sampled areas of the North Sea (Ref. 22.30). However, there are inherent difficulties in predicting changes in species composition (Ref. 22.31), assessments consider broad taxonomic groupings such as ‘copepods’ as receptors. It is acknowledged that whilst the exact species composition is likely to change, the effects on the structure and functioning of the community remain unknown.

22.6.54 In addition to distribution shifts, there has also been a change in the phenological cycles of plankton with a trend for earlier seasonal plankton cycles in the southern North Sea being observed. Peaks in dinoflagellates in the North Sea have occurred 23 days earlier, diatoms 22 days earlier, copepods 10 days earlier, and other holozooplankton groups 10 days earlier than in the 1960s (Ref. 22.32).

22.6.55 It is feasible that the Spring bloom and peaks in plankton abundance at Sizewell may advance under a warming climate due to phenological changes. However, advancing phenological cycles would be limited by day length and solar elevation preventing primary production in the relatively turbid coastal waters at Sizewell in early Spring.

22.6.56 Despite warming sea temperatures, North Sea primary productivity has also seen significant declines between 1988 and 2013, however, effects are regional. The negative relationship has been explained by indirect effects of thermal stratification influencing environmental conditions such as nutrient availability, light climate and plankton movement in the water column rather than direct temperature related effects on physiology (Ref. 22.33). Phytoplankton growth in the permanently mixed regions off the East Anglian coast have been least affected by temperature rises due to natural mixing and the overriding effects of turbidity. In the areas off the East Anglian coast (of relevance to Sizewell) annual primary productivity has been relatively consistent (Ref. 22.33). Therefore, whilst future sea warming has the potential to interact with thermal discharges and will be considered further, the baseline productivity of the system is not expected to change due to warming alone.

22.6.57 A recent study on harmful algal bloom species showed that the habitat suitability of some species is likely to increase towards the end of the century, particularly in the North Sea (Ref. 22.34). Although actual blooms cannot be predicted that far in advance, the occurrence of some harmful algal bloom species is more likely in the future due to climate change. Much of this change is driven by projected increasing sea temperatures. Harmful algal species can be harmful to marine life and humans. Effects with the potential to enhance phytoplankton biomass will consider the increased presence of harmful algal bloom species under future climate scenarios.

Ocean acidification

22.6.58 Towards the end of the 21st century, ocean acidification may become an environmental concern around the UK, affecting calcification of certain plankton species (Ref. 22.29). Calcifying plankton, such as coccolithophores, may exist as part of the microflagellate component of the plankton in the GSB, however the system is diatom dominated (**Section 22.6.b**) and ocean acidification is not considered further in assessments.

Future Climate assessments

22.6.59 Future sea temperatures are not included in the current UK Climate Projections (UKCP18) marine climate predictions. Sea warming scenarios for Sizewell are based on UKCP09 SRES A1B data, which provides predictions of future climate for 2070-2100 relative to a baseline of 1961-1999 for the broad Sizewell area, provided in **Appendix 21E** of this volume.

22.6.60 Warming sea temperatures have the potential to act in-combination with impacts from the proposed development and have been assessed for Marine Ecology and Water Quality as part of the Sizewell C Project wide In-Combination Climate Impact (ICCI) assessment in **Volume 2**, **Chapter 26** of the **ES**.

22.6.61 Impacts associated with the proposed development that have been considered in relation to future sea warming due to climate change consist of:

- entrainment temperatures exceeding upper incipient lethal temperature limits for longer periods of the year;
- an increase in the likelihood and/or spatial extent of cooling water discharges exceeding absolute temperature thresholds[15] resulting in acute effects; and
- extending the duration of the year that seasonal chlorination may be applied, due to phenological responses associated with elevated water temperature.

[15] Thermal uplifts above ambient are predicted to be largely independent of ambient sea temperature. Therefore, thermal uplift areas would remain largely unchanged under future climate scenarios.

c) Construction

22.6.62 The construction phase, including commissioning, of the proposed development has the potential to effect plankton receptors. Construction is anticipated to last approximately nine to 12 years, to allow a starting point for assessment purposes an indicative construction start date of 2022 is applied.

22.6.63 This section considers the development components and associated activities that were identified during scoping, provided in **Appendix 22M** of this volume, to result in pressures warranting further investigation.

i. Coastal defence feature

22.6.64 Construction and maintenance activities for the HCDF and SCDF generally occur above MHWS and are therefore not predicted to affect plankton receptors. Therefore, no **significant** effects on plankton receptors are predicted.

ii. Beach landing facility

22.6.65 The beach landing facility (BLF) would be built at the beginning of the construction phase, year 0 of the Sizewell C Project to facilitate deliveries including AILs by barge (**Plate 22.1**). Once constructed, deliveries would occur throughout the construction phase between the approximate period of 31st March to 31st October. This section describes the impacts associated with the installation and operation of the BLF during the construction phase. Scoping identified that dredging activities represents the primary activity with the potential to effect plankton communities. Pressures with the potential to affect plankton are presented in **Table 22.18.**

Table 22.18: Pressures associated with BLF activities during the construction phase with the potential to affect plankton receptors.

Pressure	Activities resulting in pressure.	Justification
Removal (reprofiling) of substratum.	Navigational dredging[16].	The restricted spatial footprint of dredging activities means losses due to dredging would be indicernable at the population level (**Table 22.19**). No further assesment is made.
Changes in suspended sediments.	Navigational dredging.	Navigational dredging would cause temporary increases in SSC. Reductions in light availability due to increases in SSC can effect phytoplankton productivity and biomass. SSC

[16] Navigational dredging encompassing the initial capital dredge and subsequent maintenance dredging requirements at the BLF, provided in **Section 22.3.i)** of this chapter.

Pressure	Activities resulting in pressure.	Justification
		may affect zooplankton through mechanical stress or reductions in feeding efficiency.
Contaminant resuspension.	Navigational dredging.	Resuspension of pollutants and nutrients from contaminated sediments has the potential to influence plankton communities (**Table 22.19**). The sandy nature of the sediments within the GSB, low organic content and contamination levels present a low risk of releases of sediment-bound contaminants or nutrients to the water column, provided in **Section 22.4** of this chapter. No further assessments is made. Dredging activities would be subject to marine licence conditions, which would include the requirement to verify sediment quality prior to dredging activities.
Sedimentation rate changes.	Navigational dredging.	Deposition of suspended sediments can lead to smothering of plankton that spend some or all their life cycle on or near the seabed such as bentho-pelagic zooplankton and the resting life stages of phytoplankton (cysts) and zooplankton (eggs).
Underwater noise.	Impact piling and dredging.	Impact piling for the installation of the BLF and dredging activities would introduce noise in the marine environment. Assessment of effects on zooplankton is considered.
Changes in wave energy and bed sheer stress.	Physical presence of structure.	Localised changes in wave energy and bed sheer stress are predicted in proximity of the navigational channel and the BLF structure, provided in **Appendix 20A** of this volume. Small-scale hydrological changes in the shallow subtidal areas close to the BLF are predicted to have negligible effects on plankton communities. No further assesment is made.
Disturbance	Artificial lighting.	Artificial lighting is a likely requirement on the BLF and moored vessels would introduce light into the marine environment. Light spill could attract some zooplankton at night as well as increase zooplankton vulnerability to predation by visually hunting fish (Ref. 22.35). Light spill also has the potential to increase the photoperiod for primary producers, by allowing primary production to continue when natural light levels are limited. Mitigation measures as part of the site Lighting Strategy aims to minimise light spill into the marine environment. The area of water exposed to light spill would be minimal and high rates of light attenuation would occur in the turbid nearshore waters. Effects on plankton

Pressure	Activities resulting in pressure.	Justification
		communities in the GSB are predicted to be negligible. No further assesment is made.
Abrasion	Mooring of barges.	Mooring of barges and construction vessel positioning and anchoring would cause surface abrasion and compact surface sediments potentially crushing plankton with a benthic association and resting stages (eggs and cysts). The small spatial scale of such impacts is predicted to have negligible effects on plankton communities. No further assesment is made.

Changes in suspended sediment concentration: Beach landing facility

22.6.66 Sediments moved and agitated by plough dredging would be redistributed by ambient flows away from the dredge area. Navigational dredging for the BLF would include an initial capital dredge followed by maintenance dredging to maintain the navigable channel, provided in **Section 22.3.i** of this chapter. Following the capital dredge, a plume with an instantaneous suspended sediment concentration (SSC) of >100mg/l above daily maximum background levels is expected to form inshore over an area of up to 108ha at the sea surface and 83ha as a depth averaged plume. A small area of up to 7ha would experience an instantaneous SSC plume of >1,000 mg/l above background levels. The requirement for maintenance dredging would depend on ambient conditions and the tolerance of the barges. Assessments assume maintenance dredging of approximately 10% of the initial capital volume to occur at approximately monthly intervals during the campaign period when the BLF is in most frequent use, provided in **Section 22.3.i** of this chapter. Maintenance dredging is predicted to result in up to 28ha of sea surface expected to experience >100mg/l, and 1ha expected to experience >1,000 mg/l above background SSC on each occasion, provided in **Section 22.3.i)** of this chapter and **Appendix 22J** of this volume.

22.6.67 Ambient conditions at the site are highly variable, provided in **Section 22.4** of this chapter and the surface waters are considered as '*intermediate turbidity'* according to WFD criteria. Dredging would temporarily increase the classification to '*turbid*'. However, SSC would return to background levels several days after dredging activity ceases.

22.6.68 The duration of the SSC plume is short-lived and transient; however, maintenance dredging increases the frequency of smaller scale impacts. Maintenance dredging would result in the plume reoccurring at approximately monthly intervals during the campaign period and throughout the construction phase.

22.6.69 The amount of change and extent of the plume results in an impact magnitude of medium.

Phytoplankton sensitivity to changes in suspended sediment concentration: Beach landing facility

22.6.70 Phytoplankton exposed to increases in SSC may be susceptible to reductions in productivity. The short duration and transitory nature of the plume indicate that small declines in primary productivity may occur, but recovery would be rapid following cessation of the dredging activity. A full sensitivity assessment is provided in **Table 22.19**.

22.6.71 The sensitivity of phytoplankton populations to increases in SSC is low.

22.6.72 The impact of increased SSC resulting from dredging activities is predicted to have a minor adverse effect on phytoplankton. Effects are predicted to be short-lived and **not significant** relative to natural variation in biomass.

22.6.73 The potential exists for dredging activities to occur simultaneously at the site. The effects of increases in SSC is considered further as part of the inter-relationships, provided in **Section 22.6v** of this chapter.

Zooplankton sensitivity to changes in suspended sediment concentration: Beach landing facility

22.6.74 Increases in SSC may have adverse effects on fitness of some zooplankton taxa by decreasing ingestion rates and/or egg production rates. High natural fecundity and exchange with the wider southern North Sea afford a high degree of resilience (**Table 22.19**).

22.6.75 The sensitivity of zooplankton to dredging at the BLF is low.

22.6.76 The impact of increased SSC resulting from dredging activities is predicted to have a minor adverse effect on zooplankton receptors. Effects are predicted to be short-lived and **not significant** relative to natural variation in population abundance.

Table 22.19: Summary of plankton sensitivity to dredging pressures associated with the proposed development.

Pressure	Receptor group.	Sensitivity
Removal of substrate	Zooplankton	Zooplankton with a benthic association may incur mortality due to dredge extraction. The restricted spatial footprint of dredging activities (**Table 22.10**) means losses due to dredging would be indicernable at the population level and resistance is high. Zooplankton are fecund and exchange with the wider southern North Sea affords a high degree of resilience. Zooplankton are assessed as not sensitive to sediment extraction. No further assesment is made.
	Resting stages (zooplankton eggs and phytoplankton cysts)	Many species of marine phytoplankton and zooplankton have a dormant resting stage within their life cycle. Phytoplankton cysts and zooplankton eggs can sink out of the water column and rest on the seabed. Bioturbation, tidal scour, and movement of sediments can resuspend cysts and induce germination under favorable conditions (Ref. 22.36). Anthropogenic activities that mobilise seabed sediments can re-suspend resting plankton stages (Ref. 22.37; 38). Naturally high sediment resuspension rates within the Sizewell Bay and the small dredge area in relation to available seed-stock indicates plankton populations will be resistant to inoculation of the water column, or to damage of eggs and cysts following dredging. Recruitment from the adult population would replenish losses of eggs and cysts. Plankton resting stages are assessed as not sensitive to sediment extraction. No further assesment is made.
Suspended sediment concentration (SSC)	Phytoplankton	Phytoplankton diversity and biomass may be affected by dredging due to light limitation and resuspension of nutrients or contaminants (Ref. 22.39)[17]. Strong linear relationships have been found between suspended particulate matter and light attenuation (*Kd*) across UK marine waters (Ref. 22.40) and biomass and primary productivity are particularly sensitive to variations in suspended sediment concentrations (Ref. 22.41).

[17] Resuspended pollutants including trace metals have the potential to influence community composition (Ref. 22.535). The sandy nature of the sediments within the GSB, low organic content and low contamination levels present a low risk of releases of sediment-bound contaminants or nutrients to the water column, provided in **Section 22.4** of this chapter. Accordingly, pressures associated with resuspension of nutrients and/or contaminants have been scoped out and changes in light climate are the primary impact of dredging on phytoplankton.

Pressure	Receptor group.	Sensitivity
		In the southern North Sea, during the Winter months, low surface irradiance and rapid attenuation of photons within the water column cause strong light limitation. Growth of phytoplankton is stimulated in Spring when nutrients are available, temperature increases, and light is no longer limiting. At Sizewell, light limitation is the primary factor controlling photosynthesis up to mid-May, see **Appendix 22H** of this volume. The potential influence of SSC on phytoplankton will therefore vary according to time of year. The short duration (days) and transitory nature of the dredge plumes (**Table 22.11**) indicate that small declines in primary productivity may occur. Recovery would be rapid following cessation of the dredging activity. The sensitivity of phytoplankton populations within the GSB due to increases in SSC due to dredging events is predicted to be low.
Suspended sediment concentration (SSC)	Zooplankton	Many species of zooplankton live in turbid environments and are adapted to encountering a wide range of suspended sediment concentrations (Ref. 22.42; 43). Evidence of the sensitivity of zooplankton to increased SSC in the marine environment is limited with most work focussing on benthic assemblages so evidence for copepods and hyperbenthic mysids is considered as proxy for the wider zooplankton community. Benthio-pelagic mysids are the most common and abundant component of the larger zooplankton fraction surveyed within the GSB. Mysids are adapted to highly turbid environments (Ref. 22.44). Copepods demonstrate species-specific responses to elevated levels of SSC. The feeding efficiency of the *Paracalanus* sp. decreases with elevated SSC (100mg/l), irrespective of food availability (Ref. 22.42), whilst ingestion rates of *Acartia tonsa* were not affected by suspended particle concentrations up to 95mg/l (Ref. 22.45). Higher SSC may result in increased ingestion of non-prey items. Detritus has a lower nutritional value and the relationship between 'net growth efficiencies' of estuarine and coastal copepods and the percentage of detritus in the diet has been shown to be inversely proportional (Ref. 22.46). Copepod egg production rates may also be adversely influenced by increases in suspended particulate matter as observed in *Eurytemora affinis* (Ref. 22.47). Egg production rates in *Paracalanus* sp. also decreased with elevated suspended sediment levels at low food concentrations but remained unaffected when food availability was high. Viability of eggs was not affected by SSC (Ref. 22.42).

Pressure	Receptor group.	Sensitivity
		The sensitivity of zooplankton to increases in SSC is likely to be species specific and dependent on natural food availability. Reductions in feeding rates and fecundity may occur in sensitive taxa. However, the baseline conditions within the GSB mean zooplankton are adapted to large daily and seasonal changes in SSC, provided in **Section 22.4** of this chapter. The short duration (days) and transitory nature of the dredge plumes mean reductions in fitness are likely to be indicernable at the population level and high natural fecundity and exchange with the wider southern North Sea afford a high degree of resilience. The sensitivity of zooplankton populations to increases in SSC due to dredging events is predicted to be low.
Sedimentation	Zooplankton	Deposition of suspended sediment arising from dredge disposal can cause smothering and burial of animals associated with the seabed or change the sediment characteristics (Ref. 22.48). Dredge disposal is assumed to occur locally therefore changes in sediment characteristics are considered unlikely. Smothering may affect plankton that spend some or all of their life cycle on or near the seabed. The adult phases of the pelagic plankton community are not predicted to be directly affected by elevated sedimentation rates. Species inhabiting sandy bottoms are capable of withstanding sediment deposition, although adults have a higher tolerance than juveniles and both tolerate deposition of sand, as found at the proposed dredge locations, provided in **Section 22.3.i)** of this chapter, better than mud (Ref. 22.49). Species with a benthic association, such as mysids are adapted to high sediment environments (Ref. 22.44) and are predicted to be largely insensitive to sedimentation associated with dredging activities. The amphipods *Bathyporeia elegans* and *Corophium volutator* are common and abundant at Sizewell, provided in **Appendix 22C** of this volume. The species are considered within Group 3 of the AMBI sedimentation species; *"species are insensitive to higher amounts of sedimentation, but don't easily recover from strong fluctuations in sedimentation"* (Ref. 22.50) In close proximity to dredging activities sedimentation may be sufficient to cause localised mortality. However, zooplankton are predicted to be resistant to sedimentation levels predicted throughout much of the impacted area, provided in **Section 22.3.i).v** of this chapter. Any losses would be expected to recover quickly due to the temporary nature of the dredge activities and the ability of the species to recolonise.

Pressure	Receptor group.	Sensitivity
		The sensitivity of zooplankton populations to increases in sedimentation due to the dredging activities at the proposed development is predicted to be low.
	Phytoplankton	In turbid coastal waters benthic primary productivity is limited. The effects of sediment deposition on phytoplankton is not assessed further.
	Resting stages (zooplankton eggs and phytoplankton cysts)	Phytoplankton resting cysts and zooplankton eggs within benthic sediments may be susceptible to smothering following sedimentation of dredge spoil. The depth of sediment deposition across the majority of the GSB area following dredge activities is predicted to be small in relation to available seed-stock area, and tidal resuspension of deposited sediments occurs, provided in **Appendix 22J** of this volume. Plankton populations are predicted to be resistant to potential losses of resting stages due to smothering. Recruitment from the adult population would replenish losses of eggs and cysts. Plankton resting stages are assessed as not sensitive to sediment deposition and are not assessed further.

Changes in sedimentation rates: Beach landing facility

22.6.77 Sediment suspended by plough dredging and dispersed by ambient flows would subsequently be deposited onto the seabed. Sedimentation is typified by 'light sedimentation', with a small area of up to 3ha expected to experience sediment deposition of >50mm. A very small area (1ha) could experience over 300mm of deposition. It is expected that all suspended sediment would be deposited within hours of dredging and then dispersed by natural resuspension, leaving just 3ha where sediment thickness remains >20mm after 15 days. The pressure would reoccur from maintenance dredging at approximately monthly intervals during the campaign period; however, sediment deposition in this case is not expected to exceed 20mm, provided in **Section 22.3.i** of this chapter.

22.6.78 Impact magnitude is assessed as low due to the small spatial footprint of sediment deposition at ecologically relevant depths and rapid dispersal of deposited sediments.

Zooplankton sensitivity to changes in sedimentation rates: Beach landing facility

22.6.79 The sensitivity of zooplankton populations to increases in sedimentation due to dredging events is predicted to be low, provided in **Table 22.19**.

22.6.80 Sediment deposition following dredging for the BLF is predicted to have minor adverse effects on zooplankton. Effects are **not significant**.

Underwater noise and vibration: navigational dredging and impact piling

22.6.81 Navigational dredging and impact piling during BLF construction would introduce noise and vibration to the marine environment. This has the potential to affect zooplankton receptors by causing physical damage or inducing behavioural or physiological changes.

22.6.82 Invertebrates are expected to be sensitive to particle motion rather than sound pressure changes (Ref. 22.51). However, there is currently a lack of information and no guidelines on the levels of particle motion that are likely to have detrimental effects on zooplankton or other marine animals (Ref. 22.52). Therefore, published sound pressure thresholds for fish without a swim bladder that 'hear' by particle motion detection (Ref. 22.53) are applied as a proxy to estimate the areas in which zooplankton would be exposed to this pressure **Table 22.71**. Sensitivity assessments consider the relevant literature on potential responses to noise.

22.6.83 Underwater noise modelling was used to calculate the areas in exceedance of these thresholds, provided in **Appendix 22L** of this volume.

22.6.84 Dredging auditory impact ranges for potential mortality or recoverable injury are predicted to be limited to within 25m (<0.25ha) of the source (**Table 22.72**) and are short term events. The small spatial extent and precautionary thresholds (see sensitivity assessment) indicates that underwater noise from dredging is would have negligible effects on plankton receptors and is not assessed further.

22.6.85 For impact piling during BLF construction, two strike energy scenarios have been modelled for the installation of the 12 piles: 90kJ and a 200kJ. Up to 1,500 strikes per pile is assumed. Based on 200kJ, the threshold for potential mortality would be crossed within 40m (<1ha) of the source, while the threshold for recoverable injury would be crossed over 2ha, as provided in **Table 22.75**. Piles are expected to be installed consecutively (not concurrently), with five piles installed per day. The duration of the activity is very short term (days).

22.6.86 Impact magnitude is assessed as low for impact piling, reflecting the limited areas in exceedance of thresholds for mortality or injury and the short duration of the pressure.

Zooplankton sensitivity to underwater noise and vibration

22.6.87 Zooplankton would be exposed to noise associated with BLF construction. As some invertebrate groups within the zooplankton can detect particle motion, the sensitivity of zooplankton to noise is assessed. Noise effects on benthic invertebrates (including larval stages) are assessed in **Section 22.7** of this chapter, whilst effects on ichthyoplankton is assessed in **Section 22.8** of the same chapter.

22.6.88 It is precautionarily assumed that mortality would occur in zooplankton within the area that exceeds the relevant threshold for fish without a swim bladder, i.e. <1ha for impact piling. Besides mortality, it is possible that the introduction of noise would induce behavioural alterations in zooplankton. Such effects appear most likely in crustaceans, as evidence suggests that this group is able to detect particle motion (Ref. 22.51). However, the ability to detect particle motion appears to be five orders of magnitude weaker in crustaceans than in fish (Ref. 22.51). Therefore, behavioural effects are likely to be spatially limited.

22.6.89 Mortality would be restricted to a very small spatial area with a very small proportion of the population of zooplankton within the GSB exposed. Potential behavioural effects may occur at greater distances from the sound source. Effects on zooplankton fitness is not establish. Zooplankton are precautionarily assessed as having low sensitivity to noise associated with BLF piling activities.

22.6.90 The low impact magnitude and low sensitivity of zooplankton to underwater noise and vibration indicate a minor adverse effect on this receptor. The effect is **not significant**. Confidence in this assessment is low due to the using fish assessment criteria, however, the assessment is considered precautionary.

iii. Combined drainage outfall

22.6.91 This section describes the impacts associated with the installation and operation of the combined drainage outfall (CDO) during the construction phase. It is anticipated that construction of the CDO would begin early in the construction phase and would be the main route for construction discharges. Pressures with the potential to effect plankton are presented in **Table 22.20**.

Table 22.20: Pressures associated with CDO activities during the construction phase with the potential to affect plankton receptors.

Pressure	Activities resulting in pressure.	Justification
Changes in suspended sediments.	Capital dredging and disposal.	Dredging would cause temporary increases in SSC. Reductions in light availability due to increases in SSC can effect phytoplankton productivity and biomass. SSC may affect zooplankton through mechanical stress or reductions in feeding efficiency.

Pressure	Activities resulting in pressure.	Justification
Sediment-ation rate changes.	Capital dredging and disposal.	Deposition of suspended sediments can lead to smothering of bentho-pelagic zooplankton.
Pollution and other chemical changes.	Construction discharges of heavy-metals.	Heavy-metal contaminants in construction discharges including dewatered groundwater have the potential to exert toxicological effects on plankton receptors. Effects on phytoplankton and zooplankton are considered.
Pollution and other chemical changes.	Nutrients	Nutrient discharges including all sources of DIN and phosphate during construction discharges of treated sewage and groundwater and commissioning discharges (including phosphate) have the potential to effect primary production. Effects on phytoplankton are assessed.
	Un-ionised ammonia.	Potential toxicological effects may arise from un-ionised ammonia from treated sewage and commissioning discharges.
Synthetic compound contaminat-ion.	Commission-ing discharges of hydrazine.	Commissioning discharges of hydrazine during cold-flush testing of reactor would be discharged through the CDO. The potential toxicological effects are assessed.
	Discharges of drilling wastewater chemicals.	Tunnel boring machine (TBM) chemicals may be used during drilling of the cooling water intakes and outfall tunnels. Drilling waste water containing small volumes of drilling chemical leachate would be discharged via the CDO. The potential toxicological effects are assessed.

Changes in suspended sediment concentration: construction of combined drainage outfall

22.6.92 Dredging and local dredge disposal for the installation of the CDO headworks would lead to elevated suspended sediment concentrations (SSC). Plumes with instantaneous SSC of >100mg/l above background levels are expected to form over areas of up to 89ha at the surface. A small area of 1ha is expected to experience an instantaneous SSC of >1,000mg/l above background at the sea surface, provided in **Section 22.3.i** of this chapter.

22.6.93 Ambient conditions at the site are highly variable, provided in **Section 22.4** of this chapter, and the surface waters are considered as '*intermediate turbidity'* according to WFD criteria provided in **Appendix 21E** of this volume. Dredging would temporarily increase the classification to '*turbid'*. However, SSC would return to background levels several days after dredging activity ceases, provided in **Section 22.3.i** of this chapter. The increase in SSC would occur once for the installation of the CDO head.

22.6.94 Increases in SSC would be large relative to baseline conditions, however, the plume is highly transient and its intermediate spatial footprint results in an impact magnitude of medium.

Phytoplankton sensitivity to changes in suspended sediment concentration

22.6.95 Phytoplankton exposed to increases in SSC may be susceptible to reductions in productivity. A sensitivity assessment to changes in SSC is provided in **Table 22.19**. The short duration and transitory nature of the plume suggests that a small decline in primary productivity may occur, but recovery would be rapid following cessation of the dredging activity. The sensitivity of phytoplankton is predicted to be low.

22.6.96 The impact of increased SSC resulting from dredging activities for the installation of the CDO is predicted to have a minor adverse effect on phytoplankton. Effects are predicted to be short-lived and **not significant** relative to natural variation.

Zooplankton sensitivity to changes in suspended sediment concentration

22.6.97 Increases in SSC may have adverse effects on fitness of some zooplankton taxa by decreasing ingestion rates and/or egg production rates. Effects are likely to be species specific and dependent on natural food availability. High natural fecundity and exchange with the wider southern North Sea afford a high degree of resilience (**Table 22.19**). The sensitivity of zooplankton is predicted to be low.

22.6.98 The impact of increased SSC resulting from dredging activities for the installation of the CDO is predicted to have a minor adverse effect on zooplankton. Effects are predicted to be short-lived and **not significant** relative to natural variation.

Changes in sedimentation rates: construction of combined drainage outfall

22.6.99 Sediment suspended by dredging and dredge disposal for the installation of the CDO would subsequently be deposited onto the seabed. Sediment deposition would be classified as 'light' throughout the plume footprint, with sediment thickness not expected to exceed 50mm and only expected to exceed 20mm over 1ha. It is predicted that all suspended sediment would be deposited within hours of dredging and then dispersed by natural resuspension, leaving no area where sediment thickness remains >20mm thicker than it was prior to dredging after 15 days, provided in **Section 22.3.i)** of this chapter. These levels of sediment deposition would occur once for the installation of the CDO head.

22.6.100 As no area would be exposed to greater than ‘light’ deposition and deposited sediments would be rapidly dispersed, impact magnitude is assessed as very low.

22.6.101 The sensitivity of zooplankton to sediment deposition has been assessed as low (**Table 22.19**).

22.6.102 Sediment deposition following dredging for the CDO headwork installation is predicted to have negligible effects on plankton receptors. Effects are **not significant**.

Heavy metal contamination: dewatering discharges

22.6.103 During construction of the main development site, groundwater discharges would be made via the CDO. Exploratory boreholes across the main development site quantified the concentrations of dissolved metals within the groundwater. The worst-case construction discharges for trace metals would be during the 28-day dewatering of the cut-off wall around the main construction site (Case A: **Plate 22.1**). The dewatering phase would result in an estimated 300,000m^3 of groundwater being discharged at a rate of 124l/s. After the initial dewatering phase nominal discharges of 15l/s would continue throughout the construction phase to remove rainwater and seepage through the cut-off wall, provided in **Appendix 21E** of this volume.

22.6.104 In the dewatering phase two groundwater metals, zinc and chromium failed initial EQS screening and a General Estaurine Transport Model simulation was undertaken to determine the mixing rates and spatial extent of the impacts.

22.6.105 The mean background concentration of zinc in the environment is 15.12µg/l whilst the EQS is 6.8µg/l as an annual average. Since the background levels are in exceedance of the EQS, zinc discharges could not be assessed under standard procedures. Modelling predicted the point at which zinc concentrations would be indiscernible from background based on analytical detection limits of 0.4µg/l. Therefore, the threshold value for zinc was set at 15.52µg/l. Thus, the amount of change relative to baseline is approximately 2.5%. Modelling demonstrated that zinc concentrations would only be discernible above background over a mean sea surface area of 0.11ha. At the seabed, zinc concentrations are not predicted to exceed background concentrations.

22.6.106 Chromium has a mean EQS concentration of 0.6 µg/l and a 95th percentile EQS concentration of 32µg/l. Chromium background concentrations of 0.4-0.57µg/l are reported for the site. As a precautionary measure the higher background concentration was applied to give a mean EQS threshold of 0.03µg/l. A sea surface area of 5.49ha exceeded the mean EQS, at the seabed chromium did not exceed EQS concentrations. The 95th percentile

EQS concentration (32µg/l) was not exceeded, as provided in **Appendix 21E** of this volume.

22.6.107 The initial dewatering drawdown phase is a short-term activity (28 days). Areas impacted extend over a very limited spatial area and the amount of change is small relative to the baseline conditions. The impact magnitude is assessed as very low.

22.6.108 A very small proportion of the plankton community within the GSB would be exposed to heavy metal concentrations in exceedance of EQS thresholds or natural background concentrations. In the tidally dominated system exposure would be limited. No discernible changes in plankton communities are predicted. Plankton within the GSB are not sensitive to heavy metal discharges from the CDO.

22.6.109 Heavy metal discharges from the CDO are predicted to have negligible effects on plankton receptors. Effects are **not significant**.

Nutrient enrichment: construction discharges

22.6.110 During construction and commissioning relatively small quantities of nitrate and phosphate; primarily from the use of conditioning chemicals in the various circuits but also from treated sewage may be discharged. Nutrient discharges have the potential to enhance phytoplankton biomass particularly if they occur during periods of nutrient limitation. Potential effects on primary production within the GSB are assessed, and the potential for indirect food webs effects are considered.

22.6.111 The peak nitrogen and phosphate additions from the proposed development were compared to the daily exchange of water in the tidal system and the additional nutrient terms were modelled using the Combined Phytoplankton and Macroalgae model.

22.6.112 Construction nutrient discharges represent approximately 1% or less of the exchange rates and would be indistinguishable from background nutrient variation. The magnitude of impact is low.

22.6.113 The Combined Phytoplankton and Macroalgae model predicts that construction nutrient additions would increase annual gross primary production within the tidal excursion by <0.2%, provided in **Appendix 22H** of this volume. Such changes are orders of magnitude below the natural variation in chlorophyll *a* biomass, provided in **Section 22.4** of this chapter. It is recognised that whilst the Combined Phytoplankton and Macroalgae model produces outputs at daily intervals, nutrient inputs are simulated as an annual mean. Therefore, it is feasible that phytoplankton would be more sensitive should greatest inputs occur during periods of nutrient limitation. However, poor light penetration due to turbid conditions means the coupling between nutrient inputs and eutrophication are weakened in the southern North Sea, which is defined as a Non Problem Area based on the OSPAR Common Procedure Assessment for Eutrophication (Ref. 22.54). Phytoplankton biomass within the GSB is not sensitive to construction nutrient discharges.

22.6.114 Construction phase nutrient inputs are predicted to have negligible effects on phytoplankton biomass. Effects are **not significant** relative to natural variability in phytoplankton biomass.

Indirect food web effects of nutrient discharges

22.6.115 Increases in primary production at the base of coastal food webs has the potential to cause bottom-up effects. The Combined Phytoplankton and Macroalgae model predicted negligible changes in gross primary productivity and no indirect food web effects are predicted.

Un-ionised ammonia: treated sewage discharges

22.6.116 Ammonia is a commonly occurring pollutant that enters waterbodies from diffuse and point sources including sewage effluents, industrial and agricultural activities and decomposition of organic matter. Ammonia exists in the toxic un-ionised phase (NH_3) and as ionised ammonium (NH_4^+). The relative proportion of each form depends on the temperature, salinity and pH of the water. Higher temperatures and pH favour ammonia, whilst higher salinity favours ammonium (Ref. 22.21). Treated sewage discharges from the CDO have the potential to exert toxicological effects on plankton receptors should ammonia levels exceed EQS values of 21µg/l.

22.6.117 The highest routine sewage discharges are anticipated during Case D, as provided in **Plate 22.1,** and a worst-case un-ionised ammonia discharge would occur in the unlikely event of a sewage only discharge. In this situation dilution modelling predicts exceedance of EQS concentrations up to 6.3m from the point of discharge. EQS exceedance is within 4m of the discharge for all other construction scenarios provided in **Appendix 21E** of this volume.

22.6.118 The magnitude of impact is assessed as low as discharges could occur throughout the construction phase.

Plankton sensitivity to un-ionised ammonia

22.6.119 A very small proportion of the plankton community within the GSB would be exposed to un-ionised ammonia concentrations in exceedance of EQS but in the tidally dominated system exposure would be brief. Phytoplankton and zooplankton are assessed together.

22.6.120 Boardman *et al.,* (2004) reported 48-hour no observed effect concentrations (NOEC) of 0.45mg/l of juvenile mysids exposed to un-ionised ammonia (Ref. 22.55). Concentrations sufficient to cause reductions in photosynthetic activity in phytoplankton or mortality in zooplankton following short-term exposure far exceed the concentrations predicted at the outfall (Ref. 22.21). Plankton receptors are not sensitive to the un-ionised ammonia discharges at the population level.

22.6.121 Un-ionised ammonia discharges from the CDO are predicted to have negligible effects on plankton communities. Effects are **not significant**.

Tunnelling chemical discharges

22.6.122 Based on current understanding of the underlying geology a TBM slurry method with bentonite is the most likely scenario for tunnelling. Spoil from the cutting face would be transported to a temporary stockpile for onward management. Groundwater would be generated from digging the galleries allowing access to the tunnels and tunnelling itself. During the transport and processing of spoil material, groundwater and potentially residual TBM chemicals would be produced in wastewater that would be transported landward, treated as required and discharged from the CDO.

22.6.123 Bentonite is a clay mineral regularly used in construction and offshore drilling operations. A bentonite recovery system would be utilised; however, bentonite is assessed due to the potential to increase the SSC in the receiving waters. Bentonite is included on the OSPAR list of substances that pose little or no risk to the environment. Modelling accounted for a tunnelling wastewater discharge rate of 34.4l/s and a discharge of 8.8mg/l bentonite. The predicted concentration of bentonite in suspension would be orders of magnitude lower than baseline SSC, provided in **Section 22.4** of this chapter, with 95th percentile concentrations of 10µg/l restricted to sea surface areas of <11ha and mean concentrations of 10µg/l less than 1.5ha, provided in **Appendix 21E** of this volume. In the tidally dominated environment characterised by high resuspension rates, the potential for sedimentation of fine materials to cause ecological effects during normal tunnelling processes is negligible. No further assessment is made.

22.6.124 To envelope alternative tunnelling methods, assessments considered the use of indicative ground conditioning TBM chemicals. Representative chemicals from those applied for Hinkley Point C assessments are used to envelope potential tunnelling options at this stage. These include the anti-clogging agent BASF Rheosoil 143 and the soil conditioning additive CLB F5 M, provided in **Chapter 21** of this volume. The potential worst-case tunnelling scenario would occur when two cooling water tunnels are being excavated simultaneously (Case E; **Plate 22.1**).

22.6.125 Modelling predicted that the mean sea surface area in exceedance of the BASF Rheosoil 143 PNEC was restricted to 1ha (95th percentile 5.8ha). The seabed is never exposed to concentrations above the predicted no-effect concentration (PNEC) provided in **Table 22.21**. The sea surface area exposed to CLB F5 M in exceedance of the PNEC was restricted to 3.1ha as a mean concentration (95th percentile 25ha). The seabed is never exposed to concentrations above the PNEC, provided in **Appendix 21E** of this volume.

22.6.126 Tunnelling is predicted to be a medium-term impact lasting several years in total. The use of TBM surfactants in the tunnelling process remains to be confirmed and assessments present a precautionary approach enveloping worst-case representative chemicals. A small spatial area is predicted to exceed the PNEC at the sea surface whilst the seabed would not be exposed to concentrations above the PNEC.

22.6.127 The impact magnitude is assessed to be low.

Table 22.21: Areas of PNEC exceedance for different TBM discharges.

TBM chemical and active substance.	PNEC (mean).	Discharge conditions (concentration and flow rate).	Mean surface exceedance (and 95th percentile).	Mean seabed exceedance (and 95th percentile).
BASF Rheosoil 143: sodium lauryl ether sulphate.	40µg/l	23.13mg/l at 34.4l/s	1.01ha (5.83ha)	0ha
CLB F5 M: mono- alkyl sodium sulphates[18]	4.5µg/l	7.71mg/l at 34.4l/s	3.14ha (25.0ha)	0ha

Plankton sensitivity to tunnelling chemicals

22.6.128 Limited empirical evidence is available for the effects of TBM surfactants on marine plankton and evidence is drawn from freshwater mesocosm experiments. The effects of anionic surfactants alkyl ethoxylate sulphate (AES) and alkyl sulphate (AS), used in CLB F5 M, on periphytion, protozoa and invertebrates following 8-week exposures in stream mesocosm experiments was tested. A NOEC of 251µg/l for AES and 224µg/l for AS was reported (Ref. 22.56).

22.6.129 Stream mesocosms exposed for 30-days to AES were compared to control stream invertebrate communities. The mesocosms treated with

[18] Ethoxylated sulphates are another active substance considered but have a less precautionary PNEC (35µg/l).

concentrations of 0.7, 1.27, 2.2, and 4.31mg/l were between 85-95% similar throughout the course of the experiment. The maximum concentration treatment (10.18mg/l) was 70 % similarity to controls. Two weeks after exposure to AES ended communities treated with 10.18mg/l showed recovery (Ref. 22.57).

22.6.130 These examples draw on literature from freshwater communities and the physico-chemical properties of the aqueous solution are important considerations determining solubility and toxicity of contaminants. However, they indicate that higher concentrations than those predicted at Sizewell are required to cause toxicity or community effects. Laboratory experiments have shown LC_{50} acute toxicity of alkyl ether sulphates on freshwater invertebrates ranging from 0.37 to 50mg/l (Ref. 22.58). Toxicity is likely to be both highly species-dependent, and reliant on the alkyl chain length and number of ethoxylate groups. Furthermore, biodegradation of AS and AES surfactants is rapid for all chain lengths (Ref. 22.58).

22.6.131 A very small proportion of the plankton community within the GSB would be exposed to TBM surfactants and concentrations are unlikely to cause toxicological effects. Plankton receptors are precautionarily predicted to have low sensitivity to the representative TBM discharges assessed.

22.6.132 TBM discharges are predicted to have minor adverse effects on plankton receptors. Effects are **not significant**.

Commissioning discharges: Hydrazine

22.6.133 During cold flush testing a number of chemicals would be released that required further investigation for potential water quality issues, provided in **Section 22.5dii** of this chapter. Of these, hydrazine used to prevent corrosion of the reactor units, failed the initial screening and is considered in more detail. Based on the Rochdale envelope approach, modelling took the precautionary position of both reactors being commissioned simultaneously with hydrazine discharged into the receiving waters via the CDO. The worst-case discharge scenario is assessed. Background concentration for hydrazine for modelling purposes was assumed to be zero.

22.6.134 There is no established EQS for hydrazine. The marine chlorophyte *Dunaliella tertiolecta* has been shown to have the lowest acute toxicity to hydrazine with a six-day EC_{50} for growth inhibition of 0.4µg/l (Ref. 22.59). These results form the basis for precautionary PNEC thresholds, provided in **Appendix 21E** of this volume. A chronic PNEC of 0.4 ng/l has been calculated for long term discharges (calculated as the mean of the concentration values) and an acute PNEC of 4 ng/l for short term discharges (represented by the 95^{th} percentile). These thresholds are considered as precautionary triggers for further ecological investigation.

22.6.135 Assessments used in support of Canadian Federal Water Quality Guidelinesfor hydrazine indicate concentrations below 0.2µg/l (200ng/l) have a low probability of adverse effects for marine life. In the freshwater environment, where more data is available, a threshold of 2.6µg/l has been applied (Ref. 22.60). **Table 22.22** shows the areas of exceedance for different hydrazine release scenarios.

22.6.136 Commissioning is likely to last several years; however simultaneous discharges of hydrazine are considered unlikely and the assessment is precautionary. The impact magnitude is assessed as medium.

Table 22.22: Areas of PNEC exceedance for hydrazine discharges during commissioning (grey boxes = not applicable).

Model run	Effect category Concentration (ng/l)	95th percentile surface (ha)	95th percentile seabed (ha)	mean surface (ha)	mean seabed (ha)
15µg/l at 83.3l/s	Chronic PNEC , 0.4ng/l (mean)			30.5	2.92
	Acute PNEC, 4ng/l (95th percentile)	12.9	2.92		
	Canadian Federal Water Quality Guidelines 200ng/l.	0.34 (100th percentile: 18.5 ha)	0		

Phytoplankton sensitivity to hydrazine

22.6.137 The sensitivity of the diatoms *Thalassiosira weissflogii* and *Skeletonema* sp., and the microflagellate *Micromonas pusilla* was tested in response to hydrazine. The most sensitive species was *M. pusilla* with a 96-hour EC_{50} of 1.27µg/l for inhibition and 1.80µg/l for growth rate (Ref. 22.61).

22.6.138 The diatom species were both over an order of magnitude less sensitive to hydrazine; *Sketetonema* sp had a 72-hour EC_{50} of 37.6µg/l for biomass whilst *T. weissflogii* had a 72-hour EC_{50} of 140.5µg/l (Ref. 22.61). These concentrations correspond to similar values reported for brown algae gametophytes (Ref. 22.62).

22.6.139 The concentrations observed for effects in diatoms and microflagellates and brown algae gametophytes are higher than in close proximity to the point of discharge from the CDO. An area of less than 1ha exceeds 200ng/l as a 95th percentile during the highest concentration discharge scenario, provided in **Table 22.22**. This represents half the concentration observed to cause growth inhibition in the most sensitive species (*D. tertiolecta*) following six-day exposures (Ref. 22.59). Therefore, any adverse effects on the most sensitive phytoplankton species would be highly localised and a very small proportion of the population would be exposed.

22.6.140 Phytoplankton in the receiving waters are not sensitive to hydrazine discharges.

22.6.141 Hydrazine discharges during commissioning are predicted to have negligible effects on phytoplankton populations. Effects are **not significant**.

Zooplankton sensitivity to hydrazine

22.6.142 Limited data exists on the toxicity of marine invertebrates to hydrazine. However, 48-hour exposures of the marine copepod *A. tonsa* demonstrated NOEC for hydrazine of 50µg/l (Ref. 22.61). *Acartia tonsa* is abundant in the waters off Sizewell and is a commonly used laboratory model species. Whilst it is acknowledged that other species may be more sensitive than *A. tonsa*, the test concentration is over 3-fold higher than the undiluted commissioning discharges (15µg/l), which rapidly dilute. As such it is a highly conservative experiment. Furthermore, these results are similar to freshwater crustaceans, with examples of 48-hour exposure concentrations of 160µg/l for EC_{50} in *Daphnia pulex* (Ref. 22.63).

22.6.143 Concentrations of hydrazine are predicted to be below levels sufficient to cause adverse effects in zooplankton and only an area of 0.34ha (95th percentile) is above the Canadian Federal Water Quality Guidelines for a low probability of adverse effects for marine life (200ng/l) (Ref. 22.60).

22.6.144 Zooplankton in the receiving waters are not sensitive to hydrazine discharges.

22.6.145 Hydrazine discharges during commissioning are predicted to have negligible effects on zooplankton populations. Effects are **not significant**.

Indirect effects of hydrazine discharges

22.6.146 The rate of hydrazine degradation depends on water quality parameters such as hardness and organic content (Ref. 22.64). Furthermore, degradation is concentration dependent and studies at concentrations relevant to the proposed development using water collected from the GSB have shown rapid degradation rates with a half-life of 49 minutes (Ref. 22.65).

22.6.147 Bioaccumulation of hydrazine was tested on freshwater guppies (0.5mg/l test concentration). Results showed a bioconcentration factor[19] of 288l/kg observed (Ref. 22.64). Hydrazine does not meet the criteria for bioaccumulation (Ref. 22.60; 62). No indirect food webs effects from hydrazine bioaccumulation are predicted.

iv. Cooling water infrastructure

22.6.148 This section describes the impacts associated with the construction and installation of the cooling water intake and outfall headworks. Pressures with the potential to effect plankton are presented in **Table 22.23**.

Table 22.23: Pressures associated with cooling water intake and outfall installation activities during the construction phase with the potential to affect plankton receptors.

Pressure	Activities resulting in pressure.	Justification
Changes in suspended sediments.	Preparation dredging and disposal.	Dredging prior to the installation of the cooling water intake and outfall headworks would cause temporary increases in SSC. Reductions in light availability due to increases in SSC can effect phytoplankton productivity and biomass. SSC may affect zooplankton through mechanical stress or reductions in feeding efficiency.
	Drilling of vertical connecting tunnels.	Drilling for the vertical connection shafts would result in SSC plumes that would be indiscernable from background conditions, see **Appendix 22J** of this volume. No further assessement is made.
Sediment-ation rate changes.	Capital dredging and disposal.	Deposition of suspended sediments can lead to smothering of bentho-pelagic zooplankton.
	Drilling of vertical connecting tunnels.	Drilling for the vertical connection shafts would result in spoil deposition in the immediate vicinity of the headwork within the dredge footprint. Wider sedimentation would be minimal. No further assessment is made, see **Appendix 22J** of this volume.
Synthetic compound contamination.	Discharges of drilling wastewater chemicals.	TBM waste water containing small volumes of drilling chemical leachate would be discharged via the CDO and have been assessed as part of the CDO assessment.
Underwater noise.	Dredging	The effects of underwater noise from dredging activities is considered to have negligible effects

[19] The bioconcentration factor is the ratio of the chemical in biota relative to the concentration in water. A bioconcentration factor of below 1,000 is typically considered to have low bioaccumulation potential.

Pressure	Activities resulting in pressure.	Justification
		on zooplankton receptors. No further assessment is made.

Changes in suspended sediment concentration: Cooling water infrastructure

22.6.149 Dredging and local dredge disposal for the installation CWS intake and outfall headworks would lead to elevated SSC. Plumes with instantaneous SSC of >100mg/l above background levels are expected to form over an area of up to 373ha (depth averaged, and 291ha at the sea surface). A smaller area of up to 14ha is expected to experience a depth averaged instantaneous SSC of >1,000mg/l above background levels (34ha at the sea surface), provided in **Section 22.3.i** of this chapter.

22.6.150 Ambient SSC at the site is highly variable. Mean surface suspended particulate matter values at Sizewell during April to August are 31mg/l with maximum values of 80mg/l. Near-bed conditions are considerably more turbid beyond the Sizewell-Dunwich Bank. Two minilanders deployed between November 2018 and February 2019, at the proposed cooling water intake head locations showed mean SSC concentrations of 450-510mg/l at 1.4m above the bed. In both locations maximum SSC exceeded 2,000mg/l, as provided in **Section 22.4** of this chapter**; Table 22.13**. As such, the precautionary dredge plume is low relative to natural background concentrations.

22.6.151 Dredging would temporarily increase the classification of the surface waters to '*turbid'*. However, SSC would return to background levels several days after dredging activities cease. The increase in SSC would occur a total of six times for the installation of CWS infrastructure (once for each intake and outfall head). The timings of the SSC plumes associated with the installation of each headwork would not overlap.

22.6.152 While increases in SSC would be relatively large relative to baseline conditions and occur multiple times, the transient nature of the plumes and their intermediate spatial footprint result in an impact magnitude of medium.

Phytoplankton sensitivity to changes in suspended sediment concentration

22.6.153 Phytoplankton exposed to increases in SSC may be susceptible to reductions in productivity (**Table 22.19**). The short duration and transitory nature of the plume suggests that a moderate decline in primary productivity may occur, but recovery would be rapid following cessation of the dredging activity. The sensitivity of phytoplankton is predicted to be low.

22.6.154 The impact of increased SSC resulting from dredging activities for the cooling water headworks is predicted to have a minor adverse effect on phytoplankton. Effects are predicted to be short-lived and **not significant** relative to natural variation.

Zooplankton sensitivity to changes in suspended sediment concentration

22.6.155 Increases in SSC may have adverse effects on fitness of some zooplankton taxa by decreasing ingestion rates and/or egg production rates. Effects are likely to be species specific and dependent on natural food availability. High natural fecundity and exchange with the wider southern North Sea afford a high degree of resilience. The sensitivity of zooplankton is predicted to be low.

22.6.156 The impact of increased SSC resulting from dredging activities is predicted to have a minor adverse effect on zooplankton communities. Effects are predicted to be short-lived and **not significant** relative to natural variation.

Changes in sedimentation rates: Cooling water infrastructure

22.6.157 Sediment suspended by dredging and dredge disposal for the installation of the CWS intake and outfall headworks would subsequently be deposited onto the seabed. Sediment deposition would be classified as 'light' over most of the plume footprint, with sediment thickness expected to exceed 50mm over a maximum of 7ha per headwork dredge event. Larger areas of 106ha for CWS intakes and 40ha for CWS outfalls are expected to experience sediment deposition of >20mm, while up to 2ha may experience >300mm of deposition per head.

22.6.158 Modelling predicts that all suspended sediment would be deposited within hours of dredging and then dispersed by natural resuspension and deposition, leaving no area where sediment thickness of >20mm thicker than it was prior to dredging after 15 days, provided in **Section 22.3.i** of this chapter. These levels of sediment deposition would occur six times for the installation of CWS infrastructure (once for each intake and outfall head).

22.6.159 As a limited area would be exposed to greater than 'light' deposition and deposited sediments would be rapidly dispersed, the impact magnitude is assessed as low.

Zooplankton sensitivity to changes in sedimentation rates

22.6.160 Sedimentation may be sufficient to cause localised mortality of zooplankton with a benthic association in close proximity to the dredge activity where sediment thicknesses exceed 50mm (7ha). However, bentho-pelagic zooplankton are predicted to be resistant to sedimentation levels predicted throughout much of the impacted area. Any losses would be expected to recover quickly due to the temporary nature of the dredge activities and high natural resuspension provided in **Table 22.19**. The sensitivity of zooplankton populations to increases in sedimentation due to dredging events is predicted to be low.

22.6.161 Sediment deposition following dredging for the cooling water infrastructure is predicted to have minor adverse effects on zooplankton. Effects are **not significant**.

v. Fish return and recovery systems

22.6.162 Two fish recovery and return (FRR) systems would be constructed, one for each reactor. The FRR tunnels would be drilled beneath the seabed with arisings transported to landward for disposal. This section describes the impacts associated with the installation and of the FRR systems during the construction phase. Pressures with the potential to effect plankton are presented in **Table 22.24**.

Table 22.24: Pressures associated with FRR activities during the construction phase with the potential to affect plankton receptors.

Pressure	Activities resulting in pressure.	Assessed	Justification
Changes in suspended sediments.	Preparation dredging and disposal.	Yes	Dredging prior to the installation of the cooling water intake and outfall headworks would cause temporary increases in SSC. Reductions in light availability due to increases in SSC can effect phytoplankton productivity and biomass. SSC may affect zooplankton through mechanical stress or reductions in feeding efficiency.
Sedimentation rate changes.	Preparation dredging and disposal.	Yes	Deposition of suspended sediments can lead to smothering of bentho-pelagic zooplankton.

Changes in suspended sediment concentration: Fish recovery and return systems

22.6.163 It is likely that the FRR systems would be installed separately approximately one year apart in sequence with the reactor they are associated with (**Plate 22.1**). Therefore, modelling considered FRR dredging of the two headworks to be temporally distinct events. Plumes with instantaneous SSC of >100mg/l above daily maximum background levels are expected to form over instantaneous areas of up to 89ha at the surface. A small area of 1ha is expected to experience an instantaneous SSC of >1,000mg/l above background at the sea surface provided in **Section 22.3.i)** of this chapter and **Appendix 22J** of this volume.

22.6.164 Ambient conditions at the site are highly variable, provided in **Section 22.4** of this chapter, and the surface waters are considered as '*intermediate turbidity'* according to WFD criteria, provided in **Appendix 21E** of this volume. Dredging would temporarily increase the classification to '*turbid'*. However, SSC would return to background levels several days after dredging activity ceases.

22.6.165 These increases in SSC would occur twice for the installation of the FRR system (once for each head). The timings of the SSC plumes associated with the installation of each head would not overlap.

22.6.166 While increases in SSC would be relatively large relative to baseline conditions, the transient nature of the plumes and their intermediate spatial footprint result in an impact magnitude of medium.

Phytoplankton sensitivity to changes in suspended sediment concentration

22.6.167 Phytoplankton exposed to increases in SSC may be susceptible to reductions in productivity, provided in **Table 22.19**. The short duration and transitory nature of the plume suggests that a small decline in primary productivity may occur, but recovery would be rapid following cessation of the dredging activity. The sensitivity of phytoplankton is predicted to be low.

22.6.168 The impact of increased SSC resulting from dredging activities for the installation of the FRRs is predicted to have a minor adverse effect on phytoplankton. Effects are predicted to be short-lived and **not significant** relative to natural variation.

Zooplankton sensitivity to changes in suspended sediment concentration

22.6.169 Increases in SSC may have adverse effects on fitness of some zooplankton taxa by decreasing ingestion rates and/or egg production rates. Effects are likely to be species specific and dependent on natural food availability. High natural fecundity and exchange with the wider southern North Sea afford a high degree of resilience (**Table 22.19**). The sensitivity of zooplankton is predicted to be low.

22.6.170 The impact of increased SSC resulting from dredging activities for the installation of the FRRs is predicted to have a minor adverse effect on zooplankton. Effects are predicted to be short-lived and **not significant** relative to natural variation.

Changes in sedimentation rates: Fish recovery and return systems

22.6.171 Sediment suspended by dredging and dredge disposal for the installation of the two FRR systems would subsequently be deposited onto the seabed. Sediment deposition would be classified as ‘light’ throughout the plume footprint, with sediment thickness not expected to exceed 50mm and only 1ha expected to exceed 20mm. It is predicted that all suspended sediment would be deposited within hours of dredging and then dispersed by natural resuspension, leaving no area where sediment thickness remains >20mm thicker than it was prior to dredging after 15 days, provided in **Section 22.3.i** of this chapter.

22.6.172 As no area would be exposed to more than ‘light’ deposition, and deposited sediments would be rapidly dispersed, the impact magnitude is assessed as very low.

22.6.173 The sensitivity of zooplankton to sediment deposition has been assessed as low, provided in **Table 22.19**.

22.6.174 Sediment deposition following dredging for the FRR headwork installations is predicted to have negligible effects on plankton receptors. Effects are **not significant**.

vi. Inter-relationship effects

22.6.175 This section provides a description of the identified inter-relationships that have the potential to effect plankton receptors from construction of the proposed development. These are the effects arising from construction work acting in-combination to form additive, synergetic or antagonistic effects.

In-combination effects from simultaneous dredging activities

22.6.176 During the construction phase, there is the potential that simultaneous dredging activities could occur. Maintenance dredging for the BLF is anticipated to occur at approximately monthly intervals during the campaign period. As a worst-case, it is assumed there is a temporal and spatial coincidence of the plumes from maintenance dredging for the BLF (plough dredger) and dredging (cutter suction dredger) and disposal of (a) cooling water infrastructure and (b) the southern FFR.

22.6.177 The suspended sediment plumes from the BLF maintenance dredge and the cooling water infrastructure do not interact, forming two discrete plumes. Therefore, the concurrent activities result in a greater spatial area of impacts rather than interactive effects. Increases in the total size of the instantaneous SSC plume and areas of sedimentation at ecologically relevant levels are minimal.

22.6.178 The suspended sediment plume from the BLF maintenance dredge and the FRR dredge plume do interact. At the sea surface the maximum instantaneous area exceeding 100mg/l increases to 111ha. This increase is greater than the sum of the two individual activities, however, the plume is highly transient and the total duration of increases in SSC would be reduced due to the temporal overlap. The original assessment of individual activities for each development component causing changes in SSC and sedimentation on plankton receptors remains unchanged. It is predicted that the effect on plankton receptors will be **not significant**.

d) Operation

22.6.179 The indicative timeline for the proposed development to become fully operational is 2034, with the earliest operational date assumed to be 2030, provided in **Plate 22.1**, following a construction and commissioning period of nine to 12 years provisionally commencing in 2021.

22.6.180 This section considers the development components and associated activities that were identified during scoping, provided in **Appendix 22M** of this volume, with the potential to cause significant effects on plankton receptors.

i. Coastal defence feature

22.6.181 This section considers the operation and maintenance of the hard-coastal defence feature (HCDF) and soft coastal defence feature (SCDF).

22.6.182 Ongoing shoreline retreat has the potential to cause future exposure of the HCDF. This is not predicted to occur for at least several decades or possibly beyond the operational phase of the proposed development. The potential for exposure would be reduced due to the SCDF, which would slow shoreline retreat at the frontage of the proposed development and because beach management (secondary mitigation) would be applied to maintain a shingle beach in front of the HCDF, provided in **Volume 2 Chapter 20** of the **ES**.

22.6.183 The effects on plankton receptors resulting from the coastal defence features are predicted to be **not significant**.

ii. Beach landing facility

22.6.184 The BLF would facilitate occasional AIL deliveries during the operational life of the station approximately every 5-10 years. This section describes the impacts associated with the operation of the BLF during the operational phase. When the BLF is operational an initial large maintenance dredging event would be required followed by smaller maintenance dredging to maintain the planar surface during operations. Scoping identified that dredging activities represents the primary activity with the potential to effect plankton receptors. Pressures with the potential to effect plankton are presented in **Table 22.25**.

Table 22.25: Pressures associated with BLF activities during the operational phase with the potential to affect plankton receptors.

Pressure	Activities resulting in pressure.	Justification
Changes in suspended sediments.	Navigational dredging.	Navigational dredging would cause temporary increases in SSC. Reductions in light availability due to increases in SSC can effect phytoplankton productivity and biomass. SSC may affect zooplankton through mechanical stress or reductions in feeding efficiency.
Sedimentation rate changes.	Navigational dredging.	Deposition of suspended sediments can lead to smothering of bentho-pelagic zooplankton.

Changes in suspended sediment concentration: Beach landing facility

22.6.185 Sediments moved and agitated by plough dredging would be redistributed by ambient flows away from the dredge area.

22.6.186 The SSC plume would resemble that described in the construction phase. A plume with an instantaneous suspended sediment concentration (SSC) of >100mg/l above daily maximum background levels is expected to form inshore over an area of up to 108ha at the sea surface and 83ha as a depth averaged plume. Maintenance dredging would result in up to 28ha of sea surface expected to experience >100mg/l above background SSC on each occasion provided in **Section 22.3.i** in this chapter.

22.6.187 Ambient conditions at the site are highly variable, provided in **Section 22.4** of this chapter, and the surface waters are considered as '*intermediate turbidity*' according to WFD criteria, provided in **Appendix 21E** of this volume. Dredging would temporarily increase the classification to '*turbid*'. However, SSC would return to background levels several days after dredging activity ceases.

22.6.188 The duration of the SSC plume is short-lived and transient; however, maintenance dredging increases the frequency of smaller scale impacts. The amount of change and extent of the plume results in an impact magnitude of medium.

Phytoplankton sensitivity to changes in suspended sediment concentration: Beach landing facility

22.6.189 Phytoplankton exposed to increases in SSC may be susceptible to reductions in productivity. The short duration and transitory nature of the plume indicate that small declines in primary productivity may occur, but recovery would be rapid following cessation of the dredging activity, provided in **Table 22.19**. The sensitivity of phytoplankton populations to increases in SSC is predicted to be low.

22.6.190 The impact of increased SSC resulting from dredging activities is predicted to have a minor adverse effect on phytoplankton. Effects are predicted to be short-lived and **not significant** relative to natural variation in biomass.

Zooplankton sensitivity to changes in suspended sediment concentration: Beach landing facility

22.6.191 Increases in SSC may have adverse effects on fitness of some zooplankton taxa by decreasing ingestion rates and/or egg production rates. High natural fecundity and exchange with the wider southern North Sea afford a high degree of resilience, provided in **Table 22.19**. The sensitivity of zooplankton to dredging at the BLF is predicted to be low.

22.6.192 The impact of increased SSC resulting from dredging activities is predicted to have a minor adverse effect on zooplankton communities. Effects are predicted to be short-lived and **not significant** relative to natural variation in population abundance.

Changes in sedimentation rates: Beach landing facility

22.6.193 Sediment moved and suspended by plough dredging and redistributed by ambient flows would subsequently be deposited onto the seabed. Sedimentation is typified by ‘light sedimentation’, with a small area of up to 3ha expected to experience sediment deposition of >50mm. A very small area (1ha) could experience over 300mm of deposition. It is expected that all suspended sediment would be deposited within hours of dredging and then dispersed by natural resuspension, leaving just 3ha where sediment thickness remains >20mm after 15 days. The pressure would reoccur due to the requirement for maintenance dredging; however, sediment deposition in this case is not expected to exceed 20mm, provided in **Section 22.3.i** of this chapter.

22.6.194 Impact magnitude is assessed as low due to the small spatial footprint of sediment deposition at ecologically relevant depths and rapid dispersal of deposited sediments.

Zooplankton sensitivity to changes in sedimentation rates: Beach landing facility

22.6.195 Sedimentation may cause localised mortality of zooplankton with a benthic association in close proximity to the dredge activity where sediment thicknesses exceed 50mm (3ha). However, zooplankton are predicted to be resistant to sedimentation levels predicted throughout much of the impacted area. Any losses would be expected to recover quickly due to the temporary nature of the dredge activities (**Table 22.19**). The sensitivity of zooplankton populations to increases in sedimentation due to dredging events is predicted to be *Low*.

22.6.196 Sediment deposition following dredging for the BLF is predicted to have minor adverse effects on zooplankton. Effects are **not significant**.

iii. Combined drainage outfall

22.6.197 Operational discharges are not anticipated from the CDO. The headwork is not expected to be decommissioned following the construction phase and would remain in place.

iv. Cooling water infrastructure

Cooling water abstraction

22.6.198 This section describes the impacts associated with the operation of the cooling water infrastructure relating to water abstraction. The primary effects on plankton from cooling water abstraction relate to entrainment of phytoplankton and zooplankton and impingement of larger taxa such as gelatinous zooplankton. Pressures with the potential to effect plankton are presented in **Table 22.26.**

Table 22.26: Pressures associated with cooling water abstraction.

Pressure	Justification
Entrainment	Water, and associated biota, abstracted at the intake heads would transit towards the forebays. Biota too small to be impinged on the drum screens would be entrained through the power station condensers. During entrainment plankton receptors would be subject to thermal, chemical and mechanical pressures. The effects on plankton individuals and populations within the GSB is assessed. The effects of future climate change and warming sea temperatures in relation to entrainment mortality is also considered.
Impingement	Abstracted planktonic organisms that are larger than the drum screen mesh size would be impinged and returned to the recieving waters via the FRR system. Most planktonic organisms are too small to be impinged and assessments consider large planktonic organisms such as gelatinous zooplankton.

Cooling water abstraction: Entrainment

22.6.199 Planktonic organisms that are too small to be impinged by the fine mesh drum and band screens would be entrained through the power station condensers (primary entrainment).

22.6.200 The filtration systems on the cooling water infrastructure are important considerations to prevent clogging and damage. The mesh size used determines the relative proportion of organisms that are impinged or entrained. Depending upon the size of a species, individuals will either be exclusively impinged or entrained, whilst a fraction may go via both routes. At Sizewell B a 10mm mesh size is employed. The proposed mesh size at Sizewell C is 10mm. Details of the entrainment assumptions and considerations are provided in **Section 22.8c** of this chapter; **Table 22.103** and **Appendix 22G** of this volume.

22.6.201 During entrainment passage, biota would be subject to thermal uplifts of 11.6°C, seasonal chlorination at an initial TRO dosage of 0.2mg/l, mechanical turbulence and fluctuations in pressure (up to +3 atmospheres). Daily discharges of hydrazine would also enter the cooling water stream, provided in **Section 22.5b** of this chapter. Discharges are not continuous and would occur for 2.3 hours a day based on a 69ng/l strategy or 4.6 hours a day for the 34ng/l strategy.

22.6.202 Abstraction would occur throughout the life-cycle of the power station and is considered a long-term impact. However, the volume of water abstracted in the open coastal system is small relative to the tidal exchange. Sizewell C would abstract water at a rate of 132m^3/s, which is equivalent to approximately 1.35% of the tidal volume in the abstraction risk zone. Seawater exchange within the tidal volume is approximately 10% each day, therefore abstraction is approximately 7.4-fold lower than water exchange rates.

22.6.203 The impact magnitude is assessed as medium[20].

Phytoplankton sensitivity to entrainment

22.6.204 This section considers the evidence of the sensitivity of phytoplankton to primary entrainment and determines the likelihood of seasonal effects. Effects can be mediated through loss of cell numbers, reductions in biomass,

[20] Entrainment predictions apply specific assessments to determine population level effects on phytoplankton and zooplankton. The assessments therefore incorporate both receptor sensitivity and impact magnitude. Consideration is paid to the long-term nature of the effects.

and perturbations in the diversity or the community composition due to differential tolerance (Ref. 22.66; 67).

22.6.205 Effects of entrainment of phytoplankton populations can be challenging to identify in-situ due to high natural variability and mixing with the receiving waters. However, the inability to detect effects does not infer no effect is present. Therefore, a range of field, laboratory and modelling studies are used to assess the potential for effects.

22.6.206 The resistance of phytoplankton to primary entrainment is dependent on a number of factors including ambient temperature, the thermal uplift, the concentration of chlorine additions, and the duration of exposure (Ref. 22.66; 68).

22.6.207 Ambient water chemistry also influences resistance and site-specific chlorine dose-responses have been observed. For example, three-hour incubations with phytoplankton entrained at the Fawley, Kingsnorth, Bradwell and Sizewell A power stations indicated the chlorine dose required to cause 50% reductions in primary production ranged from 0.11mg/l at Kingsnorth to 0.29mg/l at Sizewell. Agricultural and industrial run-off leading to increased ammonia levels at the estuarine sites was proposed as the factor behind the elevated toxicity of chlorination in comparison to the open coast station at Sizewell (Ref. 22.69).

22.6.208 To determine the combined effects of thermo-chemical pressures experienced during entrainment the growth and recovery of samples of the phytoplankton community collected from Sizewell Bay were tested. Phytoplankton parameters; chlorophyll *a*, cell abundance and species diversity were analysed and experiments were repeated with Spring and Summer plankton communities (Ref. 22.70). Results showed statistically significant effects on the Spring and Summer phytoplankton communities, the greatest loss in chlorophyll *a* (73%) occurred following addition of chlorine and hydrazine and over 90% losses in cell numbers occurred following chlorine additions. The results are consistent with field evidence gathered at power stations from around the world, provided in **Table 22.27**. Large reductions in picoplankton, and a relatively lower effect on the larger nanoplankton was responsible for the greater reductions in cell numbers than chlorophyll *a* (Ref. 22.70). As such, species specific responses to chlorine dosing were observed and these responses were seasonal.

22.6.209 The Summer community, characterised by lower biomass and dominated by smaller diatoms and dinoflagellates was more sensitive than the Spring community, characterised by large diatoms and high biomass. This corresponds to previous studies which show seasonal effects and have found larger taxa to be more resistant than smaller phytoplankton provided in **Table 22.27**.

22.6.210 Following experimental exposure to entrainment conditions Sizewell Bay phytoplankton showed signs of recovery (photosynthetic efficiency) following initial decreases indicating that the remaining cells continued to be viable (Ref. 22.70).

22.6.211 Recovery of phytoplankton that survive entrainment is possible and phytoplankton in warm effluent waters may experience elevated growth rates. In the Autumn (October to December) entrained phytoplankton in un-chlorinated discharged water showed increases in primary production (Ref. 22.71). During periods of light limitation in the turbid inshore water as Sizewell thermal uplifts are predicted to have minimal effects on growth rates, provided in **Appendix 22H** of this volume. It has been postulated that power stations can act as a selective predator that reduce the abundance of certain species (particularly the smaller size fraction phytoplankton) whilst enhancing the growth of some surviving species (Ref. 22.66; 72). However, field evidence for such effects is lacking and mixing with receiving waters is likely to limit effects to localised areas. Furthermore, other studies have demonstrated phytoplankton cells that survived entrainment re-established pre-chlorination growth rates with no clear species selectivity (Ref. 22.73).

Table 22.27: Summary of field evidence for phytoplankton sensitivity to entrainment through seawater cooled power stations.

Site	Entrainment	Results	Reference
Millstone Point nuclear power station Long Island Sound, USA.	ΔT of 13ºC, chlorine added betwen 0.1 – 1.2mg/l, 2 minute transit time.	Phytoplankton productivity decreased by a maximum of 83% following residual chlorine aditions of 1.2mg/l. A decrease of 79% was found following additions of 0.1mg/l at the intakes. ·Entrainment absence of chlorination (during the Autumn) had little (or slight stimulatory) effects on phytoplankton productivity.	(Ref. 22.71)
Madras Atomic Power Station, Chennai, India.	ΔT of 10ºC, standard TRO dosing of 0.3 - 0.4mg/l (shock dose applied once a week at double concnetration).	54-65% reductions in gross primary production (GPP) at the point of the outfall. Localised changes in species composition were observed, whilst overall diversity remained consistent. GPP in the absence of thermal pressures still reduced by 50% showing the importance of chemical stress.	(Ref. 22.67)
Two power stations in southern California, USA.	ΔT of 9 to 11ºC and chlorine dosages of 0.2 – 1mg/l.	Phytoplankton cell numbers and biomass reduced 42% and 34%, respectively following entrainment. Entrainment mortality was taxa specific and seasonal; large dinoflagellates incurred lower mortality (33%) than smaller diatoms (46%), leading to greater dominance of tolerant species and lower diversity (H') in the outfalls. The effects of phytoplankton mortality were greatest in the warmest months when ambient temperatures were between 17ºC and 20ºC. No clear reductions in phytoplankton occurred when intake temperatures were below 15ºC	(Ref. 22.66)
Chalk Point, Maryland, USA (estuarine power station).	15-minute entrainment including chlorination and ΔT of 6ºC.	Over 90% reductions in primary productivity following chlorination, 30% reductions when exposed to thermal effects alone.	(Ref. 22.74)
Koeberg Nuclear Power Station, North Cape Town, South Africa.	10 to 30-minute passage time, ΔT of 8.9ºC, chlorine 0.25mg/l	55% reductions in chlorophyll *a* and 38% reductions in primary production.	(Ref. 22.68)
Wolsong nuclear power plant, Korea		Mean chlorophyll *a* decreased by 54% following entrainment. Greater entrainment effects on microplankton and picoplankton in comparison to nanoplankton.	(Ref. 22.75)

22.6.212 Considerable evidence has shown that phytoplankton are sensitive to entrainment, however, effects at the population level are less clearly defined. To address this question specifically to Sizewell a Combined Phytoplankton and Macroalgae model was applied to predict the net effect of entrainment on phytoplankton populations. The model produces production curves at daily intervals at the spatial scale of the tidal excursion for a reference run (no power station), and with Sizewell B and Sizewell C accounted for, as provided in **Appendix 22H** of this volume.

22.6.213 Results from the Combined Phytoplankton and Macroalgae model indicated that the additional mortality term due to the power stations (90% loss of cell numbers) is most apparent during the Spring bloom, with little differences at other times of the year. The overall primary production within the GSB and tidal excursion would decrease by approximately 5.3% with the proposed development operating in conjunction with Sizewell B, in comparison to a scenario with no power station. For the modelled year, a reduction in gross annual production from a theoretical 77.47gC/m^2/y, in the absence of either power station, to 73.34gC/m^2/y with both stations operating was predicted and presented in **Appendix 22H**[21] of this volume. Annual variation in the biomass reduced would be anticipated as entrainment mortality is not absolute and depends on the natural standing stock. However, interannual changes would reflect the percentage difference from the reference.

22.6.214 These results are comparable to those predicted for a tidal segment of a steam electric power station on the Patuxent River, Maryland where chlorination during entrainment caused >90% loss of primary productivity in the cooling water. The overall loss of productivity to the tidal system was calculated to be approximately 6.6%. Field studies did not detect reductions in primary productivity in the vicinity of the outfall (Ref. 22.74). Phytoplankton have rapid generation rates and under suitable conditions, a 5% loss in population size (commensurate with the effect of both power stations) in a parcel of water could recover after less than an hour based on the assumption that phytoplankton divide during a 12-hour light period (Ref. 22.76).

22.6.215 The context of losses in annual primary productivity from the operation of the proposed development must be considered with respect to the natural variability in phytoplankton populations. Environment Agency data collected from the area from 1992 to 2013 indicates that the standard deviation of monthly mean chlorophyll *a* concentrations deviates by 42% of the mean,

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[21] The total reduction in productivity was conservatively modelled based on 90% losses of phytoplankton abundance observed during laboratory experiments with seasonally collected phytoplankton samples. This is considered to be conservative as chlorophyll *a* incurred lower levels of losses (72%) in the worst-case chlorination strategy (Ref. 22.70). Furthermore, chlorination is not intended in water temperatures below 10ºC and mortality would be anticipated to be lower in the cooler months.

and annual chlorophyll *a* values varies by 45% of the mean, provided in **Section 22.4** of this chapter. Accordingly, effects from the proposed development are predicted to be an order of magnitude smaller than natural variation. Indirect food web effects due to entrainment of phytoplankton are predicted to be minimal as taxa that graze on phytoplankton would be adapted to naturally large variations in phytoplankton standing stock, as provided in **Appendix 22H** of this volume.

22.6.216 Entrainment of phytoplankton in cooling water abstracted by the proposed development is likely to cause localised effects in terms of biomass, abundance, and community composition at the point of the outfall. However, phytoplankton sampling as part of the BEEMS monitoring programme has demonstrated strong seasonal cycling in community composition but no significant differences between four sampling stations at the Sizewell B intake, Sizewell B outfall, the proposed Sizewell C intake/outfall location, and a reference site beyond the extent of the current Sizewell B discharge plume (Ref. 22.25; 77).

22.6.217 At an individual level phytoplankton have little resistance to primary entrainment, however at the population level rapid generation rates and higher water exchange compared to abstraction indicates sensitivity will be *Low*.

22.6.218 Entrainment is predicted to have minor adverse effects on phytoplankton communities within the GSB. Effects are **not significant** relative to high levels of natural variability.

22.6.219 The in-combination effects of entrainment and thermal uplifts on phytoplankton productivity is considered further in **Section 22.6.d vi** of this chapter

Zooplankton sensitivity to entrainment

22.6.220 The BEEMS Comprehensive Entrainment Monitoring Programme (CEMP) involved taking pumped water samples from the Sizewell B forebay for 24 hours on 40 occasions over a 12-month period between May 2010 and May 2011. CEMP studies at Sizewell B have identified forty-nine invertebrate taxa in zooplankton samples entrained throughout the year. The lowest entrainment rates occur between January and March, with March being the minimum. Maximum zooplankton entrainment rates occur in May before declining gradually through the Summer and Autumn.

22.6.221 Entrainment estimates have been scaled to predict annual entrainment rates for Sizewell C, assuming all four pumps are operating throughout the year resulting in maximal abstraction and flow rates. The combination of predicted entrainment numbers and entrainment mortality, derived from literature and Entrainment Mimic Unit studies, has been applied to predict population levels effects, as in **Appendix 22G** of this volume. Entrainment Mimic Unit studies expose organisms to a combination of thermal and chemical stressors including the intake and outfall pressure profile designed to mimic the entrainment conditions at Sizewell C.

22.6.222 Zooplankton taxa were grouped into 10 functional groups and entrainment predictions are provided in **Table 22.28**.

Table 22.28: Total annual predicted entrainment rates for zooplankton groups at Sizewell B and Sizewell C.

Functional group.	% of total.	Total Sizewell B.	Predicted total Sizewell C..
Copepods	72.07	2.122 $x10^{11}$	5.433 $x10^{11}$
Bentho-pelagic taxa	13.44	3.958 $x10^{10}$	1.013 $x10^{11}$
Primarily benthic taxa and their larvae	4.54	1.338 $x10^{10}$	3.426 $x10^{10}$
Invertebrate eggs	2.48	7.301 $x10^{9}$	1.869 $x10^{10}$
Foraminifera	2.46	7.245 $x10^{9}$	1.855 $x10^{10}$
Gelatinous plankton.	1.25	3.683 $x10^{9}$	9.430 $x10^{9}$
Tunicates	0.12	3.441 $x10^{8}$	8.809 $x10^{8}$
Nematodes	0.06	1.700 $x10^{8}$	4.354 $x10^{8}$
Non-determinate taxa	2.88	8.467 $x10^{9}$	2.168 $x10^{10}$
Other non-key taxa	0.71	2.084 $x10^{9}$	5.336 $x10^{9}$
Total	100	294,468,363,746	753,953,367,837

22.6.223 Zooplankton have high rates of natural mortality due to predation. Entrainment from the proposed development would increase the rate of local mortality and could have localised effects on food availability for other species in the food web.

22.6.224 To determine the effects of entrainment on the local populations, reductions in numbers of mysids, gammarids and copepods within the tidal volume of water at risk of abstraction have been estimated. Assessments were based on the abundance of a taxa in the volume of water at risk of abstraction and predicted loss rates in a theoretical closed system under natural mortality. These loss rates are compared to losses with the addition of taxa-specific power station mortality terms, as provided in **Appendix 22G** of this volume.

Copepods

22.6.225 Copepods accounted for over 72% of the invertebrate zooplankton entrained at Sizewell B as provided in **Table 22.28**. Copepods of the genus *Acartia*

(8.3%), *Temora* (22.5%) and *Centropages* (30.8%) were the most abundantly entrained taxa. Instantaneous natural mortality rates have been estimated at between 0.7 and 0.8/d for *A. tonsa* and 0.24 for *Centropages typicus* (Ref. 22.78), provided in **Appendix 22G** of this volume.

22.6.226 Entrainment mortality terms for copepods are assumed to be 30% based on Entrainment Mimic Unit evidence. Laboratory studies investigated the mortality of *A. tonsa* exposed to temperature and chlorination individually and in-combination at ambient temperatures of 15-17.9ºC, representative of conditions off Sizewell between June and September. Temperature uplifts of 8.3-10°C resulted in no significant increases in mortality, but at higher temperatures mortality was 20% whilst chlorination and temperature combined resulted in 30% mortality (Ref. 22.79). The effects of TRO additions alone resulted in mortality rates up to 31% whilst the effects of temperature and chlorination with and without mechanical stress caused between 24-28% mortality (Ref. 22.80).

22.6.227 Entrainment by the proposed development is predicted to reduce the abundance of the copepods *A. tonsa* and *C. typicus* by approximately 0.42% and 1.27%, respectively within tidal volume of water at risk of abstraction (**Table 22.29**). Predicted losses are minimal in comparison to natural variability in population sizes, provided in **Section 22.4** of this chapter.

22.6.228 Such results are comparable to predictions that 70% mortality of copepods passaging through a nuclear power station would result in reductions of approximately 0.1 to 0.3% of the copepod production in eastern Long Island Sound, USA (Ref. 22.81).

22.6.229 Copepod populations are predicted to have low sensitivity to entrainment pressures.

Table 22.29: Estimates of Sizewell C entrainment effects on local zooplankton (accounting for the behaviour of mysids and gammarids). From Appendix 22G.

Taxon	M (d^{-1})	Annual average entrainment mortality.	Reduction in abundance within the abstraction zone of Sizewell C.
Acartia tonsa	0.7	30%	-0.42%
Centropages typicus	0.24	30%	-1.27%
Gammarids	0.06 assumed	100% assumed	-1.5%
Mysids	0.06	37%	-0.27%

Mysids

22.6.230 Mysids account for nearly 3.4% of the total invertebrate zooplankton entrained by numbers and are important components of the zooplankton community at Sizewell. Mysids are relatively long lived in comparison to copepods and natural mortality was estimated at 0.06/d based on juvenile *Metamysidopsis elongata* (Ref. 22.82).

22.6.231 Mysids were obtained from a natural mixed population at Sizewell (*Schistomysis spiritus*, *Siriella* sp., *Mysidopsis* sp. and other *Schistomysis* sp.) and exposed to chlorination and temperature individually and in-combination. Thermal uplifts above ambient temperatures, corresponding to the peak mysid abundance during May to June at Sizewell, resulted in 46% mortality (Ref. 22.83). During the warmest months, in late Summer mysid mortality was predicted to increase, potentially to over 95%. Further Entrainment Mimic Unit studies combined with statistical General Linear Models were used to predict the survival of the mysid *Neomysis integer* to entrainment conditions at Sizewell C. The effects of pressure, temperature and chlorination during conditions expected in Summer resulted in 41% to 51% survival of adult *N. integer* in comparison to 74% in controls (Ref. 22.84).

22.6.232 Entrainment predictions for mysids accounted for seasonal abundance relative to temperature dependent entrainment mortality. The average annual average mortality term applied during entrainment predictions was estimated at 37.2%.

22.6.233 Initial estimates of the population level effects on mysids predicted 6% losses. However, these predictions do not account for mysid behaviour such as the daily vertical position of mysids within the water column relative to the intakes and swimming speeds. Accounting for behaviour, entrainment is predicted to reduce mysid populations by approximately 0.27% within the tidal volume as provided in **Table 22.29**.

22.6.234 Such losses are well within the bounds of natural variation. Furthermore, sampling at Sizewell showed peak mysid abundance at the location of the proposed intakes is lower than at the Sizewell B intakes and outfalls, as provided in **Section 22.4** indicating predicted entrainment rates at the proposed development may be overestimates.

22.6.235 Mysid populations are predicted to have *Low* sensitivity to entrainment pressures.

Gammarids

22.6.236 Gammarid amphipods accounted for 8.75% of the total invertebrate zooplankton entrained by numbers at Sizewell B. The effects of entrainment on gammarid survival from the Sizewell populations is not well defined, accordingly a worst case 100% mortality term was assumed. This is likely to be highly precautionary as gammarids entrained at three power stations in the USA showed a range of survival rates from 73-96% (Ref. 22.85). Accounting for gammarid behaviour, final estimates of the reduction of the populations in the tidal volume of water at risk of abstraction was estimated at 1.5%, provided in **Table 22.29**.

22.6.237 Gammarid populations are predicted to have *Low* sensitivity to entrainment pressures.

Gelatinous zooplankton

22.6.238 Gelatinous zooplankton accounted for 1.25% of the total abundance of entrained invertebrate taxa and comprised of ctenophores, medusae, cnidarians and hydrozoa. The effects of entrainment on gelatinous zooplankton is challenging to quantify. A review of entrainment mortality indicated that soft-bodied invertebrates appear to be relatively tolerant to entrainment pressures and medusae incurred approximately 10% entrainment mortality at the Koeberg nuclear power station at South Africa (Ref. 22.68). However, prior to entrainment gelatinous zooplankton would have to pass through the drum or band screen mesh so it is precautionarily assumed that mortality of entrained gelatinous zooplankton is high.

22.6.239 Gelatinous zooplankton populations have high rates of natural variability and entrainment losses are predicted to be relatively small. Gelatinous zooplankton are predicted to have low sensitivity to entrainment.

22.6.240 Zooplankton have species-specific sensitivities to entrainment and mortality is likely to be seasonal and dependent on the ambient conditions. Entrainment is dependent on standing biomass: in years of greater abundance, larger numbers would be impinged, whilst years where numbers were naturally lower, fewer individuals would be impinged. However, the population effect would remain consistent. Mysids, gammarids and copepods represent the most abundantly entrained species at Sizewell B. Whilst mortality rates can be substantial for entrained individuals, population level effects are predicted to be low relative to natural variation. Given that abstraction rates represent approximately 1.35% of the volume of water that passages past the station and exchange rates with the wider North Sea are ca. 10% even 100% mortality of long-lived zooplankton taxa would have a minimal effect on local populations, provided in **Appendix 22G** of this volume.

22.6.241 Entrainment is predicted to have minor adverse effects on zooplankton communities within the GSB. Effects are **not significant** relative to high levels of natural variability.

The effects of climate change on entrainment predictions

22.6.242 This section considers the influence of climate change on entrainment predictions for the proposed development. The proposed development would have a long operational life cycle and the potential for warming sea temperatures could have implications for entrainment mortality. Consideration for future climate effects is a requirement of the Overarching National Policy Statement for Energy, EN-1; provided in **Volume 1, Appendix 6R** of the **ES**.

22.6.243 Mortality due to temperature shock for the egg and larval life stages of many fish and zooplankton species increases rapidly once maximum temperatures exceed 30°C (Ref. 22.86; 87). The upper incipient lethal temperature has not commonly been calculated for invertebrates or primary producers, however, upper incipient lethal temperature of 30 to 33°C (regardless of latitude) are typical (Ref. 22.88).

22.6.244 Warming sea temperatures have the potential to result in entrainment temperatures (ambient + 11.6ºC uplift) exceeding upper incipient lethal temperature limits for longer periods of the year. Future entrainment temperatures were considered for the following scenarios accounting for predicted future warming, based on UKCP09[22]; SRES A1B provided in **Appendix 21E** of this volume:

- **2030:** The decade during which the proposed development is expected to be operational (with operation anticipated to be from approximately 2034). The scenario includes both stations running simultaneously.
- **2055:** The hypothetical last likely date for Sizewell B to be operational. The scenario includes both stations running simultaneously.
- **2085:** Towards the end of the operational life of Sizewell C.
- **2110:** The hypothetical extreme date for Sizewell C to remain operational prior to decommissioning.

22.6.245 Mean daily entrainment temperatures are predicted to exceed 30ºC for 57 days in July-September by 2030. Temperature peak in early August reaching 31.3ºC. By 2055, entrainment temperatures exceed 30ºC for 100 days in much of July, August and September and continue into October.

[22] Future sea temperatures are not included in the current UKCP18 marine climate predictions.

Entrainment temperatures exceed 33ºC for 13 days in August and September, provided in **Plate 22.3;Table 22.30**).

22.6.246 Once Sizewell B ceases operation, entrainment temperatures exceeding 30ºC occur for fewer days, 92 in 2085 and maximum temperatures remain below 33ºC. In the extreme scenario of 2110, entrainment temperatures are predicted to exceed 30ºC for 105 days per annum between the beginning of July and mid-October. Entrainment temperatures above 33ºC are predicted to occur throughout much of August and into September (41 days) reaching a maximum of 33.6ºC, provided in **Plate 22.3;Table 22.30**.

Table 22.30: Predicted monthly mean entrainment temperatures (°C) Sizewell C (ambient + 11.6°C) accounting for future sea warming.

Month	2030 Entrainment.	2055 Entrainment.	2085 Entrainment.	2110 Entrainment.
January	18.5	19.1	19.8	20.5
February	17.8	18.5	19.0	19.7
March	18.1	18.8	19.3	20.0
April	20.1	20.7	21.3	21.9
May	23.5	24.1	24.7	25.3
June	26.5	27.1	27.7	28.3
July	29.5	30.2	30.8	31.5
August	31.0	31.8	32.5	33.3
September	30.2	31.0	31.8	32.6
October	27.2	28.0	28.8	29.5
November	23.6	24.3	25.2	25.9
December	20.7	21.3	22.0	22.7

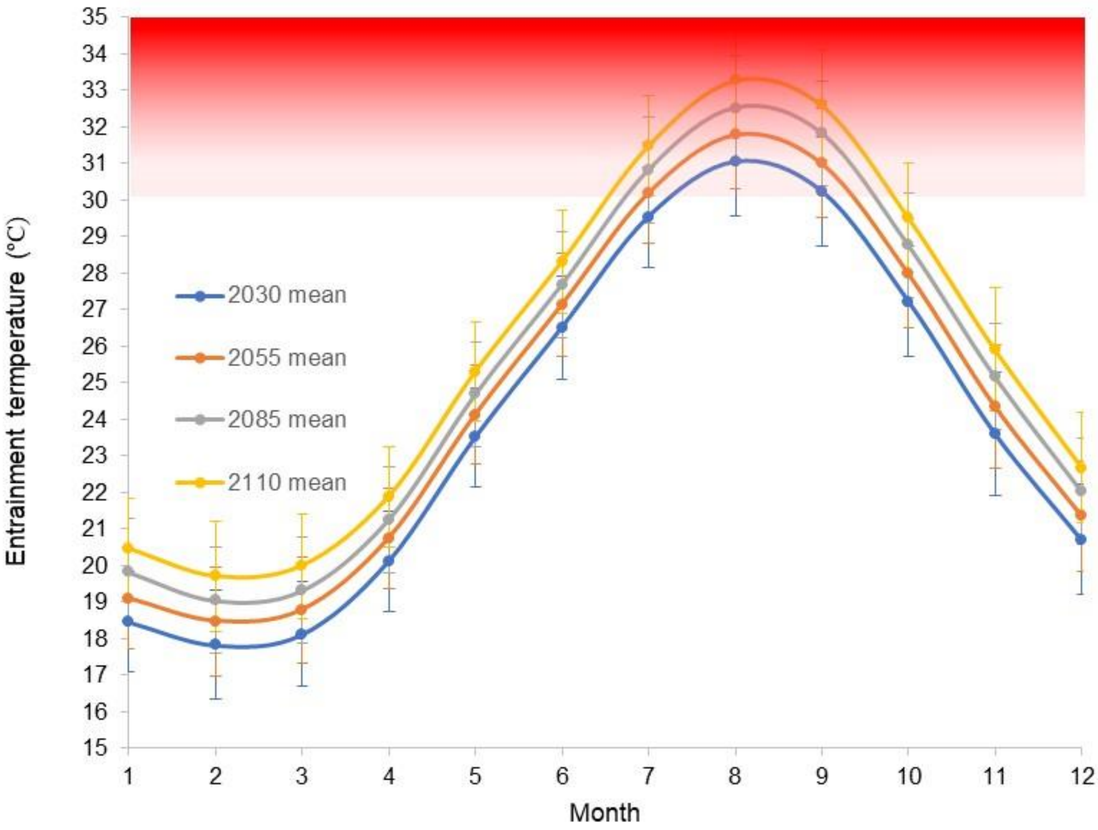
22.6.247 Higher entrainment mortality rates would likely be observed under future climate change. However, thermal lethality is highly species specific and adaptation to future climate conditions and/or potential species distribution shifts may influence the ability to tolerate thermal stress (Ref. 22.87).

22.6.248 Increases in sea temperature may also lead to small increases in the duration of chlorination. The seasonal chlorination strategy for the proposed development involves chlorination during the period of the year when water temperatures exceed 10ºC. In 2030, predicted water temperatures at the Sizewell C intakes are predicted to exceed 10ºC for 219 days per annum, from the beginning of May until the start of December. Towards the end of the operational life-cycle of the proposed development in the year 2085, climate change is predicted to result in temperatures exceeding 10ºC from late April until late December, for a total of 244 days per annum, provided in **Appendix 21E** in this volume.

22.6.249 Whilst the duration of the growing season is likely to extend in the future, day length and solar elevation would still serve to constrain the total growth period, as would the high turbidity in winter and Spring. Therefore, increases in the duration of annual chlorination may occur but are likely to be in the order of weeks at most and would occur when entrainment numbers are lower.

22.6.250 Current entrainment estimates predict very small reductions in the population's sizes of zooplankton and phytoplankton within the GSB. Whilst these values may increase slightly due to increases in entrainment temperature and prolonged seasonal chlorination, the assessment of effects would remain unchanged. Abstraction rates represent approximately 1.35% of the volume of water that passages past the station and exchange rates with the wider North Sea are ca. 10%. Therefore, even 100% mortality of long-lived zooplankton taxa would be expected to have a minimal effect on local populations, provided in **Appendix 22G** of this volume.

Plate 22.3: Mean monthly entrainment temperatures (± s.d.) under future climate predictions for Sizewell C. Shaded areas depict periods where typical upper incipient lethal temperature may be exceeded.



Cooling water abstraction: Impingement

22.6.251 Invertebrate zooplankton large enough to be impinged on the drum and band screen mesh would be returned to sea via the FRR system. The FRR and wash water would not be chlorinated, however, zooplankton would be exposed to pressure and mechanical stress and may incur higher mortality rates.

22.6.252 Specific stressor benchmarks for impingement do not exist and the benchmark value for 'death or injury by collision' of 0.1% of an average tidal volume passing through artificial structures is applied for context (Ref. 22.12). Abstraction results in ca. 1.3% of the tidal volume of water at risk of abstraction passing through the power station each day. The risk of impingement would last for the duration of the operational life-cycle of the station.

22.6.253 The impact magnitude is assessed as medium.

Zooplankton sensitivity to impingement

22.6.254 The Comprehensive Impingement Monitoring Programme (CIMP) sampled impinged fish and invertebrates at Sizewell B between February 2009 and March 2013 and again between April 2014 and December 2017, giving rise to a dataset comprising 205 samples over a nine-year period. A statistical method has been incorporated to estimate the numbers of invertebrates being impinged at Sizewell B annually, along with 95% confidence intervals. The upper confidence interval is considered as extremely precautionary, as it assumes the 95th percentile value for impingement is attained on every day of the year.

22.6.255 A total of 62 invertebrate taxa were identified in impingement samples. Ctenophores were the dominant invertebrate taxa impinged accounting for 83.7% of all individuals. Most zooplankton pass through the 10mm filtration systems at Sizewell B and form part of the entrainment assessment. Mysids were only observed in six out of 205 samples and annual gammarid impingement predictions were <100 individuals, these taxa are not considered further.

22.6.256 Impingement predictions for Sizewell C estimate a mean of 130,324,945 individual ctenophores impinged per annum, with an 95% percentile upper estimate of 416,309,076, provided in **Appendix 22I** of this volume. The sensitivity of gelatinous zooplankton to impingement is considered further.

Gelatinous zooplankton sensitivity to impingement

22.6.257 At the offshore Sizewell C sampling zooplankton sampling site ctenophore abundance peaks in July at 6.4 (± 8.3) individuals / m^3. Jellyfish abundance is low throughout most of the year but increases in August and September. At the Sizewell C sampling site, a peak of 4.2 (± 3.5) individuals / m^3 was observed in September, provided in **Section 22.6b)** of this chapter.

22.6.258 Large invertebrate individuals are susceptible to mechanical damage (Ref. 22.68) and may incur impingement mortality or reductions in fitness. The relatively low abstraction rate relative to the tidal volume and water exchange means impingement losses are predicted to be relatively small in relation to natural abundance and variability. Gelatinous zooplankton populations are predicted to have low sensitivity to impingement.

22.6.259 Impingement is predicted to have minor adverse effects on gelatinous zooplankton communities within the GSB. Effects are **not significant** relative to high levels of natural variability.

22.6.260 The potential for ctenophores blooms to increase fish mortality within the FRR system is considered in **Section 22.8.d** in this chapter.

Cooling water discharges

22.6.261 This section describes the impacts associated with the operation of the proposed development relating to cooling water discharges. Pressures with the potential to effect plankton are presented in **Table 22.31.**

Table 22.31: Pressures associated with cooling water discharges.

Pressure	Activities resulting in pressure.	Justification
Thermal discharges.	Cooling water discharges.	Discharges of heated cooling water effluent have the potential to effect plankton receptors in the receiving waters. Assessments consider the effects of secondary entrainment in the thermal plume on phytoplankton and zooplankton. The effects of future climate change and warming sea temperatures in relation to thermal discharges is also considered.
Chlorinated discharges including total residual oxidants (TROs) and chlorination by-products.	Cooling water discharges.	Seasonal chlorination of the CWS to prevent biofouling results in exceedance of EQS standards for TROs and the most abundant chlorination by-product, bromoform. The effects of chlorinated discharges on phytoplankton and zooplankton in the receiving waters is assessed.
Discharges of hydrazine.	Cooling water discharges.	Daily hydrazine releases are anticipated to prevent corrosion of critical plant. Discharges exceed applied thresholds and the effects of hydrazine discharges on phytoplankton and zooplankton in the recieving waters is assessed.
Nutrient discharges.	Cooling water discharges.	Nutrient inputs including all sources of DIN and phosphate during operational discharges have the potential to effect primary production. Effects on phytoplankton are assessed.

Cooling water discharges: Temperature changes

22.6.262 At the point of discharge heated cooling water would be discharged at ca. 11.6ºC above ambient at ca. 132m^3/s. The plume would be thermally buoyant resulting in stratification. Heat is lost from the plume directly as radiation, both to the air and receiving waters. As the thermally buoyant plume cools differences in buoyancy decrease and tidal mixing overcomes the vertical stratification. At this point heat dissipates causing a general warming effect to the receiving waters. The rate of mixing is determined by the tidal flow and the level of turbulence within the system. Strong tides at

Sizewell (>1m/s) and the interaction with the bathymetry shapes the plume profile.

22.6.263 The behaviour of the thermal plume can be characterised in three zones;

- **Near-field:** occurs at the point of discharge where the plume has restricted horizontal movement and mixes in a vertical profile.
- **Mid-field:** vertical momentum decreases, and the plume begins to travel slowly with the ambient tidal flow. Shear with the seabed causes the ambient flow to be more turbulent and interact with the edge of the thermal plume causing heat losses.
- **Far-field:** the plume is integrated in the tidal flow and mixing is subject to differences in density gradients, wave energy and bathymetry, which can cause the plume to decrease in thickness and break into filaments and eddies.

22.6.264 Plankton receptors can be affected by thermal discharges in the following ways;

- Acute effects – absolute temperature increases in the near to mid-field of the plume reach the upper thermal tolerance of sensitive species.
- Chronic effects – mean temperature uplift causes changes in physiological processes and behaviour such as feeding rates, growth, and/or reproductive output.

22.6.265 There are currently no uniform regulatory standards in place to control thermal loads in transitional and coastal waters (Ref. 22.87). Recommended thermal standards exist for SACs, SPAs and Water Framework Directive (WFD) waterbodies.

22.6.266 WFD thermal standards are considered the most appropriate for assessing the impact magnitude of thermal uplifts on plankton receptors. The WFD standards for absolute water temperature and thermal uplifts are provided in **Table 22.32** with areas of exceedance during discharges from Sizewell B and Sizewell C.

Table 22.32: WFD thermal standards and total areas of exceedance for absolute temperature and temperature uplift during the operation of Sizewell B and Sizewell C (grey boxes indicate not applicable).

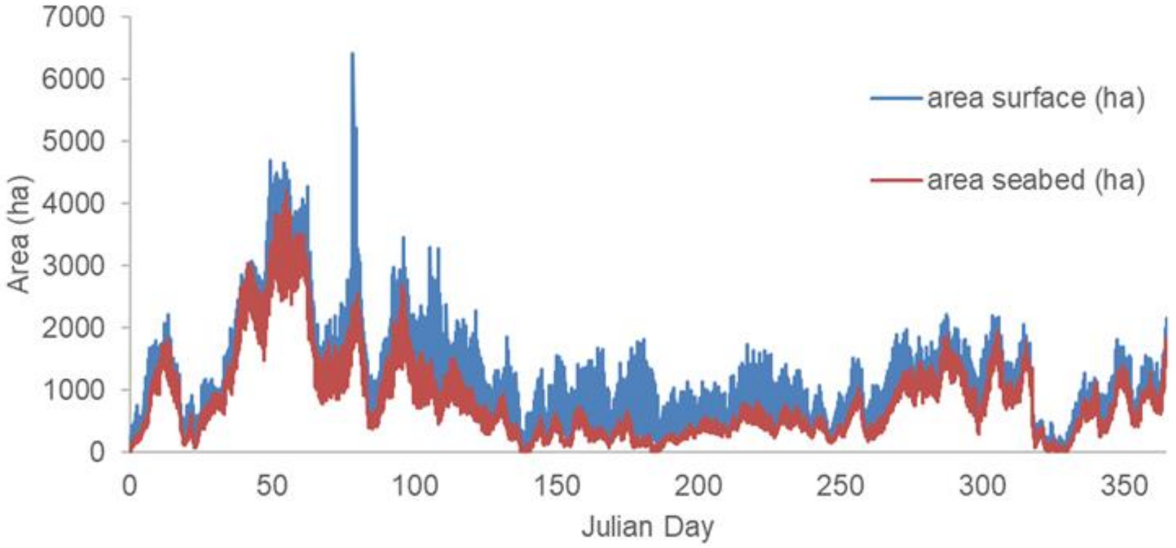
Model run	Absolute water temperature (as a 98th percentile)			Thermal uplift (as a 98th percentile)		
Sizewell B only	20°C - ≤ 23°C	Good		> 2°C	Good	Surface 2,433ha
						Seabed 2,127ha
	23°C - ≤ 28°C	Moderate	Surface 44.9ha	> 3°C	Moderate	Surface 1,263ha
			Seabed 8.75ha			Seabed 668ha
	> 28°C	Poor	Surface 0ha			
			Seabed 0ha			
Sizewell B + Sizewell C (worst case for EcIA).	20°C - ≤ 23°C	Good	-	> 2°C	Good	Surface 7,899ha
			-			Seabed 6,241ha
	23°C - ≤ 28°C	Moderate	Surface 89.6ha	> 3°C	Moderate	Surface 2,200ha
			Seabed 25.6ha			Seabed 1,553ha
	> 28°C	Poor	Surface 0.11ha			
			Seabed 0ha			
Sizewell C only	20°C - ≤ 23°C	Good	-	> 2°C	Good	Surface 1,551ha
						Seabed 170.6ha
	23°C - ≤ 28°C	Moderate	Surface 0ha	> 3°C	Moderate	Surface 305.7ha
			Seabed 0ha			Seabed 0ha
	> 28°C	Poor	Surface 0ha			
			Seabed 0ha			

22.6.267 The effects of future climate change on absolute temperature is considered, both in the presence and absence of Sizewell B operating.

22.6.268 Model runs output instantaneous thermal fields at hourly resolution for the period of one year. Accordingly, a 98th percentile represents the cumulative spatial area that individual cells (25x25m) within the model domain exceeds a threshold temperature for 7.3 days at any point during the year. The 98th percentile statistics are not necessarily consecutive and could be days or months apart.

22.6.269 Plankton have limited mobility and are transported with the tide. The size of the instantaneous plume at the surface and seabed is highly seasonal and driven by meteorology. Strong winds in the Winter period result in the largest instantaneous plume size. In February, the average plume area exceeding 2°C at the surface is 2,605ha with a maximum of 4,689ha. However, this period coincides with low biological activity. In May, the peak of the Spring bloom, the monthly average plume area above 2°C is 680ha (the average surface plume area above 3°C is 242ha) and reduces to a minimum in July of 548ha (Ref. 22.13). The annual plume size profile is illustrated in **Plate 22.4**.

Plate 22.4: Instantaneous areas where the combined Sizewell B and Sizewell C plume temperature is >2°C at the surface and the seabed.



22.6.270 The latest date Sizewell B is anticipated to remain operational is 2055 when thermal discharges would cease. The Sizewell C only plume results in smaller areas of thermal impacts further offshore than the Sizewell B station, provided in **Table 22.32** and **Appendix 21E** of this volume.

22.6.271 The impact magnitude is based on the worst-case scenario of Sizewell B and the proposed development discharging cooling water concurrently. Absolute thermal exceedance with the potential to cause acute effects is constrained to a very small area (<1ha). Modest thermal uplifts (2°C) with the potential for chronic effects can extend over instantaneous areas of thousands of hectares at the sea surface but are smallest during the peak of the growth season. Thermal discharges would occur throughout the operational life cycle of the proposed station and are long term impacts.

22.6.272 The impact magnitude is assessed as medium.

22.6.273 The effects of future climate change and warming sea temperatures in relation to thermal discharges is considered further.

Phytoplankton sensitivity to thermal discharges

22.6.274 Thermal discharges may result in acute and chronic effects on phytoplankton at different positions within the discharge plume. Sensitivity of phytoplankton has been shown to be seasonal, highly site specific and depend on the interplay of local hydrodynamics and ambient temperatures (Ref. 22.66; 68; 89).

22.6.275 Temperature is a fundamental factor governing the development of microscopic plankton communities, and influences various life processes such as growth, and community structure (Ref. 22.90). Thermal discharges from power stations have the potential to influence phytoplankton by changing growth rates and enhancing the onset of the Spring bloom (Ref. 22.87).

22.6.276 Thermal discharges from the Olkiluoto nuclear power station in the Baltic Sea advanced the Spring bloom by approximately two weeks, small increases in the abundance of some diatom species but total phytoplankton biomass was unaffected (Ref. 22.91). Salinity and nutrients were the overriding factors determining total biomass and chlorophyll *a* concentration rather than temperature (Ref. 22.91). However, in the thermal discharge area of the Loviisa power plant in the northern Baltic thermal uplifts were attributed to a longer growing season and changes in species dominance and biomass (Ref. 22.92). Productivity and growth rates in thermal discharges, particularly in the absence of chlorination, has been shown to increase production during cooler months (Ref. 22.66; 71) (**Table 22.23**).

22.6.277 At Sizewell, light limitation is the primary factor controlling photosynthesis up to mid-May, provided in **Appendix 22H** of this volume. The rate of photon absorption limits photosynthesis during periods of light limitation, during which time increases in temperature are not predicted to enhance productivity (Ref. 22.93). Therefore, thermal uplifts are not predicted to enhance the onset of the Spring bloom or dramatically enhance productivity at Sizewell during periods of light limitation.

22.6.278 During the growing season when light is not a limiting factor, for example in mid-May to mid-August, thermal uplifts may influence growth rates. The average instantaneous surface plume area above 2ºC between May and August is 672ha, provided in **Plate 22.4**, and the average surface plume area above 3ºC is 374ha (Ref. 22.13). The average surface and seabed uplift across the GSB and tidal excursion (9,670ha), simulated in the Combined Phytoplankton and Macroalgae model, is approximately 0.5ºC, as provided in **Appendix 22H** of this volume.

22.6.279 A statistical approach has been applied to predict the theoretical maximum growth rate of marine phytoplankton (μ_{max}, per day) as a function of temperature (T, °C) where, $\mu_{max} = 0.81e^{0.0631T}$ (Ref. 22.94). According to the equation, a theoretical 13% increase in maximum growth rates is possible following a 2°C uplift, whereas a 0.5°C uplift increases μ_{max} by 3.2%. Similar temperature dependant growth rates were observed by Montagnes and Franklin (2001) who noted that maximum growth rates increased linearly with temperature, until reaching species-specific maxima. Growth rates typically plateaued or declined beyond 20ºC (Ref. 22.95). These empirical results indicate that thermal uplifts may enhance growth rates in the mid and far-field of the plume during the growth season particularly when ambient water temperatures at Sizewell are below 18ºC. However, increases in growth rates in the field would be mediated by the overriding factors of nutrient availability and the light climate. For example, nutrients were the most important variable effecting phytoplankton abundance in the Lagoon of Venice, and no statistical relationship between temperature, from thermal discharges of a thermoelectric power plant, and abundance was observed (Ref. 22.96). The hydrodynamics of the open coastal site at Sizewell means water exchange with the wider environment would reduce the potential for the formation of phytoplankton blooms (Ref. 22.87). Furthermore, temperature dependent feeding rates (as described in the following sections) would provide top-down regulation of phytoplankton standing stocks.

22.6.280 To determine the potential for thermal discharges to influence phytoplankton productivity, a 0.5°C mean temperature uplift was applied to the Combined Phytoplankton and Macroalgae model. The Combined Phytoplankton and Macroalgae model is parameterised such that the light climate and nutrients are the primary factors controlling productivity. During the Spring bloom at Sizewell, phytoplankton growth rate is limited by light and temperature uplifts do not result in enhancements in productivity. Such results have been observed elsewhere (Ref. 22.93). However, additional mortality occurs due to enhanced grazing. As such, a small (1%) reduction in gross annual productivity is predicted.

22.6.281 Acute effects are predicted to cause minimal mortality to phytoplankton in the receiving waters. In the warmest months there is the potential for thermal uplifts to exceed thermal optima and cause reductions in growth in some species. However, warm Summer months are associated with the smallest instantaneous areas of thermal uplift, provided in **Plate 22.4**.

22.6.282 The sensitivity of phytoplankton to thermal uplifts would be dependent on other controlling factors. Minor seasonal increases or decreases in productivity may arise due to potential changes in growth and grazing rates. Changes in total biomass are predicted to be very small in relation to high levels of natural variability as in **Section 22.6b)**.

22.6.283 The sensitivity of phytoplankton biomass at Sizewell to thermal discharges is predicted to be low.

22.6.284 Minor adverse to beneficial effects on phytoplankton biomass in the receiving waters are predicted in response to thermal discharges. Effects are **not significant** in relation to high natural variability.

22.6.285 The in-combination effects of primary entrainment and secondary entrainment of plankton in the thermo-chemical plume is considered as an inter-relationship in **Section 22.6b)v** of this chapter.

Zooplankton sensitivity to thermal discharges

22.6.286 The majority of studies investigating the effects of cooling water on zooplankton have focused on acute mortality relating to primary entrainment rather than the implications for zooplankton in the receiving waters. Thermal discharges can cause acute effects if absolute temperatures exceed thermal tolerance in the near-field of the plume. Alternatively, chronic effects on physiological processes in the mid to far-field of the plume may occur.

22.6.287 The upper limit of thermal tolerance for the copepod *Acatia tonsa* is dependent on the acclimation temperature. Copepods acclimated at 20°C showed no effects when exposed to temperatures of 25-28°C (Ref. 22.89). Entrainment studies have shown high mysid mortality at temperatures of 28°C (Ref. 22.83). Some of the most sensitive species including euphausids (krill) have been reported to have upper incipient lethal temperatures of 25°C (Ref. 22.87).

22.6.288 With Sizewell B and Sizewell C operating simultaneously, absolute temperatures in excess of 28°C occur over a negligible area of the GSB, provided in **Table 22.32** and temperatures above 23°C occur over restricted spatial areas of 89.6ha at the surface and 25.6ha at the seabed as a 98th percentile. The most temperature sensitive zooplankton species in the receiving waters may incur localised mortality following exposure to the thermal plume near the discharge point. However, at the population level such effects would be minimal and well within the bounds of natural variability.

22.6.289 Thermal uplifts and a general warming of the receiving waters have the potential to cause chronic effects in zooplankton taxa including changes in physiological processes and behaviour.

22.6.290 Copepod growth, development, fecundity and egg hatching rates are known to increase with temperature when food is not limiting (Ref. 22.97). Gut clearance rates, have been shown to have a Q_{10} of 2.2 over a temperature range of -1 to 19.5°C (Ref. 22.98)[23]. Comparisons between laboratory and in-situ studies show that food limitation also increases with temperature and is likely a result of increased metabolic rates associated with higher energy demands (Ref. 22.99). Copepods in the mid to far-field of the thermal discharge plume, where temperatures are a few degrees centigrade above ambient, may experience small increases in feeding rates and fecundity.

22.6.291 Similar results have been observed in mysids. The mysid *Neomysis integer* showed increases in egestion rates (as a feeding proxy) with temperatures from 5-15°C and a Q_{10} of 1.9 (Ref. 22.100). Bentho-pelagic mysids, are most abundant at Sizewell between May and June when average instantaneous seabed uplifts of 2ºC occur over an area of 403ha occur in May and 315ha occur in June (**Plate 22.4**). Uplifts of 3ºC occur over an area of 95ha occur in May and 74ha occur in June (Ref. 22.13). As such, the small effects areas indicate minor increases in feeding rates would have negligible effects at the population level.

22.6.292 Purcell (2005) reviewed long term-studies of jellyfish and ctenophore species and found that 11 species increased in abundance in relation to climate variations including warming. However, three scyphozoan species (true jellyfish) including *A. aurita* in the North Sea did not increase in abundance(Ref. 22.101). Gelatinous zooplankton in the wider thermal plume may therefore experience increases in fecundity. Ctenophore abundance peaks in June, provided in **Section 22.6b)** of this chapter. The average monthly instantaneous thermal plumes above 2ºC in May and June are restricted to 680ha and 698ha, respectively (Ref. 22.13). The hydrodynamics of the offshore location and the exchange of water with the wider southern North Sea (10% per day) is predicted to reduce the probability of bloom formations.

22.6.293 Elevated temperature in the far-field of the plume is predicted to result in minor increases in feeding rates, growth and fecundity of zooplankton. However, the spatial scale of the thermal plume coupled with hydrodynamic processes means that exposure to areas of thermal uplift would be limited to a small proportion of zooplankton populations and increases in physiological processes are dependent on food availability. High natural variability in zooplankton populations and exchange of water with the wider southern North Sea are predicted to dampen any thermal effects.

[23] The Q_{10} temperature coefficient is used to describe the rate of change in physiology in response to a 10ºC increase in temperature.

22.6.294 Zooplankton are predicted to have low sensitivity to thermal discharges at the population level.

22.6.295 Thermal discharges are predicted to have minor beneficial effects at the population level. Changes in zooplankton abundance are **not significant** and would be within the bounds of natural variability.

Effects of climate changes and thermal discharges on plankton receptors

22.6.296 The influence of sea temperature warming as a result of climate change interacting with thermal discharges has been considered based on the methodology detailed in **Appendix 21E** of this volume. Future climate was considered relative to current thermal standards of thermal uplifts above ambient and absolute temperature.

22.6.297 Thermal uplifts above ambient are predicted to be largely independent of the background sea temperature. Therefore, thermal uplift areas are predicted to remain largely unchanged under future climate scenarios, as provided in **Table 22.32**.

22.6.298 To ascertain absolute temperatures in the future, the influence of climate change was added to the predicted thermal uplifts due to the proposed development. The approach considered Sizewell B and the proposed development operating together up until 2055 as a worst-case. Sizewell C operating alone in 2055 and 2085 were also considered as well as an extreme (2110) hypothetical operating scenario.

22.6.299 The thermal uplift due to the UKCP09[24] monthly increase in mean temperature, centred on 2006, was applied to this contemporary annual baseline projecting forward to 2055, 2085 and 2110. This climate uplift (98th percentile occurring in August) and the 98th percentile ambient temperature (also occurring in August) was then applied to the mean excess temperature rise due to the power stations. This is considered precautionary as the mean uplifts due to thermal discharges tend to be lower in the summer months.

22.6.300 The results indicate that future climate change is not predicted to significantly increase the absolute areas in exceedance of 28ºC, which remain under 1ha for all scenarios tested. Following the decommissioning of Sizewell B, 28ºC as an absolute temperature is not predicted to be exceeded as a 98th percentile even under the extreme climate case of the proposed development operating in 2110. Therefore, acute thermal effects in the receiving waters are predicted to remain minimal.

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[24] Future sea temperatures are not included in the current UKCP18 marine climate predictions.

22.6.301 During the operation of both stations, absolute temperatures of 23ºC increase from 89.6ha at the surface, provided in **Table 22.32,** to a worst case of 506.2ha at the surface and 264.4ha at the seabed in 2055. In the likely event Sizewell B is no longer operational in 2055, leaving Sizewell C operating alone, the exceedance of the absolute 23ºC threshold is predicted to be just 5.38ha at the surface and 0ha at the seabed.

22.6.302 By the extreme date of 2110, large areas exceed 23ºC as a 98th percentile; 7,080ha at the surface and 6,540ha at the seabed. However, the results are due to the influence of climate warming, which is predicted to be +3.045ºC as a 98th percentile across the model domain, hence a station uplift of just 0.56ºC is sufficient to exceed contemporary thermal standards.

22.6.303 In 2085, towards the end of the likely operational life-cycle of the proposed development, seabed areas in exceedance of 23ºC are predicted to occur over just 0.22ha, whereas surface exceedance occurs over an area of 69.1ha. The total area of the thermal plume above 23ºC in 2085 is therefore smaller and further offshore than the contemporary predictions for the two power stations operating together, as provided in **Table 22.32** and **Appendix 21E** of this volume.

22.6.304 Whilst climate change would act in-combination with the proposed development to increase areas of exceedance, receptors exposed would be acclimated to a modified thermal baseline. Furthermore, changes in species composition may have occurred independently of the proposed development. For species exposed to the thermal plume, effects would be similar to those predicted for the current baseline. Thermal discharges can cause seasonal effects on phytoplankton growth rates with minor reductions in the warmest Summer months for some species whereas minor increases in growth rates may occur during other periods, depending on the availability of other limiting factors. Zooplankton may respond to thermal discharges through minor increases in feeding rates, growth and fecundity. There is some evidence that gelatinous zooplankton abundance may increase in the future and warming seas may be more suitable for HABs, provided in **Section 22.4** of this chapter.

22.6.305 Confidence in predicting the exact effects of climate change and thermal discharges on plankton receptors is reduced further into the future. However, once Sizewell B ceases operation the thermal footprint from the proposed development is predicted to be smaller than the current power station. Predictions of effects based on current baselines is considered valid in light of future climate change.

Cooling water discharges: Chlorinated discharges

22.6.306 To control biofouling of critical sections of the plant during operation, intake water will be chlorinated by the addition of sodium hypochlorite. EDF Energy's operational policy for its existing UK fleet is to continuously dose during the growing season to achieve a total residual oxidant (TRO) dose of 0.2mg/l in critical sections of the CW plant and at the inlet to the condensers. Chlorination would be applied when water temperatures exceed 10ºC (Ref. 22.102).

22.6.307 The primary biocidal effects of seawater chlorination result from oxidants associated with water chemistry. These oxidants are measured and expressed as the TRO concentration. The TRO discharge concentration would be 0.15mg/l at point of discharge discharged at a rate of ca. 132m^3/s in the cooling water at a temperature of ca. 11.6 °C above ambient, provided in **Appendix 21E** of this volume.

22.6.308 The TRO result from the combination of chorine and organic material in the water, furthermore chlorination compounds are broken down to form chlorination by-products. This section considers the impact magnitude of TRO and chlorination by-product discharges.

Total residual oxidants: Impact magnitude

22.6.309 Experimental studies at Sizewell were used to model the TRO plume based on the seawater chemistry and applying an empirical demand/decay formulation coupled into the General Estaurine Transport Model for Sizewell. The EQS for TROs is 10µg/l as a 95th percentile concentration. The TRO plumes from Sizewell C and Sizewell B are spatially distinct at ecologically relevant concentrations and follow a long narrow trajectory parallel to the coast. Therefore, Sizewell C is considered separately with Sizewell B part of the baseline.

22.6.310 The Sizewell C TRO plume is highly stratified, and concentrations exceed the EQS over a moderate area of sea surface area of 338ha and a small area of seabed, 2.1ha, provided in **Figure 21.6** of **Chapter 21** and **Appendix 21E** of this volume.

22.6.311 In 2030, water temperatures at the Sizewell C intakes are predicted to exceed 10ºC from the beginning of May until the start of December. Future climate change may extend the period of the year seawater temperatures exceed 10ºC, and by proxy, the seasonal duration of chlorination under the current strategy. In the coastal waters at Sizewell, high levels of turbidity in the Winter and early Spring limit biological production, therefore, increases in the duration of annual chlorination is unlikely to extend considerably.

22.6.312 The impact magnitude for TRO discharges has been assessed as medium.

Chlorination by-products: Impact magnitude

22.6.313 Depending on the water chemistry an array of chlorination by-products can be formed in addition to TROs. Seawater is rich in bromide, which reacts with chlorination compounds to produce chlorination by-products.

22.6.314 The most abundant chlorination by-product in discharges from coastal power stations, and the only product detected in the waters off Sizewell is bromoform (Ref. 22.103) provided in **Appendix 21E** of this volume. Bromoform is lost through volatilization to the atmosphere. Loss rates were incorporated into the General Estaurine Transport Model for Sizewell to predict the extent of the bromoform plume.

22.6.315 EQS concentrations for bromoform do not exist and a PNEC of 5µg/l as a 95th percentile is applied as the recommended standard (Ref. 22.103). The bromoform plume is predicted to follow a similar trajectory to the TRO plume with a narrow, tidally transported plume forming parallel to the shore. The plume is highly stratified with PNEC concentrations exceeding 5µg/l over an area of 52ha at the surface and 0.67ha at the seabed. The Sizewell C plume is discrete from the Sizewell B plume.

22.6.316 Bromoform discharges would occur for the operational life-cycle of the proposed development and would be continuous throughout the growing season when water temperatures exceed 10^{o}C.

22.6.317 The impact magnitude for bromoform discharges has been assessed as medium.

Phytoplankton sensitivity to total residual oxidants

22.6.318 Phytoplankton in the receiving waters would experience lower doses of TROs than during primary entrainment and dilution would result in a chemical concentration gradient whereby concentrations rapidly decrease with distance from the outfall.

22.6.319 Changes in community composition have been observed following low level chlorine additions for periods of 20 days on natural phytoplankton from Vineyard Sound, USA. Phytoplankton cell density declined to approximately 50% of controls and did not recover after 20 days. Biomass and species diversity reduced by approximately 20% following chlorine additions of 50µg/l, with greater reductions observed at higher concentrations (Sanders et al., 1981).

22.6.320 The effects of low-level chlorination replicating exposure to the TRO plume (secondary entrainment) on natural Spring phytoplankton communities from Sizewell was investigated (Ref. 22.104). No differences in chlorophyll *a* or photosynthetic efficiency were observed following TRO doses from 20-

100µg/l, equating to two-, and ten-fold the EQS concentration. However, changes in community composition did occur. Smaller functional size classes were less resistant to TRO toxicity and up to 40% reductions in total cell abundance were observed after 24 hours following exposure to 100µg/l. The loss of the smaller size fraction of phytoplankton resulted in changes in average cell size and carbon content. These changes were reflected in the reciprocal increases in the relative proportion of micro- and nano-phytoplankton in comparison to large losses of pico-phytoplankton (Ref. 22.104).

22.6.321 Dosing treatments simulating the case whereby phytoplankton are entrained in a parcel of water that repeatedly transits past the discharge outfall showed that three doses of 50µg/l TRO within a 24-hour period resulted in losses in abundance of 40%. Lower doses did not result in statistically significant changes in cell abundance (Ref. 22.104).

22.6.322 Concentrations of 50µg/l are predicted to occur over a sea surface area of <9ha as a 95th percentile. Therefore, a very small proportion of phytoplankton within the tidal excursion is predicted to be exposed to concentrations sufficient to cause reductions in cell abundance or changes in species diversity and any reductions in cell abundance or species composition are predicted to be highly localised. Furthermore, recovery of phytoplankton exposed to the greater effects of primary entrainment following mixing in the receiving waters have been observed (Ref. 22.66; 72; 73).

22.6.323 The sensitivity of phytoplankton to TRO discharges is predicted to be low.

22.6.324 TRO discharges are predicted to have minor adverse effects on phytoplankton in the receiving waters. Effects are **not significant**.

Zooplankton sensitivity to total residual oxidants

22.6.325 Limited long-term data on the chronic toxicity of chlorine on marine organisms exists (Ref. 22.105) with much of the focus on acute toxic effects. The most sensitive marine species show acute toxicity at TRO concentrations between 10 and 100µg/l (Ref. 22.106).

22.6.326 Toxicity to chlorine is dependent on exposure times, acute toxicity for a range of marine species indicate a threshold of 300µg/l for exposures of 10-seconds or longer and 20µg/l for exposures of 120-minutes or longer (Ref. 22.107).

22.6.327 The toxicity to low level TRO dosing was tested in the dominant mysid species at Sizewell (*Schistomysis spiritus*). No significant mortality occurred at any of the concentrations tested (mean 15, 43 and 101µg/l TRO) following 48-hour exposure (Ref. 22.108). The lowest reported LC_{50} value for 96-hour chlorine exposure on the copepod *Acartia tonsa* is 29µg/l (Ref. 22.109). The survival and growth of the juvenile amphipod *Melita palmata* was studied over a 28-day period. Exposure to 20µg/l TRO resulted in an additional 10% mortality in comparison to controls. Growth rates were not significantly affected (Ref. 22.110).

22.6.328 Concentrations above 20µg/l are predicted to occur over a surface area of 98ha as a 95th percentile and 0.34ha at the seabed. In the tidal environment a very small proportion of the zooplankton community would be exposed to concentrations sufficient to cause mortality and exposure times would be limited.

22.6.329 Sub-lethal effects of chlorination may consist of damage to eggs, reduced hatching success, delayed larval development, gill damage and reduced respiration (Ref. 22.106). Laboratory experiments have shown reduced egg production rates in the copepod *A. tonsa* following chlorine additions but at higher doses than predicted in the receiving waters(Ref. 22.89). Reductions in feeding rates of *S. spiritus* were observed following 48-h exposure to 50 and 100µg/l TRO (Ref. 22.108). Avoidance behaviour has been observed in response to chlorinated discharges at concentrations of 20µg/l in the amphipod *Gammarus daiberi* (Ref. 22.111).

22.6.330 Sub-lethal effects reducing zooplankton fitness are possible in the vicinity of the outfall. However, a small proportion of the population would be affected and high natural fecundity and recruitment from the wider area result in low sensitivity of zooplankton to TRO discharges.

22.6.331 TRO discharges are predicted to have minor adverse effects on zooplankton in the receiving waters. Effects are **not significant** at the population level.

Plankton sensitivity to bromoform

22.6.332 The average bromoform concentration within the discharge plumes of ten European power stations, including Sizewell A, has been shown to be 16.3µg/l (Ref. 22.112), and outfall concentrations range from 1-43µg/l (Ref. 22.103). chlorination by-products associated with chlorination are predicted to have very limited toxicity once in the receiving waters (Ref. 22.103).

22.6.333 Few studies have specifically looked at bromoform in isolation from other chlorination products and plankton receptors are considered together. No observed effect concentrations (NOEC) for bromoform on a range of marine organisms including bivalve gill tissue and larvae, echinoderm larvae and bacteria ranged from 0.5 to 3.4mg/l (Ref. 22.113). The 96-h LC_{50} for mysid (24.4mg/l) and diatom mortality (11.5-12.3mg/l) are orders of magnitude above concentrations observed in the field (Ref. 22.113).

22.6.334 Plankton are predicted to be not sensitive to bromoform.

22.6.335 Discharges of chlorination by-products (bromoform) are predicted to have negligible additional effects on plankton communities in the receiving waters beyond the wider effects of TROs. Effects are **not significant**.

Indirect effects of chlorinated discharges

22.6.336 Chlorination products are rapidly degraded in the marine environment and bioaccumulation is not an important consideration (Ref. 22.105). Bromoform is the most abundant chlorination by-product and has a low bioconcentration factor. The log bioconcentration factor ranges from 1-4 in most species with the exception of shrimps where values of >8 have been reported in the literature. However, following cessation of chlorination depuration of bromoform was completed after two days from mussels (Ref. 22.113).

22.6.337 Limited environmental persistence of chlorine, and the low bioconcentration factor of bromoform in most species indicates that indirect effects due to bioaccumulation in the food web are minimal.

Implications for climate change on chlorinated discharges

22.6.338 The seasonal chlorination strategy for the proposed development involves chlorination during the period of the year when water temperatures exceed 10ºC. At the earliest time of operation of the proposed development (2030), predicted water temperatures at the Sizewell C intakes would exceed 10ºC for 219 days per annum from the beginning of May until the start of December. By the year 2085, climate change is predicted to result in temperatures exceeding 10ºC from late April until late December, for a total of 244 days per annum, provided in **Appendix 21E** of this volume.

22.6.339 Whilst the duration of the growing season is likely to extend in the future, temperature driven changes in phenology would be moderated by day length and solar elevation thus restricting the total growth period. In the coastal waters at Sizewell, high levels of turbidity in the Winter and early Spring limit biological production. When phytoplankton are light limited, increases in temperature are not predicted to enhance productivity (Ref. 22.93). Therefore, increases in the duration of annual chlorination is likely to be small, in the order of weeks at most and does not influence the assessment.

Cooling water discharges: Hydrazine

22.6.340 Hydrazine (N_2H_4) is an ammonia-derived compound with strong anti-oxidant properties, regularly used as a corrosion inhibitor in cooling water circuits of nuclear power stations, provided in **Section 22.5** of this chapter. Worst-case daily discharges from Sizewell C have been modelled based on hydrazine discharges of 24kg per annum into the cooling water flow. Conservative decay rates were incorporated into the General Estaurine Transport Model to consider two release strategies based on different pulses of 69ng/l for

2.32h a day and 34.5ng/l for 4.63h a day culminating in the same total annual load (24kg/yr).

22.6.341 The plume simulations showed that both strategies gave similar results. The hydrazine plume follows a narrow trajectory parallel to the shore. At the seabed, less than 1ha exceeds the chronic PNEC, irrespective of the release strategy. At the surface the area that exceeds the chronic PNEC is 158 and 157ha for the 69ng/l and 34ng/l releases, respectively (**Table 22.33**).

22.6.342 The acute thresholds were only exceeded in the 69ng/l release strategy over a very small area of the seabed (0.13ha). Surface exceedance extended to 17.4ha and 13.8ha in the 34.5ng/l and 69ng/l strategy, respectively provided in **Appendix 21E** of this volume; **Table 22.33**. Daily discharges would occur throughout the lifecycle of the proposed development.

22.6.343 The impact magnitude is assessed as medium.

Table 22.33: Area of the hydrazine plume in exceedance of concentration thresholds.

Hydrazine release strategy.	PNEC threshold.	Area of exceedance (ha).	
		Surface	Seabed
69ng/l for a duration of 2.32h a day	Chronic 0.4ng/l (mean)	158.1	0.56
	Acute 4ng/l (95th percentile)	13.8	0.22
34.5ng/l for a duration of 4.63h a day	Chronic 0.4ng/l (mean)	156.9	0.34
	Acute 4ng/l (95th percentile)	17.4	0

Phytoplankton sensitivity to hydrazine

22.6.344 The sensitivity of the phytoplankton to hydrazine discharges was assessed as part of the commissioning phase assessments, provided in **Section 22.6c** in this chapter. The most sensitive species to hydrazine additions was the microflagellate *Micromonas pusilla* with a 96-hour EC_{50} of 1.27µg/l for inhibition and 1.80µg/l for growth rate. The diatom species *Sketetonema* sp and *Thalassiosira weissflogii* were both over an order of magnitude less sensitive to hydrazine (Ref. 22.61).

22.6.345 Canadian Federal Water Quality Guidelines for hydrazine indicate concentrations below 0.2µg/l (200ng/l) have a low probability of adverse effects for marine life (Ref. 22.60). The most sensitive evidence for marine species is from the chlorophyte *Dunaliella tertiolecta* which showed growth inhibition at 400ng/l (Ref. 22.59).

22.6.346 The concentrations observed to induce growth inhibition are higher than the discharge concentration. Therefore, phytoplankton in the receiving waters are likely to incur minimal effects from daily operational hydrazine discharges.

22.6.347 Whilst the potential for in-combination effects of hydrazine with thermal discharges and discharges of other chemicals exists, provided in **Section 22.6c)v** of this chapter, phytoplankton in the receiving waters are predicted to be not sensitive to discharges of hydrazine.

22.6.348 Hydrazine discharges are precautionarily assessed as having a minor adverse effect on phytoplankton receptors due to the impact magnitude of *Medium* and the limited evidence base for direct effects and the potential for in-combination effects. Effects are **not significant**.

Zooplankton sensitivity to hydrazine

22.6.349 Limited data exists on the toxicity of marine invertebrates to hydrazine. However, 48-hour exposures of the marine copepod *A. tonsa* demonstrated NOEC for hydrazine of 50µg/l (Ref. 22.61). Similar results have been observed in freshwater crustaceans, with examples of 48-hour exposure concentrations of 160µg/l for *Daphnia pulex* (Ref. 22.63), and 40µg/l for the amphipod *Hyallela azteca* (Ref. 22.114).

22.6.350 Such concentrations are considerably higher than those that would be experienced by zooplankton in the Sizewell receiving water. Zooplankton in the receiving waters are predicted to be not sensitive to hydrazine discharges.

22.6.351 Hydrazine discharges are precautionarily assessed as having a minor adverse effect on zooplankton receptors due to the impact magnitude of *Medium* and the limited evidence base for direct effects and the potential for in-combination effects. Effects are **not significant**.

Indirect effects of hydrazine discharges

22.6.352 The rapid degradation rates predicted at Sizewell, and the low bioconcentration factor of hydrazine indicates that bioaccumulation potential is low (Ref. 22.60; 62). No indirect food webs effects from hydrazine bioaccumulation are predicted.

Cooling water discharges: Nutrients

22.6.353 The maximum number of people on site during the operational phase occurs when there are refuelling outages. During refuelling, nitrate and phosphate loads are increased above background concentrations and these contributions are represented by peak 24-hour loadings. The refuelling outages typically last four to six weeks but can occur at any time of year.

22.6.354 Maximum daily nitrate discharges represent approximately 2% of the total mass exchanged within the tidal system. The daily average is 0.2% of the exchange rate. For phosphates, maximum daily loadings reach 5%, whilst average annual loadings contribute a very small proportion of the daily exchange (0.03%). Phosphate is not a limiting nutrient within the GSB system and therefore the addition of more phosphate would not be expected to stimulate further growth, provided in **Section 22.4** of this chapter. Maximum loadings would be short term and small relative to the daily exchange of nutrients.

22.6.355 The impact magnitude is low.

Phytoplankton sensitivity to nutrient discharges

22.6.356 A Combined Phytoplankton and Macroalgae model was used to predict the effects of nutrients on the annual gross primary production within the tidal excursion accounting for entrainment from Sizewell B and Sizewell C during the operational phase. The model predicted annual nutrients loadings would increase production within the GSB by 0.11%, provided in **Appendix 22H** of this volume. Such changes are orders of magnitude below the natural variation in chlorophyll *a* biomass, provided in **Section 22.6b** of this chapter.

22.6.357 Phytoplankton biomass within the GSB is not sensitive to operational nutrient additions.

22.6.358 Operational phase nutrient inputs are predicted to have negligible effects on phytoplankton biomass. Effects are **not significant** relative to natural variability in phytoplankton biomass.

Indirect food web effects of nutrient discharges

22.6.359 Increases in primary production at the base of coastal food webs has the potential to cause bottom-up effects. The Combined Phytoplankton and Macroalgae model predicted negligible changes in gross primary productivity and no indirect food web effects are predicted.

v. Fish recovery and return systems

22.6.360 This section describes the impacts associated with the operation of the FRR. The FRR system is designed to minimise impacts on impinged fish and invertebrate populations. However, some species incur high mortality rates and are returned dead or moribund which, although retains biomass within the system, it provides a source of organic carbon with the potential to enhance secondary production of carnivorous zooplankton through detrital pathways. In addition to organic loading, the potential for increases in un-ionised ammonia and reductions in dissolved oxygen are considered. Pressures with the potential to effect plankton are presented in **Table 22.34.**

Table 22.34: Pressures associated with releases of dead and moribund biota from the FRR.

Pressure	Justification
Organic enrichment.	The return of dead and moribund biota represents a source of organic carbon with the potential to cause secondary production through the detrital pathways.
Reductions in dissolved oxygen.	Decaying biomass would increase the biochemical oxygen demand and has the potential to reduce dissolved oxygen levels. The waters off Sizewell are well mixed vertically facilitating reaeration at the surface and the rate of water exchange within the GSB would limit the extent and duration of any oxygen reduction. Background dissolved oxygen concentrations conforms to 'high' status within the WFD waterbody and includes the influence of Sizewell B. The biological oxygen demand from biomass discharged from the FRRs is predicted to have a negligible effect on water quality. No further assessment.
Increases in nutrient inputs.	The breakdown of organic material would realse nitrogen and phosphorous into the system. During periods of nutrient limitation increases in nutrient availability has the potential to enhance phytoplankton biomass.
Increases in un-ionised ammonia.	Decaying biomass would release ammonia into the system. The ambient conditions and rate of discharge would influence the levels of un-ionised ammonia. Assessments consider seasonal un-ionised ammonia concentrations on plankton receptors.

Fish recovery and return: organic enrichment

22.6.361 The total biomass of moribund biota predicted to be discharged from the FRR has been estimated based on abstraction rates and information on the seasonal abundance of species along with length to weight distributions of the species impinged for the existing Sizewell B station, provided in **Appendix 21F** of this volume. Assessments of biomass discharged from the FRR systems are based on rates of impingement at Sizewell B and extrapolated to Sizewell C, FRR survival rates are then incorporated into the assessment. However, they do not account for Sizewell C LVSE headwork mitigation, which is predicted to reduce impingement rates by a factor of 0.383 per cumec (Ref. 22.24). As such, they represent highly precautionary assessments applied primarily to determine the absolute worst-case potential for water quality issues (deoxygenation and nutrient enrichment).

22.6.362 The data shows seasonal variation in the discharge of moribund fish. The annual average wet biomass discharge from the FRR is predicted to be 1065.5kg/d. In March a worst-case mean biomass of 3,442kg per day is predicted to be discharged from the FRRs. Between April to September biomass discharges are predicted to be lower at a mean of 405.2kg per day. This period represents a potentially sensitive time for phytoplankton as nutrient limitation occurs from May onwards. Estimated organic enrichment is considered in further detail in **Section 22.7d)** of this chapter and **Table 22.57**.

22.6.363 Modelling indicates that dead and moribund biota discharged from the FRR would primarily settle onto the seabed in the vicinity of the two FRR outfalls. However, small proportions of the discharged material are predicted to settle throughout the GSB. For the duration of the operation phase. Impact magnitude is assessed as medium.

Zooplankton sensitivity to organic enrichment

22.6.364 Experimental evidence from UK waters has shown attraction of amphipods to baited traps with species-specific responses to fish or crustacean bait (Ref. 22.115; 116). There is some evidence of elevated populations of mysids close to the outfall of the existing Sizewell B station (Ref. 22.25), however, it is not clear if this is a result of the outfall itself or more specifically the elevated detritus from discharged dead and moribund biota. Mysid attraction to baited traps has been observed, although sample sizes were small and photophobic responses may cause a degree of attraction to the traps themselves (Ref. 22.115).

22.6.365 Dead and moribund biota entering the GSB from the FRR may result in localised increases in the population size of some secondary consumers with the potential to exploit detrital pathways. Furthermore, discards may result in localised attraction of mobile scavengers attracted to opportunistic prey availability. However, the highly connected nature of GSB to the wider North Sea is likely to dampen the effects of discards, and the low sensitivity to organic loading from the FRR is predicted to result in minor beneficial effects. Effects are **not significant** (see **Section 22.10** of this chapter for wider food web assessments).

Fish recovery and return: nutrient inputs

22.6.366 The decay of organic material would release nutrients into the system. Increases in nutrients would have the greatest potential effect on phytoplankton biomass during the growing season when light is not limiting. Between April to September mean biomass discharges are lower (assumed as a worst case to be 405.2kg per day). For much of this period (mid-May to August) the GSB experiences nutrient limitation, provided in **Appendix 22H** of this volume. Nutrient inputs were calculated based on wet weight mass conversions of 3.5% and 0.5% for nitrogen (N) and phosphorus (P), respectively. This results in daily loadings of approximately 14kg N and 2kg Pas provided in **Appendix 21F** of this volume.

22.6.367 There is a strong seasonal bias to impingement numbers, and the return of dead biomass. The most biomass is returned in January, February and March, however during this period light is the limiting factor to primary production. Dead biomass returned during the Summer months, coinciding with periods of nutrient limitation, is lower. However, as a precautionary measure the total biomass discharged per annum was modelled as a daily average equating to approximately 1065.5kg of fish (wet weight) based on a worst-case assumption of an unmitigated intake head design (i.e. the Sizewell B design). A further highly conservative assumption was applied whereby all of this dry mass of fish was assumed to be available as nitrogen and phosphate sources leading to an additional 37.3kg day of nitrogen and 5.3kg of phosphate per day, above the discharge due to sewage and conditioning chemicals. The additional inputs of N and P from decaying biomass represent an increase to a value of 0.4% and 0.3% of the daily exchange, respectively, this is provided in **Appendix 22H** of this volume.

22.6.368 A Combined Phytoplankton and Macroalgae model predicted that annual nutrients loadings due to operational nutrient discharges from Sizewell B and the proposed development would increase annual gross production within the GSB by less than 0.3%, this is provided in **Appendix 22H** of this volume. Environment Agency data collected from the area from 1992 to 2013 indicate annual chlorophyll *a* varies by 45% of the mean, provided in **Section 22.6b)** of this chapter. In light of natural variability, enhancement from FRR nutrient inputs is negligible.

22.6.369 FRR nutrient inputs are predicted to have negligible effects on phytoplankton biomass. Effects are **not significant** and predicted to be orders of magnitude below the natural variation.

Fish recovery and return: un-ionised ammonia

22.6.370 The decay of biomass released from the FRR has the potential to cause increased in un-ionised ammonia above EQS concentrations. The tissue ammonia content for fish and seasonal physio-chemical conditions were incorporated into the un-ionised ammonia calculator, provided in **Appendix 21F** of this volume. Un-ionised ammonia was calculated for Summer, and Winter when fish discharges and ambient conditions differ.

22.6.371 During the period April-September, daily discharges of 405.2kg of dead or moribund biota have the potential to cause un-ionised ammonia concentrations to exceed the EQS (21µg/l) over an area of 1.2ha (under average conditions). To account for Summer conditions, 95th percentile temperature and pH, and average salinity was considered. Under this scenario the EQS is exceeded over an area of 3.8ha.

22.6.372 To account for the worst-case scenario the highest daily discharge value (3,442kg/d in March) was applied using a 5th percentile salinity, average temperature for March and average annual pH. Under these scenarios the exceedance of the EQS occurs over an area of 6.7ha, provided in **Appendix 22F** of this volume.

22.6.373 Biomass values are based on rates of impingement at Sizewell B and extrapolated to account for abstraction volumes. They do not account for the Sizewell C intake head design that will mitigate fish entrapment and is predicted to abstract ca 60% fewer fish per cumec than Sizewell B, or any losses from the system through tidal/wave transport or consumption. Furthermore, the assessments consider discharges of dead and moribund biota form a single point source. This adds a further precautionary factor to the assessment as the two FRR units, located approximately 300m apart, would allow a greater level of initial dilution with discharges split between two spatially separated points sources. Results should, therefore, be considered as highly precautionary.

22.6.374 The maximum spatial scale of the impacts is low and differs seasonally. Discharges would occur throughout the operational phase of the proposed development; therefore, the duration is high and the amount of change seasonally variable.

22.6.375 The impact magnitude is assessed as medium*.*

Plankton sensitivity to un-ionised ammonia

22.6.376 A very small proportion of the plankton community within the GSB would be exposed to un-ionised ammonia concentrations in exceedance of EQS thresholds and in the tidally dominated system exposure would be brief. Phytoplankton and zooplankton are assessed together.

22.6.377 Boardman *et al.,* (2004) reported 48-hour no observed effect concentrations (NOEC) of 0.45mg/l of juvenile mysids exposed to un-ionised ammonia (Ref. 22.55). Concentrations sufficient to cause reductions in photosynthetic activity in chlorophytes and diatoms or mortality in zooplankton following short-term exposure far exceed the concentrations predicted at the FRR outfall (Ref. 22.21). Whilst some adverse effects may be observed in the immediate vicinity of the FRR headworks including behavioural avoidance of some mobile species, plankton receptors are not sensitive to the un-ionised ammonia discharges at the population level.

22.6.378 Un-ionised ammonia discharges from the CDO are predicted to have minor adverse effects on plankton communities. Effects are **not significant**.

vi. Inter-relationship effects

22.6.379 This section provides a description of the identified inter-relationship effects that are anticipated to occur on plankton receptors between the individual environmental effects arising from operation of the proposed development.

Entrainment and impingement in-combination

22.6.380 With a 10mm mesh size, the effects of impingement would be limited to large planktonic taxa such as gelatinous zooplankton. An assessment of the ecological effects of mesh size influencing the ratio of plankton being entrained versus impinged identified the effects would be minimal at the population level. The in-combination effects of entrainment and impingement is not predicted to alter the original assessment.

22.6.381 Minor adverse effects are predicted on zooplankton communities within the GSB as a result of impingement and entrainment. Effects are **not significant** relative to high levels of natural variability.

Entrainment and the thermal and operational nutrient discharges in-combination

22.6.382 A Combined Phytoplankton and Macroalgae model was applied to predict the net effect of entrainment and a mean 0.5ºC thermal uplift within the GSB and tidal excursion, as a result of cooling water abstraction and discharge from Sizewell B and Sizewell C operating simultaneously, provided in **Appendix 22H** of this volume. The model also incorporated nutrient additions from the operational phase.

22.6.383 Combining the effects of entrainment mortality, increased nutrient discharges and thermal uplifts, the predicted reduction in annual gross production for both stations operating is approximately 6% compared to a reference (no power station) condition. High natural variation, whereby annual chlorophyll *a* varies by 45% of the mean provided in **Section 22.6b)** of this chapter, indicates that effects from the proposed development are small relative to natural variability. Furthermore, food web effects are predicted to be minimal as taxa that graze on phytoplankton would be adapted to naturally large variations in standing stock, provided in **Appendix 22H** of this volume.

22.6.384 Entrainment acting in-combination with thermal and nutrient discharges is predicted to have minor adverse effects on phytoplankton communities within the GSB. Effects are **not significant** relative to high levels of natural variability.

Synergistic effects of chlorinated discharges and treated sewage in the cooling water system

22.6.385 During the operational phase, seasonal chlorination would be applied to protect critical plant from biofouling. Chlorination of seawater results in the liberation of a range of TROs and chlorination by-products depending on the water chemistry. Elevated organic content and ammonia can lead to the formation of chloramines and bromamines (Ref. 22.106). Increased ammonia levels at estuarine power stations has previously been proposed as the factor behind elevated toxicity of chlorination in comparison to the open coastal sites (Ref. 22.69).

22.6.386 Ammonia discharges from plant conditioning chemicals and the on-site sewage treatment would also be discharged via the cooling water outfalls. Whilst EQS levels are not predicted to be exceeded once the discharges mix with the receiving waters, there is the potential for ammonia to react with chlorinated discharges in the cooling water stream.

22.6.387 The synergistic effects of chlorination and ammonia discharges may increase the toxicity of the cooling water to entrained planktonic organisms. However, small increases in mortality are not predicted to influence entrainment predictions. Abstraction rates represent approximately 1.35% of the volume of water that passages past the station and exchange rates with the wider North Sea are ca. 10%. Therefore, even 100% mortality of long-lived zooplankton taxa would have a minimal effect on the local population.

22.6.388 The synergistic effects of chlorination and ammonia discharges are not predicted to alter the assessment of entrainment effects.

22.6.389 Minor adverse effects are predicted on phytoplankton and zooplankton communities within the GSB as a result of entrainment. Effects are **not significant** relative to high levels of natural variability.

In-combination effects in the thermo-chemical plume

22.6.390 Seasonal chlorination of critical plant would result in thermal discharges being chlorinated once water temperatures exceed 10ºC. This section considers the interactive effects of temperature and chemical discharges on phytoplankton and zooplankton.

22.6.391 Increase in temperature is known to increase chlorine toxicity, particularly when exposure temperatures approach the limits of a species' tolerance range (Ref. 22.103). Temperature dependent toxicity is suggested to be a result of increased uptake rates and physiology at higher temperatures. A 5°C increase in temperature more than halved the LC_{50} concentration of free chlorine and chloramine in 30-minute exposures in the rotifer *Brachionus plicatilis*, larvae of the American lobster *Homarus americanus*, and American oyster larvae *Crassostrea virginica* (Ref. 22.117). However, the eurythermal copepod *A. tonsa* was unaffected by temperature increases (Ref. 22.117). Chlorinated effluents typically dilute relatively quickly in receiving environments, as such the potential for synergistic interactions in the field would be reduced (Ref. 22.103). The effects of chlorination of plankton tends to be greater than temperature alone (Ref. 22.68; 118; 119).

22.6.392 A thermal and chemical concentration gradient would form, where thermal uplifts and chemical concentrations rapidly reduce from the point of discharge, as presented in **Figure 21.7** of **Chapter 21** of this volume. TROs represent the largest chemical plume exceeding EQS concentrations where toxicological effects may be influenced by thermal uplifts. TROs above EQS concentrations (10µg/l) cover a sea surface area of 338ha as a 95th percentile. At the boundary of the EQS contour thermal uplifts (98th percentile) of 3^{o}C occur, this is presented in **Figure 21.7** of **Chapter 21** of this volume. At the seabed EQS exceedance covers an area of just 2ha and is associated with 2^{o}C uplifts.

22.6.393 The most sensitive species in the individual assessments showed effect thresholds at ca.20µg/l. It is therefore unlikely that the synergstic effects of TROs and modest temperature uplifts would cause adverse effects to extend beyond the TRO EQS contour.

22.6.394 The synergistic effects of the thermo-chemical plume may result in reductions in tolerance of plankton receptors to chemical discharges in the near to mid-field of the plume. However, in the well mixed tidal environment the spatial area of impacts means a small proportion of the population would be exposed. Therefore, whilst synergistic effects may enhance toxicity in the close proximity to the discharge the original assessment of minor adverse effect on phytoplankton and zooplankton communities within the GSB is valid. Effects are **not significant** relative to high levels of natural variability.

22.7 Benthic ecology assessment

a) Introduction

22.7.1 This section follows the methodology outlined in **Section 22.3** of this chapter, to determine the potential for significant effects arising from the construction and operational phases of the proposed development on benthic ecology receptors.

22.7.2 The magnitude of the environmental impacts prior to any additional (secondary) mitigation is considered and assessed assuming the primary and tertiary measures detailed in **Section 22.5** of this chapter, are embedded. Where secondary mitigation or monitoring is deemed appropriate to minimise any adverse effects, assessments are considered further as a residual effect, provided in **Section 22.13** of this chapter.

22.7.3 The benthic ecology baseline is described and forms the basis against which to determine the effects. Effects, both beneficial and adverse, consider the sensitivity of benthic ecology receptors to the specific impact magnitude arising from activities associated with the proposed development.

b) Benthic ecology baseline environment

22.7.4 This section presents a description of the baseline environmental characteristics for benthic ecology within the footprint of the proposed development and in the surrounding area (i.e. the GSB). The baseline conditions characterise the benthic communities and habitats and provide the reference point for EcIA.

22.7.5 The full characterisation report for benthic ecology can be found in **Appendix 22C** of this volume**.**

i. Current baseline

22.7.6 The benthic ecology of the GSB has been characterised based on a series of onshore (intertidal) and offshore (subtidal) surveys, conducted between 2008 and 2017, provided in **Appendix 22C** in this volume. See also, **Figure 22.3**.

22.7.7 Onshore surveys include comprehensive fortnightly impingement sampling at Sizewell B, with a total of 202 samples collected between 2009-2017 and the abundance of impinged invertebrates recorded. An intertidal survey of the beaches in the GSB was implemented in 2011 and involved 60 quadrats ($0.0625m^2$) sampled to a depth of 15cm, at six locations across the shore.

22.7.8 Offshore surveys included:

- A total of 295 2m beam trawl samples from 84 stations and 64 commercial otter trawl samples from 11 stations, collected quarterly to annually during 2008-2014.

- Eleven subtidal surveys, comprising a total of 890 grab samples ($0.1m^2$) from 88 stations, also collected quarterly to annually during 2008-2014.

- A shallow subtidal survey, comprising 17 grab samples ($0.025m^2$) collected in 2011.

22.7.9 The subtidal survey grid evolved over time to ensure coverage of areas representative of the range of seabed habitat types present in the GSB, which were mapped during 2008 and 2009 (Ref. 22.120). The extent of the surveys was further informed based on model outputs of the predicted footprint of Sizewell C thermo-chemical plume (i.e. sampling was distributed throughout the predicted footprint of the plume). High resolution acoustic imaging surveys of the Coralline Crag formation (hard sediment consisting of biogenic debris) in the subtidal zone were also conducted twice in 2016 and again in 2018, once in 2018 and once in 2019 (Ref. 22.121; 122). Both 2018 and 2019 surveys were accompanied by a complementary multibeam echosounder (MBES) survey. The latter was accompanied by a complementary multibeam echosounder (MBES) survey.

22.7.10 Zooplankton surveys were conducted over a wide area within the GSB tidal excursion between 2008 and 2012, using 80µm and 270µm mesh to sample the smaller and larger components community, respectively provided in **Appendix 22B** in this volume. While these data were mainly used to inform the plankton baseline environment and impact assessments in **Section 22.1.1b)** of this chapter**,** they also provided information on the presence of eggs and larvae in the water column and, thus, were used to consider potential impacts on benthic ecology receptors during early, planktonic life stages.

22.7.11 Intertidal beaches within the GSB are predominantly coarse sediment with ephemeral sand veneers, harbouring sediment-dwelling organisms. The beaches of the area are not particularly diverse compared to other intertidal beaches in Europe. Intertidal surveys of the area show little evidence of spatially distinct assemblages and no benthic invertebrate species found in the intertidal zone of the GSB are of conservation importance.

22.7.12 In the subtidal zone, the same broad infaunal[25] and epifaunal[26] benthic community spans most of the GSB. Both the infauna and epifauna communities are common in a regional context and are part of a larger community distributed across the southern North Sea ‘infralittoral region’, corresponding to subtidal areas less than 50m deep.

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[25] Infaunal organisms live within seabed sediments.
[26] Epifaunal organisms live on or just above the seabed.

22.7.13 The shallow subtidal areas (down to 6m depth) that were surveyed in 2011 harbour benthic assemblages that are consistent with those found in the deeper areas of the GSB. No benthic macroflora or macroalgae were recorded during the subtidal or intertidal surveys. This is typical of turbid coastal systems like the GSB, due to light limitation at the seabed.

22.7.14 While the GSB benthic invertebrate community exhibits broad spatial homogeneity, a high level of temporal variability is nonetheless observed. The highest values of abundance, species richness and biomass are recorded between April and August, corresponding to the recruitment period for many infaunal taxa. Annual peaks of abundance vary in intensity from year-to-year and are characterised by a high proportion of *r*-selected[27] taxa, which are often found in unstable dynamic environments such as the GSB. The abundances of highly mobile benthic invertebrates (e.g. crustaceans) increase between June and September during their annual migration inshore, triggered by a seasonal increase in water temperature.

Benthic invertebrate taxa

22.7.15 Over 300 benthic invertebrate taxa were recorded during the onshore and offshore surveys of the GSB. As it is not feasible to consider the effect of each pressure associated with the proposed development on each species assessments are, where appropriate, focused on 20 key taxa belonging to the five broad taxonomic groups (molluscs, crabs and lobsters, shrimps and prawns, polychaetes and echinoderms). These taxa were selected due to their ecological importance (i.e. they are widespread and abundant), conservation importance (i.e. they have national or international conservation status) and/or socio-economic importance (i.e. they are commercially exploited locally or targeted by recreational fishers) as presented in **Table 22.35.** Their relatively high value in any or all these respects makes them an appropriate subset of taxa on which to focus assessments.

22.7.16 While two species were identified due to their conservation importance, this importance should be contextualised. The lagoon sand shrimp *Gammarus insensibilis*, protected under Schedule 5 of the Wildlife and Countryside Act 1981, is typically associated with saline lagoons but was observed outside of this habitat in the GSB, occurring at low abundance in the subtidal zone in June 2010. The Ross worm *Sabellaria spinulosa* is listed under Section 41 of the NERC Act (2006) when it forms biogenic reefs. It is also of international conservation importance under the EU Habitats Directive of 1992 when it forms reefs in Special Areas of Conservation (SACs) that are designated for

[27] *r*-selected species are small short-lived organisms, with rapid reproduction and growth rates that can make use of opportunistic resource availability. In ecological selection theory they differ from *K*-selected species that are at the other end of the spectrum and are typified by larger body size, longer life expectancy and fewer, larger offspring.

habitat protection - this does not apply to the GSB and surrounding Southern North Sea SAC. It is therefore considered a key taxon not *per se*, but in that it is foundational to a habitat of conservation importance.

Table 22.35: Overview of the key benthic taxa of the Greater Sizewell Bay and their associated ecological, socio-economic and conservation importance.

Faunal Group.	Taxon	Ecological	Socio-Economic.	Conservation
Molluscs	*Abra alba*	✓		
	Buccinum undatum		✓	
	Ensis spp.	✓		
	Limecola balthica	✓		
	Mytilus edulis	✓	✓	
	Nucula nitidosa	✓		
	Nucula nucleus	✓		
Crustaceans (crab & lobster).	*Cancer pagurus*		✓	
	Homarus gammarus		✓	
Crustaceans (shrimp & prawn).	*Bathyporeia elegans*	✓		
	Gammarus insensibilis			✓
	Corophium volutator	✓		
	Crangon crangon	✓	✓	
	Pandalus montagui	✓		
Polychaetes	*Nephtys hombergii*	✓		
	Notomastus spp.	✓		
	Scalibregma inflatum	✓		
	Spiophanes bombyx	✓		
	Sabellaria spinulosa			✓
Echinoderms	*Ophiura ophiura*	✓		

22.7.17 As species-specific assessments are limited to a subset of key taxa, a biological traits-based approach is used to describe the full infaunal and epifaunal assemblages in terms of a suite of organismal characteristics that determine biotic response to environmental changes. This way, assessments of ecological effects can be made at the community level using shared traits that are most relevant for the pressures to which benthic invertebrates would be exposed (Ref. 22.123). Here, the focus is placed on traits that reflect habitat preferences, feeding mode, reproductive strategy, mobility, morphology or population characteristics, which are weighted according to abundance and biomass distributions for infaunal and epifaunal components of the benthos. For each pressure associated with the proposed development, the most relevant biological traits are used in association with taxon groups (species to phyla) to create meaningful receptor sub-groups with which to determine the sensitivity of benthic invertebrates. For example, inspection of biological traits composition indicates that most taxa in the GSB have planktonic larval development, which highlights the importance of assessing the sensitivity of this life stage to the pressures that planktonic organisms are likely to be exposed.

22.7.18 Early life stages of benthic invertebrates found in zooplankton samples are typically part of the smaller (<4mm) zooplankton fraction, which is characterised by invertebrate eggs and the larvae of bivalves, polychaetes, bryozoans, gastropods, echinoderms, cirripeds (barnacles) and nematodes, provided in **Appendix 22B** of this volume. These taxa are present in the water column throughout the sampling season (February to July), with the timing of peaks in abundance depending on the faunal group.

22.7.19 Only one INNS was recorded in the GSB during the benthic baseline surveys, the American jacknife *Ensis leei* (previously *E. directus*), which was found in a single grab sample, provided in **Appendix 22C** of this volume. In the North Sea, 274 INNS and cryptogenic species (of uncertain origin) have been recorded. The main vector for primary introduction is vessels (ballast or hull fouling). Natural spread occurs from neighbour country and it accounts for a third of the introduced species (Ref. 22.124).

Benthic habitats

22.7.20 Benthic habitats in the GSB, unless formed by live organisms (i.e. biogenic reefs), are not treated as receptors in the benthic ecology assessments but rather are considered in terms of their role in determining the sensitivity of benthic invertebrates to pressures associated with the proposed development. For example, if most of the soft sediment in the area was changed to a hard substrate due to infrastructure installation, then this would inhibit the recovery of sediment-dwelling organisms and would be reflected in the assessment of benthic invertebrate sensitivity to habitat change.

22.7.21 The seabed in the GSB consists mainly of soft sediments, but spatial variation in habitat type is observed when habitats are classified to EUNIS

Level 4[28] (Ref. 22.120). The benthic habitats are illustrated in **Figure 22.4** and summarised as:

- Infralittoral fine sand (A5.23) is found in the north of the survey area, on the Sizewell-Dunwich Bank and along the coast from Aldeburgh to Dunwich. These areas are interspaced with infralittoral sandy mud (A5.33) and, in deeper waters, circalittoral muddy sand (A5.26).

- Along the shoreline in the shallow subtidal zone, habitats alternate between infralittoral fine sand (A5.23) and infralittoral coarse sediments (A5.13).

- Larger patches of infralittoral coarse sediments are found off Minsmere and Orford (A5.13).

- Areas off Sizewell and Thorpness, where Coralline Crag is exposed on the seabed, are classified as hard substrates including circalittoral rock (A4.13) and infralittoral mixed sediment (A5.43).

22.7.22 Two habitats of conservation and ecological importance are found in the GSB:

- The Sizewell-Dunwich Bank is likely to provide feeding grounds for higher trophic levels (fish, seals, seabirds) provided in **Appendix 22C** of this volume. The habitat is not designated but is assessed as a geomorphology receptor in **Chapter 20** of this volume.

- *Sabellaria spinulosa* reefs are present on the Coralline Crag outcrops directly off Thorpeness (inshore Coralline Crag) (Ref. 22.121) and seaward of the Sizewell-Dunwich Bank (offshore Coralline Crag) (Ref. 22.122). *Sabellaria spinulosa* reefs are protected as habitat of principle importance listed in Section 41 of the NERC Act (2006) so reefs are therefore treated as a high value receptor. Evidence of *S. spinulosa* reefs on the offshore Coralline Crag became available in summer 2019 and means that the installation of cooling water intakes for Unit 1 could have a direct impact on a *S. spinulosa* reefs and supporting habitat. Such an impact could potentially be significant. The evidence relating to the characteristics and distribution of this feature, and the approach to assessing the impact of the proposed development on this feature,

[28] The EUNIS (European Nature Information System) habitats classification is a means of standardising habitat types for conservation objectives using a hierarchical classification system.

are therefore described in detail in the section below (Offshore *Sabellaria spinulosa* reefs).

22.7.23 Annual vegetated drift lines form a qualifying feature of the Minsmere to Walberswick Heaths and Marshes SAC. This Annex I designated habitat is occurs above MHWS and is assessed in the Terrestrial Ecology and Ornithology **ES Chapter 14** of this volume.

22.7.24 Coastal habitats form part of the qualifying features of designated sites within the ZOI, provided in **Table 22.1**. The potential for marine ecology effects in these high value features has been investigated. Saline lagoons are present on the Minsmere coast and are a supporting habitat within the Minsmere-Walberswick Special Protected Area (SPA). Chemical discharges associated with the operation of the proposed development would not intersect the Minsmere coast at concentrations that could induce ecological effects, provided in **Figure 21.8** of **Chapter 21** and **Appendix 21E**, both of this volume, so these habitats are scoped out of the assessment of operational effects. During the commissioning phase, discharges associated with cold flush testing, including hydrazine, have the potential to enter coastal systems should they occur at ecologically relevant concentrations. Such impacts are considered in further detail in **Sections 22.1a)i** and **22.7b)** of this chapter.

Offshore *Sabellaria spinulosa* reefs

22.7.25 In the Summer of 2019, Ground Investigation (GI) surveys were completed to collect geotechnical data at the location of the offshore cooling water infrastructure and indicated no superficial sediment present at the proposed location for Unit 1 intake. A dedicated survey of the highly turbid offshore Coralline Crag, using acoustic methods, subsequently confirmed the presence of *S. spinulosa* reefs in the area where southern CWS intakes would be installed. The methodology and results of the survey are presented in (Ref. 22.122).

22.7.26 Scoping of the pressures and associated activities that could affect *S. spinulosa* reefs at the offshore Coralline Crag was initially informed by the Marine Ecology and Fisheries Final Scoping Report provided in **Appendix 22M** of this volume. Whilst it is noted that the *S. spinulosa* reefs within the GSB are not a qualifying feature of a designated site, the advice on operation for relevant SACs with *S. spinulosa* reefs as a qualifying feature were applied to assist identification of specific activities and pressures with the potential to affect *S. spinulosa*. Assessment of the potential impacts of the proposed development on *Sabellaria reef* has been further informed following discussions with the MMO and Natural England. Relevant construction and operational impacts on *S. spinulosa* reefs are presented in **Table 22.36** and **Table 22.37**, respectively.

22.7.27 Designated sites selected to inform scoping included the Wash and North Norfolk Coast SAC (Ref. 22.125), due to the features of interest and relative proximity to the proposed development, and the Severn Estuary SAC (Ref. 22.126), due to the presence of an operating nuclear power station (Hinkley Point B).

Table 22.36: Identification of pressures during the construction phase of the proposed development and the associated activities with the potential to affect *Sabellaria spinulosa* reefs (Unit 1).

Pressure	Activity-Pressure pathway.	*S. spinulosa* assessment.
Temperature changes.	No impact pathway for the offshore *Sabellaria* reefs during construction.	No further assessment.
Salinity changes.		
Removal of substratum (extraction).	Ground preparation associated with the installation of the southern intake headworks would result in removal of *S. spinulosa* and associated habitat.	The exact extent of the ground preparation works on the hard substratum is unclear. A precautionary assessment (incorporating other construction activities) considers the potential for temporary impacts within a 50m buffer of the headworks.
Abrasion / physical disturbance.	Construction platform activities (e.g. jack-up barges and anchoring) have the potential to cause localised surface and sub-surface abrasion.	A precautionary assessment (incorporating other construction activities) considers temporary impacts within a 50m buffer of the headworks.
Sedimentation rate changes (smothering).	Capital dredging (and to a lesser extent drilling) activities associated with the installation of offshore cooling water infrastructure would result in sedimentation rate changes. (*S. spinulosa* is not sensitive to changes in turbidity (light environment) associated with increases in suspended sediments).	Assessed for each development component.
Suspended sediment changes.		
Physical change/loss of habitat.	Ground preparation and installation of the intake headworks and associated scour protection would represent a permanent change in seabed type. Occasional maintenance works would remove fouling organisms from the headworks. Habitat change is also considered within abrasion,	In the case of reef forming *S. spinulosa* this disturbance amounts to permanent loss of habitat. A worst-case scenario of permanent habitat loss is assessed.

Pressure	Activity-Pressure pathway.	*S. spinulosa* assessment.
	sedimentation and changes in the flow regime, which are assessed individually.	
Nutrient discharges.	Small-scale nutrient discharges (including un-ionised ammonia) occur during the construction phase.	The offshore *Sabellaria* reef is well beyond the scope of the discharges. No further assessment
Heavy metal contamination.	Small-scale heavy metal discharges occur during the construction phase.	The offshore *Sabellaria* reef is well beyond the scope of the discharges. No further assessment.
Synthetic compound contamination.	Construction and commissioning discharges, including hydrazine, could affect *Sabellaria.*	Assessments consider exposure and sensitivity of *Sabellaria* reefs to commissioning discharges.
Introduction of non-indigenous species.	The intake headworks would introduce hard substrata, which could facilitate the spread of benthic INNS.	The potential for INNS to compete for space with native encrusting species such as *S. spinulosa* is considered.
In-combination effects.	Pressures during the construction phase can act in-combination to greater effect.	In-combination effects are considered in **Section 22.7b)v** of this chapter.

Table 22.37: Identification of pressures during operational phase of the proposed development and the associated activities with the potential to effect *Sabellaria spinulosa* reefs at the location of the southern cooling water intakes (Unit 1).

Pressure	Activity-Pressure pathway.	*Sabellaria* assessment.
Temperature changes.	Temperature changes arising from operational cooling water discharges have the potential to effect *Sabellaria* reefs	Assessments consider exposure and sensitivity of *Sabellaria* reefs to thermal discharges.
Salinity changes.	No impact pathway for the offshore *Sabellaria* reefs during operation.	No further assessment.
Water flow rate changes.	The physical presence of the intake headworks has the potential to cause localised changes in flow rates.	The potential for changes in hydrodynamics to alter settling behaviour is acknowledged. In a hard substrate environment, the area of changes in flow would be localised. Operational flow regimes are considered as part of the entrainment assessment.

Pressure	Activity-Pressure pathway.	*Sabellaria* assessment.
Wave exposure changes.	Wave exposure changes as a result of the offshore cooling water intakes would be negligible.	No further assessment.
Entrainment	Cooling water abstraction has the potential to remove *S. spinulosa* eggs and larvae.	Assessments consider the loss of eggs released from the offshore reef on larval supply and the potential for entrainment to reduce recruitment potential.
Wave exposure changes.	Wave exposure changes as a result of the physical presence of the intake headworks would be negligible.	No further assessment.
Physical change/loss of habitat.	The physical presence of the intake headworks would represent a permanent change in seabed type. Occasional maintenance works would remove fouling organisms from the headworks.	In the case of reef forming *S. spinulosa* this disturbance amounts to permanent loss of habitat. A worst-case scenario of permanent habitat loss is assessed.
Abrasion / physical disturbance.	Occasional operational platform activities during maintenance operations have the potential to cause localised surface and sub-surface abrasion beyond the area of 'physical loss'. Abrasion may be through activities such as anchoring, and chain drag.	Small scale effects of maintenance vessel activities on *Sabellaria* is assessed.
Nutrient discharges.	Small-scale nutrient discharges (including un-ionised ammonia) occur during the operational phase.	Assessed
Synthetic compound contamination.	Operational discharges of chlorinated compounds (TROs and bromoform), and hydrazine have the potential to effect *Sabellaria* reefs.	Assessments consider exposure and sensitivity of *Sabellaria* reefs to Operational discharges.
De-oxygenation.	Oxygen concentrations are predicted to remain within the WFD 'high' classification during the operational phase (TR490/306).	No further assessment.
Radionuclides.	Assessments pertaining to radiological considerations of the proposed development are detailed in **Volume 2 Chapter 25** of the **ES**.	

Pressure	Activity-Pressure pathway.	*Sabellaria* assessment.
Introduction of non-indigenous species.	The intake headworks would introduce anthropogenic hard substrata, which could facilitate the spread of benthic INNS.	The potential for INNS to compete for space with native encrusting species such as *S. spinulosa* is considered.
In-combination effects.	Pressures during the construction phase can act in-combination to greater effect.	In-combination effects are considered in **Section 22.7c)v** of this chapter.

22.7.28 As with other receptors, assessment of effects on the *S. spinulosa* reef accounts for the impact magnitude and sensitivity of the receptor to the given pressure, as described in **Section 22.3** of this chapter. To determine the significance of and predicted effects on *S. spinulosa* reefs at the offshore Coralline Crag, the high conservation value of the receptor is considered in relation to the features location, rarity, distribution and ecological function as described in **Table 22.38**.

Table 22.38: Factors determining the significance of potential effects on *S. spinulosa* reefs.

Factor	Considerations for determining significance.
Location	*Sabellaria spinulosa* reefs at the offshore Coralline Crag are not located within a designated site for which it is a qualifying feature. However, they are protected as *'habitats of principal importance for the conservation of biodiversity in England'* (Section 41 of the NERC Act 2006).
Rarity	*Sabellaria spinulosa* reefs have been identified along the Suffolk coast as part of the East Coast and Outer Thames Regional Environmental Characterisation (Ref. 22.127; 128). Seven major areas of *S. spinulosa* reef have been reported with varying extents from $7km^2$ and up to $50km^2$ in the East Coast region. One possible site has been identified in the North of the Outer Thames Region. *Sabellaria spinulosa* has also been identified as amongst the most abundant benthic organisms recorded during REC surveys.
Distribution[29]	The reefs associated with the offshore Coralline Crag are predicted to cover an area of approximately 18.5ha (Ref. 22.122). Within the GSB, larger reef formations are located at the exposed inshore Coralline Crag off Thorpeness, where an estimated 28ha of habitat within the study area was predicted as having a high probability of supporting *S. spinulosa* reefs and a further 24.5ha of habitat classified as having moderate probability of supporting *S. spinulosa* (Ref. 22.121). Exposed Coraline Crag provides the supporting habitat for establishment of *S. spinulosa* reefs in the GSB. The exposed area of

[29] It should be noted that traditional light-based imaging systems are not available for habitat classification in the high turbidity waters off Sizewell. Acoustic imaging video footage (ARIS camera) coupled with geophysical surveys (side-scan sonar and multibeam echosounder) were used although a degree of expert judgement is required (Ref. 22.122).

Factor	Considerations for determining significance.
	offshore Coralline Crag is estimated at 57.5ha, whilst the extent of the exposed inshore Coralline Crag is 365ha. With a total of approximately 423ha within the GSB, provided in **Appendix 22C** of this volume.
Reef Quality and Ecological Function.	*Sabellaria spinulosa* can form dense subtidal aggregations in the form of extensive 'crusts' or 'sheets', sometimes covering large areas of the seabed, which can act to stabilize sand or gravel habitats (Ref. 22.129–132). The crust formations are ephemeral in nature and are not considered as true *S. spinulosa* reef as it does not provide a biogenic habitat for associated species to establish. *Sabellaria spinulosa* formations increase in mass over time and form elevated reefs structures as new recruits are strongly stimulated to settle by cement construction on established colonies (Ref. 22.133). In reef formation, *S. spinulosa* is an ecological engineer, whereby aggregations form solid biogenic structures on the seabed (Ref. 22.131). *Sabellaria* reefs are known to enhance biodiversity and biomass in comparison with adjacent soft sediment communities (Ref. 22.130). The ecological function of *S. spinulosa* means that impacts on reefs have potential indirect effects on other benthic taxa. The reefs associated with the offshore Coralline Crag have been assessed as having 'low' (2-5cm) to 'medium' (5-10cm) elevation (Ref. 22.122) according to the Gubbay (2007) criteria (Ref. 22.134). With crusts also considered likely over a wider area (Ref. 22.122).

ii. Future baseline

22.7.29 No long-term developments or changes to human activities are planned in the GSB and, on this basis, the benthic ecology baseline is considered a suitable focus of assessments throughout the lifetime of the proposed development. However, potential effects of climate change on benthic invertebrates and coastal habitats in the North Sea have been identified in **Appendix 22C** of this volume and needs to be considered with respect to future baselines (i.e. possible deviations from the current baseline). Four major climate-related drivers of change are identified for the GSB:

- Sea temperature rise – Biodiversity loss due to temperature rise is not expected in the southern North Sea and, therefore, the key taxa used in benthic ecology assessments are expected to be present in a future, warmer climate. *Sabellaria spinulosa* reef is considered to have a low sensitivity to temperature rise in the UK, as they occur in much warmer climates such as the Mediterranean Sea in the present day (Ref. 22.135). The biological traits composition of the benthos is also not expected to change due to warming, as current evidence suggests that characteristics of benthic communities are largely retained under different climatic conditions despite substantial changes in taxa composition (Ref. 22.136; 137). However, warming is predicted to induce distributional shifts, with taxa moving northward as they follow shifts in their thermal niche (Ref. 22.138; 139). The spread of INNS with preferences for warmer or cooler water may also be positively or negatively affected by temperature rise. Of particular note for the proposed development are INNS that foul man-made structures and are projected to expand their distributions in north-west Europe, such as the Asian club tunicate *Styela clava*, slipper limpet *Crepidula fornicata* and bay barnacle *Amphibalanus improvises* (Ref. 22.140). Any influence of the proposed development (e.g. the presence of infrastructure) on the spread of INNS may therefore change in the future and is assessed in this report.

- Changes in hydrodynamics and storminess – Hydrodynamics can influence the composition and functioning of benthic communities by altering larval dispersal patterns, causing mortality (e.g. disturbance during storm events, possibly associated with climate change) and modifying primary and secondary production transport pathways between the seabed and water column, thus potentially affecting food web structure (Ref. 22.141). Currently not enough is known to accurately forecast how climate change will influence hydrodynamics and, in turn, affect the benthic features of the GSB (Ref. 22.142). *Sabellaria spinulosa* reef is considered susceptible to storms (Ref. 22.143) and may therefore be more or less prevalent within the GSB if storminess changes in the future. Declines in water clarity in the southern North Sea due to increases in suspended sediments since the mid-20th century could also be exacerbated by increased storminess. However, the influence of climate change on storm activity is currently unclear (Ref. 22.144).

- Ocean acidification –The effect of ocean acidification on the fitness of benthic organisms is complex and difficult to predict, as species could develop metabolic compensation mechanisms (Ref. 22.145). At the community level, experiments and observational studies suggest that acidification may reduce the species richness of benthic invertebrates in soft sediments (sand and mud) and hard substrates (rock and artificial structures); however, effects were generally apparent at seawater pH levels lower than are foreseeable due to ongoing anthropogenic ocean acidification (Ref. 22.146–148). Therefore, changes from baseline benthic community composition are not expected as a result of ocean acidification.

- Sea level rise – Rising sea levels have the potential to induce coastal-squeeze across the UK, with beaches becoming increasingly trapped between the sea and terrestrial barriers (e.g. coastal defences) (Ref. 22.141). Currently, sea-level rise on the Suffolk coast induces shoreline retreat and the release of sediment from the soft cliffs in the area between Lowestoft and Southwold, while the beaches of the GSB alternate between trends of erosion and accretion on the shoreline associated with the circulation of the sediment on the various littoral cells. The Sizewell-Dunwich Bank is likely to protect the coastline in the GSB from major changes by attenuating the impact of wave energy in the long-term (Ref. 22.149). The potential for sea level rise to interact with the proposed development, specifically the coastal defences, to cause coastal squeeze and/or changes to benthic invertebrate communities is considered further.

c) Construction

22.7.30 The construction phase, including commissioning, of the proposed development has the potential to affect benthic ecology receptors. Construction may begin in 2022 and last between nine and 12 years.

22.7.31 This section considers the development components and associated activities that were identified during scoping, provided in **Appendix 22M** of this volume, to result in pressures warranting further investigation.

i. Coastal defence features

22.7.32 Activities for the SCDF and HCDF generally occur above the MHWS and are therefore not predicted to affect marine benthic ecology receptors, provided in **Section 22.7.c)** of this chapter. The compaction of substratum due to heavy plant operations on the beach is the only pressure scoped in during the construction phase. Potential effects on terrestrial receptors are considered within the Terrestrial Ecology and Ornithology **ES**, **Chapter 14** of this volume.

Compaction of substratum: heavy plant operations

22.7.33 During the construction of coastal defence features, heavy plant operations would lead to compaction of beach sediments. This activity has the potential to affect benthic invertebrates by direct physical disturbance or by changing habitat suitability.

22.7.34 The spatial extent of the pressure is expected to be very small (e.g. 500m x 20m; 1ha) with increased activity concentrated around the BLF and SCDF (primarily above MHWS). This activity would occur for part of the construction phase. The impact magnitude is assessed as low due to the small spatial extent and temporary nature of the pressure.

Benthic invertebrate sensitivity to compaction of substratum

22.7.35 Intertidal benthic invertebrate communities are broadly similar throughout the GSB and not particularly diverse, reflecting the highly dynamic nature of the beaches which makes them a challenging environment for benthic biota (Ref. 22.150). Therefore, only a very small proportion of any intertidal benthic invertebrate population (and their supporting habitat) is likely to be adversely affected by sediment compaction due to heavy plant operations on the beach.

22.7.36 Once this activity is completed, recovery of soft sediment intertidal benthic invertebrate communities could occur. Given the sparse nature of intertidal benthic invertebrate fauna and the life-history constraints of inhabiting an environment as challenging as intertidal beaches, recovery is expected to be rapid.

22.7.37 As only a small proportion of any intertidal benthic invertebrate population and associated habitat would likely be adversely affected by the pressure and a quick recovery is expected, sensitivity is assessed as low.

22.7.38 The low impact magnitude and low sensitivity of intertidal benthic invertebrates to the compaction of substratum indicate a minor adverse effect on this receptor. The effect is **not significant**.

ii. Beach landing facility

22.7.39 This section describes the impacts associated with the installation and operation of the beach landing facility (BLF) during the construction phase. Scoping identified the pressures arising from activities at the BLF with the potential for effects on ecological receptors, provided in **Appendix 22M** of this volume. Pressures with the potential to affect marine benthic ecology receptors are presented in **Table 22.39**.

Table 22.39: Pressures associated with beach landing facility activities during the construction phase that have the potential to affect marine benthic ecology receptors.

Pressure	Activities resulting in pressure.	Justification
Habitat change - Reprofiling of substratum.	Navigational dredging.	Plough dredging would reprofile the subtratum (removing and displacing surface layers) and has the potential to affect benthic ecology receptors through the direct disturbance of organisms.
Changes in suspended sediments.	Navigational dredging.	Increases in SSC have the potential to affect benthic ecology receptors by impeding feeding.
Sedimentation rate changes.	Navigational dredging.	Deposition of suspended sediments has the potential to affect benthic ecology receptors through smothering.

Pressure	Activities resulting in pressure.	Justification
Underwater noise and vibration.	Navigational dredging and impact piling.	Potential to affect benthic ecology receptors by causing physical damage or inducing behavioural or physiological changes
Changes in wave exposure.	Navigational dredging and presence of structure.	Potential to affect benthic ecology receptors by altering the frequency and magnitude of disturbance.
Physical change to another seabed type.	Presence of structure.	Potential to affect benthic ecology receptors through habitat change.
Spread of non-indigenous species.	Presence of structure.	Introduction of hard substrate in a primarily soft sediment environment has the potential to affect benthic ecology receptors by facilitating the spread of non-indigenous species.

22.7.40 Construction pressures scoped out of further assessment as they have been deemed to have negligible effects on benthic receptors include:

- Contaminant resuspension – sediment samples from across the Sizewell site were analysed for chemical contaminants including heavy metals, insecticides, organotin, organic and chlorinated compounds as well as radionuclides. Following these analyses, the sediments within the GSB are considered to be uncontaminated, provided in **Section 22.4** of this chapter, and the effects of resuspension of contaminants on benthic receptors is not considered further.

- Water flow changes – The presence of the BLF piles, the mooring of a barge at the BLF and the reprofiling of the seabed (a navigational channel dug to depths up to 2m) would result in changes to water flow (-0.6 to 0.4m/s compared to background levels) and current-induced bed shear stress (up to 1.6N/m^2 above background levels). The area where previously motionless sediments would experience transport would be very small (<0.5ha), this is provided in **Appendix 20A** of this volume. Moreover, the peak increase in shear stress associated with mooring of the barge – the activity predicted to have the largest influence on water flow – is more than 30 times smaller than that caused by waves from a 1:0.2-year storm event. It is deemed that such small-scale changes to hydrodynamics would have a negligible effect on benthic ecology receptors.

- Disturbance of surface sediments (scour) – Local hydrodynamic changes due to the presence of the BLF structure would lead to scouring of the seabed. Scouring would be restricted to an area of <0.1ha in total. Such small-scale scouring is assumed to have a negligible effect on benthic ecology receptors.

- Introduction ofINNS from ballast water – Vessels using the BLF during the construction phase will conform with the International Maritime Organisation (IMO) Ballast Water Management Convention (adopted in 2004). As such, effects on benthic ecology receptors arising from the introduction of INNS from ballast water are assumed to be negligible.

Habitat Change, reprofiling of substratum: navigational dredging

22.7.41 A navigational channel and grounding surface would be profiled within the shallow subtidal zone (<6m water depth) using a plough dredger. Plough dredging does not remove sediment but rather redistributes it locally (within the GSB sediment cell). This activity has the potential to directly affect benthic invertebrates through physical disturbance and displacement of organisms.

22.7.42 Capital dredging would occur over an area of 0.91ha, lasting for 2.1 days, and a maintenance dredge of similar scale would be repeated (i.e. preparatory dredging) once per year or following large infilling episodes during the construction phase (9-12 years), with sediments to a depth >0.5m redistributed in **Section 22.3.i)** of this chapter. Monthly maintenance dredging (ca. 10% of the capital dredge volume; **Section 22.3.i)** of this chapter is expected during the campaign period. Note that dredging would continue at a reduced frequency during the operation phase (one campaign every 5-10 years). Impact magnitude is assessed as low due to the very small spatial extent of the pressure.

Benthic invertebrate sensitivity to reprofiling of substratum

22.7.43 Benthic invertebrates are grouped for assessment according to their mobility – high-mobility (mobile) *vs*. low-mobility (sessile) – which is an important trait for determining the capacity of organisms to evade direct contact with the dredge and to recolonise a disturbed area post-dredging. There is evidence for the presence of a biogenic habitat, *Sabellaria spinulosa* reef, within the GSB (Ref. 22.121). However, *S. spinulosa* reef occurs on Coralline Crag formations, away from any proposed navigational dredging activities, and is therefore not considered to be a potential receptor of this pressure.

22.7.44 Mobile epifauna, including the brown crab *C. pagurus*, common lobster *H. gammarus*, brown shrimp *C. crangon* and pink shrimp *P. montagui*, have been observed near where navigational dredging would occur. Their high mobility provides them with some capacity to escape direct contact with the dredge; however, not all individuals would evade impact.

22.7.45 A study of brown crabs found that 60% struck by a scallop dredge sustained damage and over 40% died (Ref. 22.151). Berried (i.e. carrying eggs) female brown crabs, which are relatively immobile and spend most of their time buried in the sediment (Ref. 22.152), are likely to be particularly vulnerable. However, another study found similar densities of the brown crab in areas subjected and not subjected to scallop dredging (Ref. 22.153), suggesting that populations of this species will not be significantly reduced by dredging. Like the brown crab, the brown shrimp buries itself within the sediment to avoid predation (Ref. 22.154). Therefore, any brown shrimp that remain buried during dredging would come into direct contact with the dredge, while those that swim to escape are likely to be more vulnerable to predation. Brown shrimp that experience direct physical impact tend to suffer damage to their exoskeleton, which can make them more vulnerable to infection, although this does not seem to result in significant mortality (Ref. 22.155). Little information is available on the effects of dredging on the pink shrimp, but as it shares most of its traits with the brown shrimp it is assumed to be similarly resistant to dredging. As the common lobster is typically associated with hard habitats there is little information available regarding the direct impact of dredging on this species.

22.7.46 The brown crab, brown shrimp and pink shrimp are distributed throughout the GSB, whereas the common lobster was recorded sporadically in low abundances during surveys. Any aggregations of the common lobster would likely occur in areas of hard habitat, i.e. not within the footprint of navigational dredging. Therefore, only small proportions of the populations of these species are likely to be present within the dredged area, while their high mobility would allow some individuals within the dredged area to evade impact. Moreover, as the mobile species present are widely distributed within the GSB, adult individuals (including any within the dredged area that evade impact) would be able to quickly recolonise the dredged area upon cessation of this activity.

22.7.47 As a small proportion of any mobile benthic invertebrate population is likely to be directly exposed to navigational dredging and adult individuals would be able to quickly recolonise the affected area post-dredging, mobile benthic invertebrates are assessed as having low sensitivity to this pressure.

22.7.48 In contrast, most infaunal taxa have low mobility (i.e. are sessile) and are therefore more vulnerable to direct disturbance and mortality due to this pressure. Reductions in benthic invertebrate total abundance of up to 95% can be expected within the dredged area (Ref. 22.156). However, while substantial reductions of sessile benthic invertebrates are likely to occur in the area directly disturbed by dredging, the widespread distribution of the affected key taxa and broader benthic invertebrate community means that only a small proportion of any sessile species population is likely to be directly exposed to navigational dredging.

22.7.49 Most benthic invertebrates within the GSB, including key taxa, have pelagic eggs and pelagic (planktotrophic or lecithotrophic) larvae, and would therefore be able to rapidly recolonise through larval dispersal following the cessation of dredging (Ref. 22.157; 158). Organism lifespan was most commonly within the range of 3-10 years, which suggests that it might take several years for the adult populations of some species to fully recover within the dredged area following recruitment. Indeed, a recovery period of 2-5 years following aggregate dredging is typical for sandy sediments in UK waters (Ref. 22.159). The conservation species *G. insensibilis* has direct development, provided in **Appendix 22C** of this volume, so recolonisation is more likely to occur via adult migration. The species is free-living within 5cm above seabed so individuals from surrounding areas would be capable of drift in the dredged area. Given the very small spatial extent of the pressure, recolonisation of even low-mobility taxa could be facilitated by movement of free-living adults from outside the dredged area (Ref. 22.157; 160). Recolonisation, either by recruitment or adult migration, would also be aided by the wide distribution within the GSB of the key taxa and broader benthic invertebrate community present at the dredge site. However, due to the frequent navigational dredging events during the construction phase and barges intermittently resting on the seabed within the navigational channel, a full recovery of sessile benthic invertebrates could only occur during the operation phase (when disturbance by navigational dredging and vessel activity would continue but at a lower frequency of approximately every 5-10 years).

22.7.50 While only a small proportion of any sessile benthic invertebrate population would be exposed to navigational dredging, sensitivity to this pressure is assessed as medium as frequent dredging would prevent full community recovery during the construction phase.

22.7.51 Based on the low impact magnitude and low to medium sensitivity of subtidal benthic invertebrates, sediment reprofiling associated with navigational dredging for access to the BLF is predicted to have a minor adverse effect on this receptor. The effect is **not significant**.

Changes in suspended sediments: navigational dredging

22.7.52 Following the initial capital dredge, a plume with an instantaneous SSC of >100mg/l above daily maximum background levels is expected to form inshore over an area of up to 83ha as a depth averaged plume (108ha at the sea surface). A small area of up to 7ha would experience an instantaneous SSC plume of >1,000 mg/l above background levels. Monthly maintenance dredging would result in up to 28ha experiencing a depth averaged plume of >100mg/l (17ha at the sea surface) and 1ha experiencing >1,000 mg/l above background SSC on each occasion, provided in **Section 22.3.i)** of this chapter. Preparatory maintenance dredging followed by monthly maintenance dredging would be conducted once per year throughout the construction phase.

22.7.53 Ambient SSC at the site is highly variable, as in **Section 22.4** in this chapter, and the surface waters are considered to have '*intermediate turbidity'* according to WFD criteria, provided in **Appendix 21E** of this volume. Dredging would temporarily increase the classification to '*turbid'*. However, SSC would return to background levels several days after dredging activity ceases.

22.7.54 The amount of change, spatial extent and temporary nature of the plume results in an impact magnitude of medium.

Benthic invertebrate sensitivity to changes in suspended sediments

22.7.55 Organisms that filter their food from the water column are potentially vulnerable to changes in SSC. The focus of the assessment is therefore placed on benthic invertebrates that are suspension-feeders as adults (up to 20% of infaunal and epifaunal organisms within the GSB) and those that have planktonic larvae that feed in the water column ('planktotrophic' larvae; up to 90% of infaunal organisms and almost 100% of epifaunal organisms). Most benthic invertebrate taxa (including *G. insensibilis*) in the area predicted to be affected by changes in SSC are not suspension-feeders as adults and are therefore assumed to be not sensitive to increases in SSC during the adult life-stage.

22.7.56 By interfering with suspension-feeding (Ref. 22.49; 161; 162), suspended sediments can have detrimental physiological impacts on benthic invertebrates and influence species distributions (Ref. 22.163). However, suspension-feeders with high particle selection efficiency and pseudofaeces production can be tolerant of, or even respond positively to, increased concentrations of suspended fine sediments (Ref. 22.164). Three key taxa (the razor clam *Ensis* spp., blue mussel *M. edulis*, and Ross worm *S. spinulosa*) are obligate suspension feeders and could therefore be vulnerable to elevated SSC. However, this does not appear to be the case as these taxa are often found in areas of high turbidity (Ref. 22.165–168). It is therefore unlikely that populations of suspension-feeders would be adversely affected by elevated SSC associated with navigational dredging for the BLF. Moreover, if benthic invertebrates were to be adversely affected by elevated SSC, most species within the affected area (including the suspension-feeding key taxa) have traits that allow rapid recolonisation (i.e. pelagic eggs and larvae). This would facilitate population recovery following the construction phase, when navigational dredging events would be infrequent.

22.7.57 Given the unlikelihood of an adverse response to the pressure, adult suspension-feeding benthic invertebrates are assessed as being not sensitive to elevated SSC associated with navigational dredging for the BLF.

22.7.58 During pre-adult life stages, it is possible that elevated SSC could affect benthic invertebrates by reducing food availability for planktotrophic larvae. A possible consequence of this is an extended larval development period, during which time organisms are particularly vulnerable to predation (Ref. 22.169). On the other hand, increased turbidity could make planktonic eggs and larvae less conspicuous to predators and thus reduce predation pressure (Ref. 22.170; 171). Reduced light intensity caused by turbidity could also impair anti-predator larval behaviour, e.g. selectively settling in darker areas to mitigate predation during a sessile adult life-stage (Ref. 22.172). Most benthic invertebrates in the GSB have pelagic eggs and planktotrophic larvae and would therefore be vulnerable to any effects of elevated SSC. However, there is little evidence that elevated SSC adversely affects the eggs and larvae of benthic invertebrates, with the limited available evidence suggesting a possible adverse impact on bivalve larvae when the increase in SSC is substantial (500-1000mg/l +) and prolonged (10-12 days +) but a positive effect when the increase in SSC is moderate (100-500 mg/l) (Ref. 22.169). Juvenile *G. insensibilis* have a direct development in a marsupium and are not likely to be affected by increased SSC. Moreover, if planktotrophic larvae were adversely influenced by elevated SSC, their high natural mortality means that effects would likely be indiscernible from background levels.

22.7.59 There is no clear evidence that planktotrophic larvae would be adversely affected by elevated SSC associated with navigational dredging for the BLF and this receptor sub-group is deemed not sensitive.

22.7.60 As impact magnitude is medium and benthic invertebrates are not sensitive to this pressure, changes in SSC associated with navigational dredging for access to the BLF is predicted to have a minor adverse to minor beneficial effect on this receptor. The effect is **not significant**.

Sabellaria spinulosa *reef sensitivity to changes in suspended sediments*

22.7.61 *Sabellaria spinulosa* reefs are present on Coralline Crag outcrops in the GSB. *Sabellaria spinulosa* reefs are often found in areas of high turbidity, including the immediate vicinity of aggregate dredging sites where sediment plumes are common (Ref. 22.167). Therefore, any effects of elevated SSC on suspension-feeding by *S. spinulosa* do not appear to be a major factor limiting reef distribution. On the contrary, *S. spinulosa* relies on a supply of suspended solids to build tubes that form the reef structure, and tube erosion occurs when the supply is insufficient (Ref. 22.173). Models from the Severn Estuary suggest that the optimal SSC concentrations for a closely related species (*S. alveolata*) range from ~500 to 900mg/l during neap tides to ~850 to 1600mg/l during spring tides (Ref. 22.174). As inshore daily maximum background SSC is 609 mg/l at 0.3 m above the seabed (Ref. 22.175) and the instantaneous SSC plume is predicted to raise SSC by <100mg/l in the inshore area where *S. spinulosa* reef is known to be present, reef building by *S. spinulosa* is unlikely to be impeded, and may even be enhanced, by changes in SSC associated with navigational dredging for the BLF. The SSC plume does not overlap the offshore Coralline Crag outcrops where *S. spinulosa* reef has also been observed.

22.7.62 Given that *S. spinulosa* reef is unlikely to be adversely affected by elevated SSC associated with navigational dredging for the BLF (the effect may be positive), this habitat is assessed as not sensitive.

22.7.63 As impact magnitude is medium and *S. spinulosa* reef is not sensitive to this pressure, changes in SSC associated with navigational dredging for access to the BLF is predicted to have a minor beneficial effect on this receptor. The effect is **not significant**.

Sedimentation rate changes: navigational dredging

22.7.64 Sediment suspended by plough dredging and dispersed by ambient flows would subsequently be deposited onto the seabed. Sediment deposition due to plough dredging has the potential to affect benthic invertebrates by smothering.

22.7.65 Sedimentation is classified as 'light' over most of the plume footprint, with only a small inshore area of up to 3ha expected to experience sediment deposition of >50mm. A very small area (1ha) could experience over 300mm of deposition, while a larger area of 6ha is expected to experience >20mm of deposition. It is expected that all suspended sediment would be deposited within hours of dredging and then dispersed by natural resuspension, leaving just 3ha where sediment thickness remains >20mm after 15 days. The pressure would reoccur monthly due to the requirement for maintenance dredging; however, sediment deposition in this case is not expected to exceed 20mm, provided in **Section 22.3.i)** of this chapter. A large maintenance dredge by smaller monthly maintenance dredgingwould be conducted once per year throughout the construction phase.

22.7.66 Impact magnitude is assessed as low due to the small spatial footprint of sediment deposition at ecologically relevant depths and rapid dispersal of deposited sediments.

Benthic invertebrate sensitivity to sedimentation rate changes

22.7.67 Benthic invertebrates are grouped for assessment according to their mobility – high-mobility (mobile) *vs*. low-mobility (sessile) – which is an important trait for determining the ability of an organism to resurface and avoid smothering following sediment deposition.

22.7.68 Highly mobile benthic invertebrate species within the GSB (e.g. the brown crab, common lobster, brown shrimp and pink shrimp) are assumed to be able to resurface during sedimentation and/or migrate away from the affected area. Mortality as a result of smothering is therefore considered unlikely. Any individuals that migrate out of the affected area in response to siltation would be able to recolonise upon the cessation of dredging.

22.7.69 As mobile species are unlikely to experience mortality as a result of sedimentation and any individuals that migrate from the area would be able to return immediately post-dredging, mobile benthic invertebrates are assessed as being not sensitive to this pressure.

22.7.70 Smothering due to sediment deposition is more likely to affect benthic invertebrates with low mobility (Ref. 22.49; 176). This includes most of the taxa recorded in grab samples during the surveys of the GSB and half of the 'key taxa'. Organisms that live attached to the substratum are particularly vulnerable. One such species, the blue mussel *M. edulis*, is present within the area predicted to be affected by sediment deposition. There is evidence that this species is sensitive to heavy sedimentation events (Ref. 22.133) although it can resurface when deposition is around 30mm thick (Ref. 22.177; 178). The area with a sediment thickness >20mm would be up to 6ha one hour. Most *M. edulis* individuals encountered during baseline surveys were juveniles, and there is little evidence for adult populations of taxa that live attached to the substratum within the footprint of this pressure. The types of benthic invertebrates that are relatively sensitive to smothering therefore appear to be largely excluded from the affected area by environmental conditions unrelated to the proposed development.

22.7.71 At the community level, sediment deposition resulting from dredging and dredge disposal can reduce the number of benthic invertebrate species and individuals within the affected area (Ref. 22.178; 179). However, the effect of dredge disposal on such community metrics may be insignificant when occurring amid a background of natural ecological variability (Ref. 22.180). Such variability characterises spatiotemporal patterns observed in many benthic invertebrate populations within the GSB. Moreover, the key taxa and broader benthic invertebrate community that would be exposed to changes in sedimentation rates are widely distributed within the GSB and the wider region, provided in **Appendix 22C** of this volume. Therefore, only a small proportion of any benthic invertebrate population would be exposed to this pressure and, as such, its capacity to reduce population densities is limited.

22.7.72 If populations of any sessile/low mobility benthic invertebrates are affected by sedimentation associated with navigational dredging for the BLF, then recovery would be facilitated by most species having pelagic eggs and pelagic (planktotrophic or lecithotrophic) larvae, provided in **Appendix 22C** of this volume. This would allow species to quickly recolonise through larval dispersal following the cessation of dredging (Ref. 22.157; 158). Recolonisation would be aided by the widespread distribution within the GSB of the key taxa and broader benthic invertebrate community in the area predicted to be exposed to increased sedimentation rates due to navigational dredging. The conservation species *G. insensibilis* has a direct development, provided in **Appendix 22C** of this volume, so its recolonisation strategy is more likely to occur via adult migration. The species is free-living within 5cm above the seabed so individuals from surrounding areas will be capable of drifting in the dredged area. However, due to the frequent navigational dredging events during the construction phase, a full recovery of sessile benthic invertebrates could only occur during the operation phase (when disturbance by navigational dredging would continue but at a lower frequency of approximately every 5-10 years).

22.7.73 As only a small proportion of any benthic invertebrate population would be exposed to elevated sedimentation rates and the most sensitive taxa (e.g. *M. edulis*) show a degree of tolerance to this pressure, sessile/low mobility benthic invertebrates are assessed as having low sensitivity to increases in sedimentation.

22.7.74 As impact magnitude is low and the sensitivity of benthic invertebrates range from not sensitive to low sensitivity, sedimentation rate changes associated with navigational dredging for access to the BLF is predicted to have a minor adverse effect on this receptor. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to sedimentation rate changes

22.7.75 *Sabellaria spinulosa* reef associated with Coralline Crag outcrops in the GSB (Ref. 22.121) could potentially be affected by increases in sedimentation rates resulting from navigational dredging for the BLF. The reefs are formed by the tubes of this sessile, suspension-feeding polychaete. Heavy deposition that lasts for long periods leads to smothering and mortality of *S. spinulosa* (Ref. 22.181), while the reefs it forms may remain buried or are eroded once sediment is displaced. *Sabellaria spinulosa* can, however, survive deep burial for periods of days up to several weeks (Ref. 22.181), during which time tubes can continue to be built and may extend to the sediment surface when deposition is light or occurs gradually (Ref. 22.182). Given the ability of *S. spinulosa* to withstand heavier and more prolonged sedimentation than would be associated with navigational dredging for the BLF (<10mm of sedimentation is expected in the inshore area where Coralline Crag is known to be present), it is unlikely that reef habitat would be adversely affected by this pressure. The offshore area of Coralline Crag where *S. spinulosa* reef has been observed would not experience sediment deposition as a result of navigational dredging for the BLF. *Sabellaria spinulosa* reef is therefore deemed not sensitive to this pressure.

22.7.76 As impact magnitude is low and *S. spinulosa* reef is not sensitive to this pressure, sedimentation rate changes associated with navigational dredging for access to the BLF is predicted to have a negligible effect on this receptor. The effect is **not significant**.

Underwater noise and vibration: navigational dredging and impact piling

22.7.77 Navigational dredging and impact piling during BLF construction would introduce noise and vibration to the marine environment. This has the potential to affect benthic ecology receptors by causing physical damage or inducing behavioural or physiological changes.

22.7.78 Benthic invertebrates are expected to be sensitive to particle motion and sediment-borne vibration rather than sound pressure changes (Ref. 22.51). However, there is currently a lack of information and no guidelines on the levels of these stimuli that are likely to have detrimental effects on benthic invertebrates or other marine animals (Ref. 22.52). Therefore, published sound pressure thresholds for fish without a swim bladder that 'hear' by particle motion detection (Ref. 22.53) are used as a proxy to estimate the areas in which benthic invertebrates would be exposed to this pressure. The threshold for potential mortality or recoverable injury is 213dB peak with respect to instantaneous exposure (i.e. peak energy from a single emittance of sound), while the threshold with respect to continuous exposure (i.e. repeated sounds) is 219dB and 216dB SEL_{cum} for potential mortality and recoverable injury, respectively (**Table 22.71**). While there is insufficient information to assess impact magnitude based on particle motion and sediment-borne vibration, the few studies that have monitored behavioural and physiological responses of benthic invertebrates to these stimuli are considered in the sensitivity assessment.

22.7.79 Underwater noise modelling was used to calculate the areas in exceedance of these thresholds, provided in **Appendix 22L** of this volume. Impact magnitude is informed by whichever type of exposure has the most extensive area of threshold exceedance.

22.7.80 For navigational dredging, thresholds for potential mortality or recoverable injury would be exceeded only within 25m (<0.25ha) of the source in **Table 22.72**. This pressure would last for 2.1 days during initial capital dredging, with smaller maintenance dredge events (ca. 10% of the initial dredge volume) reoccurring monthly. Capital/preparatory maintenance and monthly maintenance dredging are expected each year during the construction phase (9-12 years), after which dredge campaigns are expected every 5-10 years for the lifetime of the Sizewell C Project.

22.7.81 For impact piling during BLF construction, two strike energy scenarios have been modelled for the installation of the 12 piles: 90kJ and a 200kJ. Up to 1,500 strikes per pile is assumed. Based on the worst of the two scenarios (200kJ), the threshold for potential mortality would be crossed within 40m (<1ha) of the source, while the threshold for recoverable injury would be crossed over 2ha in **Table 22.75**. Piles are expected to be installed consecutively (not concurrently), with up to five piles installed per day.

22.7.82 Impact magnitude is assessed as low for both navigational dredging and impact piling, reflecting the limited areas in exceedance of thresholds for mortality or injury and the short duration of the pressure. The particularly small extent of the pressure for navigational dredging is offset by the recurring nature of this activity. Confidence in this assessment is low due to the reliance on sound pressure thresholds for fish without a swim bladder that 'hear' by particle motion detection in lieu of particle motion or sediment-borne vibration thresholds for benthic invertebrates. However, the assessment is considered precautionary (see the following sensitivity assessment).

Benthic invertebrate sensitivity to underwater noise and vibration

22.7.83 Benthic invertebrates at all life stages would be exposed to noise and sediment-borne vibration associated with BLF construction. Effects of this pressure on organisms from the egg and larval stages through to the adult stage are therefore considered. Effects of *S. spinulosa* reef are not considered as this receptor does not occur within the immediate vicinity of the relevant activities, and the type of organism (a polychaete) that forms this habitat is not thought to be able to detect particle motion (Ref. 22.51).

22.7.84 Very little evidence is available on the sensitivity of benthic invertebrates to anthropogenic noise and vibration, and their ability to detect – and thus potentially respond to – acoustic stimuli is poorly understood (Ref. 22.51). It is, therefore, precautionarily assumed that mortality would occur in all benthic invertebrates (including *G. insensibilis*) within the area that exceeds the relevant threshold, i.e. <1ha for both navigational dredging and impact piling. If mortality was assumed even in areas where recoverable injuries are expected, the affected area would still cover <1ha for navigational dredging and just 2ha for impact piling. Given the small spatial scale of the pressure and wide distributions of receptor benthic invertebrate taxa within the GSB and southern North Sea, the capacity for population-level effects as a direct result of mortality is very limited.

22.7.85 Besides mortality, it is possible that the introduction of noise and sediment-borne vibration would induce behavioural alterations in benthic invertebrates (including *G. insensibilis*). Such effects appear most likely in crustaceans and molluscs, as evidence suggests that these taxa are able to detect particle motion (Ref. 22.51). Indeed, behavioural and physiological responses to vibrations within the frequency range experienced in the vicinity of operations such as pile driving have been reported for benthic invertebrate species present within the GSB, including the shrimp *C.* and the bivalves *L. balthica* and *M. edulis* (Ref. 22.183–187). Tank experiments indicate that effects of noise on metabolic rates, growth, feeding, anti-predator behaviour, bioturbation and larval settlement and metamorphosis are possible (Ref. 22.188–194). Behavioural alterations may occur within areas larger than those where mortality or injury are predicted. The potential population-level consequences of behavioural alterations are unclear, but as the ability of crustaceans to detect particle motion appears to be five orders of magnitude weaker than in fish (Ref. 22.51), any effects would likely be subtle.

22.7.86 As mortality would be restricted to a very small area, while the extent and consequences of potential behaviour alterations are unclear but likely to be small, benthic invertebrates are precautionarily assessed as having low sensitivity to noise associated with BLF activities.

22.7.87 The low impact magnitude and low sensitivity of benthic invertebrates to underwater noise and vibration indicate a minor adverse effect on this receptor. The effect is **not significant**.

Changes in wave exposure: navigational dredging and presence of structure

22.7.88 Dredging of a navigational channel in the shallow subtidal zone (<6m) for access to the BLF would occur over the outer longshore bar and create a planar grounding surface. The initial dredge profile requires the redistribution of 4,600 cubic metres (m^3) of sediment by plough dredging. This activity would alter the bathymetry and therefore affect local wave exposure, provided in **Appendix 20A** of this volume.

22.7.89 The area of seabed where the change in wave energy is predicted to increase or decrease by more than five percent due to dredging of a navigational channel corresponds to 2.25ha over a 400m frontage. The peak increase in wave energy is approximately 150%, although this is for a very small area of around 500m^2. The peak decrease in wave energy is 52%. The BLF is expected to be used for deliveries throughout the construction phase (9-12 years) and the navigational channel would be maintained throughout this period.

22.7.90 The mooring of barges at the BLF will influence wave exposure only when waves are very small, and the barge sits on the seabed, as provided in **Appendix 20A** of this volume. As the influence on hydrodynamics would be very small, this activity–pressure pathway is scoped out. The presence of the BLF structure would, however, influence local hydrodynamics and alter wave exposure at Sizewell beach. The relevant aspects of the structure are the four pile pairs (eight piles) landward of the low tide mark that would support the BLF deck and the two fenders and two mooring dolphin piles that would be below MHWS, as presented in **Appendix 20A** of this volume.

22.7.91 The area of seabed where the change in wave energy is predicted to increase or decrease by more than five percent due to the presence of the BLF structure corresponds to approximately 0.1ha over a 65m frontage in the intertidal zone. Most changes are predicted to occur at the north of the BLF structure due to the ebb tidal conditions and the south-easterly waves, as provided in **Appendix 20A** of this volume. The amount of change in wave energy due to the presence of the BLF structure would be small, with a maximum increase of 20% and a maximum decrease of 17%, each within a very small area. The BLF piles would be a permanent installation.

22.7.92 For both the dredging of a navigational channel and presence of the BLF structure, impact magnitude of changes in wave exposure is assessed as low, reflecting the very small spatial extent of the pressure.

Benthic invertebrate sensitivity to changes in wave exposure

22.7.93 Changes in wave exposure due to BLF activities could influence benthic invertebrate communities in the intertidal and shallow subtidal zones.

22.7.94 The intertidal benthic invertebrates inhabiting the beach at the GSB are characterised by a similar species composition along the shore, with local differences primarily due to variation in the abundance or biomass of taxa (Ref. 22.150). Sizewell beach can be broadly characterised as a moderate energy shore composed of a matrix of sand and gravel populated by patchy, low abundance and low biomass infaunal assemblages that are tolerant of the dynamic physical environment. The dynamic nature of the beach causes the proportions of surface sand to change with tides and weather events. Consequently, intertidal benthic invertebrate populations are expected to be variable over time, provided in **Appendix 22C** of this volume.

22.7.95 The influence of navigational dredging and the presence of the BLF structure on wave exposure and, in turn, surface sediment composition in the intertidal zone could induce local changes in abundance or biomass of benthic invertebrates. A study of structure-induced changes in wave exposure suggests that erosion and accretion may also lead to localised changes in benthic biodiversity (Ref. 22.195). Given the nature of the intertidal environment and biota in the GSB, it is likely that any changes to benthic invertebrate communities induced by wave exposure would be within the range of natural variability. Furthermore, the impacted area represents a very small proportion of the intertidal area within the GSB. Intertidal benthic invertebrates are therefore assessed as not sensitive to changes in wave exposure.

22.7.96 Benthic invertebrates in the shallow subtidal zone inhabit an area where surface sediments shift on regular basis, encouraging a high natural variability in population densities and a prevalence of *r*-selected taxa. A study of benthic invertebrates in the shallow subtidal zone in the GSB showed that local differences in assemblage structure were associated with exposure to offshore waves, with an increase in abundance and biomass observed in less exposed (deeper) areas, provided in **Appendix 22C** of this volume. As depth increases, wave-induced shear stress experienced at the seabed decreases. An increase in wave energy and shear stress is predicted in the shallow subtidal zone to the north and south sides of where navigational dredging would occur; however, these areas are very small and, therefore, only a very small proportion of any benthic invertebrate population would be exposed to this pressure, as provided in **Appendix 20A** of this volume. Subtidal benthic invertebrates (including *G. insensibilis*) are therefore assessed as not sensitive to the changes in wave exposure associated with BLF.

22.7.97 The low impact magnitude and insensitivity (not sensitive) of both intertidal and subtidal benthic invertebrates to changes in wave exposure indicate a negligible effect on this receptor. The effect is **not significant**.

Physical loss / change to another seabed type: presence of structure

22.7.98 The presence of BLF piles in the intertidal and shallow subtidal zones would result in a change in seabed type from soft sediment (gravel with sand veneer) to a hard surface. Benthic species with preferences for soft or hard substrates would therefore be affected by this change in seabed type.

22.7.99 Changing the seabed from soft sediment habitat to a hard surface constitutes a large amount of change based on the Marine Evidence-Based Sensitivity Assessment benchmark threshold for changes in EUNIS classification (one Folk class[30] for > ten years). The spatial extent of change in seabed type due to BLF piles is very small (<0.01ha) in relation to the area of the GSB (>4,000ha). This change in seabed type would last for the lifetime of the proposed development. The BLF piles would persist for a long duration but occupy a very small spatial extent. Impact magnitude is therefore assessed as low.

Benthic invertebrate sensitivity to physical loss of habitat

22.7.100 The transformation of the intertidal and shallow subtidal seabed from a soft to a hard habitat due to BLF installation would cause a loss of soft sediment

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[30] The Folk classification is a means of describing sediment composition based on grain sizes and the ratios of mud, sand and gravel.

biota in the affected area and a small decline in the total area of suitable habitat for these species within the GSB.

22.7.101 Intertidal benthic invertebrate communities are broadly similar throughout the GSB and not particularly diverse, reflecting the highly dynamic nature of the beaches which makes them a challenging environment for benthic biota (Ref. 22.150). Therefore, only a very small proportion of any intertidal benthic invertebrate population (and their supporting habitat) is likely to be adversely affected by BLF installation.

22.7.102 Within the area where the BLF piles are installed, recovery of soft sediment intertidal benthic invertebrate communities would not be possible as the seabed would be transformed to a hard habitat. Species that prefer hard surfaces and were previously absent or rare would, however, be able to colonise. The likelihood of this occurring is supported by the presence of the pelagic larvae of benthic encrusting organisms, such as barnacles (Cirripedia) and bryozoans, in zooplankton samples collected from the GSB, as provided in **Appendix 22B** of this volume.

22.7.103 Given that only a small proportion of any intertidal benthic invertebrate population and associated habitat would likely be adversely affected by the presence of the BLF structure sensitivity is assessed as low.

22.7.104 As in the intertidal zone, the transformation of the shallow subtidal seabed from a soft to a hard habitat due to the presence of the BLF piles would cause a loss of soft sediment biota in the affected area and a small decline in the total area of suitable habitat for these species within the GSB. The key benthic invertebrate taxa and broader community type (i.e. community cluster) that would be affected by the installation of the BLF are widely distributed within the GSB and the wider region. Therefore, only a very small proportion of any subtidal benthic invertebrate population (and their supporting habitat) is likely to be adversely affected by the presence of the BLF. *Gammarus insensibilis* can be found across most of the Northern part of the GSB at low density, provided in **Appendix 22C** of this volume. Few individuals may be disturbed by the installation of the BLF but again, only a small proportion of the population would be adversely affected. Community recovery would not be possible in the small area affected by permanent habitat change, but colonisation by encrusting organisms is possible.

22.7.105 The low impact magnitude and low sensitivity of both intertidal and shallow subtidal benthic invertebrates to the pressure indicate a minor adverse effect on this receptor. The effect is **not significant**.

Spread of non-indigenous species: presence of structure

22.7.106 BLF piles located within the marine environment would introduce hard substrata to an area consisting primarily of soft sediments, which could facilitate the spread of benthic INNS that prefer hard habitats and have detrimental effects on indigenous species.

22.7.107 The area of new three-dimensional surface (piles) available to INNS would be <0.01ha in both the subtidal and intertidal zones, which is less than the Marine Evidence-Based Sensitivity Assessment pressure benchmark for colonisation (1ha) (Ref. 22.11). These surfaces would be available for colonisation for the lifetime of the proposed development. While BLF piles could facilitate the spread of INNS for a long duration, the very small spatial scale of the structure results in an impact magnitude of very low.

Benthic invertebrate sensitivity to the spread of non-indigenous species

22.7.108 The introduction of hard substrata to a soft sediment environment is typically followed by rapid colonisation by fouling organisms. If the introduced habitat is atypical of the area, then this could allow INNS that would otherwise be unable to colonise to become established. Indeed, artificial structures are known to be more susceptible to colonisation and biotic invasion by fouling organisms than natural habitats (Ref. 22.196–198). Once a NIS has colonised an artificial structure, the population can then act as a steppingstone for further geographical spread (Ref. 22.199; 200).

22.7.109 Benthic invertebrate INNS can exert a range of effects on marine ecosystems, of which the most common is the displacement of indigenous species (Ref. 22.201). Only one subtidal INNS was recorded in the GSB during the Sizewell C benthic baseline surveys, the American jacknife *E. leei* (previously *E. directus*), which was found in a single grab sample, provided in **Appendix 22C** of this volume. This species has been present on East Anglian coasts since 1990 (Ref. 22.202). As *E. leei* lives in soft sediments, the addition of new artificial hard substrate would not influence its distribution within the GSB or the southern North Sea. There remains a risk, however, that the new hard substrata will allow the colonisation of fouling INNS not currently established within the area, as planktonic larvae from distant populations settle onto the structures (Ref. 22.203), which could then spread into other areas of the GSB and the wider region.

22.7.110 Natural hard substrata are present in subtidal areas of the GSB in the form of 420ha of Coralline Crag outcrops (where *S. spinulosa* reefs are present), while coarse sediment is intermittently distributed among finer sediments (Ref. 22.204). Various fouling organisms inhabit these natural hard substrates, with 53 taxa found in the grab samples classified as organisms that 'live attached to the substratum' in the biological traits assessment, as provided in **Appendix 22C** of this volume. These include taxa that are recognised as early colonisers of artificial structures made of concrete or steel, such as the blue mussel *M. edulis* and barnacles (Ref. 22.203; 205). None are INNS. It is likely that such taxa would colonise new infrastructure in the GSB shortly after colonisation, thus limiting the availability of habitat for INNS not currently in the area.

22.7.111 Subtidal benthic invertebrates are precautionarily assessed as having low sensitivity to this pressure. This reflects the composition of the subtidal fouling community in the GSB and the limited effects of documented INNS expansion on indigenous communities in the North Sea. This assessment also accounts for the possibility that the physical structure will facilitate the spread of INNS in the region.

22.7.112 Intertidal areas appear to be more susceptible to colonisation by INNS than subtidal areas (Ref. 22.200; 206). Hard intertidal habitats with no natural counterparts may be particularly susceptible, as there may be no indigenous fouling community to colonise the substrata (Ref. 22.200). This applies to the GSB, where the intertidal zone is predominantly soft sediment and there are no natural hard habitats.

22.7.113 While artificial hard substrates in the intertidal zone may be particularly susceptible to INNS colonisation, the tendency for INNS colonisation to expand the species pool rather than displace indigenous species in the North Sea is again worth noting (Ref. 22.207). Moreover, the absence of natural hard substrates in the intertidal zone of the GSB means that there is very limited capacity for the introduction of artificial hard substrates to affect the broader intertidal benthic ecology in the area. However, the possibility of the physical structure acting as a steppingstone for further geographical spread is again noted. Intertidal benthic invertebrates are deemed to have low sensitivity to this pressure.

22.7.114 As impact magnitude is very low and both subtidal and intertidal benthic invertebrates have low sensitivity to this pressure, the spread of INNS due to the presence of the BLF piles is predicted to have a negligible effect on benthic receptors during the construction phase. The effect is **not significant**.

iii. Combined drainage outfall

22.7.115 This section describes the impacts associated with the installation and operation of the combined drainage outfall (CDO) during the construction phase. Scoping identified the pressures arising from activities at the CDO with the potential for effects on ecological receptors, provided in **Appendix 22M** of this volume. Pressures with the potential to affect marine benthic ecology receptors are presented in **Table 22.40.**

Table 22.40: Pressures associated with CDO activities during the construction phase that have the potential to affect benthic ecology receptors.

Pressure	Activities resulting in pressure.	Justification
Removal of substratum (extraction).	Dredging.	Potential to affect benthic ecology receptors through the direct disturbance of organisms.
Changes in suspended sediments.	Dredging and disposal.	Increases in SSC have the potential to affect benthic ecology receptors by impeding feeding.
Sedimentation rate changes.	Dredging and disposal.	Deposition of suspended sediments has the potential to affect benthic ecology receptors through smothering.
Physical change to another seabed type.	Presence of structure.	Potential to affect benthic ecology receptors through habitat change.
Spread of INNS.	Presence of structure.	Introduction of hard substrate to a primarily soft sediment environment has the potential to affect benthic ecology receptors by facilitating the spread of INNS.
Pollution and other chemical changes.	Construction discharges of un-ionised ammonia and heavy metals.	Potential to affect benthic ecology receptors through toxicological stress.
Synthetic compound contamination.	Construction discharges of tunnelling chemicals.	Tunnel boring machine (TBM) chemicals may be used during drilling of the cooling water intakes and outfall tunnels. Drilling wastewater containing small volumes of drilling chemical leachate would be discharged via the CDO. The potential toxicological effects are assessed
Synthetic compound contamination.	Commissioning discharges of hydrazine.	Commissioning discharges of hydrazine during cold-flush testing would be discharged through the CDO. The potential toxicological effects are assessed

22.7.116 Construction pressures scoped out of further assessment as they have been deemed to have negligible effects on benthic receptors include:

- Contaminant resuspension – The sediments within the GSB are considered to be uncontaminated and the effects of resuspension of contaminants on benthic receptors is not considered further, as provided in **Section 22.4** of this chapter.

- Nutrient enrichment – The small quantities of nitrate and phosphate that may be discharged into the GSB via the CDO during the construction phase are expected to influence annual gross primary production by orders of magnitude below the natural variation in chlorophyll *a* biomass, provided in **Section 22.6.b)** in this chapter. Such small-scale changes to primary production would have negligible indirect effects on benthic ecology receptors.

- Underwater noise and vibration – Thresholds for mortality or recoverable injury (using fish without a swim bladder that 'hear' by particle motion detection as a proxy for benthic invertebrates) are not crossed due to dredging activities associated with CDO installation. Effects on benthic ecology receptors are therefore considered negligible.

- Introduction of Invasive Non-Native Species – Vessels involved in CDO construction will operate in accordance with IMO regulations. As such, effects on benthic ecology receptors arising from the introduction of INNS in ballast water are assumed to be negligible.

Removal of substratum (extraction): dredging

22.7.117 Prior to installation of the CDO head and scour protection, surficial soft sediment in the shallow subtidal zone (<6m) would be removed by dredging via a cutter suction dredger and returned to the marine environment at a local disposal site presumed to be within the GSB. This activity has the potential to directly affect benthic invertebrates through physical disturbance and displacement of organisms.

22.7.118 An area of approximately 0.13ha of surficial sediment would be dredged and dredging is expected to occur once and take less than 24 hours, provided in **Section 22.3.i)** of this chapter.

22.7.119 Following dredging, installation of infrastructure would replace the existing habitat over a small area (see Physical loss / change to another seabed type: presence of structure) and soft-sediment would be back-filled.

22.7.120 Impact magnitude is assessed as very low based on the limited spatial extent of dredging relative to the extent of the affected habitat (subtidal sand) in the GSB.

Benthic invertebrate sensitivity to removal of substratum (extraction)

22.7.121 The benthic invertebrate taxa potentially affected by the removal of substratum associated with dredging for CDO installation are the same as those potentially affected by the reprofiling of substratum associated with navigational dredging for access to the BLF, provided in **Section 22.7.c** of this chapter.

22.7.122 The assessment of benthic invertebrate sensitivity was conducted using the same approach applied to navigational dredging and both high-mobility (mobile) and low-mobility (sessile) benthic invertebrates (including *G. insensibilis*) were deemed to have low sensitivity to this pressure. The reduced sensitivity of sessile benthic invertebrates compared to that for navigational dredging (medium) reflects the smaller extent of exposure (0.13ha *vs*. 0.91ha); provided in **Section 22.3.i)** in this chapter and the expected recovery of populations within the majority (84%) of the dredge footprint following CDO head installation (whereas maintenance dredging during the construction phase would prevent full recovery of benthic invertebrate populations within the navigational channel).

22.7.123 Based on the very low impact magnitude and low sensitivity of benthic invertebrates to this pressure, sediment extraction associated with dredging for CDO installation is predicted to have a negligible effect on this receptor. The effect is **not significant**.

Changes in suspended sediments: dredging and disposal

22.7.124 Dredging and dredge disposal will cause the formation of a plume with elevated suspended sediment concentration (SSC). Changes in SSC have the potential to affect benthic invertebrates by interfering with feeding.

22.7.125 Plumes with instantaneous SSC of >100mg/l above daily maximum background levels are expected to form inshore over an instantaneous depth averaged area of up to 28ha (89ha at the sea surface). A small area of 1ha is expected to experience an instantaneous SSC of >1,000mg/l above background at the sea surface, provided in **Section 22.3.i)** of this chapter.

22.7.126 Ambient conditions at the site are highly variable, provided in **Section 22.4** of this chapter and the surface waters are considered to have '*intermediate turbidity*' according to WFD criteria, provided in **Appendix 21E** of this volume. Dredging would temporarily increase the classification to '*turbid*'. However, SSC would return to background levels several days after dredging activity ceases. The increase in SSC would occur once for the installation of the CDO head.

22.7.127 Increases in SSC would be relatively large relative to baseline conditions; however, the plume is highly transient and its intermediate spatial footprint result in an impact magnitude of medium.

Benthic invertebrate sensitivity to changes in suspended sediments

22.7.128 The benthic invertebrate taxa potentially affected by changes in SSC associated with dredging and dredge disposal for CDO installation are largely the same as those potentially affected by changes in SSC due to navigational dredging for access to the BLF, provided in **Section 22.7.c** of this chapter. As such, the assessment of subtidal benthic invertebrate sensitivity was conducted using the same approach as applied to navigational dredging and produced the same result, with suspension-feeding benthic invertebrates and benthic invertebrates with planktotrophic larvae (larvae that feed in the water column) both determined to be not sensitive to increases in SSC. Benthic invertebrates that do not feed on suspended matter (including *G. insensibilis*) are assumed to be not sensitive to changes in SSC.

22.7.129 As impact magnitude is medium and benthic invertebrates are not sensitive to this pressure, changes in suspended sediments resulting from dredging and dredge disposal for CDO installation are predicted to have a minor adverse to minor beneficial effect on this receptor. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to changes in suspended sediments

22.7.130 The sensitivity of *S. spinulosa* reef to changes in SSC associated with dredging and dredge disposal for CDO installation is the same as the sensitivity of this receptor to changes in SSC due to navigational dredging for access to the BLF. As such, *S. spinulosa* reef is determined to be *Not Sensitive* to this pressure. A short-term increase in tube growth is possible for *S. spinulosa* on the inshore Coralline Crag outcrops.

22.7.131 As impact magnitude is medium and *S. spinulosa* reef is not sensitive to this pressure, changes in suspended sediments resulting from dredging and dredge disposal for CDO installation are predicted to have a minor beneficial effect on this receptor. The effect is **not significant**.

Sedimentation rate changes: dredging and disposal

22.7.132 Sediment suspended by dredging and dredge disposal for the installation of the CDO would subsequently be deposited onto the seabed. Sediment deposition has the potential to affect benthic invertebrates by smothering.

22.7.133 Sediment deposition would be classified as 'light' throughout the plume footprint, with sediment thickness not expected to exceed 50mm and only expected to exceed 20mm over 1ha. It is predicted that all suspended sediment would be deposited within hours of dredging and then dispersed by natural resuspension, leaving no area where sediment thickness remains >20mm thicker than it was prior to dredging after 15 days, provided in

Section 22.3.i) of this chapter. These levels of sediment deposition would occur once for the installation of the CDO head.

22.7.134 As no area would be exposed to greater 'light' deposition and deposited sediments would be rapidly dispersed, impact magnitude is assessed as very low.

Benthic invertebrate sensitivity to sedimentation rate changes

22.7.135 The benthic invertebrate taxa that would be affected by sedimentation associated with dredging and dredge disposal for CDO installation are the same as those potentially affected by sedimentation associated with navigational dredging for access to the BLF, provided in **Section 22.7.c** of this chapter. As such, the assessment of subtidal benthic invertebrate sensitivity was conducted using the same approach applied to navigational dredging and produced the same result, with mobile benthic invertebrates determined to be not sensitive and sessile/low mobility benthic invertebrates (including *G. insensibilis*) determined to have low sensitivity.

22.7.136 As impact magnitude is very low and that the sensitivity of benthic invertebrates ranges from not sensitive to low, sedimentation rate changes associated with dredging and dredge disposal for CDO installation are predicted to have a negligible effect on this receptor. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to sedimentation rate changes

22.7.137 The sensitivity of *S. spinulosa* reef to sedimentation due to dredging and dredge disposal associated with CDO installation is the same as the sensitivity of this receptor to sedimentation caused by navigational dredging for access to the BLF in **Section 22.7.c** of this chapter. As such, *S. spinulosa* reef is determined to be not sensitive to this pressure.

22.7.138 As impact magnitude is very low and *S. spinulosa* reef is not sensitive to this pressure, sedimentation rate changes associated with dredging and dredge disposal for CDO installation are predicted to have a negligible effect on this receptor. The effect is **not significant**.

Physical loss / change to another seabed type: presence of structure

22.7.139 The installation of the CDO head and scour protection would result in a change in seabed type from soft sediment (fine to medium sand) to a hard surface. Benthic species with preferences for soft or hard substrates would therefore be affected by this change in seabed type.

22.7.140 Changing the seabed from a soft sediment habitat to a hard surface constitutes a large amount of change based on the Marine Evidence-Based

Sensitivity Assessment benchmark threshold for changes in EUNIS classification (one Folk class for > ten years). The spatial extent of habitat change is very small (<0.1ha) in relation to the area of the GSB (>4,000ha). This change to seabed type would last for the lifetime of the proposed development. The very small spatial extent but long duration of the pressure constitutes a low impact magnitude.

Benthic invertebrate sensitivity to physical loss of habitat

22.7.141 The transformation of the seabed from a soft habitat to a hard habitat would reduce the total area of suitable habitat for subtidal soft sediment invertebrates within the GSB. The benthic invertebrates inhabiting the area (including *G. insensibilis*) where the CDO outfall head would be installed would have been largely removed by dredging prior to installation. Therefore, it is unlikely that any additional effect could occur as a result of CDO installation.

22.7.142 While the area within the footprint of CDO outfall head would no longer be able to support soft sediment invertebrates following installation, species that prefer hard surfaces and were previously absent or rare would be able to colonise. The likelihood of this occurring is supported by the presence of the pelagic larvae of benthic encrusting organisms, such as barnacles (Cirripedia) and bryozoans, in zooplankton samples collected from the GSB, provided by **Appendix 22B** in this volume.

22.7.143 As benthic invertebrate taxa within the footprint of the CDO head would have already been lost due to other activities, this receptor is deemed to be not sensitive to this pressure.

22.7.144 As impact magnitude is low and benthic invertebrates are not sensitive to this pressure, a negligible effect of physical change to another seabed type is predicted. The effect is **not significant**.

Spread of non-indigenous species: presence of structure

22.7.145 The introduction of hard substrata to an area consisting primarily of soft sediments could facilitate the spread of INNS that prefer hard habitats and have detrimental effects on indigenous species.

22.7.146 The area of new three-dimensional surface available to INNS due to the presence of the CDO head would be <0.1ha, which is less than the Marine Evidence-Based Sensitivity Assessment pressure benchmark for colonisation (1ha) (Ref. 22.11). This surface would be available for colonisation for the lifetime of the Sizewell C Project. While the pressure has a long duration, the very small spatial scale of the structure results in an impact magnitude of very low.

Benthic invertebrate sensitivity to the spread of non-indigenous species

22.7.147 The sensitivity of benthic invertebrates to the spread of INNS due to the presence of the CDO head would be the same as the sensitivity of this receptor to the presence of BLF piles in the subtidal zone, provided in **Section 22.7.c** of this chapter. As such, benthic invertebrates have low sensitivity to this pressure.

22.7.148 As impact magnitude is very low and benthic invertebrates have low sensitivity to this pressure, the spread of INNS due to the presence of the CDO head is predicted to have a negligible effect on this receptor during the construction phase. The effect is **not significant**.

Construction discharges of un-ionised ammonia

22.7.149 Ammonia is a commonly occurring pollutant that enters waterbodies from diffuse and point sources including sewage effluents, industrial and agricultural activities and decomposition of organic matter. Ammonia exists in the toxic un-ionised phase (NH_3) and as ionised ammonium (NH_4^+). The relative proportion of each form depends on the temperature, salinity and pH of the water. Higher temperatures and pH favour ammonia, whilst higher salinity favours ammonium (Ref. 22.21). Treated sewage discharges from the CDO have the potential to exert toxicological effects on plankton receptors should ammonia levels exceed EQS values of 21µg/l.

22.7.150 The highest routine sewage discharges are anticipated during Case D (**Plate 22.1**) and a worst-case un-ionised ammonia discharge would occur in the unlikely event of a sewage only discharge. In this situation dilution modelling predicts exceedance of EQS concentrations up to 6.3m from the point of discharge. EQS exceedance is within 4m of the discharge for all other construction scenarios, provided in **Appendix 21E** of this volume.

22.7.151 The magnitude of impact is assessed as low as discharges could occur throughout the construction phase.

Benthic invertebrate sensitivity to un-ionised ammonia

22.7.152 Un-ionised ammonia is more toxic to aquatic life than the ionised form as it can most readily gain entry to aquatic organisms, predominantly via the gills in invertebrates such as crustaceans (Ref. 22.55; 208).

22.7.153 Mortality would not be predicted to occur due to rapid mixing of discharges of ammonia from the CDO. Moreover, the very small spatial extent of the footprint exceeding the EQS and the wide distributions of benthic invertebrate species within the GSB mean that a very small fraction of any population would be exposed to un-ionised ammonia concentrations above the EQS.

Benthic invertebrates are, therefore, assessed as not sensitive to this pressure.

22.7.154 As impact magnitude is low and benthic invertebrates are not sensitive to this pressure, un-ionised ammonia discharges from the CDO are predicted to have a negligible effect on this receptor. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to un-ionised ammonia

22.7.155 The *S. spinulosa* reefs within the GSB are not present within the footprint of this pressure. This receptor would therefore not be directly exposed to ammonia discharges. It is possible that the pelagic eggs and larvae of *S. spinulosa* would be exposed to elevated un-ionised ammonia concentrations. However, the very limited footprint of the pressure and its distance from *S. spinulosa* reefs mean that a very small proportion of the species' eggs and larvae would be exposed to this pressure. Such a low level of exposure is not expected to inhibit reef formation or development via reduced recruitment. *Sabellaria spinulosa* reef is therefore assessed as being not sensitive to this pressure.

22.7.156 As impact magnitude is low and *S. spinulosa* reef is not sensitive to this pressure, un-ionised ammonia discharges from the CDO are predicted to have a negligible effect on *S. spinulosa* reef. The effect is **not significant**.

Construction discharges of heavy metals

22.7.157 During construction of the main development site, groundwater discharges would be made via the CDO. Exploratory boreholes across the main development site quantified the concentrations of dissolved metals within the groundwater. The worst-case construction discharges for trace metals would be during the 28-day dewatering of the cut-off wall around the main construction site, provided in Case A: **Plate 22.1**. The dewatering phase would result in an estimated 300,000m^3 of groundwater being discharged at a rate of 124l/s. After the initial dewatering phase nominal discharges of 15l/s would continue throughout the construction phase to remove rainwater and seepage through the cut-off wall, provided in **Appendix 21E**.

22.7.158 In the dewatering phase two groundwater metals, zinc and chromium failed initial EQS screening and a General Estaurine Transport Model exercise was undertaken to determine the mixing rates and spatial extent of the impacts.

22.7.159 The mean background concentration of zinc in the environment is 15.12µg/l whilst the EQS is 6.8µg/l as an annual average. Since the background levels are in exceedance of the EQS, zinc discharges could not be assessed under standard procedures. Modelling predicted the point at which zinc concentrations would be indiscernible from background based on analytical detection limits of 0.4µg/l. Therefore, the threshold value for zinc was set at

15.52µg/l. Thus, the amount of change relative to baseline is approximately 2.5%. Modelling demonstrated that zinc concentrations would only be discernible above background over a mean sea surface area of 0.11ha. At the seabed, zinc concentrations are not predicted to exceed background concentrations.

22.7.160 Chromium has a mean EQS concentration of 0.6 µg/l and a 95th percentile EQS concentration of 32µg/l. Chromium background concentrations of 0.4-0.57µg/l are reported for the site. As a precautionary measure the higher background concentration was applied to give a mean EQS threshold of 0.03µg/l. A sea surface area of 5.49ha exceeded the mean EQS, at the seabed chromium did not exceed EQS concentrations. The 95th percentile EQS concentration (32µg/l) was not exceeded, provided in **Appendix 21E** of this volume.

22.7.161 The initial dewatering drawdown phase is a short-term activity (28 days). Areas impacted extend over a very limited spatial area and the amount of change is small relative to the baseline conditions. The impact magnitude is assessed as very low.

Benthic invertebrate sensitivity to heavy metals

22.7.162 Exposure to moderate concentrations of heavy metals can produce a variety of non-lethal effects on an organism, such as morphological changes, growth inhibition, behaviour changes or alterations to reproduction (Ref. 22.209). Chromium and zinc are naturally present in seawater and are essential metals to life; however, they can become toxic at elevated concentrations. Levels of essential trace metals in organisms can be regulated to some degree through uptake (e.g. via passive absorption or via food) and clearance (e.g. via excretion) mechanisms. Benthic invertebrates show large variation in their responses to heavy metal contamination, with some organisms capable of regulation and maintaining constant body concentrations via various uptake and clearance mechanisms, while others tend to accumulate heavy metals within their bodies depending on seawater concentrations (Ref. 22.210). The accumulation of metals in body tissues can, however, occur even in animals capable of regulation, resulting in acute or chronic detrimental effects (Ref. 22.210; 211).

22.7.163 The highly restricted spatial extent of the heavy metal plumes above EQS concentrations indicated that a very limited proportion of even the most sensitive taxa would be exposed. Benthic invertebrates are, therefore, assessed as being not sensitive to this pressure.

22.7.164 As impact magnitude is very low and benthic invertebrates are not sensitive to this pressure, heavy metal contamination due to construction discharges from the CDO is predicted to have a negligible effect on this receptor. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to heavy metals

22.7.165 The *S. spinulosa* reefs within the GSB are not present within the footprint of this pressure. This receptor would therefore not be directly exposed to elevated concentrations of heavy metals. It is, however, possible that the pelagic eggs and larvae of *S. spinulosa* would be exposed to elevated heavy metal concentrations which could have toxicological effects. The limited footprint of the pressure and its distance from *S. spinulosa* reefs mean that a very small proportion of the species' eggs and larvae would be exposed to this pressure. Such a low level of exposure is not expected to inhibit reef formation or development via reduced recruitment. *Sabellaria spinulosa* reef is therefore assessed as being not sensitive to this pressure.

22.7.166 As impact magnitude is very low and *S. spinulosa* reef is not sensitive to this pressure, heavy metal contamination due to construction discharges from the CDO is predicted to have a negligible effect on this receptor. The effect is **not significant**.

Tunnelling chemical discharges

22.7.167 Based on current understanding of the underlying geology a TBM slurry method with bentonite is the most likely scenario for tunnelling. Spoil from the cutting face would be transported to a temporary stockpile for onward management. Groundwater would be generated from digging the galleries allowing access to the tunnels and tunnelling itself. During the transport and processing of spoil material, groundwater and potentially residual TBM chemicals would be produced in wastewater that would be transported landward, treated as required and discharged from the CDO.

22.7.168 Bentonite is a clay mineral regularly used in construction and offshore drilling operations. A bentonite recovery system would be utilised; however, bentonite is assessed due to the potential to increase the SSC in the receiving waters. Bentonite is included on the OSPAR list of substances that pose little or no risk to the enviornment. Modelling accounted for a tunnelling wastewater discharge rate of 34.4l/s and a discharge of 8.8mg/l bentonite. The predicted concentration of bentonite in suspension would be orders of magnitude lower than baseline SSC, provided in **Section 22.4** of this chapter, with 95^{th} percentile concentrations of 10µg/l restricted to sea surface areas of <11ha and mean concentrations of 10µg/l less than 1.5ha, provided in **Appendix 21E** of this volume. In the tidally dominated environment characterised by high resuspension rates, the potential for sedimentation of fine materials to cause ecological effects during normal tunnelling processes is negligible. No further assessment is made.

22.7.169 To envelope alternative tunnelling methods, assessments considered the use of indicative ground conditioning TBM chemicals. Representative chemicals from those applied for Hinkley Point C assessments are used to envelope potential tunnelling options at this stage. These include the anti-clogging agent BASF Rheosoil 143 and the soil conditioning additive CLB F5 M, provided in **Chapter 21** of this volume. The potential worst-case tunnelling scenario would occur when two cooling water tunnels are being excavated simultaneously, provided in Case E; **Plate 22.1**.

22.7.170 Modelling predicted that the mean sea surface area in exceedance of the BASF Rheosoil 143 PNEC was restricted to 1ha (95th percentile 5.8ha). The seabed is never exposed to concentrations above the PNEC, provided in **Table 22.20**. The sea surface area exposed to CLB F5 M in exceedance of the PNEC was restricted to 3.1ha as a mean concentration (95th percentile 25ha). The seabed is never exposed to concentrations above the PNEC, provided in **Appendix 21E** of this volume. Tunnelling is predicted to last up to several years and, therefore, exposure to these concentrations could occur for this duration.

22.7.171 As the seabed would not be exposed to concentrations above the PNEC and the areas exceeding PNECs at the sea surface are small, impact magnitude for benthic receptors is assessed as very low.

Benthic invertebrate sensitivity to tunnelling chemicals

22.7.172 As surfactant PNECs are predicted to be exceeded only in surface waters and not at the seabed, the assessment of benthic invertebrate sensitivity to tunnelling chemical discharges focused on planktonic egg and larval stages but not the adult stage. A study of the effects of surfactants used in CLB F5 M – alkyl ethoxylate sulphate (AES) and alkyl sulphate (AS) – reported reductions in fertilised egg development and larvae survival at concentrations of 0.5mg/l and 1.0mg/l, respectively, in the marine bivalves *Mercenaria mercenaria* and *Crassostrea virginica* (Ref. 22.212). While these species are not present within the GSB, this study provides some indication of surfactant concentrations at which toxicological effects on eggs and larvae may occur. No additional studies of the effects on invertebrate eggs or larvae of relevant active substances were highlighted in a recent review of the fate and toxicity of surfactants in the marine environment (Ref. 22.213). However, acute and chronic toxicity of surfactants to marine invertebrates ranged from 0.1 to 1,000mg/l, with acute effects occurring at concentrations >10mg/l on average (Ref. 22.213). Biodegradation of AS and AES is rapid (Ref. 22.58) and the concentrations predicted in the GSB due to discharges from the CDO are generally lower than those known to cause detrimental ecological effects. Moreover, the small footprint of the pressure combined with the wide distribution of benthic invertebrate species within the GSB and southern North Sea indicate that a very small proportion of any population is likely to be exposed to elevated surfactant concentrations. *Gammarus insensibilis* reproduces with direct development of juveniles in a marsupium therefore the species will not be affected by tunnelling chemicals.

22.7.173 As exposure to tunnelling chemicals would be minimal and restricted to planktonic eggs and larvae, and because available evidence suggests that predicted concentrations are unlikely to cause toxicological effects, benthic invertebrates are assessed as being not sensitive to this pressure.

22.7.174 The very low impact magnitude and insensitivity of benthic invertebrates to tunnelling chemical discharges indicate a negligible effect of this pressure. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to tunnelling chemicals

22.7.175 As *Sabellaria spinulosa* has pelagic eggs and larvae, it is possible that surfactants in surface waters could have toxicological effects on this species during its early life stages, which could affect recruitment onto reefs. In the absence of evidence regarding the toxicity of relevant surfactants to *S. spinulosa*, it is assumed that this species is similarly insensitive to concentrations expected within the GSB as other benthic invertebrates. Moreover, *S. spinulosa* reefs within the GSB are located away from the CDO and, therefore, only a small proportion of its eggs and larvae are likely to be exposed to elevated concentrations of surfactants. *Sabellaria spinulosa* reef is therefore assessed as being not sensitive to this pressure.

22.7.176 The very low impact magnitude and insensitivity of *S. spinulosa* reef to tunnelling chemical discharges indicate a negligible effect of this pressure. The effect is **not significant**.

Commissioning discharges of hydrazine

22.7.177 During cold flush testing a number of chemicals would be released that required further investigation for potential water quality issues, provided in **Section 22.5** of this chapter. Of these, hydrazine used to prevent corrosion of the reactor units, failed the initial screening and is considered in more detail. Based on the Rochdale envelope approach, modelling took the precautionary position of both reactors being commissioned simultaneously with hydrazine discharged into the receiving waters via the CDO. The worst-case discharge scenario is assessed. Background concentration for hydrazine for modelling purposes was assumed to be zero.

22.7.178 There is no established EQS for hydrazine. The marine chlorophyte *Dunaliella tertiolecta* has been shown to have the lowest acute toxicity to hydrazine with a six-day EC_{50} for growth inhibition of 0.4µg/l (Ref. 22.59). These results form the basis for precautionary PNEC thresholds, provided in **Appendix 21E** of this volume. A chronic PNEC of 0.4 ng/l has been calculated for long term discharges (calculated as the mean of the concentration values) and an acute PNEC of 4 ng/l for short term discharges (represented by the 95th percentile). These thresholds are considered as precautionary triggers for further ecological investigation.

22.7.179 Assessments used in support of Canadian Federal Water Quality Guidelines for hydrazine indicate concentrations below 0.2µg/l (200ng/l) have a low probability of adverse effects for marine life. In the freshwater environment, where more data is available, a threshold of 2.6µg/l has been applied (Ref. 22.60). **Table 22.41** shows the areas of exceedance for different hydrazine release scenarios.

22.7.180 Commissioning is likely to last several years; however simultaneous discharges of hydrazine are considered unlikely and the assessment is precautionary.

22.7.181 The impact magnitude is assessed as medium.

Table 22.41: Areas of PNEC exceedance for different hydrazine discharge scenarios during commissioning (grey boxes are N/A).

Hydrazine release strategy	Threshold	Area of exceedance (ha)			
		95th percentile seabed	95th percentile surface	Mean seabed	Mean surface
83.3l/s discharge rate at 15µg/l.	Chronic, 0.4ng/l (mean)			2.92	30.5
	Acute, 4ng/l (95th percentile)	2.92	12.9		
	200ng/l	0.34 (100th percentile: 18.5 ha)	0		

Benthic invertebrate sensitivity to hydrazine

22.7.182 The assessment was focused both on adult benthic invertebrates, whose exposure to hydrazine would occur only at the seabed, and the pelagic eggs and larvae of benthic invertebrates, which would be exposed to hydrazine in the water column. Few ecotoxicology studies are available on the sensitivity of benthic invertebrates to hydrazine, with studies on species found within the GSB particularly scarce. Therefore, all available evidence pertaining to benthic invertebrates was utilised.

22.7.183 Regarding the early life-stages of benthic invertebrates, tests on bivalve (oyster) larvae demonstrated toxicity at concentrations of in the region of 6µg/l of hydrazine for exposure periods up to 48h (Ref. 22.62). The most sensitive crustacean species (a freshwater amphipod) had a 48h LC_{50} of 40µg/l hydrazine (Ref. 22.62). Another study found that elevated hydrazine concentrations (in 24- and 48-hour tests) did not increase mortality of larvae of the polychaete *Lanice conchilega*, which is found locally in high abundances in the GSB (Ref. 22.61). This species appeared to have low sensitivity up to concentrations of 1500µg/l. Tests on the Pacific oyster (*C. gigas*) found that concentrations of 10–1,000µg/l resulted in 55–65% normal embryo development, compared to 70% in controls (Ref. 22.214). This study indicates that while oyster larvae are susceptible to hydrazine exposure, the threshold for toxicity is in the range of concentrations that would only be reached at the point of discharge. It is possible that the eggs or larvae of benthic invertebrate species in the GSB would exhibit greater sensitivity. However, their wide distributions and high fecundity suggest that, irrespective of toxicity to exposed organisms, any population-level effects would likely be minimal. As such, planktonic eggs and larvae are assessed as having a low sensitivity to this pressure.

22.7.184 Adult invertebrates are expected to be less sensitive than earlier life stages. Chronic exposure of adult benthic invertebrates to mean hydrazine concentrations of 0.4µg/l would occur over seabed areas of <3ha. Such concentrations are orders of magnitude lower than observed effect thresholds (Ref. 22.62). Moreover, the wide distributions of benthic invertebrates within the GSB (including *G. insensibilis*) mean that a very small proportion of any adult population would be exposed to concentrations above the PNEC. As no mortality is expected and exposure of adult benthic invertebrates to hydrazine would be minimal, this sub-receptor is assessed as not sensitive.

22.7.185 As impact magnitude is medium and sensitivity of benthic invertebrate ranges from not sensitive to low, commissioning discharges of hydrazine are predicted to have a minor adverse effect on this receptor. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to hydrazine

22.7.186 The instantaneous hydrazine concentration at the inshore Coralline Crag habitat was modelled to determine the potential for exposure of *S. spinulosa* to commissioning hydrazine discharges. The peak concentration of hydrazine at the seabed during a month-long simulation was estimated to be 0.05ng/l, well below both the chronic and acute PNEC. At the surface, a maximum concentration of 0.5ng/l, above the chronic PNEC, was recorded for a period of 15 minutes during the model simulation (Ref. 22.65).

22.7.187 The *Sabellaria spinulosa* reefs within the GSB are not present within the footprint of the hydrazine discharge therefore it would not be directly exposed to hydrazine concentrations above PNECs. It is possible that the pelagic eggs and larvae of *S. spinulosa* would be exposed to elevated hydrazine concentrations, which could affect recruitment onto reefs. However, surface concentrations of hydrazine never exceed the acute PNEC in the vicinity of the inshore Coralline Crag habitat. There are no studies of the effects of hydrazine on *S. spinulosa* eggs or larvae. Studies on the larvae of another polychaete present within the GSB, *Lanice conchilega*, suggest very limited sensitivity (Ref. 22.214). Irrespective of possible toxicological effects a small proportion of planktonic eggs and larvae would be exposed to hydrazine at ecologically relevant concnetrations. Sensitivity is assessed as low as a highly precautionary measure.

22.7.188 As impact magnitude is medium and *S. spinulosa* reef has low sensitivity to this pressure, commissioning discharges of hydrazine are predicted to have a minor adverse effect on this receptor. The effect is **not significant**.

Coastal habitats sensitivity to hydrazine

22.7.189 The Minsmere sluice controls the sea water that can flow into various drainage channels including those used to periodically supply a saline input to the Minsmere salt marshes. Should hydrazine concentrations at ecologically relevant concentrations occur at times when the sluice is open, there is the potential it could effect the designated habitats associated with the RSPB Minsmere reserve within the Minsmere to Walberswick Special Area of Protection (SPA) and Ramsar site (**Table 22.1**). At Sizewell the tide floods in a southerly direction. The proposed development, and CDO, is south of the Minsmere sluice and discharges are only transported northward on an ebb tide, when water levels are falling. Modelling results show that at the position of the Minsmere Sluice, the chronic and acute PNEC concentrations at the surface and seabed are never exceeded. The monthly discharge simulation indicated maximum instantaneous hydrazine concentrations of 0.12ng/l at the location of the Minsmere Sluice. No effects are predicted on the coastal habitats at Minsmere due to commissioning releases of hydrazine (Ref. 22.65). As described in **Section 22.7.b)** of this chapter, the saline lagoon habitats received saline inputs through slow percolation through the dune system (rather than overtopping). The rapid degradation rates of hydrazine and low initial concentrations indicate negligible ecological effects due to the proposed development.

iv. Cooling water system

22.7.190 This section describes the impacts associated with the installation and operation of the cooling water system (CWS) intakes and outfalls during the construction phase. Scoping identified the pressures arising from activities at the CWS with the potential for effects on ecological receptors, provided in **Appendix 22M** of this volume. Pressures with the potential to affect marine benthic ecology receptors are presented in **Table 22.42.**

Table 22.42: Pressures associated with CWS activities during the construction phase that have the potential to affect benthic ecology receptors.

Pressure	Activities resulting in pressure	Justification
Removal of substratum (extraction).	Dredging	Potential to affect benthic ecology receptors through the direct disturbance of organisms.
Abrasion / physical disturbance.	Construction platform operations.	The use of jack-up barges and the anchoring of vessels have the potential to affect benthic ecology receptors through the direct disturbance of organisms.
Changes in suspended sediments.	Dredging and disposal.	Increases in SSC have the potential to affect benthic ecology receptors by impeding feeding.
Sedimentation rate changes.	Dredging and disposal.	Deposition of suspended sediments has the potential to affect benthic ecology receptors through smothering.
Sedimentation rate change (spoil pile formation).	Drilling	Sedimentation of fine materials associated with drill arisings would result in negligible sedimentation (fractions of a millimetre) over the GSB. Spoil piles consisting of relatively coarse particles (>1mm) would form within close proximity to the drill site, see **Appendix 22J** of this volume. In soft sediment environmentas spoil heaps would form within the footprint of the dredged area and would represent minimal effects. However, spoil heaps are considered further in relation to potentially sensitive benthic receptors.
Underwater noise and vibration.	Dredging	Potential to affect benthic ecology receptors by causing physical damage or inducing behavioural or physiological changes
Physical change to another seabed type.	Presence of Structure.	Physical change to another seabed type has the potential to affect benthic ecology receptors through habitat change.
Spread of INNS.	Presence of structure.	Introduction of hard substrate to a primarily soft sediment environment has the potential to affect benthic ecology receptors by facilitating the spread of INNS.

22.7.191 Construction pressures scoped out of further assessment as they have been determined to have negligible effects on benthic receptors include:

- Contaminant resuspension - The sediments within the GSB are considered to be uncontaminated and the effects of resuspension of contaminants on benthic receptors is not considered further, provided in **Section 22.4** of this chapter. Sediment monitoring requirements prior to dredge activities are outlined in **Section 22.3.i)** of this chapter.

- Increases in SSC and sedimentation from drilling - The increase in SSC associated with the drilling sediment plume (<10mg/l) would not be detectable above background levels. Potential effects of the plume on benthic ecology receptors would therefore be negligible and are scoped out.

- Increases in underwater noise and vibration associated with drilling the vertical connection shafts for the cooling water infrastructure were predicted to be highly localised, as provided in **Appendix 22L** of this volume and represent a negligible effect for benthic receptors. No further assessment is made.

- Introduction of invasive non-indigenous species – Vessels involved in CWS construction will operate in accordance with International Maritime Organisation (IMO) regulations. As such, effects on benthic ecology receptors arising from the introduction of INNS in ballast water are assumed to be negligible.

Assessment approach for *Sabellaria spinulosa* reefs at the southern intake location (Unit 1)

22.7.192 Physical pressures directly and indirectly associated with the installation of the cooling water intakes represent the primary impact pathway for *S. spinulosa* reefs at the Coralline Crag. Two low-velocity side-entry (LVSE) headworks would be installed at the offshore Coralline Crag and would represent permanent loss of some reef/habitat. The maximum dimensions of the LVSE headworks encompassing all design options is 50 x 10m including hydrodynamic nose cones designed to minimise the abstraction risk zone and thereby reduce fish impingement (Ref. 22.24). Within the hard substratum environment of the Coralline Crag, nominal scour protection at the base plate is anticipated.

22.7.193 During the installation of offshore wind turbines, common practice is to microsite installations to avoid *S. spinulosa* reefs allowing a minimum of a 50m buffer from construction impacts. However, the complexity and extent of the interconnected Sizewell C cooling water infrastructure dictates that the only micrositing that is now possible is the choice between the three potential intake locations for the two intake locations (the intake heads and tunnels must be seismically qualified and the location of each component requires extensive deep core sampling to determine geotechnical suitability of the sites and in the case of the tunnels, the route to the station).

22.7.194 The approach for determining effects of installation of the cooling water intakes during the construction phase is to consider a 50m buffer zone surrounding the intake headworks as an ‘impact area’. This is a precautionary assessment as pressures would be localised. However, it enables a coherent framework for considering in-combination pressures associated with construction activities within a defined area. Scoping for construction pressures is provided in **Table 22.36**.

22.7.195 Three potential positions have been identified for the installation of the two headworks in **Plate 22.5**. A Rochdale envelope approach considers the individual headwork locations and the different combined options.

22.7.196 Assessments consider the proportion of viable *S. spinulosa* habitat (exposed Coralline Crag) and existing reef impacted relative to the current extent. The area of impacted reef and viable habitat within the 50m buffer zone is presented in **Table 22.43**. The eastern intake location is associated with the greatest overlap with existing *S. spinulosa* reef formations, provided **Plate 22.5.**

Plate 22.5: Locations of Unit 1 cooling water intake headworks options (two to be installed) at the offshore Coralline Crag. Headworks and a 50m construction buffer zone are shown relative to the predicted extent of *S. spinulosa* reef formations (Ref. 22.122)**.**

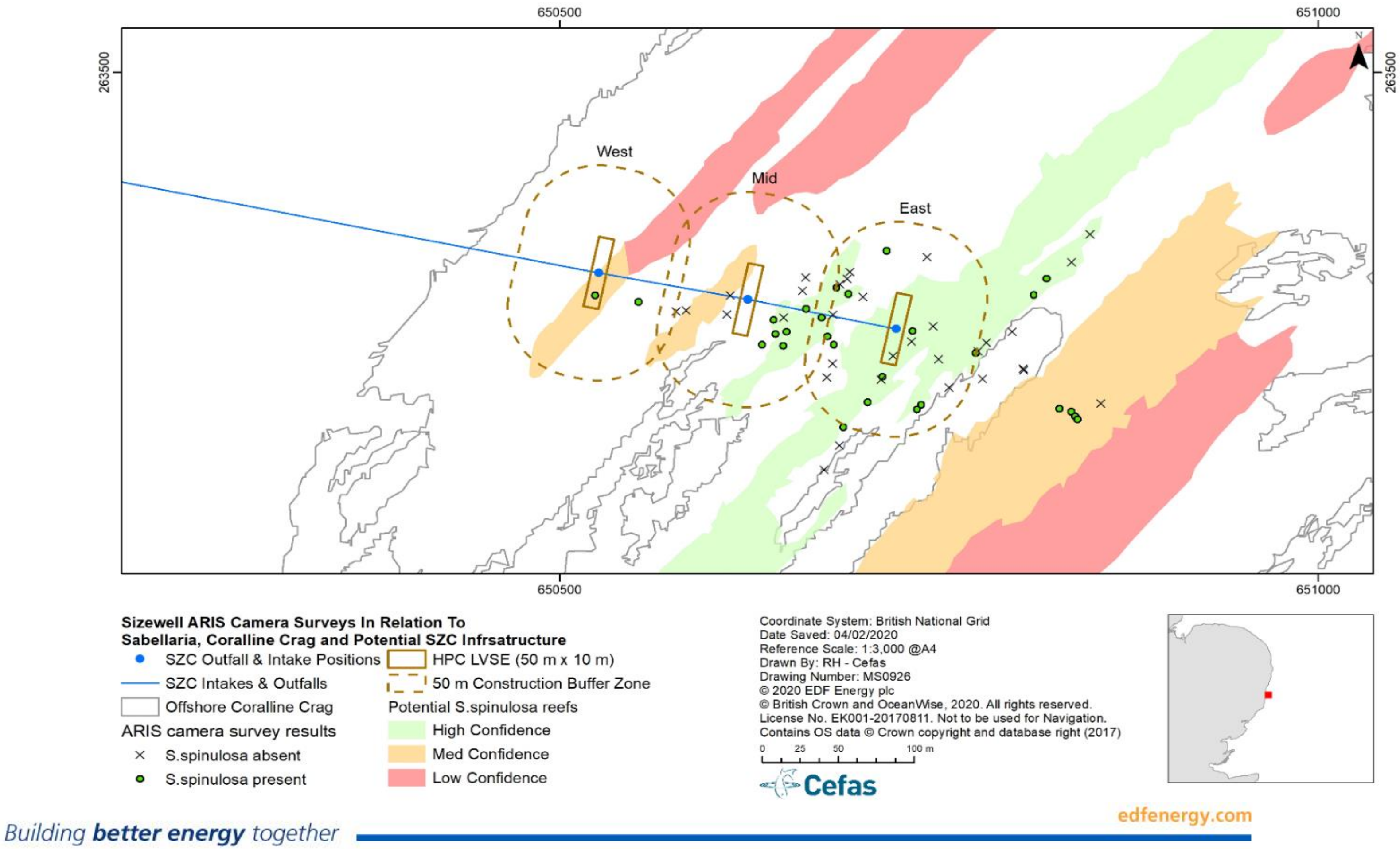

Table 22.43: Area[31] and percentage of *Sabellaria spinulosa* reef (18.5ha) and available habitat (57.5ha) within the 50m construction buffer zones of Unit 1 intake headworks on the offshore Coralline Crag. The surface area for combined intake headworks accounts for the buffer area overlap (see Plate 22.5).

Individual intake headwork and 50m buffer	West	Mid	East
Reef: area (ha) and % of offshore *S. spinulosa* reef	0.31ha 1.7%	0.41ha 2.2%	0.74ha 4.0%
Habitat: area (ha) and % of offshore Coralline Crag	1.43ha 2.5%	1.41ha 2.5%	1.37ha 2.4%
Combined intake headworks and 50m buffer	**West & Mid**	**Mid & East**	**West & East**
Reef: area (ha) and % of offshore *S. spinulosa* reef	0.70ha 3.8%	1.10ha 5.9%	1.05ha 5.7%
Habitat: area (ha) and % of offshore Coralline Crag	2.76ha 4.8%	2.70ha 4.7%	2.81ha 4.9%

22.7.197 The worst-case scenario would result in a total area of impacted habitat of 2.8ha, representing approximately 5% of the 57.5ha offshore Coralline Crag. Across the GSB the impact area represents less than 1% of the total exposed Coralline Crag (423ha) habitat.

22.7.198 It should be noted that the Coralline Crag is a dynamic environment affected by both migration of adjacent sandwaves and processes of sediment removal and deposition (Ref. 22.120; 204). Furthermore, *S. spinulosa* is an ephemeral species. *Sabellaria spinulosa* formations are often broken up during Winter storms and reforming via settlement the following Spring (Ref. 22.130–132). Therefore, the current extent of the habitat and reef would be expected to change through time. Furthermore, reef extents are based on predictive methods and should be considered indicative (Ref. 22.122).

Removal of substratum (extraction): dredging

22.7.199 Prior to the installation of cooling water infrastructure dredging and/or ground preparation would be required. Extraction activities have the potential to directly affect benthic invertebrates through physical disturbance and displacement of organisms.

[31] It should be noted that traditional light-based imaging systems are not available for habitat classification in the high turbidity waters off Sizewell. Acoustic imaging video footage (ARIS camera) coupled with geophysical surveys (side-scan sonar and multibeam echosounder) were used although a degree of expert judgement is required (Ref. 22.122).

22.7.200 The proposed location of the two northern CWS intakes (Unit 2) and two outfalls is within soft sediment environments offshore of the Sizewell-Dunwich Bank. The southern intakes, associated with Unit 1, would be positioned on exposed Coralline Crag deposits, with no or minimal overlying sediment. Prior to installation of the CWS intake and outfall headworks, surficial soft sediment would be removed by dredging using a cutter suction dredger and returned to the marine environment at a local disposal site proposed to be within the GSB, see **Appendix 22K** of this volume. Precautionary assessments of dredge areas and volumes for plume modelling assumed overlying sediments of approximately 6m deep at the locations of all headworks. The estimated total surface area of soft sediment impacted would be <3ha, as presented in **Table 22.10**. However, this assessment is considered precautionary as it assumes all areas are within soft sediment habitats of 6m depth. Geological interpretation of the overlying sediment indicates sediment thicknesses vary between tens of centimetres to more than two metres in the area of the northern intakes and outfalls and is minimal at the location of the southern intakes.

22.7.201 Following dredging, installation of infrastructure would replace the existing habitat over a small area (see Physical loss / change to another seabed type: presence of structure) and soft-sediment would be back-filled.

22.7.202 The impact magnitude for soft sediment habitat is assessed as low based on the limited spatial extent of dredging relative to the extent of the affected habitat (subtidal sand) in the GSB.

22.7.203 In the location of the exposed Coralline Crag, at the southern intakes, ground preparations are anticipated over a smaller spatial area than dredging in soft sediment environment. However, to encompass the full suite of environmental impacts on the Coralline Crag habitat during the construction phase a 50m buffer area has been emplaced surrounding the headworks (**Plate 22.5**).

22.7.204 This buffer area incorporates all ground preparation and extraction activities. The worst-case scenario for impacts on the habitat would be the scenario whereby the west and east headwork locations are selected with a total area of impacted habitat of 2.8ha. In such a case a total of less than 5% of the offshore Coralline Crag habitat would be potentially impacted. Across the GSB the impact represents less than 1% of the total exposed Coralline Crag (423ha).

22.7.205 Construction activities for the installation of the intakes would result in pressures for a medium duration.

22.7.206 Impact magnitude for the Coralline Crag hard sediment habitat is assessed as low based on the limited spatial extent of the impact relative to the extent of the affected hard sediment habitat (Coralline Crag) in the GSB.

Benthic invertebrate sensitivity to removal of substratum (extraction)

22.7.207 The benthic invertebrate taxa potentially affected by the removal of soft sediment substratum and abrasion associated with dredging and ground preparation for CWS installation are largely the same as those potentially affected by the removal of substratum associated with navigational dredging for access to the BLF, provided in **Section 22.7.c** of this chapter. The main difference is that lagoon sand shrimp *G. insensibilis* has not been observed in the area where CWS intake and outfall heads would be installed. Therefore, this species of conservation importance is not expected to be affected by this pressure.

22.7.208 The sensitivity assessment for benthic invertebrates was conducted using the same approach as applied to navigational dredging and produced the same result, with mobile benthic invertebrates deemed to have low sensitivity and sessile benthic invertebrates deemed to have medium sensitivity (*S. spinulosa* is considered in more detail in the following assessment). These sensitivities primarily reflect the small proportion of any benthic invertebrate population that would be exposed to the pressure. In contrast to dredging for the BLF, recovery of the benthic community would not be interrupted by maintenance dredging but would be possible only outside the footprint of the CWS intake and outfall heads. Recovery of mobile epifauna would likely occur through adult migration immediately after the cessation of this activity, while sessile benthic invertebrates, whose recovery relies on recruitment of individuals transitioning from a pelagic larval life-stage to and adult benthic life-stage, may take several years to fully recover.

22.7.209 Based on the low impact magnitude and low to medium sensitivity of benthic invertebrates, sediment extraction associated with the installation of cooling water infrastructure is predicted to have a minor adverse effect on benthic invertebrates. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to removal of substratum (extraction)

22.7.210 *Sabellaria spinulosa* reefs at the offshore Coralline Crag would be exposed to extraction and ground preparation activities associated with the installation of the cooling water intakes for Unit 1. Assessments consider the precautionary stance that construction activities, including substrate extraction and ground preparation, would cause impacts within the 50m buffer zone surrounding the intake headworks. Impacts on both the existing reef and viable Coralline Crag habitat are considered.

22.7.211 The area of impacted reef and viable habitat within the 50m buffer zone is presented in **Table 22.43**. The worst-case extent of existing reef within the 50m buffer potentially exposed to construction pressures is 1.1ha (eastern and mid locations) and equates to less than 6% of the reef area at the offshore Coralline Crag (approximately 18.5ha). The best-case position of the intakes, based on current reef extent, results in exposure of 0.7ha (western and mid locations), less than 4% of the of the reef area at the offshore Coralline Crag.

22.7.212 The sessile *S. spinulosa* would be intolerant to substratum extraction or ground preparation works and the areas directly impacted would suffer mortality. However, a small proportion of the existing reef or viable habitat would be exposed within the precautionary 50m buffer area, presented in **Table 22.43**. *Sabellaria spinulosa* reefs are both spatially patchy and temporally dynamic with natural cycles of development and degradation (Ref. 22.133; 167; 215). Providing reefs have sufficient larval supply, rapid recolonisation processes can occur, for example *S. spinulosa* formations settled and grew back within 18 months following marine aggregate dredging at the Hasting Shingle Bank License Area (Ref. 22.216). Evidence suggests the GSB reefs are supported by an important larval supply as major *S. spinulosa* reef populations are present in the Suffolk coastal area (Ref. 22.127). *Sabellaria spinulosa* larvae are reported during plankton surveys in the waters off Sizewell, including at abundances of approximately 2,500 ind.m^3 in July at the sampling station near the Sizewell C cooling water infrastructure (Ref. 22.25). As extraction and ground preparations would result in temporary pressures, recovery of lost reef material within the 50m buffer zone would be predicted to occur within years of the pressure ceasing. As a small proportion of the *S. spinulosa* reef would be lost by substratum extraction, and due to the high recolonization capacity of *S. spinulosa* populations in the GSB, the sensitivity to this pressure is assessed as low.

22.7.213 As impact magnitude is low and *S. spinulosa* reef sensitivity to this pressure is low, sediment extraction associated with substratum extraction for the southern CWS intake headworks is predicted to have a minor adverse effect on this receptor. While the effect is minor, the high conservation value of this receptor must be considered when determining its significance. In such an instance the factors described in **Table 22.38** are considered. A small proportion of the *S. spinulosa* reef or viable habitat would be exposed to construction pressures within the precautionary buffer area. The low elevation reefs at the offshore Coralline Crag would be anticipated to recover following temporary works within the wider buffer area. No significant effects on the distribution or functioning of the reef are predicted.

22.7.214 Monitoring of the *S. spinulosa* reef extent on the offshore Coralline Crag is recommended during both pre- and post-construction of cooling water infrastructure (22.12c).

Abrasion / physical disturbance: construction platform operations

22.7.215 Activities associated with construction platform operations (e.g. the use of jack-up barges and anchoring) have the potential to cause highly localised surface and sub-surface abrasion. For the outfalls and northern intakes, which are located in soft sediment environments, impacts would occur within areas where biota would have already been removed by dredging. Effects on benthic ecology receptors would therefore be negligible in these cases and are scoped out.

22.7.216 For the southern intakes, positioned on hard Coralline Crag deposits, ground preparations for the installation of infrastructure are expected to occur over a smaller area. As such, the use of jack-up barges and anchoring may disturb previously undisturbed sediment and affect benthic ecology receptors. The impact of these activities is encompassed within the 50m buffer zone used to assess the construction impacts associated with the installation of the southern intakes. This resulted in an impact of low magnitude and a minor adverse effect on benthic invertebrates and *S. spinulosa* reef. This effect represents the combined impact of sediment extraction and construction platform operations. No significant effects on the distribution or functioning of the reef are predicted.

Changes in suspended sediments: dredging and disposal

22.7.217 Dredging and local dredge disposal for the installation CWS intake and outfall headworks would lead to elevated suspended sediment concentrations (SSC). Changes in SSC have the potential to affect benthic invertebrates by interfering with feeding.

22.7.218 Plumes with instantaneous SSC of >100mg/l above daily maximum background levels are expected to form over an instantaneous depth averaged area of up to 373ha (291ha at the sea surface), provided in **Section 22.3.i)** of this chapter**.** A smaller area of up to 14ha is expected to experience a depth averaged instantaneous SSC of >1,000mg/l above background levels (34ha at the sea surface), provided in **Section 22.3.i)** of this chapter.

22.7.219 Ambient conditions at the site are highly variable,**Section 22.4** of this chapter, and the surface waters are considered to have *'intermediate turbidity'* according to WFD criteria, provided in **Appendix 21E** of this volume. Dredging would temporarily increase the classification to *'turbid'*. However, SSC would return to background levels several days after dredging activity ceases. The increase in SSC would occur a total of six times for the installation of CWS infrastructure (once for each intake and outfall head). The timings of the SSC plumes associated with the installation of each head would not overlap.

22.7.220 While increases in SSC would be relatively large relative to baseline conditions and occur multiple times, the transient nature of the plumes and their intermediate spatial footprint result in an impact magnitude of medium.

Benthic invertebrate sensitivity to changes in suspended sediments

22.7.221 The benthic invertebrate taxa potentially affected by changes in SSC associated with dredging and dredge disposal for CWS installation are largely the same as those potentially affected by changes in SSC due to navigational dredging for access to the BLF, provided in **Section 22.7.c** of this chapter.

22.7.222 The assessment of benthic invertebrate sensitivity was conducted using the same approach as applied to navigational dredging and produced the same result, with suspension-feeding benthic invertebrates and benthic invertebrates with planktotrophic larvae (larvae that feed in the water column) both determined to be not sensitive to increases in SSC. Benthic invertebrates that do not feed on suspended matter are assumed to be not sensitive to changes in SSC. *Gammarus insensibilis* was present in low abundance in the north of the GSB in the shallows in front of the Sizewell station complex. No individuals were found near the CWS location, so the species is considered as not sensitive to the pressure.

22.7.223 As impact magnitude is medium and benthic invertebrates are not sensitive to this pressure, changes in suspended sediments resulting from dredging and dredge disposal for CWS installation are predicted to have a minor adverse to minor beneficial effect on this receptor. The effect is **not significant.**

Sabellaria spinulosa reef sensitivity to changes in suspended sediments

22.7.224 In contrast to dredging for the other components of the proposed development, the SSC plume from dredging for the installation of CWS infrastructure could intersect *S. spinulosa* reef on offshore, not inshore, Coralline Crag outcrops. Maximum background SSC is >2,000mg/l at the offshore outcrops, compared to 609mg/l in inshore areas, and the instantaneous SSC plume is predicted to raise SSC by <100mg/l. Therefore, the increase in SSC due to dredging for the installation of CWS infrastructure would be comparatively small in relation to background variability. Nevertheless, the sensitivity of *S. spinulosa* reef to changes in SSC associated with dredging and dredge disposal for CWS installation is precautionarily considered the same as the sensitivity of this receptor to changes in SSC due to navigational dredging for access to the BLF, provided in **Section 22.7.c** of this chapter. Short-term increase in tube growth is possible for *S. spinulosa* on the offshore Coralline Crag outcrops as increased suspended sediment could be making certain particle sizes more readily available as source of building material (Ref. 22.173). As such, *S. spinulosa* reef is determined to be not sensitive to this pressure.

22.7.225 As impact magnitude is medium and *S. spinulosa* reef is not sensitive to this pressure, changes in suspended sediments resulting from dredging and dredge disposal for CWS intake and outfall installation are predicted to have a minor beneficial effect on this receptor. The effect is **not significant**.

Sedimentation rate changes: dredging and disposal

22.7.226 Sediment suspended by dredging and dredge disposal for the installation of the CWS intake and outfall headworks would subsequently be deposited onto the seabed. Sediment deposition has the potential to affect benthic invertebrates by smothering.

22.7.227 Sediment deposition would be classified as ‘light’ over most of the plume footprint, with just 7ha expected to experience sediment deposition in exceedance of 50mm per headwork dredge event. Larger areas of 106ha for CWS intakes and 40ha for CWS outfalls are expected to experience sediment deposition of >20mm, while up to 2ha may experience >300mm of deposition per head.

22.7.228 Modelling predicts that all suspended sediment would be deposited within hours of dredging and then dispersed by natural resuspension and deposition, leaving no area where sediment thickness of >20mm thicker than it was prior to dredging after 15 days, provided in **Section 22.3.i)** of this chapter. These levels of sediment deposition would occur six times for the installation of CWS infrastructure (once for each intake and outfall head).

22.7.229 As a limited area would be exposed to greater than ‘light’ deposition and deposited sediments would be rapidly dispersed, the impact magnitude is assessed as low.

Benthic invertebrate sensitivity to sedimentation rate changes

22.7.230 Benthic invertebrates that would be affected by sedimentation associated with dredging and dredge disposal for CWS installation are largely the same as those potentially affected by sedimentation associated with navigational dredging for access to the BLF, provided in **Section 22.7.c** of this chapter. *Gammarus insensibilis* was present in low abundance in the north of the GSB in the shallows in front of the Sizewell station complex. No individuals were found near the CWS location, so the species is considered as not sensitive to the pressure.

22.7.231 The assessment of benthic invertebrate sensitivity was conducted using the same approach as applied to navigational dredging and produced the same result, with mobile benthic invertebrates deemed to be not sensitive and sessile benthic invertebrates deemed to have low sensitivity.

22.7.232 As impact magnitude is low and the sensitivity of benthic invertebrate ranges from not sensitive to low, sedimentation rate changes associated with dredging and dredge disposal for CWS installation are predicted to have a minor adverse effect on this receptor. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to sedimentation rate changes

22.7.233 Sediment suspended by dredging for the installation of CWS infrastructure could be deposited on *S. spinulosa* reef on offshore Coralline Crag outcrops. Light sedimentation of <10mm is expected, which corresponds to that expected at the inshore Coralline Crag outcrops due to dredging for other components of the proposed development. The sensitivity of *S. spinulosa* reef to sedimentation due to dredging and dredge disposal associated with CWS installation is therefore the same as the sensitivity of this receptor to sedimentation caused by navigational dredging for access to the BLF provided in **Section 22.7.c** of this volume. As such, *S. spinulosa* reef is deemed to be not sensitive to this pressure.

22.7.234 As impact magnitude is low and *S. spinulosa* reef is not sensitive to this pressure, sedimentation rate changes associated with dredging and dredge disposal for CWS installation are predicted to have a negligible effect on this receptor. The effect is **not significant**.

Sedimentation rate changes (spoil pile formation): drilling

22.7.235 Vertical connection shafts would be drilled through the centre of the cooling water intakes *in-situ* to connect the headworks to the subterranean cooling water tunnels. Spoil piles, consisting of relatively coarse particles (>1mm), would form in the vicinity of the drill sites and, depending on the dredge requirements, have the potential to affect benthic invertebrates by smothering. Beyond the initial deposition of drill arisings, fine sediments would settle to depths of fractions of a millimetre on neap tides and be re-suspended on springs **Table 22.10** and **Appendix 22J** of this volume. As such the only impact on benthic communities is anticipated in the localised area of deposition of drill arisings.

22.7.236 The extent of the footprint would be dependent on the release depth and tidal conditions. The spoil pile would form a conical shape with deepest deposits of coarse material closest to the drill site and shallower smaller sized deposits at greater distances. Assuming release at the surface, and given the local flow conditions and water depths, the coarsest fractions of sediment (>10mm) are expected to settle within 60m of the drill site. Particles sizes of 1mm would be deposited within 200m of the drill site. A gradient in sediments depths would occur with deepest deposits (up to meters) at the drill site with mean deposit depths of 0.5m to 50mm radiating from the source. Spoil deposits would be eroded during periods of strong tidal flow, associated with spring tides and during storms. As such the impact would be short-term as provided in **Appendix 22J** of this volume.

22.7.237 In the soft sediment environment at the northern intakes and outfalls, the footprint of the spoil heap primarily sits within the area pre-impacted by capital dredging for the installation of the headworks, provided by **Table 22.11**. Any additional effect on benthic ecology receptors due the coarse fraction of the spoil pile would occur over a very small area. The impact magnitude for drill arisings at the northern intakes and outfall would be low.

22.7.238 The southern intakes would be located on exposed Coralline Crag, where substrate removal and ground preparations works are anticipated over a smaller spatial area than in the soft sediment environments associated with the northern intakes and outfall structures. A 50m buffer surrounding the headworks (50m x 10m LVSE + 50m buffer) has been applied to assess construction impacts, which is precautionary. The deepest deposits of coarse material (>10mm fraction) are predicted to occur within the 50m impact buffer area around the headworks with shallower, smaller size fraction deposits over larger areas (up to 200m). It should be noted that the spoil pile is anticipated to form in a tidally parallel conical formation. As such impacted areas would be greater in a north-south orientation and have a restricted east-west extent. The duration of the impact is expected to be short-term due to erosion of the spoil heap by tidal flows and storms. The spatial extent and the short duration of the impact gives rise to an impact magnitude of low.

Benthic invertebrate sensitivity to spoil pile formation

22.7.239 In close proximity to the drill site benthic receptors would have been pre-impacted or removed entirely during dredge activities, which has been assessed. At 60m to 200m from the drill site, less coarse sediment (around 1mm) would settle onto the seabed, potentially affecting benthic ecology receptors that have not largely been removed by dredge activities. The thickness of this sediment could be >50mm, which constitutes greater than ‘light’ deposition. Benthic invertebrates that would be affected by spoil pile formation associated with drilling for the CWS are the same as those potentially affected by sedimentation associated with dredging for CWS installation.

22.7.240 Benthic invertebrate sensitivity to smothering from spoil pile formation (50mm deposition depth) is expected to be largely be the same as sensitivity to sedimentation of the plume caused by dredging. Declines in sessile benthic invertebrate populations within the footprint are possible, though recovery would ensue as deposited sediment is dispersed over time during spring flows. Mobile benthic invertebrates are deemed to be not sensitive and sessile benthic invertebrates deemed to have low sensitivity to this pressure. A minor adverse effect is therefore predicted. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to spoil pile formation

22.7.241 A precautionary approach assumes drill arisings are sufficient to cause smothering and mortality of *Sabellaria spinulosa* reef within the 50m buffer where the thickest deposition of coarse material is anticipated. Combined with the impacts from other headwork installation activities and assuming total loss of reef within the 50m buffer, between 4 to 6% (depending on the location of the headworks) of the existing reef area at the offshore Coralline Crag (approximately 18.5ha) would be lost, as provided in **Table 22.43**. However, the impact is short-lived and rapid recovery following dredge activities (Ref. 22.216) suggests reefs within the 50m buffer could recover within years of the impact.

22.7.242 Beyond the area where deep burial may lead to smothering and mortality of *S. spinulosa* reefs, shallower deposition of smaller particles sizes (1mm) would occur. Sedimentation of >50mm is expected, but sediment would be dispersed during spring flows. *Sabellaria spinulosa* can survive deep burial up to several weeks (Ref. 22.181). Given the ability of *S. spinulosa* to withstand heavy and prolonged sedimentation, it is unlikely that reef exposed to this pressure outside the 50m buffer would be degraded. *Sabellaria spinulosa* reef is precautionarily assessed as having low sensitivity to this pressure.

22.7.243 As impact magnitude is low and *S. spinulosa* reef has low sensitivity to this pressure, spoil pile formation associated with drilling for the CWS is predicted to have a minor adverse effect on this receptor. The effect is **not significant**.

Underwater noise and vibration: dredging

22.7.244 Dredging and drilling for CWS installation would introduce noise and vibration to the marine environment. This has the potential to affect benthic ecology receptors by causing physical damage or inducing behavioural or physiological changes.

22.7.245 As with assessments for BLF activities in **Section 22.7.c** of this chapter, fish without a swim bladder that ‘hear’ by particle motion are used as a proxy to estimate the spatial extent of impact on benthic invertebrates. The threshold for potential mortality or recoverable injury is 213dB with respect to instantaneous exposure (i.e. peak energy from a single emittance of sound), while the threshold with respect to continuous exposure (i.e. repeated sounds) is 219dB and 216dB for potential mortality and recoverable injury, respectively provided for in **Table 22.71**. Underwater noise modelling was used to calculate the areas in exceedance of these thresholds, as provided in **Appendix 22L** of this volume. Impact magnitude is informed by whichever type of exposure has the most extensive area of threshold exceedance.

22.7.246 Potential effects on benthic ecology receptors due to drilling are scoped out as thresholds for potential mortality or recoverable injury would not be exceeded. For dredging, thresholds for potential mortality or recoverable injury would be crossed only within 25m (0.25ha) of the source, provided in **Table 22.96**. Dredging is expected to occur once and last for less than 24 hours for each of four intake heads and two outfall heads.

22.7.247 Impact magnitude for navigational dredging is assessed as very low, reflecting the very limited area in exceedance of thresholds for mortality or injury and the short duration of the pressure. Confidence in this assessment is low due to the reliance on sound pressure thresholds for fish without a swim bladder that 'hear' by particle motion detection in lieu of particle motion or sediment-borne vibration thresholds for benthic invertebrates. However, the assessment is considered precautionary.

Benthic invertebrate sensitivity to underwater noise and vibration

22.7.248 Benthic invertebrates that would be affected by underwater noise and vibration associated with dredging for CWS installation are largely the same as those potentially affected by underwater noise associated with navigational dredging for access to the BLF, as provided for in **Section 22.7.c** of this chapter**.** No *G. insensibilis* individuals have been observed near the CWS intake and outfall heads, so this species of conservation importance is not expected to be affected by this pressure. As polychaetes are not thought to be able to detect particle motion (Ref. 22.51), effects on *S. spinulosa* reef are not assessed.

22.7.249 The assessment of benthic invertebrate sensitivity was conducted using the same approach as applied to BLF activities and produced the same result, with benthic invertebrates deemed to have low sensitivity.

22.7.250 As impact magnitude is very low and benthic invertebrates have low sensitivity to this pressure, underwater noise associated with dredging for CWS installation is predicted to have a negligible effect on this receptor. The effect is **not significant**.

Physical loss / change to another seabed type: presence of structure

22.7.251 The installation of the two northern CWS intake headworks and two outfall headworks, along with scour protection, would result in a permanent change of seabed type from soft sediment (muddy sand) to a hard surface. Benthic species with preferences for soft or hard substrates would therefore be affected by this change in seabed type.

22.7.252 Changing the seabed from a soft sediment habitat to a hard surface constitutes a large amount of change based on the marine evidence-based sensitivity assessment benchmark threshold for changes in EUNIS classification (one Folk class for > ten years).

22.7.253 The spatial extent of habitat change is very low. The outfall heads are assumed to be approximately 16m x 16m blocks and hence would affect an area of 256m^2 per head and 512m^2 in total. The assumed dimensions for the intake heads are 50m x 10m, including nominal scour protection at the base plate, amounting to 500m^2 for each of the two northern intake heads.

22.7.254 In the soft sediment environment the addition of scour protection is anticipated. The two outfalls having a combined footprint of 2,420m^2 are provided in **Appendix 20A** of this volume. Scour assessments assumed a 32.5m x 10m LVSE headwork atop unlimited surficial sediments. This allows maximum, worst-case scour depth and area estimates to be established. Furthermore, scour assessments consider a simple block structure, rather than any hydrodynamic efficiencies incorporated into the LVSE design. The design of the LVSE headworks has been progressed to include the addition of nose ramps. The nose ramps allow greater hydrodynamic efficiencies reducing water velocities at the face, thereby providing embedded mitigation to reduce the abstraction risk zone and ultimately fish impingement (Ref. 22.24). The largest headwork design, including nose ramps, would be 50m x 10m, with the long axis parallel to the tidal trajectory. Assuming a simple block design and unlimited overlying sediment, predictions of scour area increase to by 31% to 2,039m^2 per intake headwork with a maximum scour depth of 4.26m. The two intakes would therefore have a total scour area of 4,078m^2 including the headwork itself. This assessment is considered to be highly precautionary as a) it does not take into consideration the purpose of the nose ramps is to increase hydrodynamic efficiency and b) geological interpretation of the overlying sediment indicates sediment thicknesses vary between tens of centimetres to more than two metres in the area of the northern intakes and outfalls and is minimal at the location of the southern intakes, which is located on exposed Coralline Crag material. As such, scour depths and areas would be restricted by underlying bedrock. The application of scour protection would reduce the scour footprint. In total, the northern intakes and outfalls would cause a small amount (<1ha) of soft sediment habitat to be replaced by hard structure/bedrock in relation to the area of soft sediment habitat in the GSB (>4,000ha).

22.7.255 This change in seabed type would be permanent. The very small spatial extent but long duration of the pressure constitutes a low impact magnitude.

22.7.256 The installation of the two southern CWS intake heads would result in a change in seabed type from a Coralline Crag habitat to an artificial hard structure. In the case of *S. spinulosa* reef assessments, permanent habitat loss is assumed.

22.7.257 On the exposed Coralline Crag substrate nominal scour protection at the base of the headworks is anticipated with each headwork being approximately 50m x 10m (1,000m^2 for both headworks). The change in seabed type would be permanent.

22.7.258 The area of exposed offshore Coralline Crag habitat is 57.5ha, with a further 365ha of exposed Coralline Crag present inshore.

22.7.259 The very small spatial extent but permanent loss of habitat constitutes a *Low* impact magnitude.

Benthic invertebrate sensitivity to physical loss / change to another seabed type

22.7.260 The transformation of the seabed from a soft habitat to a hard habitat would reduce the total area of suitable habitat for subtidal soft sediment invertebrates within the GSB. The benthic invertebrates inhabiting the area where the CWS intake and outfall heads would be installed would have been largely removed by dredging prior to installation. Therefore, it is unlikely that any additional effect could occur as a result of CWS installation.

22.7.261 While the area within the footprint of CWS intake and outfall heads would no longer be able to support soft sediment invertebrates following installation, species that prefer hard surfaces and were previously absent or rare would be able to colonise. The likelihood of this occurring is supported by the presence of the pelagic larvae of benthic encrusting organisms, such as barnacles (Cirripedia) and bryozoans, in zooplankton samples collected from the GSB, provided in **Appendix 22B** of this volume.

22.7.262 As benthic invertebrate taxa within the footprint of the CWS intake and outfall heads would have already been lost due to other activities, this receptor is deemed to be not sensitive to this pressure.

22.7.263 As impact magnitude is low and benthic invertebrates are *Not Sensitive* to this pressure, a negligible effect of physical change to another seabed type is predicted. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to physical loss of habitat

22.7.264 Coralline Crag would be replaced by a hard (artificial) habitat due to the installation of the two southern CWS intake heads. *Sabellaria spinulosa* reef in the location of the headworks would have already been removed by extraction and ground preparation works prior to installation of the headwork. Whilst it is recognised that *Sabellaria* species may form on artificial structures

(Ref. 22.217), a precautionary stance assumes no potential for recovery on the installation due to the potential for occasional maintenance works to remove fouling organisms.

22.7.265 Therefore, the installation of intake heads and scour protection would result in a permanent reduction in the area of suitable habitat (Coralline Crag outcrops) by approximately 0.1ha. This represents less than 0.2% of the available offshore habitat and 0.02% of the habitat at the scale of the GSB.

22.7.266 The present extent of *S. spinulosa* partially coincides with the locations of the proposed headworks set out in **Plate 22.5**. Given the ephemeral nature of *S. spinulosa*, the distribution and extent of reef is likely to change by the time of construction. A worst-case scenario would be to assume the 0.1ha habitat loss coincides with loss of reef at the time of construction. In such a scenario, approximately 0.5% of the 18.5ha of existing reef extent at the offshore Coralline Crag could be permanently lost. It is noted that at the time of construction the extent of the reef may be larger or smaller, changing the relative proportion lost, and may/may not coincide with the location of the intakes.

22.7.267 Whilst *S. spinulosa* reef is intolerant to direct habitat loss, the spatial extent of permanent losses of habitat or potential reef area are very low. *Sabellaria spinulosa* reefs are considered to have low sensitivity to habitat loss.

22.7.268 As impact magnitude is low and *S. spinulosa* reef have low sensitivity to the scale of habitat loss, minor adverse effects are predicted. The effect is **not significant**.

Spread of non-indigenous species: presence of structure

22.7.269 The introduction of hard substrata to an area consisting primarily of soft sediments could facilitate the spread of INNS that prefer hard habitats and have detrimental effects on indigenous species.

22.7.270 The area of new three-dimensional surface be available to INNS due to the presence of CWS intake and outfall heads would be approximately 1ha, which is less than the Marine Evidence-Based Sensitivity assessment pressure benchmark for colonisation (1ha) (Ref. 22.11). This surface would be available for colonisation for the lifetime of the Sizewell C Project. While the pressure has a long duration, the small spatial scale of the structure results in an impact magnitude of low.

Benthic invertebrate sensitivity to the spread of non-indigenous species

22.7.271 The sensitivity of benthic invertebrates to the spread of INNS due to the presence of the CWS intake and outfall heads would be the same as the sensitivity of this receptor to the presence of BLF piles in the subtidal zone in

Section 22.7.c of this chapter. As such, benthic invertebrates have low sensitivity to this pressure.

22.7.272 As impact magnitude is low and benthic invertebrates have low sensitivity to this pressure, the spread of INNS due to the presence of the CWS intake and outfall heads is predicted to have a minor adverse effect on this receptor during the construction phase. The effect is **not significant**.

v. Fish recovery and return

22.7.273 This section describes the impacts associated with the installation and operation of the fish recovery and return (FRR) system during the construction phase. Scoping identified the pressures arising from activities at the FRR with the potential for effects on ecological receptors, see **Appendix 22M** of this volume. Pressures with the potential to affect marine benthic ecology receptors are presented in **Table 22.44.**

Table 22.44: Pressures associated with FRR activities during the construction phase that have the potential to affect benthic ecology receptors.

Pressure	Activities resulting in pressure	Justification
Removal of substratum (extraction).	Dredging	Potential to affect benthic ecology receptors through the direct disturbance of organisms.
Changes in suspended sediments.	Dredging and disposal.	Potential to affect benthic ecology receptors by impeding feeding.
Sedimentation rate changes.	Dredging and disposal.	Deposition of suspended sediments has the potential to affect benthic ecology receptors through smothering.
Physical change to another seabed type.	Presence of structure.	Potential to affect benthic ecology receptors through habitat change.
Spread of non-indigenous species.	Presence of structure.	Introduction of hard substrate to a primarily soft sediment environment has the potential to affect benthic ecology receptors by facilitating the spread of non-indigenous species.

22.7.274 Construction pressures scoped out of further assessment as they have been determined to have negligible effects on benthic receptors include:

- Contaminant resuspension – The sediments within the GSB are considered to be uncontaminated and the effects of resuspension of contaminants on benthic receptors is not considered further in **Section 22.4** of this chapter.

- Underwater noise and vibration – Thresholds for mortality or recoverable injury (using fish without a swim bladder that 'hear' by particle motion detection as a proxy for benthic invertebrates) are not crossed due to dredging activities associated with FRR installation. Effects on benthic ecology receptors are therefore considered negligible.

- Introduction of non-indigenous species – Vessels involved in FRR construction will operate in accordance with IMO regulations. As such, effects on benthic ecology receptors arising from the introduction of INNS in ballast water are assumed to be negligible.

Removal of substratum (extraction): dredging

22.7.275 Prior to installation of the FRR system and scour protection, surficial soft sediment in the shallow subtidal zone (<6m) would be removed by dredging via a cutter suction dredger and returned to the marine environment at a local disposal site presumed to be within the GSB. This activity has the potential to directly affect benthic invertebrates through physical disturbance and displacement of organisms.

22.7.276 Installation of the two FRR outfall heads and the scour protection would result in the combined removal of approximately 0.26ha of surficial sediment. Dredging is expected to occur once and last for less than 24 hours per head, provided in **Section 22.3.i)** of this chapter.

22.7.277 Following dredging, installation of infrastructure would replace the existing habitat over a small area (see Physical loss / change to another seabed type: presence of structure) and soft-sediment would be back-filled.

22.7.278 Impact magnitude is assessed as very low based on the limited spatial extent of dredging relative to the extent of the affected habitat (subtidal sand) in the GSB.

Benthic invertebrate sensitivity to removal of substratum (extraction)

22.7.279 The benthic invertebrate taxa potentially affected by the removal of substratum associated with dredging for FRR installation are the same as those potentially affected by the removal of substratum associated with navigational dredging for access to the BLF provided in **Section 22.7.c** of this chapter.

22.7.280 The assessment of benthic invertebrate sensitivity was conducted using the same approach applied to navigational dredging and both mobile and sessile/low mobility benthic invertebrates were deemed to have low sensitivity to this pressure. The reduced sensitivity of sessile/low mobility benthic invertebrates (including *G. insensibilis*) compared to that for navigational dredging (medium) reflects the smaller extent of exposure (0.26ha *vs*. 0.91ha; provided in **Section 22.3.i)** of this chapter, and the expected recovery of populations within the majority (84%) of the dredge footprint following the installation of FRR heads (whereas maintenance dredging during the construction phase would prevent full recovery of benthic invertebrate populations within the navigational channel).

22.7.281 Based on the very low impact magnitude and low sensitivity of benthic invertebrates to this pressure, sediment extraction associated with dredging for FRR installation is predicted to have a negligible effect on this receptor. The effect is **not significant**.

Changes in suspended sediments: dredging and disposal

22.7.282 Dredging and local dredge disposal for the installation of the FRR system would lead to elevated SSC. Changes in SSC have the potential to affect benthic invertebrates by interfering with feeding.

22.7.283 It is likely that the FRR systems would be installed separately approximately one year apart in sequence with the reactor they are associated with, provided in **Plate 22.1**. Therefore, modelling considered FRR dredging of the two headworks to be temporally distinct events. Plumes with instantaneous SSC of >100mg/l above daily maximum background levels are expected to form inshore over an instantaneous depth averaged area of up to 28ha (89ha at the sea surface). A small area of 1ha is expected to experience an instantaneous SSC of >1,000mg/l above background at the sea surface as presented in **Section 22.3.i)** of this chapter.

Benthic invertebrate sensitivity to changes in suspended sediments

22.7.284 The benthic invertebrate taxa potentially affected by changes in SSC associated with dredging and dredge disposal for FRR installation are largely the same as those potentially affected by changes in SSC due to navigational dredging for access to the BLF, provided in **Section 22.7.c** of this chapter. As such, the assessment of subtidal benthic invertebrate sensitivity was conducted using the same approach as applied to navigational dredging and produced the same result, with suspension-feeding benthic invertebrates and benthic invertebrates with planktotrophic larvae (larvae that feed in the water column) both determined to be not sensitive to increases in SSC. Benthic invertebrates that do not feed on suspended matter (including *G. insensibilis*) are assumed to be not sensitive to changes in SSC.

22.7.285 As impact magnitude is medium and benthic invertebrates are not sensitive to this pressure, changes in suspended sediments resulting from dredging and dredge disposal for FRR installation are predicted to have a minor adverse to minor beneficial effect on this receptor. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to changes in suspended sediments

22.7.286 The sensitivity of *S. spinulosa* reef to changes in SSC associated with dredging and dredge disposal for FRR installation is the same as the sensitivity of this receptor to changes in SSC due to navigational dredging for access to the BLF, provided in **Section 22.7.c** of this chapter. As such, *S. spinulosa* reef is determined to be not sensitive to this pressure. Short-term increases in tube growth is possible. A short-term increase in tube growth is possible for the *S. spinulosa* on the inshore Coralline Crag outcrops.

22.7.287 As impact magnitude is medium and *S. spinulosa* reef is not sensitive to this pressure, changes in suspended sediments resulting from dredging and dredge disposal for FRR installation are predicted to have a minor beneficial effect. The effect is **not significant**.

Sedimentation rate changes: dredging and disposal

22.7.288 Sediment suspended by dredging and dredge disposal for the installation of the two FRR systems would subsequently be deposited onto the seabed. Sediment deposition has the potential to affect benthic invertebrates by smothering.

22.7.289 Sediment deposition would be classified as 'light' throughout the plume footprint, with sediment thickness not expected to exceed 50mm and only expected to exceed 20mm over 1ha. It is predicted that all suspended sediment would be deposited within hours of dredging and then dispersed by natural resuspension, leaving no area where sediment thickness remains >20mm thicker than it was prior to dredging after 15 days, as provided in **Section 22.3.i)** of this chapter. These levels of sediment deposition would occur for each of the two FRR headwork installations.

22.7.290 As no area would be exposed to greater 'light' deposition and deposited sediments would be rapidly dispersed. Impact magnitude is assessed as very low.

Benthic invertebrate sensitivity to sedimentation rate changes

22.7.291 The benthic invertebrate taxa that would be affected by sedimentation associated with dredging and dredge disposal for FRR installation are the same as those potentially affected by sedimentation associated with navigational dredging for access to the BLF, as provided in **Section 22.7.c** of this chapter. As such, the assessment of subtidal benthic invertebrate sensitivity was conducted using the same approach as applied to navigational dredging and produced the same result, with mobile benthic invertebrates determined to be not sensitive and sessile/low mobility benthic invertebrates (including *G. insensibilis*) determined to have low sensitivity.

22.7.292 As impact magnitude is very low and that the sensitivity of benthic invertebrate ranges from not sensitive to low, sedimentation rate changes associated with dredging and dredge disposal for FRR installation are predicted to have a negligible effect on this receptor. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to sedimentation rate changes

22.7.293 The sensitivity of *S. spinulosa* reef to sedimentation due to dredging and dredge disposal associated with FRR installation is the same as the sensitivity of this receptor to sedimentation caused by navigational dredging for access to the BLF, as provided in **Section 22.7.c** of this chapter. As such, *S. spinulosa* reef is determined to be not sensitive to this pressure.

22.7.294 As impact magnitude is very low and *S. spinulosa* reef is not sensitive to this pressure, sedimentation rate changes associated with dredging and dredge disposal for FRR installation are predicted to have a negligible effect on this receptor. The effect is **not significant**.

Physical loss / change to another seabed type: presence of structure

22.7.295 The installation of the FRR outfall heads and scour protection would result in a change in seabed type from soft sediment (fine to medium sand) to a hard surface. Benthic species with preferences for soft or hard substrates would therefore be affected by this change in seabed type.

22.7.296 Changing the seabed from a soft sediment habitat to a hard surface constitutes a large amount of change based on the Marine Evidence-Based Sensitivity Assessment benchmark threshold for changes in EUNIS classification (one Folk class for > ten years). The spatial extent of habitat change is very small (<0.1ha) in relation to the area of the GSB (>4,000ha). This change to seabed type would last for the lifetime of the Sizewell C Project. The very small spatial extent but long duration of the pressure constitutes a low impact magnitude.

Benthic invertebrate sensitivity to physical loss of habitat

22.7.297 The transformation of the seabed from a soft habitat to a hard habitat would reduce the total area of suitable habitat for subtidal soft sediment invertebrates within the GSB. The benthic invertebrates inhabiting the area (including *G. insensibilis*) where the FRR outfall heads would be installed would have been largely removed by dredging prior to installation. Therefore, it is unlikely that any additional effect could occur as a result of FRR installation.

22.7.298 While the area within the footprint of FRR outfall heads would no longer be able to support soft sediment invertebrates following installation, species that prefer hard surfaces and were previously absent or rare would be able to colonise. The likelihood of this occurring is supported by the presence of the pelagic larvae of benthic encrusting organisms, such as barnacles (Cirripedia) and bryozoans, in zooplankton samples collected from the GSB, provided in **Appendix 22B** of this volume.

22.7.299 As benthic invertebrate taxa within the footprint of the FRR heads would have already been lost due to other activities, this receptor is deemed to be not sensitive to this pressure.

22.7.300 As impact magnitude is low and benthic invertebrates are not sensitive to this pressure, a negligible effect of physical change to another seabed type is predicted. The effect is **not significant**.

Spread of non-indigenous species: presence of structure

22.7.301 The introduction of hard substrata to an area consisting primarily of soft sediments could facilitate the spread of INNS that prefer hard habitats.

22.7.302 The area of new three-dimensional surface available to INNS due to the presence of FRR outfall heads would be <0.1ha, which is less than the Marine Evidence-Based Sensitivity Assessment pressure benchmark for colonisation (1ha) (Ref. 22.11). This surface would be available for colonisation for the lifetime of the Sizewell C Project. While the pressure has a long duration, the very small spatial scale of the structure results in an impact magnitude of very low.

Benthic invertebrate sensitivity to the spread of non-indigenous species

22.7.303 The sensitivity of benthic invertebrates to the spread of non-native species due to the presence of the FRR heads would be the same as the sensitivity of this receptor to the presence of BLF piles in the subtidal zone, provided in **Section 22.7.c** of this chapter. As such, benthic invertebrates have low sensitivity to this pressure.

22.7.304 As impact magnitude is very low and benthic invertebrates have low sensitivity to this pressure, the spread of INNS due to the presence of the FRR head is predicted to have a negligible effect on this receptor during the construction phase. The effect is **not significant**.

vi. Inter-relationship effects

22.7.305 This section provides a description of the identified inter-relationships that have the potential to affect benthic ecology receptors during the construction phase of the proposed development. These are the effects arising from additive, synergetic or antagonistic impacts of activities. Pressures with the potential to affect marine benthic receptors are presented in **Table 22.45**.

Table 22.45: Pressures associated with inter-relationships among activities during the construction phase with the potential to affect benthic ecology receptors.

Pressure	Activities resulting pressure	Justification
Combined constructions pressures associated with the installation of the Unit 1 cooling water intakes on *S. Spinulosa.*	A 50m buffer zone surrounding the intake headworks was precautionarrily assessed as the area of *S. Spinulosa* reef / supporting habitat exposed to temperary pressures associated with: • Substrate extraction / ground preperation. • Abrastion / physical disturbance (e.g. jack-up barges and anchoring). • Spoil heaps from drill arisings.	Removal of substratum and abrasion has the potential to affect *S. spinulosa* through the direct disturbance of organisms. Drilling the vertical connection shafts would cause sediment deposition at depth capable of causing local smoothering. A precautionary assessment considers effects within a 50m buffer around headworks encompassing construction platform activities and provides a coherent framework for considering in-combination pressures associated with construction activities within a defined area.
Removal/reprofiling of substratum.	Navigational dredging and dredging for infrastructure installation.	Potential to affect benthic ecology receptors through the direct disturbance of organisms.
Changes in suspended sediments.	Navigational dredging and dredging and disposal for infrastructure installation.	Potential to affect benthic ecology receptors by impeding feeding.
Sedimentation rate changes.	Navigational dredging and dredging and disposal for infrastructure installation.	Potential to affect benthic ecology receptors through smothering.
Physical change to another seabed type.	Combined presence of infrastructure components.	Potential to affect benthic ecology receptors through habitat change.
Spread of non-indigenous species.	Combined presence of infrastructure components.	Introduction of hard substrate to a primarily soft sediment environment has the potential to affect benthic ecology receptors by facilitating the spread of non-indigenous species.

Combined constructions pressures on *S. spinulosa*

22.7.306 Prior to the installation of cooling water infrastructure dredging and/or ground preparation would be required. Activities associated with construction platform operations (e.g. the use of jack-up barges and anchoring) would occur causing surface (and sub-surface) abrasion or physical damage to *S. spinulosa* reefs and supporting habitat. Furthermore, drilling through the centre of the headworks to connection the subterranean tunnels, would cause sediment deposition at depths capable of causing mortality due to smothering. Each pressure has been assessed individually but consideration has been given to the impacts acting in-combination within an area surrounding the headwork. Assessments, therefore, consider the precautionary stance that construction activities would cause impacts within a 50m buffer zone surrounding the intake headworks, provided in **Plate 22.5**.

22.7.307 The area of impacted reef and viable habitat within the 50m buffer zone is presented in **Table 22.43**. The worst-case extent of existing reef within the 50m buffer potentially exposed to construction pressures is 1.07ha (eastern and mid locations) and equates to 6% of the reef area at the offshore Coralline Crag (approximately 18.5ha). The best-case position of the intakes, based on current reef extent results in exposure of 0.67ha (western and mid locations), less than 4% of the of the reef area at the offshore Coralline Crag. The worst-case scenario for impacts on the habitat would result in a total area of impacted habitat of 2.7ha, representing less than 5% of the 57.5ha offshore Coralline Crag, set out in **Table 22.43**. Across the GSB the impact area represents less than 1% of the total exposed Coralline Crag (423ha).

22.7.308 A small proportion of the *S. spinulosa* reef or viable habitat would be exposed to construction pressures within the precautionary buffer area. Construction activities are medium-term. As extraction and ground preparations would result in temporary pressures, recovery of lost reef material within the 50m buffer zone would be predicted to occur within years of the pressure ceasing and recovery through recolonization[32].

22.7.309 Minor adverse effects on *S. spinulosa* reefs are predicted. Determination of the significance of the predicted effect accounted for several factors described in **Table 22.38**. No significant effects on the distribution or functioning of the reef are predicted.

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[32] *Sabellaria spinulosa* formations settled and grew back within 18 months following marine aggregate dredging at the Hasting Shingle Bank License Area (Ref. 22.216).

22.7.310 Monitoring of the *S. spinulosa* reef extent on the offshore Coralline Crag is recommended during both pre- and post-construction of cooling water infrastructure as described in **Section 22.7.c** of this chapter.

Removal/reprofiling of substratum: dredging (combined components)

22.7.311 During the construction phase, navigational dredging is expected to occur and then reoccur to maintain accessibility of the BLF to vessels (0.91ha), while dredging would also be conducted prior to the installation of headworks for the CDO (0.13ha), CWS (2.77ha) and FRR (0.26ha). Sediment suspended by navigational dredging would be naturally dispersed within the GSB, while sediment extracted for the construction of other development components would be returned to the marine environment at local disposal sites presumed to be within the GSB. Therefore, a net removal of sediment from the GSB is not expected. Sediment extraction and redistribution during dredging has the potential to directly affect benthic invertebrates through physical disturbance and displacement of organisms.

22.7.312 The combined extent of sediment extraction and redistribution is very small (4.07ha) in comparison to the area of the GSB (>4,000ha). The duration of the pressure is the lifetime of the Sizewell C Project for navigational dredging (dredge campaigns occurring annually during the construction phase, then once every 5-10 years during the operation phase) and ranges from days to permanent in areas where dredging is conducted to install hard infrastructure. Due to the limited spatial extent of the pressure, impact magnitude is assessed as low.

Benthic invertebrate sensitivity to removal of substratum (extraction)

22.7.313 The sensitivity of this receptor to the removal of substratum was determined to be low to medium for dredging associated with each development component. The same sensitivities are applied here for the combination of all development components (BLF, CDO, CWS and FRR). The rationale supporting this sensitivity assessment is provided in the assessment of the BLF in **Section 22.7c** of this chapter.

22.7.314 As impact magnitude is *Low* and benthic invertebrates have low to medium sensitivity to this pressure, sediment extraction associated with navigational dredging for access to the BLF and dredging for the installation of CDO, CWS and FRR infrastructure combined is predicted to have a minor adverse effect on this receptor. The effect is **not significant**.

Changes in suspended sediments: dredging and dredge disposal (combined development components)

22.7.315 During the construction phase, sediments would be suspended by navigational dredging for access to the BLF and by dredging and dredge disposal for the installation of CDO, CWS and FRR infrastructure. Changes in suspended sediment concentration (SSC) have the potential to affect benthic invertebrates by interfering with feeding.

22.7.316 Maintenance dredging for the BLF is anticipated to occur at approximately monthly intervals during the campaign period. As a worst-case, it is assumed there is temporal and spatial coincidence of the plumes from maintenance dredging for the BLF (plough dredger) and dredging (cutter suction dredger) and disposal for the installation of: a) CWS headworks and b) the southern FFR headworks.

22.7.317 The suspended sediment plumes from BLF maintenance dredging and dredging to install CWS infrastructure would not intersect, forming two discrete plumes. Therefore, the concurrent activities result in a greater spatial extent of the pressure rather than interactive effects. Increases in the total size of the instantaneous SSC plume at ecologically relevant levels are minimal. The total area with SSC above 100mg/l at the sea surface would be 308ha, as in **Section 22.3.i)** of this chapter. This area is only slightly larger than the area that would have an SSC above 100mg/l due to dredging for CWS installation alone (291ha).

22.7.318 The suspended sediment plumes from BLF maintenance dredging and dredging to install the FRR head would intersect. At the sea surface, the maximum instantaneous area exceeding 100mg/l would be 111ha. This increase is greater than the sum of the two individual activities (106ha). However, the plume is highly transient, and the total duration of elevated SSC would be reduced due to the temporal overlap. Moreover, the affected area is not substantially larger than the area where SSC would exceed 100mg/l due to dredging for FRR installation alone (89ha).

22.7.319 The possible co-occurrence of maintenance dredging of the navigational channel with dredging for infrastructure installation would not significantly increase the spatial extent of SSC plumes. The SSC plumes associated with dredging activities for different components of the infrastructure would not overlap temporally. Therefore, the combined impact of dredging activities on SSC would not exceed that of the components alone. Impact magnitude is medium.

Benthic invertebrate sensitivity to changes in suspended sediments

22.7.320 Benthic invertebrates were determined to be not sensitive to changes in SSC due to dredging and dredge disposal associated with each development component. The same sensitivity is applied here for the combination of all development components (BLF, CDO, CWS and FRR). The rationale supporting this sensitivity assessment is provided in the assessment of the BLF in **Section 22.7.c** of this chapter.

22.7.321 As impact magnitude is medium and benthic invertebrates are not sensitive to this pressure, changes in SSC associated with dredging for all development components combined is predicted to have a minor adverse to minor beneficial effect on this receptor. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to changes in suspended sediments

22.7.322 *Sabellaria spinulosa* reef was determined to be not sensitive to changes in SSC due to dredging and dredge disposal associated with each development component. Short-term increases in tube growth is possible. The same sensitivity is applied here for the combination of all development components (BLF, CDO, CWS and FRR). The rationale supporting this sensitivity assessment is provided in the assessment of the BLF in **Section 22.7.c** of this chapter.

22.7.323 As impact magnitude is medium and *S. spinulosa* reef is not sensitive to this pressure, changes in SSC associated with dredging for all development components combined is predicted to have a minor beneficial effect on this receptor. The effect is **not significant**.

Sedimentation rate changes: dredging and dredge disposal (combined components)

22.7.324 During the construction phase, sediments would be suspended and later deposited onto the seabed due to navigational dredging for access to the BLF and dredging and dredge disposal for the installation of CDO, CWS and FRR infrastructure. Sediment deposition has the potential to affect the benthos by smothering animals.

22.7.325 Temporal coincidence of sediment plumes associated with different dredging activities is possible if maintenance dredging for the navigational channel cooccurs with dredging to install CWS infrastructure or the southern FFR outfall head. No other dredging activities would co-occur. As sedimentation associated with maintenance dredging is negligible, < 20mm; provided in **Section 22.3.i)** of this chapter, its potential temporal coincidence with other dredging activities would not lead to an increase in overall impact. The combined impact magnitude of dredging across development components is therefore low.

Benthic invertebrate sensitivity to sedimentation rate changes

22.7.326 The sensitivity of benthic invertebrates to changes in SSC was determined to range from not sensitive to low for dredging and dredge disposal associated with each development component. The same sensitivity is applied here for the combination of all development components (BLF, CDO, CWS and FRR). The rationale supporting this sensitivity assessment is provided in the assessment of the BLF in **Section 22.7.c** of this chapter.

22.7.327 As impact magnitude is low and the sensitivity of benthic invertebrates to this pressure ranges from not sensitive to low, sedimentation rate changes associated with dredging for all development components combined is predicted to have a minor adverse effect on this receptor. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to sedimentation rate changes

22.7.328 *Sabellaria spinulosa* reef was determined to be not sensitive to changes in SSC due to dredging and dredge disposal associated with each development component. The same sensitivity is applied here for the combination of all development components (BLF, CDO, CWS and FRR). The rationale supporting this sensitivity assessment is provided in the assessment of the BLF in **Section 22.7.c** of this chapter.

22.7.329 As impact magnitude is low and *S. spinulosa* reef is not sensitive to this pressure, sedimentation rate changes associated with dredging for all development components combined is predicted to have a negligible effect on this receptor. The effect is **not significant**.

Physical loss / change to another seabed type: presence of structure (combined components)

22.7.330 Benthic species with preferences for soft or hard substrates would be affected by a change in seabed type from soft sediment to a hard surface. Such a change in seabed type would occur in the subtidal zone due to the installation of the BLF, CDO head, northern CWS intake and outfall heads, and FRR outfall heads. The southern intake heads would be installed on the offshore Coralline Crag deposits and, thus, would not contribute to the overall extent of soft sediment habitat loss in the GSB. The effect of the southern CWS intake heads on the loss of Coralline Crag habitat is assessed in **Section 22.7c)iii** of this chapter. In the intertidal zone, changes to seabed type would occur only as a result of BLF installation. The approximate area of seabed that would be changed from soft sediment to a hard surface for each development component according to the engineering design are presented in **Table 22.46**. It should be noted that dimensions are based current engineering designs at the time of assessment but are indicative to inform assessments and are subject to modification based on constructability.

Table 22.46: Indicative area (m^2) of change in soft sediment seabed habitat due to the installation of hard infrastructure in the Greater Sizewell Bay (Appendix 20A).

Component	Area of habitat change (m^2)		Description
	Intertidal	Subtidal	
Beach landing facility.	2	12	Eight steel tubular piles of 1m diameter and four piles (fenders and dolphins) of 1.52 m diameter in the subtidal zone. Two steel tubular piles of 1m diameter in intertidal soft sediments.
Combined drainage outfall.	-	207	One concrete block and scour protection within subtidal soft sediment environment.
Fish recovery and return.	-	414	Two concrete heads and scour protection within subtidal soft sediment environment.
CWS outfalls.		2,420	Two cooling water outfall headworks and scour protection within subtidal soft sediment environment.
CWS Intakes.		4,078	Two cooling water intakes and scour protection within a soft sediment environment (Unit 2)[33].
Total	2	7,131	

22.7.331 The combined extent of change to another seabed type within the subtidal zone is very small (<1ha) in comparison to the area of the GSB (>4,000ha of available soft sediment habitat within the GSB). Changing the seabed type from a soft sediment habitat to a hard surface constitutes a large amount of change based on the Marine Evidence-Based Sensitivity Assessment benchmark threshold for changes in EUNIS classification (one Folk class for > ten years). This change in seabed type would last for the lifetime of the proposed development.

22.7.332 The very small spatial extent of the pressure and the long-term presence in the marine environment results in an impact magnitude of *Low*.

Benthic invertebrate sensitivity to physical loss of habitat

22.7.333 Subtidal soft sediment benthic invertebrates were determined to be *not sensitive* to physical change to another seabed type due to the installation of

[33] Assessments of change in soft sediment seabed account for the infrastructure and total extent of the scour pit. The application of scour protection would reduce the scour footprint. Therefore, assessments are precautionary.

hard infrastructure, as biota would have been largely removed by dredging prior to installation. The same sensitivity is therefore applied here for the combination of all development components (BLF, CDO, CWS and FRR).

22.7.334 Given that impact magnitude would be low, and that benthic invertebrates are not sensitive to this pressure, the physical change to another seabed type associated with the installation of all development components combined is predicted to have a negligible effect on this receptor.

Spread of non-indigenous species: presence of structure (combined components)

22.7.335 The introduction of hard substrata to an area consisting primarily of soft sediments could facilitate the spread of INNS that prefer hard habitats. Five development components would contribute to the introduction of new hard substrata within the GSB, both in the intertidal zone (BLF piles), and subtidal zone (BLF piles, CDO head, CWS intake and outfall heads and FRR heads).

22.7.336 A descriptor for good environmental status (GES) under the Marine Strategy Framework Directive is "*Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems*"[34]. The proposed development would not directly introduce INNS. Measures to mitigate INNS, including compliance with the IMO Ballast Water Management Convention are detailed in the **CoCP** (Doc Ref. 8.11). The marine evidence-based sensitivity assessment pressure benchmark for colonisation (1ha) (Ref. 22.11). A three-dimensional surface area of hard surface would be added to the marine environment, most of which would be subtidal, with <0.01ha added to the intertidal zone due to the presence of BLF piles. The total surface of hard substrate introduced is predicted to be less than 2ha[35] cumulatively between the discrete structures of the six cooling water headwords and the inshore FRR, CDO and BLF. Each development component would be a permanent feature within the GSB. The total three-dimensional surface area of new hard habitat would be very small at the scale of the GSB and whilst the structures exceed the benchmark for the pressure, they are spatially distinct, provided in **Figure 20.1**.

22.7.337 A precautionary impact magnitude of medium is applied.

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[34] Adverse effects may be at the individual (e.g. pathogens), population (genetic change through hybridization), community (structural shift), habitat (changes to physical-chemical conditions) or ecosystem (changes to energy flows or organic cycling) levels (Ref. 22.300).

[35] Based on the surface are of the proposed infrastructure and the assumption of the cooling water infrastructure protruding approximately 4m from the seabed, and scour protection protruding approximately 1m from the seabed.

Benthic invertebrate sensitivity to introduction or spread of non-indigenous species

22.7.338 The introduction of hard substrata to a soft sediment environment is typically followed by rapid colonisation by fouling organisms. If the introduced habitat is atypical of the area, then this could allow INNS that would otherwise be unable to colonise to become established. Indeed, artificial structures are known to be more susceptible to colonisation and biotic invasion by fouling organisms than natural habitats (Ref. 22.196–198). Once an INNS has colonised an artificial structure, the population can then act as a steppingstone for further geographical spread (Ref. 22.199; 200).

22.7.339 Benthic invertebrate INNS can exert a range of effects on marine ecosystems, of which the most common is the displacement of indigenous species (Ref. 22.201). Only one subtidal INNS was recorded in the GSB during the Sizewell C benthic baseline surveys, the American jacknife *E. leei* (previously *E. directus*), which was found in a single grab sample, provided in **Appendix 22C** of this volume. This species has been present on East Anglian coasts since 1990 (Ref. 22.202). As *E. leei* lives in soft sediments, the addition of new artificial hard substrate would not influence its distribution within the GSB or the southern North Sea. There remains a risk, however, that the new hard substrata will allow the colonisation of fouling INNS not currently established within the area, as planktonic larvae from distant populations settle onto the structures (Ref. 22.203), which could then spread into other areas of the GSB and the wider region.

22.7.340 Effects of INNS colonisation on native benthic invertebrate biota in the North Sea appear at present to be an expansion of the species pool rather than species displacement (Ref. 22.207). A 40-year annual time-series (1970-2009) from tidal flats in the Wadden Sea (southern North Sea) found that warming coincided with the introduction of four non-native benthic invertebrate species, which largely explained an expansion of the total species pool over time. The establishment of INNS did not appear to have had detrimental effects on the native biota, as a temporal increase in the number of species per site was mainly due to native species occurring at more sites than they had previously (Ref. 22.218).

22.7.341 The sensitivity of subtidal benthic invertebrates to the spread of INNS due to infrastructure installation was determined to be low for each development component. The same sensitivity is applied here for the combination of all development components (BLF, CDO, CWS and FRR).

22.7.342 The spread of INNS due to the presence of all development components combined is predicted to have a minor adverse effect on this receptor. The effect is **not significant**.

22.7.343 The potential in-combination influence of infrastructure (combined components) and temperature uplifts – due to cooling water discharges and climate change – on benthic ecology receptors via the spread of INNS are assessed for the operation phase.

d) Operation

22.7.344 Both units of the Sizewell C power station are anticipated to be operational by 2034. For assessment purposes the earliest date the proposed development may become operational is 2030, as set out in **Plate 22.1**, following a construction and commissioning period of nine to 12 years provisionally commencing in 2022.

22.7.345 This section considers the development components and associated activities that were identified during scoping, provided in **Appendix 22M** of this volume, with the potential to cause significant effects on benthic ecology receptors. Effects are generally assessed with respect to the current baseline, but consideration is given to future baselines in **Section 22.7.b** of this chapter, where appropriate.

i. Coastal defence features

22.7.346 This section describes the impacts associated with the coastal defence features during the operation phase. Scoping identified the pressures associated with the HCDF and SCDF with the potential for effects on ecological receptors as set out in **Appendix 22M** of this volume. The only pressure identified for benthic ecology receptors is the presence of the structure within the context of future emergence regime changes due to shoreline retreat (i.e. coastal squeeze).

Emergence regime changes and loss of habitat: presence of structure

22.7.347 The coastal defences for the proposed development would consist of both a HCDF and SCDF made of beach grade sediments, as in **Section 22.3.i)** of this chapter. As the SCDF is eroded, shingle would be transported along the intertidal beach by the bidirectional wave climate, which results in relatively slow longshore dispersion. That is, the SCDF would maintain the affected beaches in their present form for longer than would be the case in the absence of the proposed development. During high-water levels some of the shingle may contribute to the supra-tidal beach, thereby potentially causing growth in that habitat.

22.7.348 If ongoing shoreline retreat progresses, depleting the SCDF, mitigation would be used to maintain the shingle beach and longshore shingle transport corridor, as provided in **Section 20.14** of **Chapter 20** of this volume. Coastal squeeze would not occur until the SCDF were depleted and the supra-tidal shingle habitat began to narrow. Beach maintenance activities, especially beach recharge, may reduce the effects of coastal squeeze.

22.7.349 The supralittoral frontage adjacent to the proposed development forms part of the non-statutory designated Suffolk Shingle Beaches Country Wildlife Site as set out in **Table 22.1**. The site supports a matrix of vegetated shingle. Impacts on vegetated shingle is considered within the Terrestrial Ecology and Ornithology **ES**, **Chapter 14** of this volume. However, it is important to note Sizewell C frontage has a very narrow supra-tidal zone that does not support annual vegetated shingle habitat. Furthermore, the designated annual vegetated shingle habitat on the Minsmere SSSI designed sites frontage was destroyed due to erosion in 2011, further details are provided in **Chapter 20** of this volume.

22.7.350 Whilst beach mitigation is being employed, shingle transport along the Sizewell C frontage would be maintained and no measurable effect on the non-statutory designated Suffolk Shingle Beaches Country Wildlife Site would occur.

22.7.351 Mitigation would cease at the end of decommissioning, or sooner under certain circumstances, provided in **Chapter 20** of this volume.

22.7.352 Below MHWS (assessed herein), the worst-case scenario of the installation of the HCDF could result in a localised (across the frontage of the proposed development), but permanent loss of soft sediment intertidal habitat. The impact magnitude is assessed as low.

Benthic invertebrate sensitivity to emergence regime changes

22.7.353 Intertidal benthic invertebrate communities are broadly similar throughout the GSB and not particularly diverse, reflecting the highly dynamic nature of the beaches which makes them a challenging environment for benthic biota. Moreover, the hostile nature of the intertidal beaches means it is unlikely that benthic invertebrate communities will change significantly from the current baseline by the time this pressure occurs (after 2053 in the absence of mitigation). Therefore, only a very small proportion of any intertidal benthic invertebrate population would be adversely affected by the presence of the HCDF and the associated localised reduction in intertidal habitat due to coastal squeeze. Moreover, the presence of the SCDF would maintain the current habitat in its present state for longer than would be the case in the absence of the proposed development.

22.7.354 As only a small proportion of any intertidal benthic invertebrate population and associated habitat would likely be adversely affected by the pressure, sensitivity is assessed as low.

22.7.355 The low impact magnitude and low sensitivity of intertidal benthic invertebrates to emergence regime changes indicate a minor adverse effect on this receptor. The effect is **not significant**.

ii. Beach landing facility

22.7.356 This section describes the impacts associated with the operation of the beach landing facility (BLF) during the operation phase. Pressures with the potential to affect marine benthic ecology receptors are the same as those identified for the construction phase, as provided in **Table 22.18**. For navigational dredging, pressures reoccur less frequently than during the construction phase as dredge activities are expected once every 5-10 years rather than annually. As a precautionary assumption, the impact magnitude applied during the construction phase is applied during the operation phase. Benthic invertebrate sensitivity and, therefore, the predicted effects are also precautionarily maintained for the operational phase assessment. It should be noted, however, that while repeated annual dredging during the construction phase would prevent a full recovery of the benthic invertebrate community in the affected area, recovery would be possible in between disturbances caused by the less frequent dredging campaigns during the operation phase (expected once every 5-10 years). The predicted effects of BLF activities on benthic ecology receptors during the operation phase are summarised in **Table 22.47.** The full impact assessment is consistent with that presented for the construction phase in **Section 22.7.b)** of this chapter.

Table 22.47: Summary of impact magnitude, sensitivity of benthic ecology receptors and the effects and significance of pressures associated with BLF activities during the operation (and construction) phase.

Pressure	Activities resulting in pressure.	Impact magnitude.	Sensitivity	Effect and significance.
Reprofiling of substratum.	Navigational dredging.	Low	Low / Medium	minor adverse (**not significant**)
Changes in suspended sediments.	Navigational dredging.	Medium	Not Sensitive.	minor adverse / minor beneficial (**not significant**)
Sedimentation rate changes.	Navigational dredging.	Low	Not Sensitive / Low	negligible / minor adverse (**not significant**)
Underwater noise and vibration.	Navigational dredging.	Low	Low	minor adverse (**not significant**)
Changes in wave exposure.	Navigational dredging and	Low	Not Sensitive.	negligible (**not significant**)

Pressure	Activities resulting in pressure.	Impact magnitude.	Sensitivity	Effect and significance.
	presence of structure.			
Physical change to another seabed type.	Presence of structure.	Low	Low	minor adverse (**not significant**)
Spread of non-indigenous species.	Presence of structure.	Very Low.	Low	negligible (**not significant**)

iii. Combined drainage outfall

22.7.357 This section describes the impacts associated with the operation of the CDO during the operation phase. The headwork is not expected to be decommissioned following the construction phase and would remain in place, but no discharges would occur. Pressures with the potential to continue to affect marine benthic ecology receptors are consistent with those already assessed in the construction phase, provided in **Table 22.48**.

Table 22.48: Summary of impact magnitude, sensitivity of benthic ecology receptors and the effects and significance of pressures associated with CDO activities during the operation (and construction) phase.

Pressure	Activities resulting in pressure	Impact magnitude	Sensitivity	Effect and significance
Spread of non-indigenous species.	Presence of structure.	Very Low.	Low.	negligible (**not significant**).

22.7.358 Operation phase pressures scoped out of further assessment as they have been deemed to have negligible effects on benthic receptors include:

- Water flow changes – The presence of the CDO head would result in localised changes in water flow. Current flow changes have not been calculated but are expected to be minor and restricted to a very small area (0.02ha) of the shallow subtidal zone near the structures, provided in **Appendix 20A** of this volume. It is deemed that such small-scale changes to hydrodynamics would have a negligible effect on benthic ecology receptors.

- Changes in wave exposure – It is expected that the influence of the CDO head on waves will be similar to that of a large nearshore boulder, with both the amount and spatial extent of the changes predicted to very minor in **Appendix 20A** of this volume. Such small-scale changes in wave exposure are assumed to have a negligible effect on benthic ecology receptors.

- Disturbance of surface sediments (scour) – While scour protection would limit scouring caused by the presence of the CDO head, sediments around the perimeter of the scour protection would likely be disturbed by 'edge scour', provided in **Appendix 20A** of this volume. Such small-scale scouring is assumed to have a negligible effect on benthic ecology receptors.

iv. Cooling water system

22.7.359 This section describes the impacts associated with the operation of the cooling water system (CWS) intakes and outfalls during the operation phase. Pressures with the potential to affect marine benthic ecology receptors resulting from the physical presence of the CWS infrastructure are the same as those identified for the construction phase, provided in **Table 22.49**.

22.7.360 Operation phase pressures with the potential for effects on ecological receptors are presented in **Table 22.50**.

Table 22.49: Summary of impact magnitude, sensitivity of benthic ecology receptors and the effects and significance of pressures associated with CWS activities during the operation (and construction) phase.

Pressure	Activities resulting in pressure	Impact magnitude	Sensitivity	Effect and significance
Spread of non-indigenous species[36].	Presence of structure.	Low	Low	Minor adverse (**not significant**)

Table 22.50: Pressures associated with CWS activities during the operation phase that have the potential to affect benthic ecology receptors.

Pressure	Activities resulting in pressure	Justification
Entrainment	Cooling water abstraction.	Potential to affect benthic invertebrates too small to be impinged. These organisms would become entrained within the CWS flow and

[36] The interrelationship between the availability of colonising space and thermal discharges is assessed in further detail in **Section 22.7.d)vi** of this chapter.

Pressure	Activities resulting in pressure	Justification
		pass through the condensers to be returned to the receiving waters via the CWS outfalls. Receptors would be exposed to mechanical, thermal and chemical pressures. The effects of entrainment on larvae recruitment (parimarily for *S. pinulosa*) is assessed.
Impingement	Cooling water abstraction.	Potential to affect larger benthic invertebrates that would be impinged on the drum screens and returned to the receiving waters via the FRR. Receptors would be exposed to mechanical pressure.
Temperature changes.	Cooling water discharges.	Potential to affect benthic ecology recptors by causing acute or chronic stress.
Synthetic compound contamination.	Discharges of total residual oxidants (TRO), chlorination by-products and hydrazine.	Potential to affect benthic ecology receptors through toxicological stress.
Abrasion / physical disturbance.	Maintenance operations.	Vessel anchoring and chain drag have the potential to affect benthic ecology receptors through the direct disturbance of organisms.

22.7.361 Operation pressures that have been scoped out of further assessment as they are considered to have negligible effects on benthic receptors include:

- Nutrient enrichment – The small quantities of nitrate and phosphate that may be discharged into the GSB via the CWS outfalls during the operation phase are expected to influence annual gross primary production by orders of magnitude below the natural variation in chlorophyll *a* biomass, provided in **Section 22.6.b)** of this chapter. Such small-scale changes to primary production would have negligible indirect effects on benthic ecology receptors.

- Water flow changes – The physical presence of the CWS intake and outfall heads would result in localised changes in water flow. Current flow changes have not been calculated estimated scour extents (a precautionary proxy for hydrodynamic changes) are expected to be restricted to a very small area (approximately 0.15ha for each head including the headwork area), provided in **Appendix 20A** of this volume. It is deemed that such small-scale changes to hydrodynamics would have a negligible effect on benthic ecology receptors. The effects of water abstraction resulting in impingement and entrainment of benthic taxa is assessed including the abstraction risk zone of the intake heads.

- Disturbance of surface sediments (scour) – While scour protection would limit scouring caused by the presence of the CWS intake and outfall heads, sediments around the perimeter of the scour protection would likely be disturbed by 'edge scour', provided in **Appendix 20A** of this volume. Such small-scale scouring is assumed to have a negligible effect on benthic ecology receptors.

Entrainment: cooling water abstraction

22.7.362 During cooling water abstraction, planktonic organisms too small to be impinged by the fine mesh drum and band screens (10mm mesh is anticipated[37]) would enter the cooling water system and be entrained; that is, pass through the power station cooling system before being discharged back into the environment via the CWS outfalls.

22.7.363 The proposed CWS intakes and outfalls are 3km offshore and are part of a waterbody with a 16km tidal excursion to the north and south. The predicted abstraction rate during maximum operational output is approximately $132m^3/s$. The daily volume abstracted is approximately 13% of the water exchanged each day and 1.35% of the total volume of the tidal excursion, provided in **Appendix 22G** of this volume. Entrained organisms at Sizewell C would be subject to a variety of physical and chemical stressors before they are returned to sea. These stressors include rapid fluctuations in pressure (up to +3 atmospheres), mechanical turbulence, a rapid increase in temperature of about 11.6°C and seasonal chlorination at an initial TRO dosage of 0.2mg/l.

22.7.364 The entrained organisms would experience thermal and contaminant concentrations in exceedance of regulatory standards. The volume of water abstracted is small relative to the tidal exchange, but the pressure would occur throughout the 60-year life cycle of the power station. Impact magnitude is therefore assessed as medium.

22.7.365 It should be noted that entrainment predictions apply specific assessments to determine population level effects on receptors. The assessments therefore incorporate both receptor sensitivity and impact magnitude. The long-term nature of the pressure is considered.

[37] Details of the entrainment assumptions and assessment considerations are provided in **Section 22.8d)** of this chapter; **Table 22:93**.

Benthic invertebrate sensitivity to entrainment

22.7.366 As entrainment would affect small planktonic organisms, the sensitivity assessment considers species that are bentho-pelagic as adults (i.e. spend part of their time in the water column) and species that are primarily benthic as adults but have planktonic eggs and/or larvae. Other benthic invertebrates are assumed to be insensitive to entrainment.

22.7.367 A Comprehensive Entrainment Monitoring Programme (CEMP) at Sizewell B recorded 49 invertebrate taxa in the cooling water system (Ref. 22.219). These have been arranged into groups for the purposes of the environmental impact assessment, based on similarities in planktonic life habit, taxonomy or form. Of these groups, bentho-pelagic taxa represent 13.4% of the total abundance, including gammarids (8.7%), mysids (3.4%) and cumaceans (1.3%). The larvae of taxa that are primarily benthic (mostly barnacles) represent 4.5%, while invertebrate eggs represent 2.5%. Most entrained invertebrate zooplankton were pelagic copepods (72.1%), which are considered as plankton receptors. Estimated effects of entrainment on invertebrates were calculated by adding mortality at the local population level within the volume of water at risk of abstraction by the power station (1.3% of the total volume of the bay and tidal excursion). Mysids and gammarids are used as proxies for the wider community of bentho-pelagic organisms[38], while barnacle larvae are used as a proxy for possible effects on benthic invertebrates with planktonic early life-stages, provided in **Appendix 22G** of this volume. The assessment considers the effects of primary entrainment within the tidal excursion of the GSB and uses available evidence to predict reductions in population size.

22.7.368 Juvenile mysids (*Metamysidopsis elongata*) have a natural mortality term of 0.06 / d (Ref. 22.82). Accounting for seasonal abundance relative to temperature dependent entrainment mortality, the average annual mortality of mysids during entrainment was estimated at 37.2%. In the absence of literature values, the natural mortality term for gammarids was assumed to be the same as mysids (0.06/d), and a conservative assumption of 100% mortality was applied to entrainment predictions, provided in **Appendix 22G** of this volume. This is likely to be highly precautionary, as survival of gammarids entrained at three power stations in the USA ranged from 73-96% (Ref. 22.85).

22.7.369 Entrainment assessments for mysid and gammarid population abundances considered behavioural factors such as swimming speeds and vertical position within the water column, allowing the risk of entrainment to be more

[38] Mysids and gammarids were also considered as proxies for the wider community in the plankton entrainment assessments.

accurately estimated. Reductions of 0.3% in the local mysid population and 1.4% in the local gammarid population are predicted in **Appendix 22G** of this volume.

22.7.370 Natural mortality rates for barnacle (*Balanus* sp.) larvae are assumed to be 0.145/d (Ref. 22.78), and a conservative assumption of 100% mortality was applied to entrainment predictions, provided in **Appendix 22G** of this volume. The entrainment assessment for larvae abundances considered behavioural factors such as the positive phototactic response of barnacle larvae (90% of all later stage barnacle nauplii are found near the surface), allowing entrainment risk to be more accurately estimated. A reduction of 0.7% in the local barnacle larvae population is predicted, provided in **Appendix 22G** of this volume. As benthic invertebrate eggs and larvae are generally part of the smaller zooplankton fraction (<4mm) within the GSB, provided in **Appendix 22B** of this volume, it is assumed that the mesh size used on the drum screen in the CWS system would not affect the level of population loss due to entrainment.

22.7.371 At the individual level, resistance of benthic ecology receptors to entrainment is expected to be low and high mortality rates are possible. However, large population sizes and tidal replenishment (tidal exchange rates are approximately 7.8-fold higher than the abstraction volume) mean losses are likely to be small at the population scale, with reductions in bentho-pelagic adult and pelagic larvae population abundances predicted to be indiscernible above natural variation. Benthic ecology receptors are, therefore, assessed as having low sensitivity to the pressure at the population level.

22.7.372 *Gammarus insensibilis* was present in low abundance in the north of the GSB in the shallows in front of the Sizewell station complex and no individuals were found near the CWS location. Additionally, the juvenile stages have direct development in a marsupium (Ref. 22.220), therefore exposure to entrainment is low. The species is therefore considered as *Not Sensitive* to the pressure.

22.7.373 Entrainment associated with cooling water abstraction for the proposed development is predicted to have a minor adverse effect on benthic invertebrates. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to entrainment

22.7.374 A stable reef requires a sustained supply of larvae from the plankton to support the accretion and development of existing reefs (Ref. 22.221). Activities that affect the supply of *S. spinulosa* larvae or their recruitment success could therefore have an indirect effect on *S. spinulosa* reefs. Potential effects of entrainment on *S. spinulosa* consider two aspects:

- **Loss of seed stock:** The potential for entrainment mortality to reduce the overall standing stock of *S. spinulosa* eggs and planktonic larvae, and thus potential recruits is assessed.

- **Effects on recruitment:** The Unit 1 intake structures would be located within an area that supports *S. spinulosa* reef like formations. The potential for entrainment to remove larvae during the recruitment stage is considered.

22.7.375 With respect to effects on the standing stock of larvae, the eggs and larvae of *S. spinulosa* would be entrained along with other small planktonic organisms. The risk of egg entrainment would likely be particularly high during spawning by *S. spinulosa* that inhabit the area around the southern intakes. Estimates of entrainment mortality rates and population reductions are not available for *S. spinulosa* eggs and larvae. However, various aspects of the development and behaviour of *S. spinulosa* (e.g. broadcast spawner, high fecundity, long planktonic larval phase, low self-recruitment) indicate high dispersal potential, provided in **Appendix 22C** of this volume. *Sabellaria spinulosa* larvae have been reported during plankton surveys in the waters off Sizewell inshore and offshore of the Sizewell Dunwich Bank indicating a wide distribution (Ref. 22.25). As such, larval supply within the GSB is likely to be supported not only by the population within the GSB but also populations in the wider Suffolk area, where *S. spinulosa* is one of the most abundant benthic invertebrate species (Ref. 22.127; 128). As the water abstraction rate would represent a small proportion of the water exchanged with the wider southern-North Sea, the supply of *S. spinulosa* eggs and larvae within the GSB is unlikely to be substantially reduced by entrainment. Precautionary[39] population reductions of the order predicted for the larvae of other benthic invertebrates (1%) are considered likely, provided in **Appendix 22G** of this volume. *Sabellaria spinulosa* reef is precautionarily assessed as having low sensitivity to reductions in the standing stock of eggs and larval caused by entrainment.

22.7.376 With respect to effects on recruitment to reefs adjacent to the southern CWS intakes, it is possible that abstraction would disrupt this process. After approximately 6-7 weeks in the plankton, *S. spinulosa* larvae start to settle if they encounter suitable habitat with conspecific cues (Ref. 22.133). As the southern CWS intakes would be located within an area of suitable habitat, it is possible that entrainment could locally reduce the number of settling larvae and resulting in less recruitment to *S. spinulosa* reefs in the immediate vicinity of the intake surfaces. However, the high densities of *S. spinulosa* larvae

[39] A reduction of 0.7% in the local barnacle larvae population is predicted assuming 100% entrainment mortality (**Appendix 22G**)

(up to 15,000 ind.m^3) in plankton samples collected at the Sizewell B intake (Ref. 22.25) suggests that entrainment for Sizewell C is unlikely to appreciably deplete the surrounding water of potential recruits.

22.7.377 The abstraction risk zone of the Sizewell C intake heads varies with the intake velocity. At an intake velocity of 0.05m/s the abstraction risk zone extends from approximately 5.5m to 7m from the intake surfaces when the tide is running but reduces to 3.7m or less at tidal velocities of less than or equal to 0.2m/s (Ref. 22.24). It is therefore likely that any effects on *S. spinulosa* reef quality due to impoverished recruitment, would be limited to a narrow-elongated area in the immediate vicinity of intakes.

22.7.378 *Sabellaria spinulosa* reefs are assessed as having low sensitivity to reductions in recruitment caused by entrainment.

22.7.379 Entrainment associated with water abstraction for the proposed development is predicted to have a minor adverse effect on the *S. spinulosa* reef at the offshore Coralline Crag only. The effect is **not significant** based on the assessment outcome and the factors described in **Table 22.38** for determining significance of effects on a habitat of principle importance.

22.7.380 Monitoring of the *S. spinulosa* reef extent on the offshore Coralline Crag is recommended periodically during the operational phase as described in **Section 22.7.c** of this chapter.

The effects of climate change on entrainment predictions

22.7.381 The proposed development has a long operational lifespan and the potential warming of sea temperatures due to climate change could have implications for entrainment mortality. Mortality due to temperature shock for the eggs and larvae of many fish and invertebrates increases rapidly once maximum absolute temperatures exceed 30°C (Ref. 22.86; 87). The thermal death point or upper incipient lethal temperature has not commonly been calculated for invertebrates, however, an upper incipient lethal temperature of 30 to 33°C (regardless of latitude) is typical (Ref. 22.88).

22.7.382 Warming sea temperatures could cause entrainment temperatures (ambient + 11.6°C uplift) to exceed upper incipient lethal temperature limits for longer periods of the year than is expected in the present day. Future entrainment temperatures were considered for the following scenarios accounting for predicted future warming based on UKCP09[40]; SRES A1B, provided in **Appendix 21E** of this volume:

[40] Future sea temperatures are not included in the current UKCP18 marine climate predictions.

- **2030:** The decade during which the proposed development is expected to be operational (with operation anticipated to be from approximately 2034). The scenario includes both stations running simultaneously.

- **2055:** The hypothetical last likely date for Sizewell B to be operational. The scenario includes both stations running simultaneously.

- **2085:** Towards the end of the operational life of Sizewell C.

- **2110:** The hypothetical extreme date for Sizewell C to remain operational prior to decommissioning.

22.7.383 Mean daily entrainment temperatures are predicted to exceed 30ºC for 57 days by 2030 and 100 days per year by 2055. Following the end of operation of Sizewell B, entrainment temperatures are predicted to exceed 30ºC for 92 days by 2085 and 105 days by 2110. Higher entrainment mortality rates would likely occur as result of exceeding the temperature threshold for more days per year. However, thermal lethality is highly species specific and adaptation to future climate conditions and potential species distribution shifts may influence the ability of biota to tolerate thermal stress (Ref. 22.87), thus influencing entrainment mortality rates.

22.7.384 Increases in temperature may also lead to small increases in the duration of chlorination. The seasonal chlorination strategy for the proposed development involves chlorination during the period of the year when water temperatures exceed 10ºC. In 2030, predicted water temperatures at the Sizewell C intakes are predicted to exceed 10ºC for 219 days per annum. Towards the end of the operational lifespan of the proposed development, in 2085, climate change is predicted to result in temperatures exceeding 10ºC for a total of 244 days per annum, provided in **Appendix 21E** of this volume. An extension to the seasonal chlorination period could potentially increase the annual mortality rate of entrained taxa.

22.7.385 Current entrainment estimates predict very small reductions in the populations of bentho-pelagic invertebrates and the pelagic eggs and larvae of taxa that are primarily benthic as adults. This primarily reflects the small proportion of individuals that would be exposed to the pressure rather than high rates of survival. Indeed, a highly conservative 100% mortality rate was assumed for the barnacle larvae and mysids, on which assessments were largely based. Therefore, while actual mortality rates during entrainment may increase slightly due to climate change, the assessment of effects would remain unchanged due to the conservative nature of current assumptions. The effects of entrainment on benthic invertebrates and *S. spinulosa* reef would therefore remain minor adverse and **not significant**.

Impingement: cooling water abstraction

22.7.386 During cooling water abstraction, larger organisms would be removed before water enters the CWS to prevent blocking of the condenser tubes. These organisms would be removed through impingement on drum screens, which are expected to have a 10mm mesh size as Sizewell B. Following impingement, organisms would be returned to sea via the FRR system.

22.7.387 Details of the impingement prediction assumptions and assessment considerations are provided in **Section 22.8.d)** of this chapter**; Table 22.108**. A predicted cooling water abstraction rate of 132m^3/s would result in approximately 1.3% of the tidal volume passing through the power station each day. Specific pressure benchmarks for impingement do not exist and the benchmark value for 'death or injury by collision' of 0.1% of an average tidal volume passing through artificial structures is applied for context (Ref. 22.12). Thermal and chemical impacts would be mitigated through engineering designs and the primary pressures for impinged organisms would be mechanical stress. Water abstraction and impingement of organisms would occur for the operational lifetime of the proposed development. Impact magnitude is assessed as medium.

Benthic invertebrate sensitivity to impingement

22.7.388 Seven benthic invertebrate species that were recorded during a CIMP at Sizewell B, provided in **Appendix 22C** of this volume, are the focus of the assessment. Potential losses of commercially important species are considered by estimating impingement in relation to the annual local fishery catch, provided in **Appendix 22I** of this volume. While *Sabellaria spinulosa* reefs are present within the GSB, this receptor was scoped out of the assessment as the sessile, attached organism that forms the reef is not susceptible to impingement. Annual predictions for species at Sizewell C impingement were made by fitting a statistical model to the CIMP, data, raised for the increase in abstraction rate at Sizewell C compared to Sizewell B, provided in **Appendix 22I** of this volume.

22.7.389 All relevant benthic invertebrates within the GSB were determined to be not sensitive to impingement, provided in **Table 22.51**. While some acute effects are possible at the individual level, most impinged organisms are expected to be returned to the receiving waters alive. Moreover, benthic invertebrate taxa that would be affected by this pressure are generally expected to be impinged in very low numbers. Impingement of species with local commercial value is predicted to be very small in relation to the total annual catch of fisheries (0.01-0.62%; **Table 22.51**).

22.7.390 As impact magnitude is medium and benthic invertebrates are not sensitive to this pressure, impingement is predicted to have a minor adverse effect on benthic receptors. The effect is **not significant**.

Table 22.51: Sensitivity of key benthic invertebrate taxa recorded during impingement monitoring at Sizewell B.

Key taxa	Evidence	Sensitivity
Cancer pagurus (brown crab)	One of the most commonly impinged benthic invertebrate taxa during impingement monitoring at Sizewell B, provided in **Appendix 22C** of this volume. Due to its importance for local fisheries, the species has been considered as part of the predicted annual impingement assessment for selected species at Sizewell C. Crustaceans are robust organisms, so live animals are expected to be returned to the receiving waters through the FRR. The predicted annual impingement (in equivalent adult value EAV[41], numbers) is 4,940 individuals. Predicted impingement EAV (weight) is 2.5 tons (t), which equates to 0.55% of the local fishery catch, provided in **Appendix 22I** of this volume.	Not Sensitive.
Crangon crangon (brown shrimp)	The most abundant benthic invertebrate collected during the impingement monitoring programme at Sizewell B, provided in **Appendix 22C** of this volume. As with *C. pagurus*, its importance for local fisheries means that it has been considered as part of the predicted annual impingement assessment for selected species at Sizewell C. Crustaceans are robust organisms, so live animals are expected to be returned to the receiving waters through the FRR. Indeed, experiments found that the survival rate for *C. crangon* recovered from the Sizewell B system was 94.3% (Ref. 22.222). The predicted annual impingement (EAV, numbers) is 3,310,851 individuals. Predicted impingement EAV (weight) is 4.3t and this equates to 0.62% of the local fishery catch, provided in **Appendix 22I** of this volume. Fisheries landing values are considered to represent a small proportion of the population, as such losses at the population level are considered negligible.	Not Sensitive.
Homarus gammarus (European lobster)	Lobster are a large crustacean that grows up to 50cm long. The species has a thick exoskeleton and the capacity to regenerate limbs by successive moults. These characteristics make it robust to the physical effects of impingement. Only four individuals were caught during impingement monitoring at Sizewell B,	Not Sensitive.

[41] The EAV calculation is a method to determine the proportion of a known size distribution of juvenile fish that will survive to adulthood and spawn. The method uses growth and natural mortality at length as its basis.

Key taxa	Evidence	Sensitivity
	suggesting that few individuals are likely to be impinged during the operation of the proposed development. However, this may be partly due to the low abundance of the species within the GSB. While locally uncommon, *H. gammarus* is common in the southern North Sea. The predicted annual impingement (EAV, numbers) is 26 individuals. Predicted impingement EAV (weight) is 0.01t and this equates to 0.01% of the local fishery catch, provided in **Appendix 22I** of this volume. Fisheries landing values are considered to represent a small proportion of the population, as such losses at the population level are considered negligible.	
Pandalus montagui (pink shrimp)	Widespread and abundant within the GSB. The species represented 11% of the total abundance of invertebrates collected during impingement monitoring at Sizewell B, provided in **Appendix 22C** of this volume. No landings were recorded for the species in the fishing area around the GSB, so the species was not included in predicted annual impingement assessments provided in **Appendix 22I** of this volume. However, similar to *C. crangon* and other crustaceans, the species is likely be robust with regard to the physical effects of impingement.	Not Sensitive.
Abra alba (white furrow shell)	Present throughout the year in the GSB, with high abundance between the months of June and October, provided in **Appendix 22C** of this volume. *Abra alba* has a brittle shell, which may provide limited protection to impinged individuals that are forced against the drum screen. However, less than 100 individuals were recorded during impingement monitoring at Sizewell B. Therefore, a negligible proportion of the local population is expected to be impinged during the operation of the proposed development.	Not Sensitive.
Mytilus edulis (common mussel)	Found throughout the GSB; however, abundances are low and most individuals recorded during surveys were juveniles, provided in **Appendix 22C** of this volume. The species were recorded as part impingement monitoring program at Sizewell B (<0.01%) possibly the result of detachment of fouling organisms. Moreover, *M. edulis* is commonly found on the rocky shores of open coasts (Ref. 22.223), indicating that the species is robust to physical disturbance. The species is therefore likely to be resistant to physical contact with the drum screen and would likely be alive when returned to the receiving waters through the FRR.	Not Sensitive.
Ophiura ophiura (brittlestar)	Highly abundant (up to 750 individuals per 1,000m^2) in the GSB, particularly between March and September in **Appendix 22C** of this volume. Less than 300 individuals, identified either as *O. ophiura* or simply as brittle stars (Ophiuroidea), were recorded during	Not Sensitive.

Key taxa	Evidence	Sensitivity
	impingement monitoring at Sizewell B. The abundance of ophiuroids near the Sizewell C intake location is similar to what is found near the Sizewell B intake, so the impingement of *O. ophiura* due to the operation of the proposed development is expected to be very low in relation to its population size in the GSB. Ophiuroids are fragile but can readily regenerate damaged or lost appendages unless all arms are lost. Therefore, of the few individuals impinged, many would likely be alive when returned to the receiving waters through the FRR.	

Temperature changes: cooling water discharges

22.7.391 Cooling water would be discharged from the outfalls at 11.6°C warmer than the ambient temperature of the receiving waters and at a rate of 132m^3/s. The thermal effluent would be buoyant, thus resulting in thermal stratification of the water column in the area surrounding the outfalls. As discharges cool, differences in buoyancy decrease and tidal mixing would overcome vertical stratification. At this point, heat dissipates and causes a general warming of the receiving waters. The rate of mixing is determined by the tidal flow and the level of turbulence within the system. The interaction between strong tides (>1m/s) and the bathymetry of the GSB would shape the plume profile.

22.7.392 There are currently no uniform regulatory standards in place to control thermal loads in transitional and coastal waters (Ref. 22.87). However, recommended thermal standards exist for SACs, SPAs and WFD waterbodies. Unlike chemical standards, which are typically based on concentrations that induce biological responses, thermal standards are not necessarily ecologically meaningful. As such, thermal standards are used only as trigger values for further investigation of potential ecological effects.

22.7.393 WFD thermal standards are considered the most appropriate for assessing the impact magnitude of temperature changes due to cooling water discharges for benthic ecology receptors. Temperatures at the seabed and in surface waters are considered because of their relevance for adult benthic invertebrates and for the pelagic eggs and larvae of benthic invertebrates, respectively.

22.7.394 The areas of exceedance of WFD standards for absolute water temperature and thermal uplifts for Sizewell B alone, Sizewell B and Sizewell C operating together and Sizewell C alone are presented in **Table 22.32**. The latest operational phase for Sizewell B is assumed to be 2055, after which point discharges would come from Sizewell C only. **Table 22.52** presents increase in exceedance of thermal standards when Sizewell C and Sizewell B operate concurrently (i.e. the additional impact of Sizewell C above the operating baseline) and of Sizewell C alone.

Table 22.52: Water Framework Directive thermal standards and areas of exceedance for absolute temperature and temperature change thresholds at the seabed and sea surface when the operation of Sizewell C adds to the thermal plume of Sizewell B and when Sizewell C is in operation alone (grey boxes = not applicable).

	Absolute water temperature (as a 98th percentile)			Temperature change (as a 98th percentile)		
Status	**Temp.**	**Area**		**Temp.**	**Area**	
		> Sizewell B baseline.	**Sizewell C alone.**		**> Sizewell B baseline.**	**Sizewell C alone.**
Good				> 2ºC	Seabed 4,114ha.	Seabed 171ha.
					Surface 5,456ha.	Surface 1,551ha.
Moderate	> 23ºC	Seabed 16.8ha.	Seabed 0ha.	> 3ºC	Seabed 885ha.	Seabed 0ha.
		Surface 44.7ha.	Surface 0ha.		Surface 927ha.	Surface 306ha.
Poor	> 28ºC	Seabed 0ha.	Seabed 0ha.			
		Surface 0.11ha.	Surface 0ha.			

22.7.395 Absolute temperature would not exceed 28ºC at the seabed, which is the thermal standard associated with 'poor' thermal status. At the sea surface, a negligible area (0.11ha) is expected to exceed this temperature due to operation of the proposed development when Sizewell B is also in operation. Areas of 16.8ha at the seabed and 44.7ha at the sea surface are expected to exceed 23ºC (as a 98th percentile) due to discharges from the proposed development when Sizewell B is operational, constituting a 'moderate' status, provided in **Figure 21.5** of **Chapter 21** of this volume. No area would exceed 23ºC when the proposed development is operated alone.

22.7.396 In terms of temperature change, thermal uplifts of >2ºC would occur over an additional area of 4,114ha at the seabed and 5,456ha at the sea surface (as a 98th percentile) due to discharges from the proposed development when Sizewell B is operational, resulting in 'good' status. These areas would be reduced to 171ha and 1,551ha, respectively, for operation of the propose development alone. Smaller areas of 885ha and 927ha would experience uplifts of >3ºC at the seabed and sea surface, respectively, resulting in 'moderate' thermal status. However, when only the proposed development is in operation, no area of the seabed would experience an uplift of >3ºC, while the area that would experience this uplift at the sea surface would be 306ha.

22.7.397 The above outputs are from model runs for instantaneous thermal fields at hourly resolution for the period of one year. Accordingly, the 98th percentile represents the cumulative area of individual cells (25x25m) within the model domain that exceed a threshold temperature for a total of 7.3 days within a year. The points in time when a cell exceeds thresholds are not necessarily consecutive (they could be days or months apart) and different cells may exceed thresholds at different times. Therefore, the spatial extents presented in **Table 22.32** do not represent the footprint of the thermal plume at a particular point or period in time, but rather the total area that exceeds thermal thresholds for at least 7.3 days over the course of a year.

22.7.398 Impact magnitude is assessed assuming the worst-case scenario of concurrent cooling water discharges from the proposed development and Sizewell B. The footprint of the thermal uplift plume is larger than that of the absolute temperature plume. A moderate amount of change (+3°C) is expected over an area of almost 1,000ha at the seabed and sea surface due to discharges from the proposed development. Cooling water discharges would occur throughout the operational lifetime of the proposed development, though discharges from Sizewell B are expected to cease in 2055. At this point, a smaller temperature uplift (2°C) would occur over a smaller area at the seabed (<200ha), while at the sea surface the area exceeding a 3°C would be substantially reduced (306ha). Noting the detachment of thermal standards from biological thresholds and the precautionary use of the 98th percentile in assessing the spatial extent of the thermal plume, impact magnitude is assessed as medium.

Benthic invertebrate sensitivity to temperature changes

22.7.399 Benthic invertebrates are ectotherms. As their body temperature is externally regulated, they are subjected to the ambient thermal conditions, which affects their behaviour and physiology (Ref. 22.224). The potential effects of cooling water discharges on benthic organisms fall under three categories (Ref. 22.87):

- Chronic effects due to long-term increases in mean temperature on biological processes (growth, reproduction).
- Acute effects where absolute temperatures approach lethal levels.
- Stress caused by short-term fluctuations associated with the passage of thermal fronts.

22.7.400 As biological response to increases in temperature are species-specific, assessments consider the effect on survival and life history of the key taxa identified in the GSB, see **Appendix 22C** of this volume. Pelagic eggs and larvae of benthic invertebrates are considered as a separate sub-receptor of this pressure. The assessment draws on experimental and observational evidence relating to the acute and chronic response of organisms to temperature uplifts, as well as documented latitudinal and depth distributions of species. Regarding latitudinal distributions, a species was considered less sensitive to mean thermal uplifts if its range extends to low latitudes (i.e. warm waters) and more sensitive if its range is restricted to high latitudes (i.e. cold waters). Regarding depth distributions, a species was considered less sensitive to temperature fluctuations if it inhabits shallow waters (i.e. intertidal and shallow subtidal zones, where temperatures fluctuate daily) and more sensitive if it only inhabits deeper waters (where temperature is relatively stable).

22.7.401 The sensitivity of benthic invertebrates within the GSB to temperature changes due to cooling water discharges ranged from not sensitive to low, as set out in **Table 22.53**. There is little evidence that acute effects are likely. However, some cold-water species, such as the bivalve *L. balthica*, are predicted to incur chronic effects associated with reduced growth and/or reproduction over a limited spatial area, while species that prefer relatively warm water, such as shrimp *C. crangon*, may experience increases in physiological processes. Differences in species responses to the thermal plume may lead to changes in community composition. However, the broad similarity of benthic invertebrate community composition inside and outside the footprint of the thermal plume from Sizewell B, provided in **Appendix 22C** of this volume, suggests that any changes would be very minor. Such minor changes are unlikely to alter the functioning of the benthic ecosystem within the GSB.

22.7.402 As impact magnitude is medium and the sensitivity of benthic invertebrates to this pressure ranges from not sensitive to low, temperature changes associated with cooling water discharges are predicted to have a minor adverse to minor beneficial effects on benthic invertebrate receptors depending on the taxon. The effect is **not significant**.

Table 22.53: Sensitivity of key benthic invertebrate taxa and pelagic eggs and larvae to temperature change due to cooling water discharges from the cooling water system outfalls.

Key taxa	Evidence	Sensitivity
Abra alba (white furrow shell)	Distribution extends from Norway to the Mediterranean (Ref. 22.225) and from the infralittoral zone to about 60m depth, provided in **Appendix 22C** of this volume. The broad latitudinal range of the species suggests resistance to increases in mean temperature, while its presence in the intertidal zone implies resistance to temperature fluctuations. These suggestions are supported by the persistence of *Abra alba* populations in vicinity of two nuclear power stations (Penly and Graveline) on the French coast (Ref. 22.226; 227). The species has a short life span, rapid growth, long larval stage and can spawn multiple times within a year, which makes it an opportunistic taxon as well as a pioneer species capable of rapidly colonising muddy-sand substrate previously disrupted (Ref. 22.228).	Not Sensitive.
Ensis spp. (razor shell)	Distribution extends from Norway to the Mediterranean and west Africa, suggesting tolerance to increases in mean water temperature within the GSB. Moreover, *Ensis* spp. is a burrow-dweller, provided in **Appendix 22C** of this volume, and can adapt its behaviour to temperature fluctuations, as observed during extreme cold events (Ref. 22.229). No mortality is expected due to cooling water discharges during the operation of the proposed development. Temperature is an important trigger for gametogenesis and spawning, with higher temperatures tending to extend the spawning period and cause a greater number of gametes to be released (Ref. 22.230; 231), as is observed in southern populations (Ref. 22.231). The effects of potential changes to spawning within the zone of influence are unclear; however, the widespread distribution of the species in the GSB and southern North Sea indicate that population-level effects are unlikely.	Not Sensitive.
Limecola balthica (Baltic tellin)	Distribution extends along the European coasts from the White Sea to Portugal, but has contracted at its southern limit due to warming (Ref. 22.232). The species appears to be sensitive to warmer Winter temperatures (Ref. 22.233), which are associated with reduced fecundity , earlier and reduced recruitment (Ref. 22.234; 235) and reduced condition (Ref. 22.236). Experiments showed that a 2.5°C increase in Winter temperatures led to fewer eggs being produced, while growth and survival were impaired at temperatures >20°C under laboratory conditions (Ref. 22.234; 237). Chronic effects on individuals within the zone of influence are possible. However, the species has high fecundity (Ref. 22.238) and there is potential for recruitment from source populations outside the zone of influence. Indeed, *L. balthica* is a characteristic taxon within the fine muddy sands of the Suffolk coast (Ref. 22.239) and a small proportion of the local population would be exposed to the thermal plume.	Low
Mytilus edulis (common mussel)	Distribution extends from the Arctic to the Mediterranean, suggesting tolerance to increases in mean water temperature within the GSB. Few mussel beds are found along the Suffolk coast and most of the individuals found in the GSB are juveniles, possibly due to the limited availability of hard substrate for attachment, provided in **Appendix 22C** of this volume. Experiments show that elevated	Not Sensitive.

Key taxa	Evidence	Sensitivity
	temperature does not affect the growth of the species, as it adapts its metabolic and feeding rate to temperature change (Ref. 22.240; 241). *Mytilus edulis* populations around Great Britain have a thermal tolerance limit of about 29°C (Ref. 22.242; 243).	
Nucula nitidosa and *N. nucleus* (bivalve mollusc).	Direct evidence on the tolerance of this genus to elevated temperature is scarce. The distributions of *N. nitidosa* and *N. nucleus* extend from south Norway to Africa, suggesting tolerance to increases in mean water temperature within the GSB. On the other hand, both species are restricted to deeper subtidal areas of the GSB, suggesting lower tolerance to temperature fluctuations than would be implied if these species were found in intertidal or shallow subtidal areas. Indeed, a negative correlation between depth and thermal tolerance has been demonstrated for circalittoral bivalves (Ref. 22.244). As both species are common in the subtidal muddy sands of the Suffolk coastal region (Ref. 22.245), individuals within the zone of influence constitute a small proportion of the local population. Both species also have high fecundity (Ref. 22.246). Therefore, if reproduction is inhibited by warming, recruitment could occur via source populations outside the zone of influence.	Low
Buccinum undatum (common whelk).	Widely distributed throughout the North Atlantic. An experiment on the thermal tolerance of the species shows adaptation to temperatures above those currently experienced in its natural environment (Ref. 22.247). Indeed, its abundance increased in an area under the influence of the thermal plume from a nuclear power station in Bradwell, with the species recorded very close to the outfall structure (Ref. 22.248). However, the thermal tolerance observed during experiments comes at an energetic cost, with warming reducing the number of offspring (Ref. 22.247). Few *B. undatum* individuals were collected in the GSB during baseline surveys, provided in **Appendix 22C** of this volume, although the gears used in the surveys were not selected to target this species. The species is, however, common in the southern North Sea. Therefore, a small proportion of the local population would be exposed to this pressure. Moreover, the mobility of the species would allow it to migrate in or out of the zone of influence according to its temperature preference.	Not Sensitive.
Cancer pagurus (brown crab).	Distribution extends from Norway to west Africa, suggesting tolerance to increases in mean water temperature within the GSB. The species is also found from intertidal to subtidal areas (90m depth), suggesting tolerance of temperature fluctuations and a wide thermal range. These suggestions are reaffirmed by an experiment which found that the first signs of heat stress occurred at 31°C for crabs collected in the North Sea near Hartlepool during summer and 23°C for crabs collected during Winter (Ref. 22.249). Another experiment showed increased thermal tolerance of *C. pagurus* following heat-shock (1h exposure to lethal temperature) (Ref. 22.250). The species is highly mobile and undertakes migration between inshore and offshore areas on an annual basis (Ref. 22.251). Heat stress could therefore be avoided by adult movement if physiological tolerance is exceeded.	Not Sensitive.
Homarus gammarus	Distribution extends from Norway to the Mediterranean, suggesting tolerance to increases in mean water temperature within the GSB. Elevated temperature tends to increase moult frequency and, therefore, enhance the growth of this species, as well as bringing forward spawning period (Ref. 22.252). A high mortality rate has been observed for juveniles kept in tanks at 28°C (Ref. 22.253); however, areas predicted to exceed 28°C in the GSB are <1ha at the seabed. Moreover, the high mobility of *H. gammarus* would allow it to avoid	Not Sensitive.

Key taxa	Evidence	Sensitivity
(European lobster)	exposure to such temperatures and access alternative areas that are within its preferred temperature range. While this would lead to a small, very localised reduction in population density, it would likely also prevent any acute or chronic effects on the species.	
Crangon crangon (brown shrimp)	The population in the GSB is part of a larger interconnected southern North Sea population, extending from Spurn Head to Dungeness and including the Dutch and Belgian coasts (Ref. 22.254). The species is adaptable to a wide range of environmental temperatures due to both physiological (i.e. seasonal plasticity in thermal preference) and behavioural (i.e. seasonal offshore migration) adaptations (Ref. 22.224; 255). The species may even benefit from warming inside the zone of influence, as higher recruitment has been observed under warmer mean temperatures from January through August (Ref. 22.256). However, as a very small proportion of the population would be exposed to thermal uplifts, any effects on individuals would likely be undetectable at the population level.	Not sensitive.
Pandalus montagui (pink shrimp)	Distribution extends from Greenland and Iceland to the British Isles. The species is common in the GSB and the wider North Sea, provided in **Appendix 22C** of this volume, but as the GSB is close to the southern limit of the species it likely has a low tolerance to increases in temperature. The species is, however, highly mobile and has been observed moving to reach its preferred temperature range (Ref. 22.257). Therefore, behavioural avoidance of exposure to lethal temperatures within the GSB is possible. This would lead to a very localised reduction in population density. It is unclear whether any individuals would suffer mortality as a result of temperature uplifts, but any such effect would likely be restricted to a very small proportion of the local population.	Low
Bathyporeia elegans (sand hopper, amphipod)	Distribution extends from Norway to west Africa and from the infralittoral zone to 40m depth (Ref. 22.225). These observations suggest a tolerance to increases in mean temperature within the GSB as well as temperature fluctuations. The growth rate of amphipods is regulated by temperature, with moulting frequency increasing in warmer water. Amphipods reach sexual maturity after a fixed number of moults and, therefore, an increase in temperature could hasten the onset of sexual maturity for individuals within the zone of influence of the thermal plume. The consequences of early recruitment on the population are unclear; however, no mortality is expected. *Bathyporeia elegans* is typical of sandbank habitats along the Suffolk coast, where it can occur in high abundances (Ref. 22.258; 259). A small proportion of its local population would therefore be exposed to this pressure.	Not Sensitive.
Gammarus insensibilis (lagoon sand shrimp).	Distribution extends from England to the Mediterranean, with the Humber Estuary considered to be the northern limit of the species (Ref. 22.220). *Gammarus insensibilis* is relatively common in waters to the south of the GSB, suggesting that it prefers relatively warm water. Moreover, the species primarily inhabits saline lagoons, including those near the GSB (Ref. 22.260), where it experiences temperature and salinity fluctuations to which organisms adapt by changes in reproductive strategies (Ref. 22.220). The thermal plume would not influence the saline lagoons, but individuals found offshore occur within the modelled footprint of the thermal plume, provided in **Appendix 22C** of this volume. The latitudinal distribution and habitat preferences of this species suggest that it is likely to be tolerant of this pressure.	Not Sensitive.

Key taxa	Evidence	Sensitivity
Corophium volutator (mud shrimp)	Distribution extends from Norway to the Mediterranean and from the intertidal zone to the sublittoral fringe. These observations suggest a tolerance to increases in mean temperature within the GSB and temperature fluctuations. Indeed, an ability to tolerate chronic temperature uplift and survive temperatures up to 30-35°C has been recorded (Ref. 22.261). No mortality is expected due to cooling water discharges within the GSB. Reproduction may be inhibited at higher temperatures, with greater breeding success observed at 15°C than at 23°C (Ref. 22.262). However, *C. volutator* is one of the most abundant organisms on estuarine mudflats in Suffolk and has a great potential for recovery (Ref. 22.263). Therefore, any effects of temperature uplifts on reproductive output within the zone of influence would likely be undetectable at the population level.	Not Sensitive.
Nephtys hombergii (catworm)	Distribution extends from the Barents Sea to the Mediterranean, suggesting a tolerance to increases in mean temperature within the GSB. Moreover, *N. hombergii* is commonly found in the first few centimetres of surface sediment in the lower intertidal areas, suggesting a tolerance to extreme temperature fluctuations (Ref. 22.264). Indeed, the species has been found to survive summer temperatures of 30-35°C (Ref. 22.265). The production of a spawning hormone does, however, appear to be initiated at low temperatures (Ref. 22.266). Therefore, while no mortality is expected, an increase in Winter temperature due to cooling water discharges in the GSB could reduce the fecundity of *N. hombergii* within the zone of influence (Ref. 22.267). The widespread distribution of the species in the GSB and southern North Sea indicate that a small proportion of its population would be exposed to this pressure. Moreover, recruitment within the zone of influence could occur via the pelagic larvae of this species sourced from outside the zone of influence.	Not Sensitive.
Notomastus spp. (bristleworm)	Distributed along most European coasts and is found in the shallow subtidal zone, where temperature can show large fluctuations. The taxon is found in lagoons in the Mediterranean where temperatures regularly exceed 30°C (Ref. 22.268). Moreover, *Notomastus* spp. has high fecundity and is an opportunist, with the ability to rapidly increase in abundance if conditions become unfavourable to more competitive species (Ref. 22.268).	Not sensitive.
Scalibregma inflatum (polychaete)	Direct evidence on the tolerance of this species to elevated temperature is scarce. However, its distribution extends from the Arctic to all European coasts, suggesting a tolerance to increases in mean temperature within the GSB. The species' ability to migrate vertically within its tube, which can extend to a depth of 13cm below the sediment surface (Ref. 22.269), is likely to confer a tolerance to temperature fluctuations. *Scalibregma inflatum* is a widespread and numerically dominant benthic invertebrate within the GSB and is widely distributed in the southern North Sea. It has high fecundity, as observed in numerous pronounced recruitment events during baseline surveys, provided in **Appendix 22C** of this volume. Therefore, in addition to its apparent tolerance to cooling water discharges within the GSB, only a small proportion of the local population would be exposed to the pressure, and any localised declines in population density would likely be followed by rapid recolonization sourced from outside the zone of influence.	Not Sensitive.
Spiophanes bombyx	Direct evidence on the tolerance of this species to elevated temperature is scarce. It is found on most British coasts and has been recorded in the Mediterranean, suggesting a tolerance to increases in mean temperature within the GSB. It also inhabits sediments from	Not Sensitive.

Key taxa	Evidence	Sensitivity
(bristleworm)	the infralittoral down to 60m depth, suggesting tolerance to temperature fluctuations and a wide thermal range. Additionally, *S. bombyx* is an opportunistic species with a short life span, high dispersal potential and high reproductive rates (Ref. 22.270). It is often found during the early successional stages of variable, unstable habitats that and is quick to colonize following perturbation (Ref. 22.271).	
Sabellaria spinulosa (Ross worm)	Distribution extends from Iceland to the Mediterranean and the Indian Ocean, suggesting a tolerance to increases in mean temperature within the GSB. The species is also found in the shallow subtidal zone, suggesting a possible tolerance to temperature fluctuations. Indeed, its life strategy allows it to tolerate environmental fluctuations by having a high rate of reproduction during favourable conditions (Ref. 22.272). There are currently no published laboratory studies on the thermal tolerance of *S. spinulosa*; however, the species has been identified as a warm water species and is more sensitive to extreme cooling events than warming events (Ref. 22.167). It has been suggested that warming is likely to facilitate a northward expansion of its distribution, provided it can find suitable hard substrate (Ref. 22.273).	Not Sensitive.
Ophiura ophiura (britlestar)	Distribution extends from Norway to the Mediterranean and from the lower intertidal to about 200m. These observations suggest a tolerance to increases in mean temperature within the GSB and temperature fluctuations. Experiments on the species have shown that under chronic increases in temperature, the species up-regulates its metabolism, resulting in an increase in movement speed and arm regeneration (Ref. 22.274). The species tends to escape disturbance by moving horizontally rather than burying itself in the sediment (Ref. 22.275) and its high mobility should allow it to escape any thermal stress associated with cooling water discharges within the GSB. The species is common in the GSB and the wider North Sea, provided in **Appendix 22C** of this volume. Therefore, potential behavioural responses to temperature uplifts would lead to a very localised reduction in population density but likely have little effect at the broader population level.	Not Sensitive.
Planktonic eggs and larvae of benthic invertebrates.	Benthic invertebrates in the GSB primarily have planktonic egg and larval development, provided in **Appendix 22C** of this volume. Planktonic eggs and larvae would only be affected by the thermal plume as it mixes with the receiving waters and, thus, dilutes and cools (Ref. 22.87). Most studies investigating the effects of cooling water on planktonic early life stages of invertebrates have focused on acute mortality during primary entrainment in the cooling water system rather than the implications in the receiving waters. Planktonic invertebrate eggs and larvae are unlikely to experience chronic effects in receiving waters, as the water masses they occupy would move away from the outfall causing heat losses. However, when the water masses are near the point of discharge, the absolute temperature could reach the upper tolerance limit of some sensitive species and, thus, induce acute effects, resulting in direct mortality and/or reducing their fitness. The spatial scale of the thermal plume coupled with hydrodynamic processes means that exposure to areas of thermal stress would be limited to a few hours each tide for a small proportion of populations. As benthic invertebrate eggs and larvae are produced in very high numbers by populations with broad spatial distributions, and incur high natural mortality (mainly through predation), it is expected that any deleterious effect of cooling water discharges would be highly localised and undetectable at the population level (Ref. 22.87).	Not Sensitive.

Sabellaria spinulosa reef sensitivity to temperature changes

22.7.403 It is possible that exposure to temperature changes due to cooling water discharges would affect reef formation and development by *Sabellaria spinulosa.*

22.7.404 Recent surveys have confirmed the presence of *S. spinulosa* reef on the inshore Coralline Crag which is under the influence of the Sizewell B thermal plume (Ref. 22.121). An additional 24.0ha of the inshore Coralline Crag would be exposed to a 3°C uplift (98th percentile) and 48.5ha would be exposed to a 2°C uplift due to concurrent operation of the proposed development with Sizewell B, compared to Sizewell B alone. This constitutes a 65% and a 32% increase in the extent of the exposed Coralline Crag habitat exposure to 2°C and 3°C uplifts, respectively see **Figure 21.4** and **Figure 21.8** of **Chapter 21** of this volume.

22.7.405 *Sabellaria spinulosa* reef has also been confirmed on the offshore Coralline Crag habitat, where low to medium elevation reefs have been observed (Ref. 22.122). These reefs and supporting crag are not under the influence of Sizewell B thermal plume but would be exposed to thermal uplifts during operation of the proposed development. The design of the outfalls in deep offshore waters means there would be no exposure to 3°C uplifts (98th percentile). However, much of the offshore Coralline Crag would be exposed to a 2°C temperature uplift, provided in **Figure 21.4** and **Figure 21.8** of **Chapter 21** of this volume.

22.7.406 *Sabellaria spinulosa* is a warm water species that is more sensitive to cooling events than warming events (Ref. 22.167). It is therefore unlikely that reef integrity would be adversely affected by the expected temperature changes. Indeed, *S. spinulosa reefs* are present in the extent of the Sizewell B thermal plume and the species distribution extends to warmer waters than those of the GSB (e.g. the Mediterranean; (Ref. 22.135). Further evidence from the Severn Estuary indicates thermal effluents from the Hinkley Point power station may enhance growth of the closely related *S. alveolata* (Ref. 22.276) as accumulations are found in close proximity to the outfall. *Sabellaria spinulosa* reefs are therefore considered to have *Low* sensitivity to this pressure.

22.7.407 As *S. spinulosa* reefs are likely to be unresponsive, or even respond positively, to temperature increases associated with cooling water discharges, the effect on this receptor is predicted to be a minor beneficial effect. The effect is **not significant**.

The effects of climate change on thermal discharge predictions

22.7.408 The interaction between sea temperature warming as a result of climate change and thermal discharges has been considered based on the methodology detailed in **Appendix 21E** of this volume. Future climate was considered relative to current thermal standards of thermal uplifts above ambient and absolute temperature.

22.7.409 Thermal uplifts above ambient are predicted to be largely independent of the background sea temperature. Therefore, thermal uplift areas are predicted to remain largely unchanged under future climate scenarios, provided in **Table 22.32**.

22.7.410 To ascertain absolute temperatures in the future, the influence of climate change was added to the predicted thermal uplifts due to the proposed development. The approach considered Sizewell B and the proposed development, Sizewell C, operating together up until 2055 as a worst-case. Sizewell C operating alone in 2055 and 2085 were also considered as well as an extreme (2110) hypothetical operating scenario.

22.7.411 The thermal uplift due to the UKCP09[42] monthly increase in mean temperature, centred on 2006, was applied to this contemporary annual baseline projecting forward to 2055, 2085 and 2110. This climate uplift (98th percentile occurring in August) and the 98th percentile ambient temperature (also occurring in August) was then applied to the mean excess temperature rise due to the power stations. This is considered precautionary as the mean uplifts due to thermal discharges tend to be lower in the summer months.

22.7.412 The results indicate that future climate change is not predicted to significantly increase the absolute areas in exceedance of 28ºC, which remain under 1ha for all scenarios tested. Following the end of operation of Sizewell B, 28ºC as an absolute temperature is not predicted to be exceeded as a 98th percentile even under the extreme climate case of the proposed development operating in 2110. Therefore, acute thermal effects in the receiving waters are predicted to remain minimal.

22.7.413 During the operation of both stations, absolute temperatures of 23ºC increase from 89.6ha at the surface, provided in **Table 22.32**, to a worst case of 506.2ha at the surface and 264.4ha at the seabed in 2055. In the likely event Sizewell B is no longer operational in 2055, leaving the proposed development operating alone, the exceedance of the absolute 23ºC threshold is predicted to be just 5.38ha at the surface and 0ha at the seabed.

22.7.414 By the extreme date of 2110, large areas exceed 23ºC as a 98th percentile; 7,080ha at the surface and 6,540ha at the seabed. However, the results are due to the influence of climate warming, which is predicted to be +3.045ºC

[42] Future sea temperatures are not included in the current UKCP18 marine climate predictions.

as a 98th percentile across the model domain, hence a station uplift of just 0.56ºC is sufficient to exceed contemporary thermal standards.

22.7.415 In 2085, towards the end of the likely operational life-cycle of the proposed development, seabed areas in exceedance of 23ºC are predicted to occur over just 0.22ha, whereas surface exceedance occurs over an area of 69.1ha. The total area of the thermal plume above 23ºC in 2085 is therefore smaller and further offshore than the contemporary predictions for the two power stations operating together, provided in **Table 22.32** and **Appendix 21E** of this volume.

22.7.416 While climate change would act in-combination with the proposed development to increase areas over which thermal standards are exceeded, the key benthic invertebrate taxa are generally considered to be insensitive or to have low sensitivity to temperature increases. Therefore, the increased extent of absolute temperature exceedance is unlikely to have population-level effects. It is also worth noting that benthic invertebrate taxa within the GSB in a future, warmer climate would be acclimated to a modified thermal baseline, while any taxa not currently in the GSB but part of the future benthic ecology baseline due to climate-induced distributional shifts would presumably be adapted to warm temperatures.

22.7.417 Confidence in predicting the exact effects of climate change and thermal discharges on benthic ecology receptors is reduced further into the future. However, once Sizewell B is decommissioned the thermal footprint from the proposed development is predicted to be smaller than that of Sizewell B at present. Predictions of effects based on current baselines are therefore considered valid in light of future climate change.

Cooling water discharges of total residual oxidants

22.7.418 To control biofouling of critical sections of the plant during operation, intake water will be chlorinated by the addition of sodium hypochlorite. EDF Energy's operational policy for its existing UK fleet is to continuously dose during the growing season to achieve a TRO dose of 0.2mg/l in critical sections of the CW plant and at the inlet to the condensers. Chlorination would be applied when intake temperatures exceed 10ºC (Ref. 22.102).

22.7.419 The primary biocidal effects of seawater chlorination result from oxidants associated with water chemistry. These oxidants, which result from combination of chorine and organic material in the water, are measured and expressed as the TRO concentration. Accordingly, the sum of TROs, rather than simply chlorine, is measured. At the point of discharge from the outfall, the TRO concentration would be 0.15mg/l, discharged at a rate of 132m^3/s in the cooling water at a temperature of 11.6 °C above ambient, provided in **Appendix 21E** of this volume.

22.7.420 Experimental studies at Sizewell were used to model the TRO plume based on the seawater chemistry and applying an empirical demand/decay formulation coupled into the General Estaurine Transport Model for Sizewell. The EQS for TROs is 10µg/l as a 95th percentile concentration. The TRO plumes from the proposed development and Sizewell B are spatially distinct at ecologically relevant concentrations and follow a long narrow trajectory parallel to the coast due to tidal movements. Therefore, the proposed development, Sizewell C, is considered separately, with Sizewell B part of the baseline.

22.7.421 As benthic invertebrates could be exposed to TROs both as adults and as planktonic eggs and/or larvae, the assessment considered EQS exceedance both at the seabed and sea surface. The Sizewell C TRO plume is highly stratified, and concentrations exceed the EQS over an area of 2.1 ha at the seabed and 338ha at the sea surface, provided in **Figure 21.6** of **Chapter 21** of this volume.

22.7.422 TRO discharges would occur for the operational lifespan of the proposed development and would be continuous throughout the growing season when water temperatures exceed 10ºC. In 2030, water temperatures at the Sizewell C intakes are predicted to exceed 10ºC from the beginning of May until the start of December. Future climate change may extend the period of the year seawater temperatures exceed 10ºC and, by extension, the seasonal duration of chlorination under the current strategy. In the coastal waters of the GSB, high levels of turbidity in the Winter and early Spring limit biological production and increases in the duration of annual chlorination is unlikely to extend considerably.

22.7.423 As the EQS for TROs would be exceeded for the lifetime of the proposed development over a small area at the seabed but a larger area at the sea surface, where the pelagic eggs and larvae of benthic invertebrates would be exposed to this pressure, impact magnitude is precautionarily assessed as medium.

Benthic invertebrate sensitivity to total residual oxidants

22.7.424 The assessment was focused both on adult benthic invertebrates, whose exposure to TROs would occur only at the seabed, and the pelagic eggs and larvae of benthic invertebrates, which would be exposed to TROs in the water column. Where possible, the assessment considered evidence relating to species found within the GSB, particularly key taxa. The assessment also considered high-mobility (mobile) and low-mobility (sessile) taxa separately due differences in their capacity for behavioural avoidance of this pressure.

22.7.425 Key sessile benthic invertebrate taxa in the area where TRO concentration is predicted to exceed the EQS (2ha at >10µg/l) include bivalves, amphipods and polychaetes. Toxicological data are not available for all relevant key taxa, so evidence relating to a subset of taxa was used to provide insight into likely acute and chronic effects of TROs on sessile benthic invertebrates:

- **Bivalves:** Little information is available on the sensitivity of bivalves to TROs. Experiments on juvenile *Mytilus edulis*, which are present throughout the GSB, provided in **Appendix 22C** of this volume, found that TRO concentrations above 0.2mg/l did not induce mortality (Ref. 22.103), suggesting that acute effects of cooling water discharges are unlikely. Indeed, the antifouling dosing strategy is intended to deter settlement and growth within critical plant, rather than result in mortality. Bivalves can escape stressful TRO concentrations by shell closure, though this escape mechanism is mostly effective for short-term exposure. Prolonged shell closure requires a greater dependence on energy reserves, which affects growth and reproduction (Ref. 22.106; 107; 277). Therefore, exposure to TROs above EQS concentrations may reduce the fitness of bivalves.

- **Amphipods:** Experiments investigating the toxicity of TRO exposure were conducted on two species of amphipods. The first is *Corophium volutator*, a key taxon in the GSB, and the second is *Melita palmata. C. volutator* showed acute effects, with 50% mortality observed after 10 day exposures to concentration of 0.19-0.36mg/l, and 10% mortality at a concentration of 30µg/l (Ref. 22.278). A concentration of 30µg/l is slightly higher than that expected over 0.34ha of the seabed (as a 95th percentile) due to cooling water discharges (i.e. 20µg/l). *Melita palmata* is not present within the GSB but is common in UK waters and is often used as an indicator species. Toxicological tests showed acute effects on test organisms following 28 day exposure with 10% greater mortality at TRO concentrations of 0.2mg/l, but no chronic effect on growth (Ref. 22.110). However, such a high concentration would not occur even in the immediate vicinity of the outfall. Adults of the amphipod *Gammarus daiberi* have been shown to move to avoid TROs at a concentration of 20µg/l (Ref. 22.111). Given the small spatial extent of the seabed that would be exposed to concentrations sufficient to cause effects, amphipods, including the congener and key taxon *G. insensibilis*, may exhibit behavioural avoidance of TROs in the vicinity of the outfall.

- **Polychaetes:** Toxicity tests were performed on S. spinulosa (Ref. 22.279), a key taxon within the GSB. Results indicate that this species is tolerant of aqueous chlorine, as no acute sensitivity was observed at concentrations above 0.2mg/l, while the only chronic effect observed was an increase in tube growth (Ref. 22.279). Another study of a closely related species, S. alveolata, produced consistent results, with mortality rates after 28 days of exposure to environmentally relevant

TRO concentrations generally indistinguishable from controls (Ref. 22.280). This study did, however, suggest that sensitivity to TROs may be greater at elevated temperatures. The possible in-combination effects of thermal discharges and TROs are assessed.

22.7.426 Overall, acute effects (mortality) due to TRO discharges are expected to be minimal for sessile benthic invertebrates. However, the fitness of some taxa is predicted to be reduced in the immediate vicinity of the outfall. Sessile benthic invertebrates are therefore assessed as having low sensitivity to this pressure.

22.7.427 The key mobile invertebrate species in this area are decapods (shrimps, crabs and lobsters) and ophiuroid echinoderms (brittle stars), provided in **Appendix 22C** of this volume. As with sessile benthic invertebrates, toxicological data are not available for all mobile key taxa, so evidence relating to a subset of taxa was used to provide insight into likely acute and chronic effects of TROs:

- **Shrimps:** The toxicological effect of chlorinated water has been examined using the brown shrimp *C. crangon* (Ref. 22.281). Acute effects were recorded for 72h exposure to TRO concentrations above 0.3mg/l, while concentrations of 0.2mg/l did not induce mortality in either adults or juveniles. Therefore, no acute effects are predicted due to TRO discharges. Moreover, no sublethal effects on growth and condition were measured for TRO concentrations up to 40µg/l following 18-day expsoure, which is within the range of concentrations that would be experienced at the seabed close to the outfall.

- **Crabs and lobsters:** No information is available on the sensitivity of crabs and lobsters to chlorination; however, one of the survival strategies employed by these organisms when challenged with high stressors intensities in their environment is an escape or avoidance response by fleeing from the disturbance. Oxidants can induce such behavioural responses (Ref. 22.106; 282) and the antennae and antennules of lobsters, for example, are very sensitive to a wide range of chemicals (Ref. 22.283).

22.7.428 Mortality of mobile benthic invertebrates due to TRO discharges is considered unlikely based on the available evidence. Their high mobility would allow them to avoid exposure in the immediate vicinity of the outfall and, as key taxa are present throughout most of the GSB, see **Appendix 22C** of this volume, a small proportion of any population would be affected. However, as the ability of some taxa to detect chlorine is unknown, sensitivity of mobile benthic invertebrates to this pressure is precautionarily assessed as low.

22.7.429 The surface plume model suggests that the planktonic eggs and larvae of benthic invertebrates would be exposed to TRO concentrations exceeding the EQS (10µg/l) over 338ha of the GSB. The larvae that would be affected include bivalves, crustaceans, polychaetes and echinoderms. Evidence relating to key taxa was used, where possible; however, evidence relating to other indicator taxa was also utilised:

- **Bivalves:** The responses of bivalves exposed to chlorination indicates that larval stages are more sensitive than adults, with some variation among species (Ref. 22.284). One of the most sensitive species tested, the American oyster *C. virginica*, had a high level of mortality after 48h of exposure to 26µg/l TRO (Ref. 22.106; 109; 285), which is over twice as high as the EQS used to inform impact magnitude (20µg/l). While *C. virginica* is not present within the GSB, its sensitivity makes it a useful indicator of the possible acute effects of the TRO plume. Similar effects have been reported at a higher TRO concentration of 0.12mg/l for the blue mussel *M. edulis* (Ref. 22.286), which is a key taxon within the GSB. This concentration is similar to that discharged from the outfall (0.15mg/l) but would not be reached throughout most of the TRO plume.

- **Crustaceans, polychaetes and echinoderms:** The larvae of crustaceans, polychaetes and echinoderms show a variety of sublethal toxic effects. These include impaired swimming ability, respiration and growth for the American lobster *Homarus americanus*; development inhibition for the sandcastle worm *Phragmatopoma californica*; and a delayed development for the hermit crab *Pagurus longicarpus* (Ref. 22.281; 287). However, as most of these observations were made for TRO concentrations significantly above what is expected to be discharged into the GSB (0.15mg/l), the possible effects of lower concentrations are unclear. Further experiments conducted using the larvae of key taxa within the GSB showed a high level of survival for the European lobster *H. gammarus*, brown shrimp *C. crangon* and the edible crab *C. pagurus* at elevated TRO concentrations (Ref. 22.288–291).

22.7.430 The larvae of bivalves appear to be the most sensitive to TRO toxicity and could suffer mortality near the outfall, while the larvae of all taxonomic groups considered may incur sublethal effects due to the TRO plume. Moreover, the taxa present in the GSB are widely distributed, have high fecundity and the eggs and larvae they produce experience a high natural mortality (mainly through predation), thus limiting the potential for population-level effects beyond the range of natural variability. Therefore, planktonic eggs and larvae of benthic invertebrates are assessed as having low sensitivity to this pressure.

22.7.431 As impact magnitude is medium and benthic invertebrates have low sensitivity to this pressure, TRO discharges are predicted to have a minor adverse effect on this receptor. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to total residual oxidants

22.7.432 *Sabellaria spinulosa* reefs at the offshore Coralline Crag would not be exposed to TROs above EQS concentrations provided in **Figure 21.8** of **Chapter 21** of this volume.

22.7.433 At the Inshore Coralline Crag *S. spinulosa* experiences exposure to TROs above EQS due to existing discharges from Sizewell B. The interaction of the Sizewell C plume, at low concentrations, would result in a very small increase in the area exposed to the existing Sizewell B plume at the inshore Crag. *Sabellaria spinulosa* does not exhibit acute sensitivity to TRO concentrations above those expected for cooling water discharges, but does appear to respond to TROs with increased tube growth (Ref. 22.279). The same has been observed in the closely related species, *S. alveolata* (Ref. 22.280). However, within the GSB *S. spinulosa* are not present in areas where TRO concentrations would be sufficiently high to induce behavioural alterations. It therefore appears unlikely that this receptor would be directly affected by TRO discharges. The planktonic eggs and larvae of *S. spinulosa* would potentially be exposed to TRO concentrations above the EQS (10µg/l) over 338ha, which could indirectly affect reef formation and development if it influences recruitment. The effects of TROs on *S. spinulosa* eggs and larvae are unknown, but evidence available for the larvae of other polychaetes and other benthic larvae suggests relatively low at the concentrations anticipated in the receiving waters. Any acute or chronic effects would likely be minimal and be possibly undetectable due to high levels of natural mortality (mainly through predation). *Sabellaria spinulosa* reef is therefore precautionarily assessed as having low sensitivity to this pressure.

22.7.434 As impact magnitude is medium and *S. spinulosa* reef has low sensitivity to this pressure, TRO discharges are predicted to have a minor adverse effect on this receptor. The effect is **not significant**.

Cooling water discharges of chlorination by-products

22.7.435 In addition to the production of TROs, chlorination compounds are broken down to form chlorination by-products. Different chlorination by-products are formed depending on the water chemistry. The most abundant chlorination by-product in discharges from coastal power stations, and the only product detected in the waters off Sizewell, is bromoform (Ref. 22.103), provided in **Appendix 21E** of this volume. Bromoform is lost through volatilization to the atmosphere. Loss rates were incorporated into the General Estaurine Transport Model for Sizewell to predict the extent of the bromoform plume.

22.7.436 Chlorination by-products associated with chlorination are predicted to have very limited toxicity once in the receiving waters (Ref. 22.103). EQS concentrations for bromoform do not exist and a PNEC of 5µg/l as a 95th percentile is applied as the recommended standard (Ref. 22.103). The bromoform plume is predicted to follow a similar trajectory to the TRO plume with a narrow, tidally transported plume forming parallel to the shore.

22.7.437 As benthic invertebrates could be exposed to bromoform both as adults and as planktonic eggs and/or larvae, the assessment considered PNEC exceedance both at the seabed and sea surface. The plume is highly stratified, with PNEC concentrations exceeded over an area of 52ha at the surface and 0.67ha at the seabed. The Sizewell C plume is discrete from the Sizewell B plume.

22.7.438 Bromoform discharges would occur for the operational lifetime of the proposed development and would be continuous throughout the growing season when water temperatures exceed 10^{o}C.

22.7.439 As the PNEC for bromoform would be exceeded over a very small area at the seabed and a larger area at the sea surface for the lifetime of the proposed development, impact magnitude is assessed as medium.

Benthic invertebrate sensitivity to chlorination by-products

22.7.440 The assessment was focused both on adult benthic invertebrates, whose exposure to bromoform would occur only at the seabed, and the pelagic eggs and larvae of benthic invertebrates, which would be exposed to bromoform in the water column.

22.7.441 Evidence regarding the effects of bromoform on adult benthic invertebrates is limited. Experiments performed on adult *C. virginica* showed no mortality but some sublethal effects, such as increased respiration and reduced gonad condition, after 32 days of exposure to bromoform at 20µg/l (Ref. 22.284). This species is known to be one of the most sensitive to TRO toxicity, so its limited response to bromoform concentrations above those expected at the seabed due to chlorination by-product discharges suggests that benthic invertebrates within the GSB (including *G. insensibilis*) would be tolerant to this pressure. A study on shrimp also shows limited bioaccumulation of bromoform and rapid depuration within days of being returned to clean waters (Ref. 22.292), which reaffirms the low likelihood of chronic effects in adult benthic invertebrates. Moreover, the wide distributions of benthic invertebrate taxa within the GSB and the small footprint of the bromoform plume at the seabed mean that a very small proportion of any population would be exposed to this pressure.

22.7.442 Given the tolerance of studied taxa and the minimal exposure to bromoform concentrations above the PNEC at the seabed, adult benthic invertebrates are assessed as being not sensitive to this pressure.

22.7.443 As with the adult life-stage, very little evidence is available on the effect of the bromoform on the pelagic eggs and larvae of benthic invertebrates. One study shows significant mortality of oyster larvae *C. virginica* after 48h-exposure at 50µg/l (Ref. 22.293). However, this species is considered highly sensitive to chlorination and the concentration used in the study is an order of magnitude higher than the PNEC used to inform the impact magnitude assessment. For the larvae of other marine organisms including bivalves and echinoderms larvae, NOECs exceeded 0.5mg/l (Ref. 22.113), which is two orders of magnitude higher than the PNEC. Moreover, invertebrate larvae in the water column are subjected to the movement of the water masses, so are unlikely to stay in the area of high bromoform concentration for long period of time.

22.7.444 Given the tolerance of studied taxa and the likelihood that temporal exposure to the bromoform plume would be short, the planktonic eggs and larvae of benthic invertebrates are assessed as being not sensitive to this pressure.

22.7.445 As impact magnitude is medium and benthic invertebrates are not sensitive to this pressure, chlorination by-products are precautionarily predicted to have a minor adverse effect on this receptor. The effect is **not significant** and is unlikely to extend beyond that attributable to TROs associated with chlorination.

Sabellaria spinulosa reef sensitivity to chlorination by-products

22.7.446 *Sabellaria spinulosa* reefs on the offshore Coralline Crag are not present within the footprint of the bromoform plume where concentrations exceed the PNEC due to discharges from the proposed development (**Figure 21.8** of **Chapter 21**, this volume). Therefore, chlorination by-product discharges would not directly affect this receptor. The planktonic eggs and larvae of *S. spinulosa* would potentially be exposed to bromoform concentrations above the PNEC (5µg/l) over 52ha, which could indirectly affect reef formation and development if it influences recruitment. The effects of bromoform on *S. spinulosa* eggs and larvae are unknown, but the available evidence for the larvae of benthic invertebrates indicates insensitivity to the concentrations that would result from chlorination by-product discharges. Neither acute nor chronic effects are expected. *Sabellaria spinulosa* reefs are therefore assessed as being not sensitive to this pressure.

22.7.447 As impact magnitude is medium and *S. spinulosa* reef is not sensitive to this pressure, bromoform discharges are precautionarily predicted to have a minor adverse effect on this receptor. The effect is **not significant**.

Cooling water discharges of hydrazine

22.7.448 Hydrazine (N_2H_4) is an ammonia-derived compound with strong anti-oxidant properties, regularly used as a corrosion inhibitor in cooling water circuits of nuclear power stations. Worst-case daily discharges from Sizewell C have been modelled based on hydrazine discharges of 24kg per annum into the cooling water flow. Conservative decay rates were incorporated into the General Estaurine Transport Model to consider two release strategies based on different pulses of 69ng/l for 2.32h a day and 34.5ng/l for 4.63h a day culminating in the same total annual load (24kg/yr).

22.7.449 The plume simulations showed that both strategies gave similar results. The hydrazine plume follows a narrow trajectory parallel to the shore. At the seabed, less than 1ha exceeds the chronic PNEC, irrespective of the release strategy. At the surface the area that exceeds the chronic PNEC is 158 and 157ha for the 69ng/l and 34ng/l releases, respectively shown in **Table 22.54**.

22.7.450 The acute thresholds were only exceeded in the 69ng/l release strategy over a very small area of the seabed (0.13ha). Surface exceedance extended to 17.4ha and 13.8ha in the 34.5ng/l and 69ng/l strategy, respectively presented in **Appendix 21E** of this volume and **Table 22.54**. Daily discharges would occur throughout the lifecycle of the proposed development.

22.7.451 Daily discharges would occur throughout the lifetime of the proposed development. As PNECs would be exceeded over a small area of the seabed and somewhat larger area of the sea surface during this period under both hydrazine release scenarios, impact magnitude is assessed as medium. This assessment is highly precautionary, given the conservative nature of the PNECs used.

Table 22.54: Area of the hydrazine plume in exceedance of concentration thresholds.

Hydrazine release strategy	PNEC threshold	Area of exceedance (ha)	
		Seabed	Surface
69ng/l for a duration of 2.32h a day.	Chronic, 0.4ng/l (mean).	0.56	158.1
	Acute, 4ng/l (95th percentile).	0.22	13.8
34.5ng/l for a duration of 4.63h a day.	Chronic, 0.4ng/l (mean).	0.34	156.9
	Acute, 4ng/l (95th percentile).	0.00	17.4

Benthic invertebrate sensitivity to hydrazine

22.7.452 Benthic invertebrates would be exposed to hydrazine discharges from the CWS outfalls during the operation of the proposed development.

22.7.453 The sensitivity of benthic invertebrates to hydrazine discharges was assessed as part of the construction (commissioning) phase assessments for the CDO, presented in **Section 22.7.c)** of this chapter. The same evidence regarding the toxicity of hydrazine to adults and the eggs and larvae of benthic invertebrates is applied here. Exposure of adult benthic invertebrate populations to hydrazine above PNEC concentrations would be less than the worst-case scenario for commissioning discharges (<1ha *vs* 6ha at the seabed), while exposure of eggs and larvae would be greater (17ha vs 12ha for the acute PNEC, 158ha vs 49ha for the chronic PNEC at the sea surface). However, unlike commissioning discharges, the concentrations at which toxic effects have been observed in benthic invertebrate larvae (>10µg/l for *Crassostrea gigas*) would not even be reached at the point of discharge during the operation of the CWS; though toxicological effects may be induced at lower concentrations for species in the GSB. The results of modelling of the hydrazine plume show that concentrations above PNEC level are restricted seaward of the Sizewell-Dunwich Bank. As *G. insensibilis* is mostly found in the shallow coastal areas in the North part of the GSB, provided in **Appendix 22C** of this volume, the species is deemed not sensitive to the pressure. Overall, sensitivity of benthic invertebrates to hydrazine discharges remains the same as for the commissioning discharges assessment, with planktonic eggs and larvae deemed to have low sensitivity and adult benthic invertebrates deemed not sensitive to this pressure.

22.7.454 As impact magnitude is medium and sensitivity of benthic invertebrate ranges from not sensitive to low, discharges of hydrazine during the operation of the CWS are predicted to have a minor adverse effect on this receptor. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to hydrazine

22.7.455 The sensitivity of *S. spinulosa* reefs to hydrazine discharges was assessed as part of the construction (commissioning) phase assessments for the CDO, provided in **Section 22.7.c)** of this chapter. The same evidence is applied here.

22.7.456 *Sabellaria spinulosa* reefs on exposed Coralline Crag formations do not coincide with the footprint of this pressure, as provided in **Figure 21.8** of **Chapter 21** of this volume. This receptor would therefore not be directly exposed to hydrazine concentrations above PNECs. Acute and chronic effects on the planktonic eggs and larvae of *S. spinulosa* are possible over

17ha and 158ha, respectively, which could potentially reduce recruitment and indirectly affect reef formation and development. However, a very small proportion of pelagic eggs and larvae would be exposed to this pressure. Sensitivity is conservatively assessed as low.

22.7.457 As impact magnitude is medium and *S. spinulosa* reef has low sensitivity to this pressure, discharges of hydrazine during the operation of the CWS are predicted to have a minor adverse effect on this receptor. The effect is **not significant**.

Abrasion / physical disturbance: maintenance operations

22.7.458 During the 60-year operational life, each reactor unit would undergo refuelling and maintenance shutdowns (otherwise known as 'outages') at approximately 18-month intervals. During outages occasional maintenance of the intakes would occur. Vessel activity during for maintenance of the intakes is likely to expose benthic habitats to very small areas of impact. A worst-case assumption considers maintenance vessels would use jack-up of anchoring rather than dynamic positioning. Activities associated with maintenance operations (e.g. the use of jack-up barges and anchoring) have the potential to cause highly localised surface and sub-surface abrasion. The magnitude of impact is assessed as very low.

22.7.459 For the outfalls and northern intakes, these activities would affect benthic invertebrates in soft sediments. Benthic invertebrates would be expected to have no resistance to the pressure. However, a very small proportion of benthic habitat would be affected. Rapid infilling rates would mean habitat changes would be short-term, see **Appendix 20A** of this volume, and the recolonization would occur, as provided in **Appendix 21E** of this volume. Soft sediment benthic receptors are not sensitive to the pressure. Effects are predicted to be negligible.

22.7.460 At the southern intakes the activities would impact benthic invertebrates and potentially *S. spinulosa* reef on the offshore Coralline Crag. Localised loss of *S. spinulosa* due to abrasion or physical damaged from jack-up activities is possible. The spatial extent of the pressure would be highly localised. A small proportion of *the S. spinulosa* reef or supporting habitat would be affected. Recovery of reef material would be predicted to occur within years of the pressure ceasing and recovery through recolonization[43]. Sensitivity is assessed as low.

[43] *Sabellaria spinulosa* formations settled and grew back within 18 months following marine aggregate dredging at the Hasting Shingle Bank License Area where (Ref. 22.216).

22.7.461 Minor adverse effects on *S. spinulosa* reefs is considered a precautionary assessment. The effects are **not significant**.

v. Fish recovery and return

22.7.462 This section describes the impacts associated with the operation of the fish recovery and return (FRR) system during the operation phase. Pressures with the potential to affect marine benthic ecology receptors resulting from the presence of the FRR infrastructure are the same as those identified for the construction phase, provided below in **Table 22.55**.

22.7.463 In addition to pressures that would extend from the construction phase into the operation phase, scoping identified additional pressures arising from FRR activities during the operation phase with the potential for effects on ecological receptors, as provided in **Appendix 22M** of this volume. Pressures with the potential to affect marine benthic ecology receptors are presented in **Table 22.56**.

Table 22.55: Summary of impact magnitude, sensitivity of benthic ecology receptors and the effects and significance of pressures associated with FRR activities during the operation (and construction) phase.

Pressure	Activities resulting in pressure	Impact magnitude	Sensitivity	Effect and significance
Spread of INNS	Presence of structure	Very Low	Low	negligible (**not significant**)

Table 22.56: Pressures associated with FRR activities during the operation phase that have the potential to affect benthic ecology receptors.

Pressure	Activities resulting in pressure.	Justification
Organic loading.	Discharges of dead and moribund biota.	The return of dead and moribund biota is a source of organic carbon with the potential to influence secondary production at the seabed through detrital pathways.
Increases in un-ionised ammonia.		Decaying biomass would release ammonia into the surrounding waters, which has potential to affect benthic ecology receptors through toxicological stress.

22.7.464 Operation pressures that have been scoped out of further assessment as they are considered to have negligible effects on benthic receptors include:

- Reductions in dissolved oxygen – Decaying biomass returned to receiving waters via the FRR would increase the biochemical oxygen demand and has the potential to reduce dissolved oxygen levels. The waters off Sizewell are well mixed vertically, thus facilitating reaeration, and the rate of water exchange within the GSB would limit the extent and duration of any oxygen reduction. Background dissolved oxygen concentrations conforms to 'high' status within the WFD waterbody and this includes the influence of Sizewell B. The biological oxygen demand from biomass discharged from the FRRs is predicted to have a negligible effect on water quality.

- Nutrient enrichment – The decay of organic material would release nutrients into the system. The small quantities of nitrate and phosphate that would be released are expected to influence annual gross primary production by orders of magnitude below the natural variation in chlorophyll *a* biomass, provided in **Section 22.6.b)** of this chapter. Such small-scale changes to primary production would have negligible indirect effects on benthic ecology receptors.

- Water flow changes – The presence of the FRR heads would result in localised changes in water flow. Current flow changes have not been calculated but are expected to be moderate and restricted to a very small area (0.02ha for each head) of the shallow subtidal zone near the structures, as provided in **Appendix 20A** of this volume. It is deemed that such small-scale changes to hydrodynamics would have a negligible effect on benthic ecology receptors.

- Disturbance of surface sediments (scour): while scour protection would limit scouring caused by the presence of the FRR outfall heads, sediments around the perimeter of the scour protection would likely be disturbed by 'edge scour', as provided in **Appendix 20A** of this volume. Such small-scale scouring is assumed to have a negligible effect on benthic ecology receptors.

- Changes in wave exposure – It is expected that the influence of the FRR outfall heads on waves will be similar to that of large nearshore boulders, with both the amount and spatial extent of the changes predicted to very minor, provided in **Appendix 20A** of this volume. Such small-scale changes in wave exposure are assumed to have a negligible effect on benthic ecology receptors.

Organic loading: discharges of dead and moribund biota

22.7.465 Biota that suffer mortality as a result of the impingement process would be discharged into the receiving waters via the FRRs. Organic loading has the potential to result in smothering of sediment surfaces, deoxygenation, changes in sediment geochemistry, changes in community structure and potentially eutrophication (Ref. 22.294).

22.7.466 The total biomass of dead and moribund biota to be discharged from the FRR has been estimated based on abstraction rates and information on the seasonal abundance of species along with length-to-weight distributions of the species impinged at the existing Sizewell B station. The data show seasonal variation in discharges. The highest discharge biomass would occur in December to April, when clupeids are most abundant.

22.7.467 The annual average wet biomass discharge from the FRR is predicted to be 1065.5kg/d. In March a worst-case mean biomass of 3,442kg per day is predicted to be discharged from the FRRs. Between April to September, when benthic productivity peaks, biomass discharges are predicted to be lower at a mean of 405.2kg wet weight per day, as provided in **Appendix 21F** of this volume. These values are based on rates of impingement at Sizewell B and extrapolated to Sizewell C, FRR survival rates are then incorporated into the assessment. However, values do not account for Sizewell C LVSE headwork mitigation, which is predicted to reduce impingement rates by a factor of 0.383 per cumec (Ref. 22.24). Furthermore, the assessments consider discharges of dead and moribund biota form a single point source. This adds a further precautionary factor to the assessment as the two FRR units, located approximately 300m apart, would allow a greater level of initial dilution with discharges split between two spatially separated point sources. Modelling indicates that 88% of the dead and moribund biota discharged from the FRR would initially settle onto the seabed in the vicinity of the two FRR outfalls. The remaining 12% would mostly be widely distributed by tidal processes, throughout the GSB with a proportion being consumed by seabirds (Ref. 22.295).

22.7.468 The are no established regulatory standards for assessing organic loading to benthic systems. In the absence of established standards, pressure benchmarks proposed in Marine Evidence-Based Sensitivity Assessment as a starting point to establish the potential for effects. For organic carbon deposition the appropriate benchmark is defined as 100g organic carbon/m^2/year (Ref. 22.11). Given the potential sensitivity of benthic receptors to organic loading a further assessment is provided herein.

22.7.469 The area in the vicinity of the two FRR outfalls predicted to be impacted by organic carbon above benchmark levels was estimated based on the estimated discharge rate and carbon content of fish, provided in **Table 22.57**. The carbon content of fish biomass was derived based on carbon composition of fish processing waste being 64.7% of the dry weight and a wet weight to dry weight conversion factor of 0.48 (Ref. 22.296).

22.7.470 An annual average area of approximately 40.7ha may be exposed to organic carbon loading above benchmark values. The area effected reduces to approximately 15.5ha from April to September. Peak biomass events, occurring in March, would result in an equivalent area of 131.5ha above the benchmark, provided in **Table 22.57**. It should be noted that the assessments of the spatial area effected is considered precautionary based on the following conservative assumptions:

- Modelling of the distribution of dead and moribund fish assumes that 88% of fish would sink immediately, remaining *in-situ*. Tidal and wave driven processes in the shallow subtidal environment near the FRR headworks would prompt resuspension and thereby wider distribution of the biomass (diluting the impact).
- The assessment of impacts assumes all biomass is directly converted to organic carbon deposits. Piscivorous birds, fish and benthic invertebrates would consume a considerable proportion of the biomass.
- The assessments consider discharges of dead and moribund biota form a single point source. This adds a further precautionary factor to the assessment as the two FRR units, located approximately 300m apart, would allow a greater level of initial dilution with discharges split between two spatially separated points sources.

Table 22.57: Determination of the area potentially exposed to organic carbon enrichment above benchmark values during periods of peak discharge.

Factor	Period: Worst-case (March)	Period: Biological productivity (April to September)	Period: Average Annual
Mean daily discharges (wet mass) from both FRR systems directly extrapolated from Sizewell B:	3,442kg/d	405.2kg/d	1,065.5kg/d
Mean daily discharges (wet mass) accounting for Sizewell C LVSE impingement reduction factor (0.383):	1,318kg/d	155kg/d	408kg/d
Daily biomass sinking in proximity to the discharge point (88%):	1,160kg/d	137kg/d	359kg/d
Daily organic carbon content (wet mass x 0.48 x 0.647)	360kg/d	42.4kg/d	112kg/d
Daily pressure benchmark	0.27gC/m²/d	0.27gC/m²/d	0.27gC/m²/d

Factor	Period: Worst-case (March)	Period: Biological productivity (April to September)	Period: Average Annual
(100gC/m^2/y ÷ 365)			
Theoretical area exceeding threshold (assuming even distribution)	131.5ha	15.5ha	40.7

22.7.471 Discharges are expected throughout the year, with large seasonal fluctuations. Discharges would occur throughout the operational phase of the proposed development.

22.7.472 Impact magnitude is assessed as medium.

Benthic invertebrate sensitivity to organic loading

22.7.473 Effects of organic enrichment depend on the receiving environments capacity to respond to the pressure. If the benthic habitat is unpolluted, organic enrichment can result in increases in species diversity, abundance and total biomass. However, a tipping point is reached, whereby the capacity for the environment to process additional organic material is exceeded. This can lead to a few dominant species (such as annelids) existing at very high numbers (Ref. 22.294). It should be noted that the existing Sizewell B station has a similar level of impact to the proposed development yetwater quality sampling has shown very low organic carbon within the marine sediments, provided in **Appendix 21D** of this volume and in **Section 22.4** of this chapter. Benthic sampling has failed to determine clear evidence for changes in species composition and community structure near the Sizewell B infrastructure, as provided in **Appendix 22C** of this volume. It is therefore likely that in the tidal environment organic enrichment would stimulate secondary production rather than saturate the system.

22.7.474 The assessment of effects focuses on scavengers, predators and surface deposit feeders, as these taxa are the most likely to respond to discharges of dead and dying organisms from the FRR outfalls. Particular consideration is given to key benthic invertebrate taxa with these modes of trait expression. While *S. spinulosa* reefs are present within the GSB, this habitat is not considered a potential receptor of this pressure as its distribution is restricted to areas away from where most organic material would be deposited. Moreover, the species obtains its nutrition from suspension-feeding and is therefore not sensitive to this pressure.

22.7.475 Few benthic invertebrates within the GSB obtain their nutrition from scavenging, with <5% of infaunal and epifaunal individuals exhibiting this feeding mode, provided in **Appendix 22C** of this volume. Predators are a small component of the infauna (<10% of individuals) but make up most of the epifauna, whereas surface deposit feeders (including *G. insensibilis*) make up a substantial proportion of the infauna (~40% of individuals) but a small proportion of the epifauna (<10% of individuals). Sixteen of the twenty key taxa exhibit one or more of these feeding modes, provided in **Appendix 22C** of this volume, which includes all taxa except for *Ensis* spp., *M. edulis*, *Notomastus* spp. and *S. spinulosa*, presented in **Table 22.35**.

22.7.476 It is possible that the key taxa, along with other benthic invertebrates with the same feeding modes, would benefit from increased food availability in the GSB due to discharges of dead and moribund biota from the FRR. Their population densities may increase and their spatial distributions within the GSB may shift to reflect increased concentrations of food resources around FRR outfalls. This is supported by experimental evidence from UK waters relating to whelks, crabs, amphipods, shrimps and echinoderms, including key benthic invertebrate taxa in the GSB (Ref. 22.116; 297). Such effects on benthic invertebrates are likely to be most pronounced from December to April, when mean daily discharges are expected to be relatively high.

22.7.477 The response of scavengers, predators and surface deposit feeders (including *G. insensibilis*), to this pressure is expected to be positive, but any population-level effects would likely be small at the scale of the GSB. Benthic invertebrates are, therefore, assessed as having low sensitivity to this pressure.

22.7.478 As impact magnitude is medium and benthic invertebrates have low sensitivity to this pressure, organic loading due to discharges of dead and moribund biota from the FRR is predicted to have a minor beneficial[44] effect on this receptor. The effect is **not significant**.

Increases in un-ionised ammonia: discharges of dead and moribund biota

22.7.479 The decay of biomass released from the FRR has the potential to cause increased in un-ionised ammonia above EQS concentrations. The tissue ammonia content for fish and seasonal physio-chemical conditions were incorporated into the un-ionised ammonia calculator, provided in **Appendix 21F** of this volume. Un-ionised ammonia was calculated for Summer, and Winter when fish discharges and ambient conditions differ.

22.7.480 During the period April-September, daily discharges of 405.2kg of dead or moribund biota have the potential to cause un-ionised ammonia

[44] Whilst the effect is classified as beneficial in terms of stimulating benthic productivity, it could equally be regarded as adverse in terms of an anthropogenic perturbation from the baseline.

concentrations to exceed the EQS (21µg/l) over an area of 1.2ha (under average conditions). To account for Summer conditions, 95th percentile temperature and pH, and average salinity was considered. Under this scenario the EQS is exceeded over an area of 3.8ha.

22.7.481 To account for the worst-case scenario the highest daily discharge value (3,442kg/d in March) was applied using a 5th percentile salinity, average temperature for March and average annual pH. Under these scenarios the exceedance of the EQS occurs over an area of 6.7ha, provided in **Appendix 22F** of this volume.

22.7.482 Biomass values are based on rates of impingement at Sizewell B and extrapolated to account for abstraction volumes. They do not account for the Sizewell C intake head design that will mitigate fish entrapment and is predicted to abstract ca 60% fewer fish per cumec than Sizewell B, or any losses from the system through tidal/wave transport or consumption. Furthermore, the assessments consider discharges of dead and moribund biota form a single point source. This adds a further precautionary factor to the assessment as the two FRR units, located approximately 300m apart, would allow a greater level of initial dilution with discharges split between two spatially separated points sources. Results should, therefore, be considered as highly precautionary.

22.7.483 The maximum spatial scale of the impacts is low and differs seasonally. Discharges would occur throughout the operational phase of the proposed development; therefore, the duration is high and the amount of change seasonally variable.

22.7.484 The impact magnitude is assessed as medium.

Benthic invertebrate sensitivity to un-ionised ammonia

22.7.485 The sensitivity of benthic invertebrates to un-ionised ammonia was assessed as part of the construction phase assessments for the CDO, provided in **Section 22.7c)ii**. of this chapter. The same evidence regarding the toxicity of un-ionised ammonia to benthic invertebrates (including *G. insensibilis*) is applied here, indicating that acute effects are unlikely at the concentrations that would be experienced within most of the footprint of this pressure (Ref. 22.55; 298; 299). Some adverse effects, including behavioural alterations, may occur in the immediate vicinity of the FRR outfalls.

22.7.486 No mortality is expected to result from un-ionised ammonia derived from decaying biomass released via the FRR. Moreover, the very small spatial extent of the footprint exceeding the EQS and the wide distributions of benthic invertebrate species within the GSB mean that a very small fraction of any population would be exposed to un-ionised ammonia concentrations above the EQS. Benthic invertebrates are, therefore, assessed as not sensitive to this pressure.

22.7.487 As impact magnitude is medium and benthic invertebrates are not sensitive to this pressure, increases in un-ionised ammonia due to discharges of dead and moribund biota from the FRR are predicted to have a minor adverse effect on this receptor. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to un-ionised ammonia

22.7.488 The *S. spinulosa* reefs within the GSB are not present within the footprint of this pressure. This receptor would therefore not be directly exposed to ammonia discharges. It is possible that the pelagic eggs and larvae of *S. spinulosa* would be exposed to elevated un-ionised ammonia concentrations. However, the very limited footprint of the pressure and its distance from *S. spinulosa* reefs mean that a negligibly proportion of the species' eggs and larvae would be exposed to this pressure. Such a low level of exposure is not expected to inhibit reef formation or development via reduced recruitment. *Sabellaria spinulosa* reef is therefore assessed as being not sensitive to this pressure.

22.7.489 Un-ionised ammonia due to discharges of dead and moribund biota from the FRR are predicted to have negligible effects on *S. spinulosa* reefs. This prediction is based on the cross-tabulation of impact magnitude and sensitivity and is highly conservative given the insensitivity of the receptor. The effect is **not significant**.

vi. Inter-relationship effects

22.7.490 This section provides a description of the identified inter-relationships that have the potential to affect benthic ecology receptors during the operation phase of the proposed development. These are the effects arising from additive, synergetic or antagonistic impacts of activities. Pressures with the potential to affect marine benthic receptors are presented in **Table 22.58**.

Table 22.58: Pressures associated with inter-relationships between activities during the operation phase with the potential to affect benthic ecology receptors.

Pressure	Activities resulting in pressure	Justification
Temperature changes and synthetic compound contamination.	Thermal discharges and discharges of total residual oxidants and hydrazine.	Effects of TROs and hydrazine on benthic ecology receptors within the thermo-chemical plume could be influenced by temperature-dependent toxicity.
Entrainment, and exposure to	Cooling water abstraction and	The combination of entrainment through the CWS (primary entrainment) and

Pressure	Activities resulting in pressure	Justification
temperature changes and synthetic compound contamination.	thermo-chemical discharges.	exposure to the thermo-chemical plume (secondary entrainment) has the potential to affect benthic ecology receptors.
Impingement, and exposure to temperature changes and synthetic compound contamination.	Cooling water abstraction and thermo-chemical discharges.	Potential to affect benthic ecology receptors.
Spread of INNS.	Presence of infrastructure and cooling water discharges.	The spread INNS through the introduction of hard substrate could be exacerbated by increases in temperature.

Total residual oxidants and temperature changes: In-combination effects of the thermo-chemical plume

22.7.491 Discharges of heated cooling water from the CWS outfalls would result in a thermal plume within the GSB. Additionally, the use of chlorination to control biofouling would result in the discharge of total residual oxidants (TROs) and, thus, the formation of a chemical plume. As these pressures overlap and both have the potential to affect benthic ecology receptors, there is the need to consider whether interactions between pressures (i.e. synergistic or antagonistic effects) are likely.

22.7.492 The impact magnitude for the thermal and TRO plumes in combination depends on the area where the two pressures overlap at ecologically relevant concentrations. Benthic invertebrates could be exposed to TROs both as adults and as planktonic eggs and/or larvae, the assessment therefore considers EQS exceedance both at the seabed and sea surface. The spatial extent of the TRO plume, based on EQS exceedance (10µg/l), represents a very small area of 2.1ha at the seabed. Therefore, the potential for overlap with the thermal plume at the seabed would be limited to this area. At the sea surface, a larger area of 338ha would be in exceedance of the EQS. At the boundary of the surface EQS threshold, thermal uplifts (98^{th} percentile) are less than 3°C, as provided in **Figure 21.8** of **Chapter 21** of this volume, and mean thermal uplifts are less than 1°C. At the seabed EQS exceedance covers an area of just 2ha. Seasonal chlorination and cooling water discharges would occur throughout the lifetime of the proposed development. The overall impact magnitude is assessed as medium.

Benthic invertebrate sensitivity to total residual oxidants and temperature changes

22.7.493 The assessment was focused both on adult benthic invertebrates, whose exposure to TROs would occur only at the seabed, and the pelagic eggs and larvae of benthic invertebrates, which would be exposed to TROs in the water column. The assessment also considered high-mobility (mobile) and low-mobility (sessile) taxa separately due to differences in their capacity for behavioural avoidance of this pressure.

22.7.494 Temperature and free chlorine can have synergistic effects, particularly when exposure temperatures approach the limits of a species tolerance range (Ref. 22.103; 117). Such effects mainly occur as stress associated with higher temperatures inhibits the resistance of organisms to other contaminants. The organisms under thermal stress are therefore more likely to suffer from additional adverse effects from the TRO discharges.

22.7.495 Assessments of the effect of temperature on the key sessile taxa of the GSB showed that bivalves (*L. balthica* and *Nucula* sp.) and amphipods (*B. elegans*, *G. insensibilis* and *C. volutator*) exhibited signs of metabolic stress associated with temperature increase. These two taxonomic groups were identified as being resistant to acute and chronic effects of the TRO plume, even in the vicinity of the outfall. The interaction between temperature and TROs in the receiving waters is not clear, but it may reduce the tolerance of these taxa to TROs. However, the area where the TRO and thermal plumes overlap on the seabed is very small, while the sessile invertebrate taxa found near the outfall are present throughout most of the GSB and wider region, as provided in **Appendix 22C** of this volume. Therefore, even if toxicity of TROs were substantially increased by the thermal plume, only a very small proportion of any sessile benthic invertebrate population would be affected by this pressure. As such, sensitivity of sessile benthic invertebrates to the combined pressures is low at the population level.

22.7.496 Two mobile benthic invertebrate key taxa of the GSB are either at the southern limit of their distribution (*P. montagui*) or are sensitive to increases in temperature (*H. gammarus*). These taxa could be vulnerable to synergetic effects of the thermal and TRO plumes. However, the sensitivity assessment for mobile taxa showed that survival strategies employed by organisms when challenged with stress is to escape by fleeing the disturbance, which for TROs at EQS concentration would occur over a very small on the seabed (2.1ha). Mobile benthic invertebrates are, therefore, assessed as not sensitive to the combined pressures of thermal and TRO plumes.

22.7.497 Toxicity tests found that a 5°C increase in temperature more than halved the LC_{50} concentration of free chlorine and chloramine in 30-minute exposures in larvae of the American lobster *H. americanus* and American oyster *C.*

virginica (Ref. 22.117). Therefore, the thermal plume may increase levels of egg and/or larvae mortality caused by TROs. However, benthic invertebrate larvae are produced in very high numbers and experience a high level of natural mortality (mainly through predation). Moreover, sharp environmental gradients would form as thermal uplifts and chemical concentrations rapidly reduce from the point of discharge, as provided in **Figure 21.7** of **Chapter 21** of this volume). It is likely that deleterious effects of the discharges would be in a localised area of water near the outfall and would affect only a small proportion of any plankton group (Ref. 22.87). Planktonic eggs and larvae of benthic invertebrates and larvae are therefore assessed as having low sensitivity to the combined pressures of thermal and TRO plumes at the population level.

22.7.498 As impact magnitude is medium and the sensitivity of benthic invertebrates to these pressures ranges from not sensitive to low, the combined effect of the thermal and TRO plumes on this receptor is predicted to be minor adverse. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to total residual oxidants and temperature changes

22.7.499 There is evidence that the mortality of *S. alveolata*, a closely related species to *S. spinulosa*, in response to TRO exposure occurs at elevated temperatures that would be experienced due to cooling water discharges (23°C) (Ref. 22.280). However, this interaction between pressures was only observed at TRO concentrations an order of magnitude higher than those predicted at the seabed due to discharges from the proposed development. Moreover, *S. spinulosa* reefs are not present in the area of the seabed where thermal and TRO plumes (above EQS concentrations) overlap. Therefore, there would be no direct effect of these combined pressures on this receptor. The planktonic eggs and larvae of *S. spinulosa* would, however, be exposed to the thermo-chemical plume in the water column, which could indirectly affect reef formation and development if it influences recruitment. The combined effects of the two pressures on *S. spinulosa* eggs and larvae are unknown, but as with other benthic invertebrates it is assumed that any potential losses would be minimal at the population level due to high levels of natural mortality (mainly through predation). *Sabellaria spinulosa* reef is therefore assessed as having low sensitivity to the combination of these pressures.

22.7.500 As impact magnitude is medium and *S. spinulosa* reef has low sensitivity to these pressures, the combined effect of the thermal and TRO plumes on this receptor is predicted to be minor adverse. The effect is **not significant**.

Hydrazine and temperature changes: In-combination effects of the thermo-chemical plume

22.7.501 As with TROs, the intersection of the hydrazine plume with the thermal plume has the potential to affect benthic ecology receptors to a greater or lesser degree than the pressures would have individually. Given the relatively small area of the hydrazine plume, its area constitutes the greatest possible extent of pressure overlap. As benthic invertebrates could be exposed to hydrazine both as adults and as planktonic eggs and/or larvae, the assessment considered EQS exceedance both at the seabed and sea surface. At the seabed, acute and chronic PNECs are predicted to be exceeded over <1ha, while at the sea surface the acute PNEC would be exceeded over 17.4ha and the chronic PNEC would be exceed over 158.1ha. Discharges of hydrazine and cooling water discharges would occur throughout the lifetime of the proposed development. The overall impact magnitude is assessed as medium.

Benthic invertebrate sensitivity to hydrazine and temperature changes

22.7.502 The area where hydrazine concentration would exceed acute and chronic PNECs at the seabed would be very small (<1ha) and the concentrations to which adult benthic invertebrates would be exposed are orders of magnitude below observed effect thresholds. Therefore, even if elevated temperature uplifts substantially increased the toxicity of the hydrazine plume, effects on benthic invertebrates are unlikely. This sub-receptor is therefore deemed not sensitive to the combined pressures of thermal and hydrazine plumes.

22.7.503 Planktonic eggs and larvae of benthic invertebrates could be exposed to the combined effects of hydrazine and temperature uplifts over an area of 158.1ha. Indeed, elevated water temperatures were found to enhance the toxicity of hydrazine to fish taxa (Ref. 22.87). While synergistic effects of hydrazine and temperature uplifts on the early life-stages of benthic invertebrates are unknown, the tolerance of the larvae of a sensitive species, *C. gigas*, to concentrations above what would be experienced at the outfall suggests that effects on benthic invertebrate larvae within the GSB are unlikely at the population level. Given the relatively large spatial extent of PNEC exceedance in surface waters compared to the seabed, the pelagic eggs and larvae of benthic invertebrates are precautionarily assessed as having low sensitivity to this pressure.

22.7.504 As impact magnitude is medium and the sensitivity of benthic invertebrates to these pressures ranges from not sensitive to low, the combined effect of the thermal and hydrazine plumes on this receptor is predicted to be minor adverse. The effect is **not significant**.

Sabellaria spinulosa reef sensitivity to hydrazine and temperature changes

22.7.505 *Sabellaria spinulosa* reefs are not present in the area of the seafloor where thermal and hydrazine plumes overlap. Therefore, there would be no direct effect of these combined pressures on this receptor. The planktonic eggs and larvae of *S. spinulosa* would, however, be exposed to the thermo-chemical plume in the water column, which could indirectly affect reef formation and development if it influences recruitment. The combined effects of the two pressures on *S. spinulosa* eggs and larvae are unknown, but as with other benthic invertebrates it is assumed that any potential losses would be minimal at the population level due to high levels of natural mortality (mainly through predation). *Sabellaria spinulosa* reef is therefore assessed as having low sensitivity to the combination of these pressures.

22.7.506 As impact magnitude is medium and *S. spinulosa* reef has low sensitivity to these pressures, the combined effect of the thermal and hydrazine plumes on this receptor is predicted to be minor adverse. The effect is **not significant**.

Entrainment and exposure to thermo-chemical plume

22.7.507 Organisms surviving entrainment through the cooling water system (primary entrainment) are, at the point of discharge, subsequently exposed to thermo-chemical plume (secondary entrainment). As this would apply to every organism entrained within the CWS, the same impact magnitude used for the assessment of this pressure alone is used again here. Hence, impact magnitude is medium.

Benthic invertebrate sensitivity to entrainment and thermo-chemical plume

22.7.508 As entrainment would affect small planktonic organisms, the benthic invertebrates affected by the combination of primary and secondary entrainment are those that are bentho-pelagic as adults (i.e. spend part of their time in the water column) and those with planktonic eggs and/or larvae. Given the small population losses (<2%) predicted for each life-stage even if entrained organisms experience 100% mortality, the potential combined effects of primary and secondary entrainment are very limited at the population level. Therefore, consistent with the assessment for primary entrainment alone, benthic invertebrates are assessed as having low sensitivity to the combination of these pressures. The predicted effect therefore remains minor adverse and **not significant**.

Sabellaria spinulosa reef sensitivity to entrainment and thermo-chemical plume

22.7.509 During the operational phase minor adverse effects are predicted on *S. spinulosa* reefs formations in the immediate vicinity of the intakes headworks due to entrainment reducing the potential for larvae to settle from the plankton. Furthermore, a small proportion of planktonic larvae in the water column may be exposed to the synergistic effects of thermal and chemical discharges. As with the pelagic eggs and larvae of other benthic invertebrates, the effects of primary and secondary entrainment on early life-stages of *S. spinulosa* would be very limited at the population level. Across the wider offshore Coralline Crag habitat, small thermal uplifts of 2ºC as a 98th percentile, as provided in **Figure 21.8** of **Chapter 21** of this volume, may have a minor beneficial effect on growth of the warm water species.

22.7.510 As such highly localised reductions in reef condition are possible due to lower recruitment potential, whilst small thermal uplifts at the seabed may enhance growth. The sensitivity of this receptor is low. The resultant effect is considered to be minor adverse to minor beneficial. The effect is **not significant** based (see **Table 22.38**. Periodic monitoring is recommended to determine broad scale changes in reef extent, provided in **Section 22.12** of this chapter.

Spread of non-indigenous species: presence of infrastructure (combined components) and cooling water discharges

22.7.511 Heated effluents from cooling water discharges have the potential to beneficially or adversely influence the spread of INNS, depending on their thermal niche. The introduction of hard substrata to an area consisting primarily of soft sediments could facilitate the spread of INNS that prefer hard habitats. Inshore infrastructure (BLF piles, CDO head, and FRR heads) would be installed in areas that experience temperature uplifts >3°C (98th percentile) due to cooling water, whilst CWS intake headworks and the seabed at the outfall heads would experience 2°C uplifts, as provided in **Figure 21.7** of **Chapter 21** of this volume.

22.7.512 It is expected that the full three-dimensional surface area of installed infrastructure would approximate 2ha. This additional hard substrate would be exposed to elevated temperatures.

22.7.513 A descriptor for Good Environmental Status (GES) under the Marine Strategy Framework Directive is "*Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems"*[45]*.* The proposed development would not directly introduce INNS. Measures to mitigate INNS, including compliance with the IMO Ballast Water Management Convention are detailed in the **CoCP** (Doc Ref. 8.11) and would

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[45] Adverse effects may be at the individual (e.g. pathogens), population (genetic change through hybridization), community (structural shift), habitat (changes to physical-chemical conditions) or ecosystem (changes to energy flows or organic cycling) levels (Ref. 22.300).

be upheld during the operational phase. However, thermal discharges are recognised as potential stepping stones for the spread of INNS (Ref. 22.300), and the combined infrastructure exceed the Marine Evidence-Based Sensitivity Assessment benchmark for creation of new colonising space (>1ha) (Ref. 22.11).

22.7.514 Impact magnitude is medium.

Benthic invertebrate sensitivity to introduction or spread of non-indigenous species

22.7.515 An operating power station at Sizewell has existed since 1966. During the course of extensive benthic characterisation surveys only one INNS was recorded, the American jacknife *E. leei* (previously *E. directus*), which occurred in a single grab sample, as provided in **Appendix 22C** of this volume and **Section 22.7.b)** of this chapter. Whilst, this species is not a fouling organism and, therefore unlikely to be affected by installed infrastructure, cooling water discharges may have an effect on the species and its interaction with native taxa.

22.7.516 Effects of INNS colonisation on native benthic invertebrate biota in the North Sea appear at present to be an expansion of the species pool rather than species displacement (Ref. 22.207). A 40-year annual time-series (1970-2009) from tidal flats in the Wadden Sea (southern North Sea) found that warming coincided with the introduction of four non-native benthic invertebrate species, which largely explained an expansion of the total species pool over time. The establishment of INNS did not appear to have had detrimental effects on the native biota, as a temporal increase in the number of species per site was mainly due to native species occurring at more sites than they had previously (Ref. 22.218).

22.7.517 The combination of installed infrastructure and temperature rise due to cooling water discharges is likely to primarily benefit INNS that prefer hard habitats and originate from areas with relatively warm climates. INNS from cooler climates may be unable to colonise the new surface due to exceedance of thermal tolerances. INNS that foul man-made structures and are projected to expand their distributions in north-west Europe due to climate change include; the Asian club tunicate *Styela clava*, which can outcompete filter feeders and result in declines in mussel productivity, the slipper limpet *Crepidula fornicata* that can cause trophic competition and change sediment structure at high densities, and the bay barnacle *Amphibalanus improvises*, which can outcompete native species for space and food (Ref. 22.140). These species have not been documented in the GSB, provided in **Appendix 22C** of this volume.

22.7.518 Most key taxa within the GSB, including those that colonise hard surfaces (e.g. *M. edulis*), are not expected to decline in abundance within the area of the thermal plume. Therefore, whilst the potential exists for INNS to colonisation structures, effects may be limited to competition for space on artificial structures. If populations of INNS do become established on the structures, it is possible that they will act as steppingstones for further geographical spread. The potential role of installed infrastructure and cooling water discharges in facilitating climate-change induced shifts in the distributions of fouling species is assessed in the following section.

22.7.519 Benthic invertebrates are predicted to have low sensitivity to the spread of INNS due to the presence of infrastructure and cooling water discharges. Minor adverse effects are predicted. The effect is **not significant**.

The effects of climate change on the spread of non-indigenous species

22.7.520 The American jacknife *E. leei* was the only INNS identified in extensive characterisation surveys, as provided in **Appendix 22C** of this volume and **Section 22.7.b)** of this chapter. This burrowing species is thought to have been introduced to Europe at a similar latitude (German Bight) to the GSB, within the cooler part of its thermal niche. The distribution of *E. leei* in the North Sea (and the north-west Europe) is predicted to expand this century due to an increase in sea temperature (Ref. 22.301). Therefore, it is possible that cooling water discharges from the proposed development would benefit this species and hasten its climate change-induced geographic spread. It should be noted, however, that this species has been recorded in the UK at sites north of the GSB, including other sites in East Anglia (Ref. 22.301). *Ensis leei* has therefore already reached areas to which the GSB could act as a steppingstone, and any effect on the spread of this species would likely be minimal beyond that of climate driven processes.

22.7.521 Various benthic invertebrate INNS that foul man-made structures, such as the Asian club tunicate, slipper limpet and bay barnacle, are projected to expand their northerly distributions into north-west Europe due to climate change (Ref. 22.140). Infrastructure associated with the proposed development could act as steppingstones facilitating this range expansion, particularly considering that waters surrounding the infrastructure would be relatively warm compared to the wider region. Such an effect would constitute an increase to the rate of an ongoing process.

22.7.522 The proposed development would not alter the outcome climate change-induced spread of INNS but could potentially accelerate this process in the local area, a minor adverse effect on benthic ecology receptors is predicted. The effect is **not significant**.

22.8 Fish ecology assessment

a) Introduction

22.8.1 This section applies the methodology, outlined in **Section 22.3** of this chapter, to determine the potential for significant effects arising from the construction and operational phases of the proposed development on fish receptors.

22.8.2 The magnitude of the environmental impacts prior to any additional (secondary) mitigation is considered and assessed assuming the primary and tertiary measures, detailed in **Section 22.5** of this chapter, are embedded. Where secondary mitigation or monitoring is deemed appropriate to minimise any adverse effects, the residual effects are then assessed and considered in **Section 22.13** of this chapter.

22.8.3 The fish ecology baseline is described and forms the basis against which to determine the effects. Effects, both beneficial and adverse consider the sensitivity of fish receptors to the specific impact magnitude arising from activities associated with the proposed development.

22.8.4 For the construction and operational phases of the proposed development, the assessment of effects is based upon a tiered approach, with consideration of effects at the following levels:

- The sea-area or regional stock/population level, considering effects on the viability of the stock/population.
- Localised displacement effects, with consideration of fish receptors as prey species for designated features and as fisheries resources.

22.8.5 A tiered approach has been adopted for two reasons. Firstly, the Greater Sizewell Bay (GSB) is not a discrete system and species recorded in the GSB area are part of a larger population, that may encompass the southern North Sea, or even the whole of the North Sea. Therefore, assessments needed to consider impact in the context of the wider population to determine effects. Secondly, the assessment also recognises that local level changes in abundance or behaviour, with no bearing on the population, can cause effects at the site. Therefore, the assessment includes localised displacement effects, with consideration of fish receptors as prey species for designated features and as fisheries resources.

b) Fish ecology baseline

22.8.6 This section presents a description of the baseline environmental characteristics within the footprint of the proposed development and in the surrounding area.

22.8.7 Further detail can be found in **Appendix 22D** of this volume.

i. Current baseline

22.8.8 The fish of the GSB area have been characterised from coastal demersal and pelagic trawl surveys; ichthyoplankton sampling; entrainment and impingement monitoring at Sizewell B, and international stock assessments. The use of multiple sampling methods or gears allowed a comprehensive description of the area to be produced, since a single gear or sampling method would be unable to fully sample the entire community.

22.8.9 It should be recognised that the range of gears and methods used in the different surveys have differences in gear selectivity and associated limitations. As an example, the coastal surveys used both beam and otter trawls because each has a different 'catchability' - the ability to catch a given species. The 2m beam trawl predominantly catches small sole, whilst the otter trawl catches larger, faster individuals that can avoid the beam trawl. The open mouth of the otter trawl means that it also catches demersal animals, while the 2m beam trawl catches benthic ones.

Coastal demersal trawl surveys

22.8.10 Coastal demersal trawl surveys were carried out from 2008 to 2012. In 2008, surveys in March, May, September and October were conducted with a 2m beam trawl, and a commercial otter trawl. The March 2008 survey was a scoping survey. The 2-m beam trawl survey in May 2008 comprised of 25 stations while surveys in September and October 2008, June 2009 and June 2010, sampled 20 stations. The 2008-2010 surveys also included a grid of 6 otter trawl stations. From 2011 onwards the original survey area was extended. The wider geographic area provided further coverage of the predicted southerly thermal plume and allowed a greater degree of design flexibility. Between June 2011 and March 2012, quarterly surveys were conducted at 40 beam trawl stations (12 from the 2008 – 2010 series, 25 additional stations to the south and 3 to the north) and 10 otter trawl stations, provided in **Appendix 22D** of this volume and **Figures 22.5** and **22.6**.

22.8.11 In April and May 2015, a survey was completed using a modified Isaacs-Kidd midwater frame trawl (IKMT) which has a small mesh net (2mm) that is designed to capture juvenile fish. The survey was aimed at targeting juvenile European eels (*Anguilla anguilla*; glass eels/elvers). Three sites were surveyed; the Sizewell B intake area, Sizewell/Dunwich Bank and the proposed Sizewell C intake/outfall area, provided in **Figure 22.7**. Although only a single glass eel was captured, several other species were captured, providing additional information on the fish within the GSB area (Ref. 22.302).

22.8.12 In February 2016, a 5-day survey was carried out using an otter trawl designed to target juvenile fish including young gadoids and seabass. Three sampling sites were located outside the Sizewell-Dunwich bank ("offshore") in similar depth strata and habitats. One site was in the area of the proposed Sizewell C intake/outfall structures and the other two were some distance north and south of this. Five sites were located inside the Bank ("inshore"); the first immediately north of the Sizewell B outfall; two about 1km north and south of this, but within the Sizewell B thermal plume; and two several km north and south and outside the plume, provided in **Figure 22.8**; **Appendix 21D** of this volume.

Coastal pelagic survey

22.8.13 A dedicated acoustic survey was conducted during March and August 2015, with the aim of determining the presence of clupeid species across the bay during the Spring and Summer periods. This survey covered an area from north of Dunwich to south of Aldeburgh, provided in **Figure 22.9**. Additional information on speciation was gathered by the deployment of pelagic trawl gear to ground-truth the acoustic signals (Ref. 22.303).

Sizewell B Impingement Monitoring Programme

22.8.14 BEEMS CIMP has been conducted at Sizewell B and data has been reviewed from 2009 until 2017. Between February 2009 and March 2013, 128 24-hour samples were collected. Sampling was carried out between April – September 2014; between April 2015 and March 2016, and between June 2016 and October 2017, with gaps in sampling due to station outages. During each visit, six x one hourly and one 18-hour overnight sample was taken. Impingement samples collected data on the number and weight of fish, invertebrates and other material passing through the station cooling water systems (Ref. 22.304–308).

Sizewell B Entrainment Monitoring Programme

22.8.15 In 2010-2011, a BEEMS Automated entrainment sampling facility was installed at Sizewell B, to sample the water from the Sizewell B forebay which was pumped to a header tank. The facility consisted of ten 750l tanks each with a plankton net (five 500µm and five 270µm mesh sizes). Each net sampled for 1.5 hours, with automatic switching between nets, which allowed for 24-h sampling (unmanned overnight). Flowmeters were used to determine sampled volumes, shown in **Appendix 22G** of this volume.

22.8.16 Forty sampling visits were completed between May 2010 and May 2011. During each visit, material from the one coarse and one fine sample was combined. The coarse and fine mesh net samples consisted of fish eggs, larvae and juveniles, and invertebrates. Standard plankton sample processing techniques were employed. The samples were sorted to lowest taxonomic group, enumerated and standardised to numbers per m^3 volumes, provided in **Appendix 22G** of this volume.

Ichthyoplankton surveys

22.8.17 Zooplankton surveys occurred between 2008 and 2012, and 2014 and 2017. Fish eggs and larvae were sampled with a Gulf VII high-speed plankton sampler. A grid-like design comprising 20 to 26 stations was used for surveys from 2008-2010, while in 2011 this was extended to 25-39 stations, to better encompass the extent of the predicted warm water discharge from the proposed development. In 2012, fortnightly surveys were conducted between April and July at the locations of the Sizewell B cooling water intake and the proposed intake. Between 2014 and 2017, monthly surveys were conducted across the GSB with targeted sampling at specific locations around the Sizewell B intakes and outfalls and proposed development infrastructure, provided in **Appendix 22B** of this volume. The towed ichthyoplankton surveys provide sufficient coverage to characterise the GSB and the locations of the proposed cooling water infrastructure, allowing a degree of engineering flexibility regarding the precise location of headwork installation, which would depend on constructability. It should be noted that the zooplankton surveys had differences in spatial coverage and objectives.

River Blyth smelt surveys

22.8.18 In 2016, surveys were undertaken to determine whether the River Blyth supports a spawning population and whether the fish impinged at Sizewell are from a specific river stock or a pan-East Anglian or a wider east coast stock. In March and April 2016, fyke nets were deployed in the River Blyth, Suffolk. Three nets were placed within the estuarine portion of the river and the remaining four nets were placed in the lower tidal reach of the river, provided in **Figure 22.10**. The sampling period coincided with the main spawning migration of smelt in the adjacent rivers Yare, Wensum, Bure, Waveney and Cambridge Ouse (Ref. 22.309). A bank walk-over survey was also undertaken in May 2016 to identify potential smelt spawning substrates (Ref. 22.309).

Marine fish baseline

Demersal fish and elasmobranchs

22.8.19 During the coastal surveys, Dover sole was the most commonly occurring species, present in 68% of beam trawls and all the otter trawl samples.

Whiting was found in a third of the beam trawls and 60% of the otter trawls. Gobies, dab and flounder were also generally common. Dab were recorded in two thirds of otter trawls and 13% of beam trawls, gobies in nearly half of the beam trawls and flounder in 75% of the otter trawls. Thornback rays were common in the otter trawls, being found in 75%, though they were rarely captured in the beam trawls. Many of the remaining species were reasonably rare; 26 of the 40 taxa caught in the 2m beam trawl were present in less than 10% of tows, with 11 recorded only once, seven of the 25 species in the otter trawls were recorded only once, provided in **Appendix 22D** of this volume.

Pelagic fish

22.8.20 The 2m beam trawl and commercial otter trawl may catch pelagic fish during deployment and retrieval, although neither is specifically designed for this purpose. Herring, sprat and anchovy were caught in the coastal demersal surveys by the 2-m beam trawl and herring by the otter trawl. No mackerel or horse mackerel were caught in the BEEMS coastal sampling, but were detected during the 2009-2013 impingement sampling. Anchovy and small sprat were also captured in the ground-truthing trawls carried out for the June 2015 acoustic survey. From the acoustic data, pelagic fish were more abundant in waters further north off Minsmere than around Sizewell itself, however, fish were found at Sizewell throughout the year, as provided in **Appendix 22D** of this volume.

22.8.21 The 2009-2013 CIMP dataset identifies that the most abundant marine species from impingement samples were sprat, herring, whiting, bass, sand goby and Dover Sole (Ref. 22.304–307) (Ref. 22.304–308). The same species were also the most abundant marine species in the 2014-2017 dataset, however, there was as an abundance of anchovy, transparent goby and seabass (Ref. 22.308).

22.8.22 Over the 2010-11 twelve-month CEMP surveys, 23 fish taxa were recorded as present, as either eggs, larvae, and/or small juveniles, provided in **Table 22.59**. Although some witch (*Glyptocephalus cynoglossus*) larvae were entrained, there are no self-sustaining witch stocks in the southern North Sea (Ref. 22.310). The larvae are considered to be vagrant larvae that have drifted from more distant populations and are not part of any southern North Sea witch stock. It is also noted that sandeel (Ammodytidae) attach their eggs to the substrate, so any sandeel eggs drifting in the plankton are unlikely to be viable, provided in **Appendix 22I** of this volume.

Table 22.59: Fish taxa by early life history stage entrained at Sizewell B.

Species	Present as		
	Eggs	Larvae	Juveniles
Butterfish (*Pholis gunnellus*)			✓
Dab (*Limanda limanda*)			✓
Dover sole (*Solea solea*)	✓	✓	
Dragonets (Callionymidae)	✓	✓	
Aanchovy (*Engraulis encrasicolus*)	✓		
European flounder (*Platichthys flesus*)		✓	
European seabass (*Dicentrarchus labrax*)	✓		
Garfish (*Belone belone*)	✓		
Gobies (Gobiidae)		✓	✓
Gurnards (*Trigla* spp.)	✓		
Atlantic herring (*Clupea harengus*)		✓	✓
Lesser weever fish (*Trachinus vipera*)	✓		
Long rough dab (*Hippoglossoides platessoides*)	✓		
Pilchard (*Sardina pilchardus*)	✓	✓	
Pipe-fishes/seahorses (Syngnathidae)		✓	✓
Right eyed flatfish (Pleuronectidae)		✓	
Rocklings (*Gaidropsarus* spp./*Onos* spp.)	✓		
Sandeel (Ammodytidae)	✓	✓	✓
Sea snail (*Liparis liparis*)		✓	
Solenette (*Buglossidium luteum*)		✓	
Soles (Soleidae)		✓	
European sprat (*Sprattus sprattus*)	✓	✓	✓
Witch (*Glyptocephalus cynoglossus*)		✓	

Ichthyoplankton

22.8.23 Results of the zooplankton surveys (2008-2012 and 2014-2017) provide an indication of the presence of the eggs and larvae in the GSB. During 2008-2012, anchovy, Dover sole, and sprat were the most dominant species accounting for over 95% of the total egg abundance across the full sampling period. Rockling and seabass eggs also accounted for over 1% of the total abundance. Solenette, unidentified specimens, lesser weever, pilchard, and mackerel all contributed to the top ten most abundant species (99.84% of total egg abundance). Rockling and sprat eggs started to appear in March, followed by Dover sole eggs in April and seabass eggs in May. The highest number of fish eggs was found in June-July and mostly comprised of anchovy, provided in **Appendix 22B** of this volume.

22.8.24 Fish larvae were dominated to a lesser extent by a few highly abundant taxa. Seven taxa accounted for over 90% of abundance and included gobies, unidentified clupeids, herring, sprat, Dover sole, and anchovy. Unidentified specimens, seabass and pilchards completed the top ten most abundant species (98.66% of total larvae). Larvae of clupeids and sandeel started to appear in April followed by Dover sole in May, goby in June and anchovy in July, provided in **Appendix 22B** of this volume.

22.8.25 The trend in ichthyoplankton observed in 2008-2012 was consistent with subsequent sampling between 2014-2017 (Ref. 22.25). Anchovy was the dominant ichthyoplankton group with eggs accounting for up to 81% of the total ichthyoplankton abundance in 2016-2017. In 2015-2016 lower numbers of anchovy were found and Dover sole eggs dominated the ichthyoplankton. However, the lower anchovy numbers in 2015-2016 may be due to timing of the survey as the peak abundance may have been missed as the eggs are short lived in the plankton. Sprat and sole eggs also continued to be found regularly. Other fish eggs including seabass were observed from March to June, rocklings were recorded during March to July and sprat and solenette in April to June, all of which consisted of ≤1% of the total ichthyoplankton abundance for each year. After the anchovy spawning period finished in September, very few eggs were found until the following February.

22.8.26 Gobies continued to be the most abundant larvae in 2015-2016 and 2016-2017 surveys, but few fish larvae were found throughout the three survey years. The most common larval group were Clupeidae (likely a mix of sprat and herring), which were most abundant in 2014-2015. Fewer taxonomic groups of ichthyoplankton were found from 2014-17 with 38 taxa including eggs and larvae compared to 51, provided in **Appendix 22B** of this volume.

22.8.27 Herring eggs were rarely caught during ichthyoplankton surveys, but it is acknowledged that the sampling techniques used do not target eggs on the seabed and would only sample herring eggs that have become detached or dislodged from the seabed.

Spawning and nursery grounds

22.8.28 High intensity spawning grounds of Dover sole, and low intensity nursery grounds of Dover sole and plaice, intersect the GSB. But these ecologically important grounds are also present in the region surrounding the GSB, provided in **Figures 22.11** and **22.12**. Sprat nursery grounds are considered to coincide with the GSB and high intensity nursery grounds of herring intersect the GSB, provided in **Figure 22.13**. Low intensity nursery grounds of, whiting, cod, , thornback ray, and mackerel also occur within the GSB, yet these are also evident in the region surrounding the GSB, provided in **Figure 22.13** to **Figure 22.14** (Ref. 22.311; 312).

Migratory fish baseline

22.8.29 Within the GSB, migratory fish recorded in the CIMP dataset, as well as the juvenile European eel survey and smelt survey, are as follows:

- Smelt (Osmerus eperlanus).
- European eel (Anguilla anguilla).
- Allis shad (*Alosa alosa*).
- Twaite shad (*Alosa fallax*).
- River lamprey (Lampetra fluviatilis).
- Sea lamprey (Petromyzon marinus).
- Sea trout (*Salmo trutta*).
- Atlantic salmon (*Salmo salar*).

Smelt

22.8.30 Smelt are anadromous[46]. Adult smelt live in the marine environment but migrate to estuarine or slightly brackish rivers to spawn in early Spring (February to April). Adults then return to sea (Ref. 22.313). Smelt are present in rivers adjacent to the study area (e.g. the Rivers Waveney and Yare). Stocks in Suffolk are considered to belong to a population associated with the Norfolk Broads and the estuarine and brackish waters around Great Yarmouth and Lowestoft (Ref. 22.313). Comparative genomic analyses concluded that smelt from Sizewell and from theRiver Thames, Waveney, and Great Ouse are genetically homogeneous with no genetic structuring seen within the region (Ref. 22.314) . Furthermore, it is considered probable that the smelt originate from a very large population in the River Scheldt in Belgium. Research sampling detected thousands of adults per hour and millions of larvae per hour (Ref. 22.315), which are also considered part of the same Southern North Sea smelt population.

[46] Anadromous fish live in the marine environment but migrate into freshwater to breed.

22.8.31 A tagging study showed that there was very little residency of smelt in the estuary at Breydon Water and the results of the work demonstrate that smelt occupy more coastal/marine than estuarine/brackish habit (Ref. 22.316). The nearest estuary to the north is the Blyth, approximately 12km away. Surveying using fyke nets and kick sampling methods was carried out in the tidal and estuarine areas of the Blyth in April and May 2016 when high density spawning migrations would have been expected if the fish were undertaking spawning migrations in the river. No smelt were found in the area, there was an absence of suitable spawning substrate and a barrier to migration (Ref. 22.309). It is therefore highly unlikely that there is a spawning population in the Blyth, see **Appendix 22D** of this volume.

22.8.32 Smelt is listed as a Priority Species in Section 41 of the Natural Environment and Rural Communities (NERC) Act 2006.

European eel

22.8.33 The European eel is catadromous[47], breeding in a specific region of the North Atlantic (thought to be the Sargasso Sea). After hatching the young larvae (known as leptocephali) are transported back to European coasts by ocean currents (Ref. 22.317; 318). As they approach the continental shelf, the leptocephali become glass eels, then transition into elvers. In the North Sea, elvers ascend rivers in March and April after metamorphosis, although some may remain in estuaries or coastal waters (Ref. 22.319).

22.8.34 Little is known about the residence times of glass eels in the southern North Sea. The eels reach the coast and seek a salinity cue to transition from oceanic waters to coastal ones, so the time spent in the open North Sea is dependent on when they sense this cue. Once in freshwater, the eels spend many years growing and feeding (7-12 years for males and 9-19 years for females, termed yellow eels. On reaching a length of approximately 41cm (males) and 54-60cm (females), they begin migrating out to sea where they become silver eels (Ref. 22.317; 318; 320). Silver eels are believed to complete their return migration in deep water (~2,000m) using Gulf Stream counter-currents that help them move in a generally westward direction.

22.8.35 Sampling for glass eels on tributaries of the River Thames is carried out annually between April and September. This has also suggested that glass eels would be present in the East Anglia marine environment, prior to entering freshwater, in or around April and May (Ref. 22.321).

22.8.36 No eels were found in the BEEMS coastal trawl surveys, although it is recognised that these survey gears do not effectively target adult eels. In

[47] Catadromous fish live in freshwater but migrate to the marine environment to breed.

April/May 2015, an additional survey was undertaken targeted towards glass eels in the area of the proposed development cooling water infrastructure (Ref. 22.321). Only one glass eel was captured from the 105 valid hauls and it was concluded that this lack of glass eels at Sizewell was indicative of the extremely low local abundance and high level of dispersal of this particular life stage in this open coastal area of the North Sea (Ref. 22.321).

22.8.37 European eel is listed as critically endangered in the International Union for Conservation of Nature (IUCN) Red in 2014, is listed as a Priority Species in Section 41 of the NERC Act 2006 and has been included on the OSPAR List of Threatened and/or Declining Species and Habitats.

22.8.38 An Eels Regulations Compliance Assessment has been completed as part of the Sizewell C DCO submission, provided in **Appendix 22O** of this volume**.**

Twaite shad and Allis shad

22.8.39 Twaite shad is distributed along most of the west coast of Europe from the eastern Mediterranean Sea to southern Norway and in the lower reaches of large rivers along these coasts that are accessible to the fish (i.e. rivers that lack barriers to migration). The species has declined substantially across Europe and in the UK. It is now known to breed only in the Severn River Basin District in the Severn, the Wye, the Usk and the Tywi) and in the Solway Firth. There are also non-breeding populations in the UK off the southern and eastern coasts, at Looe Bay, Hastings and Sizewell (Ref. 22.322). Shad are anadromous.

22.8.40 The decline of the Twaite shad population has not been as severe as that of Allis shad. This is probably because of its ability to use spawning sites closer to the sea than those of Allis shad, which are not subject to the barriers to migration that block Allis shad from accessing its traditional spawning sites.

22.8.41 On the North Sea coast of Europe, adult Twaite shad are relatively common from Belgium to Denmark. Adult populations are increasing in the known German spawning rivers of the Elbe/Weser with sporadic spawning in the Ems (Ref. 22.323; 324). Twaite shad populations are also increasing in the Baltic, particularly in Poland and Lithuania where the species is classified as in good condition with increasing populations (Ref. 22.324).

22.8.42 Genetic analyses of twaite shad from Sizewell demonstrate that they do not originate from the Severn catchment (Ref. 22.322). A North Sea Twaite shad population has been identified, with low genetic diversity between fish sampled off Belgium (Scheldt) and Denmark and also the Solway Firth (Ref. 22.325). These analyses identified separation between the Baltic and North Sea populations and the North Sea population. Therefore, it would appear to most likely originate from the German rivers of the Elbe/Weser. Twaite shad also breed with variable success in the River Scheldt, Belgium. The Twaite shad caught at Sizewell are >1 year old juveniles to sexually mature adults that are part of widely dispersed feeding population in the North Sea, that are anticipated to eventually return to German rivers to reproduce.

22.8.43 Shad is listed under Appendix III of the Bern Convention and Annexes II and V of the EU Habitats Directive. Allis shad is also included on the list of Threatened and/or Declining Species produced by OSPAR, on Schedule 5 of the Wildlife and Countryside Act (1981), and as a Priority Species in Section 41 of the NERC Act 2006.

River and sea lamprey.

22.8.44 River and sea lamprey occur in estuarine/coastal environments. Both are parasitic and the adults feed by attaching to other fish. River lamprey feed in coastal areas and migrate into freshwater rivers and streams in the Spring to spawn (i.e. they are anadromous). Young adults migrate out to sea in Winter and spend one or two years feeding at sea. At the onset of maturity, the adults stop feeding and returning to suitable freshwater habitat to spawn (Ref. 22.326).

22.8.45 Sea lamprey demonstrates a similar life history to the river lampreys; however, the larval and adult stages are slightly longer (0.5-1 year longer). After metamorphosis, juvenile sea lamprey migrate directly to the sea (Ref. 22.317). Sea lamprey is uncommon in the UK and the main population centre, concentrated on the Bristol Channel, is distant from the proposed development.

22.8.46 The river lamprey is found in coastal waters, estuaries and accessible rivers in western Europe, from southern Norway to the western Mediterranean (Ref. 22.327). The rivers of the Severn Estuary are thought to be the most important areas in the UK for sea lamprey and possibly river lamprey too (Ref. 22.328).

22.8.47 Sea and river lampreys spawn in coarse, well aerated riverbeds and juveniles, known as ammocoetes, spend several years living in aerobic silt beds filtering sediments, before transforming to migrants that move downstream to sea in the Spring. After some years growing in the marine environment they move back into freshwater, migrate upstream to spawn (Ref. 22.329). River lamprey move into freshwater during the previous summer, Winter and Spring before spawning in Spring, whereas sea lamprey migrate into estuaries in the Spring and then upriver to spawn in late Spring to early Summer. The fish are semelparous and die after spawning (Ref. 22.329).

22.8.48 The southern North Sea population of river lamprey are probably one stock. Spawning takes place in the Ouse, UK and the Scheldt in the Netherlands, where the adult population is estimated to be in the 100,000s (Ref. 22.330) and in other European rivers that drain into the North Sea.

22.8.49 Genetic studies suggest that sea lamprey are a single, pan-European population (Ref. 22.331) with widespread distribution. This is thought to be determined to a large extent by the movements of the fish hosts on which the lampreys feed, and the fact that the adult lamprey do not display any apparent homing behaviour during spawning migrations (Ref. 22.332). River lamprey also display the same parasitic behaviour in the marine environment and are also not considered to home to natal rivers. As would be expected they show only low levels of genetic differentiation between local stocks across England (Ref. 22.333).

22.8.50 Sea and river lamprey are listed under Annexe II of the EU Habitats Directive and under Section 41 of the NERC Act 2006, as a priority Species.

Atlantic salmon and sea trout

22.8.51 Salmon are anadromous. They spawn in freshwater in the Autumn and Winter (usually November and December) and any surviving adults return to the sea (most salmon die after spawning). Juvenile fish spend one to three years in freshwater before migrating to sea in Springtime. After one to three years at sea, the salmon return to their home rivers as mature adults. Sea trout co-exist with salmon and have a similar lifecycle.

22.8.52 Little is known about salmon movements in the North Sea, but it is thought that they may move into the Norwegian Sea in the summer and Autumn of their first sea year, and that some could migrate as far as western Greenland during the following summer. Sea trout (caught by anglers in East Anglia) are predominantly from the NE coast of the UK with small numbers from Denmark, the Rhine and a few from Norfolk and SW England, provided in **Appendix 22D** of this volume.

22.8.53 In the nine years of CIMP at Sizewell B, no Atlantic salmon were caught and only two sea trout were caught in 2010. None of these species were caught in any of the BEEMS fishing surveys.

22.8.54 Atlantic salmon is listed under Annexe II of the EU Habitats Directive and both salmonids are listed under Section 41 of the NERC Act 2006 as a Priority Species.

Migration periods

22.8.55 **Table 22.60** lists the migration periods for life history stages of the migratory fish, based on available information.

Table 22.60: Information on migration period of migratory fish species.

Common name	Scientific name	Migration period	References
European smelt	*Osmerus eperlanus*	Adults live in the marine environment but migrate to estuarine or slightly brackish rivers in early Spring (February to April) to spawn. Adults then return to sea.	(Ref. 22.313).
European eel	*Anguilla anguilla*	Glass eels/elvers migrate into estuaries and rivers in March to April, after metamorphosis, although some may remain in estuaries or coastal waters.	(Ref. 22.319).
		Silver eels migrate to the Sargasso Sea in September to December.	(Ref. 22.318; 320).
Allis shad	*Alosa alosa*	Mature shad move up the estuaries of large rivers at the end of February, migrating into freshwater to breed during late Spring (April–June).	(Ref. 22.334).
Twaite shad	*Alosa fallax*	Mature Twaite and Allis shad that have spawned, migrate back to the sea. However, most Allis shad die after reproduction. Juvenile shad migrate down the river and then seawards to reach the marine environment by December of their first year.	
River lamprey	*Lampetra fluviatilis*	Young adults migrate from rivers to sea in Winter then spend one or two years feeding at sea. Adults migrate into estuaries in August to December and return to suitable freshwater habitat to spawn in Spring.	(Ref. 22.317; 326).
Sea lamprey	*Petromyzon marinus*	Sea lamprey spawn in May and June in British rivers, when the water temperature reaches at least 15ºC. Adults migrate back into fresh water in April and May. Sea lamprey demonstrate a similar life history to the river lamprey, but the larval and adult stages are slightly longer (0.5- 1 year longer). After metamorphosis, juvenile sea lamprey migrate directly to the sea.	(Ref. 22.317; 329)
Atlantic salmon	*Salmo salar*	Salmon spawn in freshwater after which any surviving adults return to the sea (most salmon die after spawning). Juvenile salmon spend 1-3 years in freshwater before migrating to sea in Springtime. After 1-3 years at sea, the salmon return to their home rivers as mature adults.	**Appendix 22D** of this volume.
Sea trout	*Salmo trutta*	Sea trout co-exist with salmon and have similar life-cycles. Some trout are fully resident in their natal stream or river while others undertake a smolt transformation then migrate to sea to grow (predominantly females, termed sea trout). Migrants return to spawn in their natal areas when they are sexually mature. Post smolts migrate down the East Anglian coast around late May to early June, with adults migrating through the summer.	

Summary of key fish taxa

22.8.56 For the purposes of the assessments, taxa are considered to be key in the ecosystem if they meet at least one of the following criteria:

- Socio-economic value.
- Conservation importance.
- Ecological importance.

22.8.57 Socio-economic value was based on species that contribute to the first 95% of the first sale value of commercially-landed finfish in the area off the East Anglian coast and contributes to the first 95% of total abundance in at least one of the available datasets (2-m beam trawl, otter trawl, eel surveys, annual impingement). Commercial landings are recorded using statistical rectangles that divide the southern North Sea into areas of 30 minutes latitude by 1 degree longitude and covering approximately 30 nautical miles. For the purposes of describing local commercial fisheries, six rectangles have been considered, that extend from north Norfolk to the Thames Estuary and eastwards to the middle of the North Sea, provided in **Appendix 22F** of this volume. Socio-economic value was calculated using data supplied by the Marine Management Organisation and landings and values were summed for the years 2011-2013. The fin-fish species identified as being of socio-economic importance are illustrated in **Table 22.61** and are consistent with more recent landings' statistics (2017) for ICES (International Council for the Exploration of the Seas) rectangle 33F1[48] obtained from the MMO and detailed in **Section 22.11.b)** of this chapter and **Appendix 22F** of this volume.

22.8.58 Conservation importance considered the designated status of the species. This included whether the species was listed as a Priority Species in Section 41 of the NERC Act 2006, provided in **Appendix 22D** of this volume.

22.8.59 Ecological importance was based on a species being common and/or abundant enough to play a key trophic role within the ecosystem. This considered taxon presence in at least 30% of samples and where taxon contributed to the first 95% of total abundance, in at least one of the available

[48] Smooth-hound (*Mustelus sp.*) was recorded as the sixth greatest landing by live weight in ICES rectangle 33F1 in 2017, however the first sale vale of the species does not contribute to the top 99% of landing value **Appendix 22F** of this volume. Starry smooth-hound (*M. asterias*) has been recorded in low numbers in impingement sampling at Sizewell B and in low numbers in otter trawls within the GSB, provided in **Appendix 22D** of this volume.

datasets (2m beam trawl, otter trawl, eel surveys, annual impingement), as provided in **Appendix 22D** of this volume.

22.8.60 There are 24 key taxa in the GSB in total. Several taxa fall under more than one criterion and four taxa are important with respect to all three, provided in **Table 22.61**. The selection criteria for assigning value to receptors outlined in **Table 22.2** indicated that all 24 key fish taxa have medium to high value based on socio-economic, ecological and/or conservation importance. It should be noted that many of the conservation species, such as salmonids, are extremely uncommon within the GSB. However, the key fish taxa are considered as important receptors and are assessed accordingly.

Table 22.61: Key fishes of the Greater Sizewell Bay based on socio-economic, ecological and conservation importance (salmon, in grey, were not observed during any of the surveys).

Common name.	Scientific name.	Socio-economic	Conservation	Ecological	Survey/ monitoring presence.
European sprat.	*Sprattus sprattus*	Fished in the coastal drift net fishery.	No direct conservation value. Prey species for designated seabirds and marine mammals.	Common and abundant.	Glass eel surveys. CIMP. Acoustic survey and Lowestoft frame trawl.
Atlantic herring.	*Clupea harengus*	Targeted by net fishery, locally and regionally.	Species of Principal Importance, section 41, NERC Act[49] 2006. Prey species for designated seabirds and marine mammals.	Common and abundant.	Glass eel surveys. CIMP.
Whiting	*Merlangius merlangus*	Target species for trawl and net fisheries and recreational sea angling, locally and regionally.	NERC Act Species of Principal Importance. Prey species for designated seabirds and marine mammals.	Common and abundant.	2m beam trawl. Otter trawl. CIMP.
European seabass.	*Dicentrarchus labrax*	Prior to special measures in 2016, seabass was a key target species for netting and lining fisheries as well as recreational sea angling locally and regionally.	No direct conservation value. Prey species for designated seabirds and marine mammals.	Common and abundant.	CIMP. Juvenile fish survey. River Blyth fyke net survey.
Sand gobies.	*Pomatoschistus* spp.	Not of direct value to local or regional fisheries.	No direct conservation value. Prey species for harbour porpoise.	Common and abundant.	Glass eel surveys. 2m beam trawl. CIMP.

[49] Natural Environment and Rural Communities Act 2006.

Common name.	Scientific name.	Socio-economic	Conservation	Ecological	Survey/ monitoring presence.
Dover sole.	*Solea solea*	Target species for trawl, lining and net fisheries, locally and regionally.	NERC Act Species of Principal Importance. Harbour porpoise is partially dependent on this species.	Common and abundant.	2m beam trawl. Otter trawl.
Dab	*Limanda limanda*	Target species for trawl, lining, net fisheries and sea angling, locally and regionally.	No direct conservation value. Prey species for harbour porpoise and grey seals.	Common and abundant.	Otter trawl. CIMP.
Anchovy	*Engraulis encrasicolus*	Not considered of value to local or regional fisheries.	No direct conservation value. Prey species for designated seabirds and marine mammals.	Common and abundant.	CIMP. Acoustic survey and Lowestoft frame trawl.
Thin-lipped grey mullet.	*Liza ramada*	Target species for netting fishery and recreational sea angling, locally and regionally.	No direct conservation value.	Common and abundant.	CIMP. River Blyth fyke net survey.
European flounder.	*Platichthys flesus*	Target species for trawl fishery and sea angling, locally and regionally.	No direct conservation value.	Common and abundant.	Otter trawl. River Blyth fyke net survey.
Atlantic cod.	*Gadus morhua*	Target species for trawl, netting, lining and sea angling, locally and regionally.	NERC Act Species of Principal Importance.	Common and abundant.	Otter trawl.
European plaice.	*Pleuronectes platessa*	Target species for trawl and recreational sea angling, locally and regionally.	NERC Act Species of Principal Importance.	Common and abundant.	Otter trawl.
European Smelt.	*Osmerus eperlanus*	Not considered of value to local or regional fisheries.	NERC Act Species of Principal Importance. European smelt is considered an indicator of Good		CIMP. River Blyth fyke net survey.

Common name.	Scientific name.	Socio-economic	Conservation	Ecological	Survey/ monitoring presence.
			Ecological Status for transitional waters under the Water Framework Directive.		
Thornback ray.	*Raja clavata*	Target species for trawl, netting, and recreational sea angling, locally and regionally.	No direct conservation value.	Common and abundant.	Otter trawl.
European eel.	*Anguilla anguilla*	Limited, seasonal fyke net fishery and restricted fishery due to Anglian Net Limitation Order. Recreational angling with catch and release of eels.	NERC Act Species of Principal Importance. Eel is assessed as Critically Endangered on the IUCN Red List and is on the OSPAR list of Threatened and/or Declining Species. National value through Eel Management Plans and the Anglian Eel Management Plan.		IKMT juv.eel trawl. River Blyth fyke net survey. CIMP.
Horse mackerel.	*Trachurus trachurus*	Limited catch in net fishery regionally.	NERC Act Species of Principal Importance.		CIMP.
Twaite shad.	*Alosa fallax*	Not considered of value to local or regional fisheries.	NERC Act Species of Principal Importance. Appendix III of the Bern Convention and listed in Annexes II and V of the EU Habitats Directive.		CIMP.
River lamprey.	*Lampetra fluviatilis*	Not considered of value to local or regional fisheries.	NERC Act Species of Principal Importance.		CIMP.
Mackerel	*Scomber scombrus*	Targeted by drift net fishery and recreational sea angling regionally.	NERC Act Species of Principal Importance.		CIMP.
Sea trout.	*Salmo trutta*	Limited regional drift net fishery.	NERC Act Species of Principal Importance.		Observed in CIMP.
Allis shad.	*Alosa alosa*	Not considered of value to local or regional fisheries.	NERC Act Species of Principal Importance. Appendix III of the Bern		CIMP.

Common name.	Scientific name.	Socio-economic	Conservation	Ecological	Survey/ monitoring presence.
			Convention and listed in Annexes II and V of the EU Habitats Directive. Also included on the OSPAR list of Threatened and/or Declining Species, listed on Schedule 5 of the Wildlife and Countryside Act (1981).		
Tope	*Galeorhinus galeus*	Targeted by recreational sea angling.	NERC Act Species of Principal Importance.		Otter trawl.
Atlantic salmon.	*Salmo salar*	Not considered of value to local or regional fisheries.	NERC Act Species of Principal Importance.		N/A
Sea lamprey.	*Petromyzon marinus*	Not considered of value to local or regional fisheries.	NERC Act Species of Principal Importance.		CIMP.

Fish as prey of designated species

22.8.62 Effects on the abundance and distribution of fish as a marine prey species from impacts arising from the proposed development are considered in relation to designated seabirds and marine mammals (harbour porpoise and seals). The predominant prey species for designated marine mammals and seabirds at Sizewell include (Ref. 22.335):

- Sprat.
- Herring.
- Anchovy.
- Whiting.
- Seabass.
- Dover sole.
- Gobies.
- Dab.

22.8.63 Indirect (food web) effects are considered further in **Section 22.10** of this chapter, specific effects on designated species is considered in more detail in the **Shadow HRA** (Doc Ref. 5.10).

Fish groupings for assessment purposes

22.8.64 The key taxa have been grouped into three over-arching groups: demersal fish and elasmobranchs, pelagic fish and migratory fish, provided below in **Table 22.62**. Groupings allow a coherent approach to assessing development impacts for key taxa and allows an approach whereby the potential for effects on less common or abundant taxa can be inferred.

Table 22.62: Key taxa assigned to three overarching groups.

Species	Demersal fish and Elasmobranchs	Pelagic fish	Migratory fish
Dab	✓		
Dover sole	✓		
European flounder	✓		
European plaice	✓		

Species	Demersal fish and Elasmobranchs	Pelagic fish	Migratory fish
Whiting	✓		
Atlantic cod	✓		
European seabass	✓		
Thin-lipped grey mullet	✓		
Sand gobies	✓		
Thornback ray	✓		
Tope	✓		
Anchovy		✓	
European sprat		✓	
Atlantic herring		✓	
Mackerel		✓	
Horse mackerel		✓	
European eel			✓
European smelt			✓
Allis shad			✓
Twaite shad			✓
River lamprey			✓
Sea lamprey			✓
Atlantic salmon			✓
Sea trout			✓

22.8.65 In addition to the over-arching assessment groups, assessments consider potential effects to relevant life history stages of each group (eggs, larvae, juvenile, adult). For ease of review, introductory tables identifying the relevant assessment groups for each pressure are provided for the construction and operational phases of the proposed development. Assessment tables indicate the receptors groups and rationale for the chosen groupings.

ii. Future baseline

22.8.66 The 2017 Marine Climate Change Impacts Partnership[50] review on fisheries describes the changes expected in fish and fisheries with climate change

[50] The Marine Climate Change Impacts Partnership provide the most comprehensive reviews of climate change impacts on the UK marine environment.

(Ref. 22.336), and is summarised in this paragraph. There has been a trend in recent decades for warm-affinity species to increase in abundance, and cold-affinity species to decrease in abundance, with many cold-water species moving northwards. For example, there has been a decline in abundance of Atlantic cod (linked with fishing pressure and climate), and a general northwards shift. Mackerel have shown complex changes in recent years, but with a general north and westward shift linked with sea temperature. Sea bass, a warm-affinity species, expanded distribution and increased in numbers in the early 2000s, but fishing mortality then reduced numbers again. Similarly, anchovy has expanded distribution in the North Sea in the past decade. There are exceptions to this general trend, such as sole which has shifted distribution southwards and are able to remain in shallow North Sea waters all year around. Changes in plankton phenology, provided in **Section 22.6.b)** of this chapter, has resulted in changes in timing of fish spawning with a shift of approximately 1.5 weeks earlier per decade in the southern North Sea since 1970s (Ref. 22.336).

22.8.67 The 2013 Marine Climate Change Impacts Partnership review describes some of the impacts being seen or expected in the southern North Sea specifically (Ref. 22.337). These are: anchovy and sardines (pilchard) are moving northwards; cold water species will decline or shift northwards or into deeper, cooler waters, with warm water species increasing in abundance; the North Sea will become less productive; and ocean acidification may further compromise fish physiology, growth, reproduction and behaviour. Modelling predicts that habitat suitability around the UK will increase this century for European squid, sea bass, pilchard, sprat, veined squid, John dory, anchovy, sole, plaice and whiting, and that it will decrease for saithe, hake, red mullet, haddock, halibut, mackerel and herring (Ref. 22.338). Except for sole and whiting, the southerly distribution of all species is predicted to move northwards around the UK.

c) Construction

22.8.68 The construction phase, including commissioning, of the proposed development has the potential to effect fish receptors. Construction is anticipated to last between nine and 12 years, the earliest date for construction to commence is anticipated to be 2021.

22.8.69 This section considers the development components and associated activities that were identified during scoping, provided in **Appendix 22M** of this volume, to result in pressures warranting further investigation. Construction phase pressures and fish assessment groupings are presented in **Table 22.63**.

Table 22.63: Pressures, key taxa and relevant life history stage groups and justification for the groups.

Pressure	Groupings	Justification
Physical change (to another seabed type).	• Marine fish eggs/egg cases and larvae. • Marine fish adults and juveniles.	These broad groups allow assessment of different life history stages having differing sensitivities to the pressure.
Changes in suspended sediment/solids.	• Demersal fish and elasmobranch eggs/egg cases and larvae. • Demersal juveniles and adults (and small bodied fish). • Pelagic eggs and larvae. • Pelagic juveniles and adults. • Migratory fish juveniles and adults.	Different life history stages may have differing sensitivities to the pressure, the groupings allow a full assessment across life-history stages.
Sedimentation rate changes.	• Demersal fish and elasmobranch eggs/egg cases and larvae. • Demersal juveniles and adults (and small bodied fish). • Pelagic eggs and larvae. • Pelagic juveniles and adults. • Migratory fish juveniles and adults.	Species that lay demersal eggs have the potential to be affected, the assessment grouping differentiates marine/estuarine species with demersal eggs from marine and migratory species that do not lay demersal eggs in the marine environment. To determine potential effects from the pressure to the different life history stages of the species within this grouping.
Underwater noise	• Fish with swim bladder or other air cavities to aid hearing. • Fish with swim bladder that does not aid hearing. • Fish without a swim bladder. • Demersal and pelagic fish eggs and larvae.	Groupings are the same as the categories used in (Ref. 22.53) guidelines, except for demersal and pelagic fish eggs and larvae.
Organo-metal contamination.	• Marine fish eggs and larvae. • Marine fish adults and juveniles (including	Different life history stages and species may have differing sensitivities to the pressure, the groupings allow a full assessment.

Pressure	Groupings	Justification
	small bodied individuals). • Migratory adults and juveniles.	
Hydrazine contamination.	• Marine fish eggs and larvae. • Marine fish adults and juveniles (including small bodied individuals). • Migratory adults and juveniles.	Species that lay demersal eggs have the potential to be affected, the assessment grouping differentiates marine/estuarine species with demersal eggs from marine and migratory species that do not lay demersal eggs in the marine environment. Different life history stages and species may have differing sensitivities to the pressure, the groupings allow a full assessment.
Nutrient enrichment (un-ionised ammonia).	• Demersal fish and elasmobranch eggs/egg cases and larvae. • Demersal juveniles and adults (and small bodied fish). • Pelagic eggs and larvae. • Pelagic juveniles and adults. • Migratory fish juveniles and adults.	To clearly delineate marine/estuarine species with demersal eggs from marine and migratory species that do not lay demersal eggs in the marine environment. To determine potential effects from the pressure to the different life history stages of the species within this grouping.

i. Coastal defence features

22.8.70 Activities for the SCDF and HCDF generally occur above MHWS and are therefore not predicted to affect fish receptors during the construction phase.

ii. Beach landing facility

22.8.71 This section describes the impacts associated with the installation and operation of the beach landing facility (BLF) during the construction phase. Scoping identified the pressures arising from activities at the BLF with the potential for effects on ecological receptors, provided in **Appendix 22M** of this volume. Pressures with the potential to affect fish receptors are presented in **Table 22.64**.

Table 22.64: Pressures associated with beach landing facility activities during the construction phase that have the potential to affect fish receptors.

Pressure	Activities resulting in pressure	Justification
Physical change to another seabed type.	Presence of structure.	Potential to affect fish receptors through habitat change.
Habitat change - Reprofiling of substratum (extraction).	Navigational dredging.	The proposed plough dredge method for navigational dredging, does not extract material. However, banking of redistributed sediments may occur in the local vicinity causing burial of surficial sediments and burial and stress of fish and eggs/egg cases/larvae.
Changes in suspended sediments.	Navigational dredging.	Increases in SSC have the potential to result in a range of physical and physiological effects on different life history stages and species of fish. Behavioural effects, notably avoidance behaviour, could displace species from preferred habitat or influence the passage of migratory species.
Sedimentation rate changes.	Navigational dredging.	The deposits of sediment could smother eggs/egg cases/larvae, juveniles and small bodied fish. Smothering may result in stress and potential for mortality.
Underwater noise and vibration.	Navigational dredging and impact piling.	Navigational dredging and piling for the BLF would generate underwater noise. The potential effects of underwater noise on fish receptors (eggs, larvae and juvenile and adult stages), range from mortality and injury at close range to the activity, to hearing impairment, masking, behavioural effects and barrier to movement further away from the sound source.

22.8.72 Construction pressures scoped out of further assessment as they have been deemed to have negligible effects on fish receptors include:

- Additional vessel traffic associated with the BLF, may result in a slight (few dB) increase in the ambient noise levels along the delivery route. However, the median noise levels are unlikely to be affected, as provided in **Appendix 22L** of this volume. Therefore, no further consideration is given to noise from vessel transits.

- Piling, dredging, and vessel activity associated with the BLF has the potential to resuspend sediment bound contaminants. Sediment contamination levels are below Cefas Action Level 2 and are within safe ranges for disposal at sea, as provided in **Appendix 22K** of this volume.

Therefore, resuspension of sediment contaminants following such activities is not predicted to effect marine ecology receptors. No further assessment is made.

- Artificial lighting on the BLF and moored vessels would introduce light into the marine environment. Mitigation measures as part of the site Lighting Strategy aims to minimise light spill into the marine environment. The turbidity of the waters within the GSB would result in rapid light attenuation particularly in the shallow subtidal areas where the BLF would be located. As such, negligible effects to fish receptors are predicted from light spill. No further consideration is given to light and visual disturbance to fish receptors.

22.8.73 A summary of pressures associated with dredging and piling activities, and the effects on fish receptors is provided in **Table 22.65**.

Table 22.65: Summary of evidence for assessment of effects on fish receptors arising from pressures associated with BLF dredging and piling activities.

Pressure	Receptor	Potential effect
Physical change (to another seabed type).	Marine fish eggs/egg cases and larvae.	For early life stages of marine species, metamorphosis and post-larval settlement onto the seabed may be impacted by the altered seabed habitat (soft to hard substrata). Laboratory studies indicate that metamorphosing and newly settled Dover sole prefer sandy and muddy substrata (Ref. 22.339). Plaice settlement is associated with soft substrata, with a preference for bare sediment (Ref. 22.340). Pelagic goby larvae metamorphose into juveniles, with benthic settlement. The juveniles are reported to migrate into sheltered locations such as estuaries with soft sediments, then into coastal waters (Ref. 22.341). Changes in seabed type have the potential to adversely affect nursery habitat availability.
	Marine fish adults and juveniles.	Substrate type is considered important in the recruitment of juvenile flatfish in nursery grounds, which is reflected in the abundances of juveniles (Ref. 22.342–344). Juvenile flatfish tend to prefer burial in soft rather than coarse sediment, though the preference for sediment broadens with size (Ref. 22.339; 344). As such, changes in seabed type have the potential to adversely affect nursery habitat availability.
Removal of substratum.	Marine fish eggs/egg cases and larvae.	Eggs/egg cases or larvae close to or on the seabed may be smothered by the sediment, re-distributed during navigational dredging or may be removed and displaced along with the dredged sediment during construction dredging.
	Marine and migratory fish adults and juveniles.	Sediment would be re-distributed by navigational dredging and removed and disposed of during construction dredging. This means a potential change in availability of foraging habitat, a place for the shelter of juveniles and adults, and for laying of eggs/egg cases.

Pressure	Receptor	Potential effect
Suspended sediment concentration (SSC).	Marine fish eggs/egg cases and larvae.	Increases in SSC could affect hatching success and mortality of eggs and larvae. For example, significant reductions have been identified, in the hatching success of white perch (*Morone americana*) and striped bass (*Morone saxatilis*) eggs exposed to 1000mg/l (sediment type not specified) (Ref. 22.345). The same authors identified significant reductions in the survival of striped bass larvae exposed for 48–96 hours to concentrations of ≥500mg/l (Ref. 22.345).
	Marine and migratory fish adults and juveniles.	Effects on juvenile fish and adults may differ and can be lethal and sub-lethal. Suspended sediment can affect adults and juveniles through the clogging of gills, abrasion of the body surface, reduced visual acuity, or mortality. Avoidance is also a potential response to increased suspended sediments (Ref. 22.346). Existing evidence suggests lethal effects occur at concentrations in g/l. For example, a median lethal concentration of 24.5g/l (24hr LC_{10}) has been identified for the American mummichog (*Fundulus heteroclitus),* when exposed to fuller's earth (clay-based material) in laboratory static bioassays (Ref. 22.347). A lethal response for silversides (*Menidia* spp.) exposed to fuller's earth (clay-based material) in laboratory static bioassays, was found to be at 0.58g/l (24hr LC_{10}) (Ref. 22.347). However, the predicted increases in suspended solids from dredging are in mg/l, hence effects are unlikely to be lethal. Behavioural effects, notably avoidance behaviour, could displace species from preferred habitat or influence the passage of migratory species. Increased turbidity may temporarily alter light penetration where light is a migratory cue or migratory species. The behaviour of cod experimentally exposed to suspended sediment representative of limestone and glacial clay (particle size <38µm), has been studied (Ref. 22.348). The authors observed that the cod were curious about the plume and made short, purposeful explorations then withdrew from the plume. There was no visual avoidance of the plume observed, though cod gill-cleansing was a recurrent behaviour when in contact with the plume (Ref. 22.348).
Sedimentation rate changes.	Marine fish eggs/egg cases and larvae.	Eggs/egg cases or larvae close to or on the seabed would be susceptible to mortality where smothered by the sediment redistributed during navigational dredging and smothered by deposits from construction dredging and disposal.
	Marine and migratory fish adults and juveniles.	Flatfish and demersal species that live atop or buried within the seabed may experience burial under sediment deposits. Juveniles/adults (including small bodied individuals) with limited mobility may be buried, resulting in mortality where fish cannot emerge from burial. Fish able to emerge from burial may experience stress and reduced fitness until recovery. Eels (yellow and silver eels) in the western North Sea have been reported as spending time on the seabed; however, emergence from sediment deposits is likely since the eels conduct vertical movements in the water column during the day/night, as well as swimming/drifting in mid-water (Ref. 22.320).

Pressure	Receptor	Potential effect
Underwater noise.	Marine fish eggs/egg cases and larvae.	Immobile or limited mobility eggs/larvae may be vulnerable to mortality where exposed to impulsive noise sources like piling. Piling and post-exposure effects on larvae have been investigated. For example, different larval stages of seabass, Dover sole and herring were exposed to pile-driving sound and examined short-term mortality (7-10 days post exposure) under experimental conditions. Recorded pile-driving sounds were reproduced at zero-to-peak sound pressure levels up to 210 dB re 1 μPa² (zero to peak pressures up to 32 kPa), single pulse sound exposure levels up to 186 dB re 1 μPa²s, and 216 dB re 1 μPa²s (999 strikes) for the highest cumulative sound exposure level (SEL_{cum}). No significant differences in mortality were identified between the control group and the exposure groups for any of the species or larval stages (Ref. 22.349). In another study, seabass larvae were exposed to pile-driving sound and examined long-term mortality (up to 255 days post-exposure). No significant differences in mortality were identified between the control group and the exposure groups (Ref. 22.350). The exposure of eggs/larvae to continuous noise sources like dredging, may alter growth and survival. Atlantic cod larvae exposed to regular and random noise regimes under experimental conditions were found to have reduced growth with the regular and random noise regimes, as well as faster yolk sac usage with exposure to regular noise (Ref. 22.351). With the regular noise occurring during the discrete dredging events (in each campaign), there is potential for behavioural changes and fitness reductions in egg and larvae.
	Marine and migratory fish adults and juveniles.	Should fish remain close to the noise source for 24 hours and not vacate the area then there is potential for mortality and mortal injury. Exposure within the zones of recoverable injury and TTS may reduce the survival and fitness of individuals through hearing impairment, while physical and/or physiology effects may lower fitness levels until recovery. Behavioural effects may be avoidance of the noise source, with consequences for energy expenditure, foraging, distribution, growth and survival. Masking of biological sounds used by individuals for spawning, orientation and navigation could affect recruitment, growth, survival and reproduction (Ref. 22.352). For example, controlled experiments using playback of piling noise recordings, observed a significant increase in sole swimming speed (Ref. 22.353). Playback of piling noise impaired the startle response of seabass and it was suggested this may compromise the species' anti-predator response in the wild (Ref. 22.354; 355).

Physical change (to another seabed type)

22.8.74 A total of 12 BLF piles would replace soft sediment in the intertidal and subtidal environment. This would result in a change in seabed type (from soft to hard substrata). The BLF would affect approximately 12m² of the seabed in the subtidal zone.

22.8.75 The spatial extent of physical change to another seabed type is very low in relation to the GSB. The BLF piles would be present for the lifetime of the proposed development. The magnitude of impact is *Low*.

Sensitivity assessments of effects at the sea-area or regional stock/population level: physical change (to another seabed type)

22.8.76 For the pressure of physical change in seabed, specific groupings have been used; these are explained in **Table 22.66**.

Table 22.66: Receptor groupings and justification for physical change pressure.

Pressure	Groupings	Justification
Physical change (to another seabed type).	All fish receptors.	The loss of habitat represents a very limted spatial area and alternative viable habitat for feeding, reproductive behaviours, larvae and early juvenile shelter requirements remains. Effects are considered ***negligible.***

Habitat structure changes - removal of substratum (extraction)

22.8.77 Dredging would be conducted with a plough dredger or similar, which does not remove sediment but rather redistributes sediments locally.

22.8.78 The substrate at the outer bar consists of sand with some clay present. The dredged area would be approximately 9,068m^2 (0.91ha) and is considered a very limited extent compared with the seabed area of the GSB. The substrate would be redistributed to a depth of >0.5m. Following an initial capital dredge, maintenance dredging may be required to maintain the navigable channel for the BLF. The frequency of dredge requirements would be determined by monitoring conducted during each delivery season. Overall, the magnitude of impact is low.

Sensitivity assessments of effects at the sea-area or regional stock/population level: removal of substratum

22.8.79 For the pressure of removal of substratum, specific groupings have been used; these are explained in **Table 22.67**. The effects of substratum removal from dredging are summarised in **Table 22.65**.

Table 22.67: Receptor groupings, and justification, for removal of substratum pressure.

Pressure	Groupings	Justification
Habitat structure	• Demersal fish and elasmobranch	Species that lay demersal eggs have the potential to be affected. Thus, the

Pressure	Groupings	Justification
changes - removal of substratum (extraction).	eggs/egg cases and larvae; • Demersal juveniles and adults (and small bodied fish); • Pelagic eggs and larvae; • Pelagic juveniles and adults, and; • Migratory fish juveniles and adults.	assessment grouping differentiate marine/estuarine species with demersal eggs from marine and migratory species that do not lay demersal eggs in the marine environment. To distinguish the juvenile/adult phases that consume benthic prey and thus may potentially be impacted indirectly through changes in prey availability.

Demersal fish and elasmobranch eggs /cases and larvae: sensitivity to removal of substratum

22.8.80 Spawning/nursery grounds in the GSB area include Dover sole, plaice, cod, seabass and thornback ray. The respective spawning and nursery areas extend beyond the area encompassed by the Bay, as provided in **Appendix 22D** of this volume. Less than 1ha of the seabed would be dredged for navigational access for the BLF representing a very small proportion of the available habitat. There is the possibility of smothering or stress resulting in mortality of eggs/egg cases/larvae, but losses are considered minimal when compared to the losses from natural mortality and in view of the abundances of the early life history stages occurring within the extensive spawning and nursery grounds. The sensitivity of demersal fish and elasmobranch eggs /cases and larvae to removal of substratum from navigational dredging, is predicted to be not sensitive.

22.8.81 The impact of removal of substratum and changes in habitat structure is predicted to have a negligible effect on demersal fish and elasmobranch eggs /cases and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Demersal fish and elasmobranch: sensitivity to removal of substratum

22.8.82 The area impacted by the dredging is limited in comparison to the generally large extent of habitat available to the species in this sub-group. It is anticipated that fish can continue to use spawning, nursery and foraging grounds within and beyond the GSB. The sensitivity of demersal fish and elasmobranch juveniles and adults (and small bodied fish) to removal of substratum from navigational dredging, is predicted to be not sensitive.

22.8.83 The impact of removal of substratum and changes in habitat structure is predicted to have a negligible effect on demersal fish and elasmobranch juveniles and adults (and small bodied fish). Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish eggs and larvae: sensitivity to removal of substratum

22.8.84 The BLF dredged area represents a minimal proportion of the available habitat for laying of eggs/egg cases and use by larvae. Herring, mackerel and sprat nursery grounds overlap the GSB (Ref. 22.311; 312). Generally, higher herring spawning intensities are evident beyond the GSB. Low intensity mackerel nursery grounds are thought to be present across the entire North Sea (Ref. 22.312), while indicative nursery grounds for horse mackerel are offshore in the North Sea.

22.8.85 There is the possibility of smothering or stress resulting in mortality of eggs/larvae; however, losses are considered minimal compared to the loss of eggs/larvae due to natural mortality and in view of the abundances of eggs/larvae occurring within the generally extensive spawning and nursery grounds. The sensitivity of pelagic fish eggs and larvae to removal of substratum from navigational dredging, is predicted to be not sensitive.

22.8.86 The impact of removal of substratum and changes in habitat structure is predicted to have a negligible effect on pelagic fish eggs and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish: sensitivity to removal of substratum

22.8.87 The BLF dredged area represents a minimal area in relation to ecologically relevant habitat (primarily water column) accessible to pelagic fish to forage on plankton and/or smaller fish. Foraging in the water column and the pelagic nature of species in this sub-group, means that adverse effects from the sediment removal and re-distribution are not predicted. As such, the sensitivity of pelagic fish juveniles and adults to removal of substratum from navigational dredging, is predicted to be not sensitive.

22.8.88 The impact of removal of substratum and changes in habitat structure is predicted to have a negligible effect on pelagic fish juveniles and adults. Effects are **not significant** at the sea area and regional stock/population levels.

Migratory: sensitivity to removal of substratum

22.8.89 The BLF dredged area represents a minimal area in relation to ecologically relevant foraging habitat (sediment and water column). Migratory species would still be able to forage within the GSB as well as wider habitats outside of the GSB (including brackish waters). The sensitivity of migratory fish juveniles and adults to removal of substratum is predicted to be not sensitive.

22.8.90 The impact of removal of substratum and changes in habitat structure is predicted to have a negligible effect on migratory fish juveniles and adults. No significant effects in terms of population/stock declines are expected.

Assessments of effects of localised displacement: removal of substratum

22.8.91 Displacement of fish receptors to alterative areas, due to removal of substratum, would occur over a very limited area and effect a very small proportion of fish within the GSB. Fish are not sensitive to the pressure. Substrate removal is predicted to have a negligible effect on the distribution of fish within the GSB. No significant changes in the availability of fish as prey items for designated features or as fisheries resources are predicted.

Changes in suspended sediment concentration

22.8.92 Construction of the BLF requires dredging of a navigation channel over the outer longshore bar and creation of a planar grounding surface. Navigational dredging for the BLF would include an initial capital dredging event followed by maintenance dredging to maintain the navigable channel, provided in **Section 22.3.i)** of this chapter. The initial dredge profile requires the redistribution of a total of 4,600m^3 of sediment by plough dredging. Such activities would increase suspended sediment concentrations (SSC).

22.8.93 The initial capital dredging event would cause a plume with an instantaneous suspended sediment concentration (SSC) of >100mg/l above daily maximum background levels to form inshore over an area of up to 108ha at the sea surface and 83ha as a depth averaged plume. A small area of up to 7ha would experience an instantaneous SSC of >1,000 mg/l above background levels, provided in **Section 22.3.i)** of this chapter.

22.8.94 Maintenance dredging assessments assume dredging of approximately 10% of the initial capital volume to occur at approximately monthly intervals during the campaign period when the BLF is in most frequent use, provided in **Section 22.3.i)** of this chapter. Maintenance dredging would result in up to 28ha of sea surface expected to experience >100mg/l, and 1ha expected to experience >1,000 mg/l above background SSC on each occasion.

22.8.95 Ambient conditions at the site are highly variable, as provided in **Section 22.4** of this chapter, and the surface waters are considered as '*intermediate turbidity*' according to WFD criteria, provided in **Appendix 21E** of this volume. Dredging would temporarily increase the classification to '*turbid*'. However, SSC would return to background levels several days after dredging activity ceases.

22.8.96 The instantaneous SSC plume would expose a partial area of the GSB to temporary increases in turbidity. Maintenance dredging would result in the plume reoccurring during the campaign period and throughout the construction phase. The impact magnitude is assessed as medium.

Sensitivity assessments of effects at the sea-area or regional stock/population level: changes in suspended sediment concentration

22.8.97 For the pressure of changes in suspended sediment concentration, specific groupings have been used; these are explained in **Table 22.68**.

Table 22.68: Receptor groupings and justification for suspended sediment concentration changes.

Pressure	Groupings	Justification
Changes in suspended sediment/solids.	• Demersal fish and elasmobranch eggs/egg cases and larvae; • Demersal and elasmobranch juveniles and adults (and small bodied fish); • Pelagic eggs and larvae; • Pelagic juveniles and adults, and; • Migratory fish juveniles and adults.	Different life history stages may have differing sensitivities to the pressure, the groupings allow a full assessment across life-history stages.

Demersal fish and elasmobranch eggs /cases and larvae: sensitivity to increases in suspended sediment

22.8.98 The potential for mortality of eggs and larvae would be influenced by several factors; SSC concentration, particle size, the duration of exposure, and timing of the exposure relative to the developmental stage of the eggs and larvae. Aside from direct mortality, the developing embryo in the eggs and hatched larvae could experience sub-lethal effects in the form of stress and, consequently, this could increase the likelihood of mortality. The effects of suspended sediment from dredging are summarised in **Table 22.65**.

22.8.99 The predicted rise in SSC is less than the benchmark (a change in one rank on the WFD scale for one year). Daily maximum SSC in the range 357-609mg/l have been recorded 0.3m above the seabed within the Sizewell-Dunwich Bank, provided in **Section 22.4** of this chapter. The increase in SSC from the navigational dredging relative to background conditions is modest and would be temporary.

22.8.100 Spawning/nursery grounds in the GSB area encompass Dover sole, plaice, cod, seabass and thornback ray, provided in **Appendix 22D** of this volume. While localised egg/larvae mortality may occur, the losses are generally considered minimal compared to natural mortality. The GSB is considered a very small part of spawning or nursery grounds for species in the sub-group and as such, the presence of the taxa could be maintained through natural influxes of eggs and larvae. The sensitivity of demersal fish and elasmobranch eggs /cases and larvae to increases in suspended sediment from navigational dredging, is predicted to be low.

22.8.101 The impact of increases in suspended sediment is predicted to have a minor adverse effect on demersal fish and elasmobranch eggs /cases and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Demersal fish and elasmobranch: sensitivity to increases in suspended sediment

22.8.102 Existing evidence suggests lethal effects occur at concentrations in g/l. For example, a lethal concentration of 24.5g/l (24hr LC_{10}) for the American mummichog (*F. heteroclitus*) has been identified, when exposed to fuller's earth (clay-based material) in laboratory static bioassays (Ref. 22.347). The predicted increases in suspended solids from dredging are in mg/l, hence effects are likely to be non-lethal. There is scope that juvenile and adult demersal fish can physiologically compensate for temporary suspended sediment increases, whilst some species may avoid areas of high turbidity.

22.8.103 Adult flatfish in the GSB including Dover sole, dab, plaice and flounder and other species with a benthic association (gobies, thornback ray, whiting, seabass, thin-lipped mullet), are likely to be exposed to naturally elevated suspended sediments through wave and tidal action. Hence, the resistance of those species occurring on or within the seabed is expected to be greatest. This is reflected in the notable abundances of GSB species, including whiting, gobies and similar demersal species within naturally turbid estuaries like the River Severn (Ref. 22.356).

22.8.104 There is a possibility that physiological and/or behavioural responses displacement to areas away from the plume, may increase energy expenditure. However, the increases in SSC relative to background are modest over the area of the GSB potentially utilised by juveniles and adults. The species in the sub-group exhibit the ability to compensate for increases SSC or may be able to avoid areas with elevated SSC and return once SSC is back to ambient levels, within days of the activity.

22.8.105 The sensitivity of demersal fish and elasmobranch juveniles and adults (and small bodied fish) to increases in suspended sediment from navigational dredging, is predicted to be low.

22.8.106 The impact of increases in suspended sediment is predicted to have a minor adverse effect on demersal fish and elasmobranch juveniles and adults (and small bodied fish). Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish eggs and larvae: sensitivity to increases in suspended sediment

22.8.107 Localised egg/larvae mortality may occur within the dredge plume. The losses are considered minimal compared to natural mortality. The GSB is a small part of the spawning or nursery grounds for species in the sub-group and as such, the presence of the taxa could be maintained through natural influxes of eggs and larvae. The sensitivity of pelagic fish eggs and larvae to increases in suspended sediment from navigational dredging, is predicted to be not sensitive.

22.8.108 The impact of increases in suspended sediment is predicted to have a minor adverse effect on pelagic fish eggs and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish: sensitivity to increases in suspended sediment

22.8.109 There is potential that fish may experience stress but may still tolerate the temporary SSC increase and remain in the presence of the plume. Fish may also behaviourally avoid the plume and be locally displaced; localised displacement effects are considered separately.

22.8.110 The mobility of the pelagic species provides access to habitat within and outside the GSB, during the dredging and to return to an area once SSC decrease. As such, declines in abundance and distribution of the respective stocks/populations are unlikely. The sensitivity of pelagic fish juveniles and adults to increases in suspended sediment from navigational dredging, is predicted to be low.

22.8.111 The impact of increases in suspended sediment is predicted to have a minor adverse effect on pelagic fish juveniles and adults. Effects are **not significant** at the sea area and regional stock/population levels.

Migratory fish: sensitivity to increases in suspended sediment

22.8.112 Suspended sediment plumes have the potential to cause lethal and sub-lethal effects on migratory species and potentially influence migratory behaviour due to plume avoidance. This section considers the potential for direct effects and effects on migratory behaviour.

22.8.113 A single Allis shad was recorded in the CIMP data from 2009-2013. In the 2009-2013 and 2014-2017 datasets, the impingement of Twaite shad were recorded and the majority were caught between April and July / August (Ref. 22.308). However, there are not considered to be east coast spawning rivers for Allis and Twaite shad, with adults most probably returning to continental Europe. As such, shad are scoped out from consideration.

22.8.114 Due to a very limited presence, salmon and sea trout are scoped out from consideration.

22.8.115 The known migration periods for key migratory taxa are summarised in **Table 22.60**. Considering the timings of the respective migration periods, it is unlikely that smelt, European eel, and river lamprey would be exposed to the SSC plume from the end of May to end of July. If dredging occurred during other months of the year (August-May) then the potential exists for a temporal coincidence of the SSC plume and migratory taxa.

22.8.116 However, the narrow east-west profile of the plume is unlikely to block the route of the migratory species (smelt, European eel, river and sea lamprey). The plume is anticipated to dissipate within days, thereby limiting the presence of the plume. The migratory fish may choose to move freely around the plume, although in the case of the parasitic lamprey, this would be influenced by the host’s behaviour.

22.8.117 Where light is utilised as a migration cue, the SSC plume may temporarily reduce light penetration through the water column, although this is limited to a period of days as the plume dissipates. Additionally, species moving between freshwater, brackish and the marine environment, could utilise cues that are not affected by the SSC plume, such as temperature, salinity and tidal currents for migration.

22.8.118 The plume is unlikely to inhibit foraging ability in the smelt and European eel (lamprey are parasitic) and no barrier to the migratory movement of smelt, European eel, river and sea lamprey is predicted. The sensitivity of migratory fish juveniles and adults to increases in suspended sediment from navigational dredging, is predicted to be not sensitive.

22.8.119 The impact of increases in suspended sediment is predicted to have a minor adverse effect on migratory fish juveniles and adults. Effects are **not significant** at the sea area and regional stock/population levels. The SSC plume would be of a limited magnitude and the passage of migratory fish would be unhindered.

Assessments of effects of localised displacement: changes in suspended sediment concentration

22.8.120 The avoidance of fish to sediment plumes, notably pelagic species, would be influenced by factors such as motivation, mobility and condition of the fish. Satellite data for surface suspended particulate matter showed average mean values at Sizewell during April to August of 31mg/l and average monthly maximum values of 80mg/l. Between September to March, mean suspended particulate matter values of 73mg/l were recorded in the surface waters at Sizewell, with average monthly maximum values of 180mg/l. Fish within the GSB would be acclimated to a highly variable natural background, provided in **Section 22.4** of this chapter. Thus, fish may exhibit limited movements away from the areas of highest SSC, remaining in proximity to the plume and utilising the area once the plume dissipates. Given that the limited magnitude and transient nature of the plume, the scope for fish to be displaced entirely from the plume area and not return is very limited. Fish are predicted to have *Low* sensitivity with only localised and temporary displacement of sensitive taxa likely to occur. Therefore, suspended sediment plumes are predicted to have a minor adverse effect on fish displacement. No significant changes in the availability of fish as prey items for designated features and as fisheries resources are predicted.

22.8.121 The dredge plume in relation to designated sites and foraging ranges of designated species is assessed in the **Shadow HRA** (Doc Ref. 5.10).

Changes in sedimentation rates

22.8.122 Sediment suspended by plough dredging and dispersed by ambient flows would subsequently be deposited onto the seabed. Sedimentation is typified by ‘light sedimentations’, with a small area of up to 3ha expected to experience sediment deposition of >50mm. A very small area (1ha) could experience over 300mm of deposition. It is expected that all suspended sediment would be deposited within hours of dredging and then dispersed by natural resuspension, leaving just 3ha where sediment thickness remains >20mm after 15 days. The pressure would reoccur due to the requirement for maintenance dredging; however, sediment deposition in this case is not expected to exceed 20mm, provided in **Table 22.10**. Impact magnitude is assessed as low due to the small spatial footprint and rapid dispersal of deposited sediments.

Sensitivity assessments of effects at the sea-area or regional stock/population level: changes in sedimentation rates

22.8.123 For the pressure of changes in sedimentation rates, specific groupings have been used; these are explained in **Table 22.69**. The effects of sedimentation from dredging and disposal are summarised in **Table 22.65**.

Table 22.69: Receptor groupings and justification for sedimentation from siltation rate changes.

Pressure	Groupings	Justification
Siltation rate changes.	• Demersal fish and elasmobranch eggs/egg cases and larvae; • Demersal juveniles and adults (and small bodied fish); • Pelagic eggs and larvae; • Pelagic juveniles and adults, and; • Migratory fish juveniles and adults.	Species that lay demersal eggs have the potential to be effected, the assessment grouping differentiates marine/estuarine species with demersal eggs from marine and migratory species that do not lay demersal eggs in the marine environment. To determine potential effects from the pressure to the different life history stages of the species within this grouping.

Demersal fish and elasmobranch eggs /cases and larvae: sensitivity to changes in sedimentation rates

22.8.124 The sediment deposition rate is up to the benchmark of 'Light' deposition (up to 5cm of fine material in a single event). Light deposition has the potential to smother immobile eggs and larvae on the seabed. While localised egg/larvae mortality may occur, no declines in abundance and distribution of the respective stocks/populations are expected. This is because the losses are considered minimal compared to the loss of eggs/larvae due to natural mortality and in view of the abundances of eggs/larvae occurring within the extensive spawning and nursery grounds. The sensitivity of demersal fish and elasmobranch eggs/cases and larvae to changes in sedimentation rates is predicted to be not sensitive.

22.8.125 The impact of changes in sedimentation rates is predicted to have a negligible effect on demersal fish and elasmobranch eggs/cases and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Demersal fish and elasmobranch: sensitivity to changes in sedimentation rates

22.8.126 Juvenile and adult demersal fish have the capacity to physiologically compensate for temporary sediment deposition, or to move away from affected areas. Demersal fish in the GSB are predicted to be able to tolerate similar levels of sedimentation from storms and tidal action.

22.8.127 Declines in abundance and distribution of the respective stocks/populations are unlikely, as the fish can continue to use spawning, nursery and foraging grounds within and beyond the GSB. The sensitivity of demersal fish and elasmobranch juveniles and adults to changes in sedimentation rates is predicted to be not sensitive.

22.8.128 Changes in sedimentation rates is predicted to have a negligible effect on demersal fish and elasmobranch juveniles and adults (and small bodied fish). Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish eggs and larvae: sensitivity to changes in sedimentation rates

22.8.129 The pelagic nature of the eggs and larvae for most species in this sub-group minimises exposure to the pressure.

22.8.130 While localised egg/larvae mortality may occur, no declines in abundance and distribution of the respective stocks/populations is expected. This is because the losses are considered minimal compared to the loss of eggs/larvae due to natural mortality. Also, in view of the abundances of eggs/larvae occurring within the extensive spawning and nursery grounds, generally occurring across the wider area of the North Sea and beyond. The sensitivity of pelagic fish eggs and larvae to changes in sedimentation rates is predicted to be not sensitive.

22.8.131 The impact of changes in sedimentation rates is predicted to have a negligible effect on pelagic fish eggs and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish: sensitivity to changes in sedimentation rates sensitivity to physical change in seabed type

22.8.132 Juvenile and adult pelagic fish predominately occur above the seabed and hence can avoid the risk of smothering. The mobility of adults and juveniles provides the ability to avoid deposition and return to an affected area once the impact ceases. The sensitivity of juvenile and adult pelagic fish to changes in sedimentation rates is predicted to be not sensitive.

22.8.133 The impact of changes in sedimentation rates is predicted to have a negligible effect on juvenile and adult pelagic fish. Effects are **not significant** at the sea area and regional stock/population levels.

Migratory fish: sensitivity to changes in sedimentation rates

22.8.134 Of the migratory species, eels buried in the seabed or present near the seabed would be able to emerge from the light deposition. No declines in stock/population for any migratory species are predicted. The sensitivity of migratory fish juveniles and adults to changes in sedimentation rates is predicted to be not sensitive.

22.8.135 The impact of changes in sedimentation rates is predicted to have a negligible effect on migratory fish juveniles and adults. Effects are **not significant** at the sea area and regional stock/population levels. The small spatial scale and availability of alternative foraging areas, reductions in fitness are negligible.

Assessments of effects of localised displacement: changes in sedimentation rates

22.8.136 Changes in sedimentation rates associated with dredging for the BLF is not predicted to affect the distribution of fish within the GSB. No indirect food web effects or changes in the availability of fish as prey items for designated features or as fisheries resources are expected. Fish are not sensitive to displacement resulting from sedimentation rate changes. Effects are predicted to be negligible and **not significant**.

Underwater noise

22.8.137 The interaction of the plough dredger on the seabed, the vessel and vessel-based machinery may generate underwater noise. The sounds are continuous in nature and comparatively low in frequency and intensity (Ref. 22.357).

22.8.138 Underwater noise and risk posed to fish can be characterised by a number of metrics. Peak sound pressure (or particle motion) is the maximum absolute value of the instantaneous sound pressure (or motion) during a specified time interval. Sound exposure level (SEL) is an index of the total energy in a sound. SEL is usually expressed in dB 1 μPa^2 s. The accumulation of sound energy is considered as the metric, SEL_{cum}, the linear summation of the individual sound events over the time period of interest (Ref. 22.53).

22.8.139 Underwater noise is considered in terms of the instantaneous and cumulative effects.

22.8.140 Instantaneous effects relate to the exposure of a receptor like a fish to singular emittance of sound and corresponding energy within that event. Instantaneous effects are considered in relation to the metric of peak sound pressure (or particle motion).

22.8.141 Continuous effects are where a receptor is exposed to repeated sounds, such as multiple pile strikes, and effects may be a function of the energy in all the sound events accumulated over time. Continuous effects are modelled for a 24-hour period and the SEL_{cum} metric was utilised in the modelling.

22.8.142 The first effort to develop generally applicable noise exposure criteria for fish was published by (Ref. 22.53). These criteria (here termed the Popper criteria) provide quantitative thresholds for temporary threshold shift (TTS), recoverable injury and death. Popper *et al*., (2014) defined TTS as short or long-term changes in hearing sensitivity that may or may not reduce fitness. Recoverable injury is defined as injuries, including hair cell damage, minor internal or external hematoma, which are not likely to result in mortality. Mortality and mortal injury are defined as immediate or delayed death.

22.8.143 The thresholds are formulated using the peak sound pressure level (dB peak) and the cumulative sound exposure level (SEL_{cum}). Fish are categorised according to the following three functional hearing groups:

- Fish with swim bladder or other air cavities to aid hearing, where fish primarily hear with pressure detection. Fish within this group are considered to be more acoustically sensitive.
- Fish with swim bladder that does not aid hearing, where hearing is by particle motion detection.
- Fish without a swim bladder where hearing is by particle motion detection.

22.8.144 In addition to the three hearing groups, egg and larval stages have been considered in the assessment. This is because swim bladders may develop during the larval stage and so larvae may be susceptible to pressure-related injuries like barotrauma (Ref. 22.53).

22.8.145 **Table 22.70** summarise the hearing categories of the fish receptors.

Table 22.70: Hearing categories of fish receptors (* indicates uncertainty in the role of the swim bladder in the hearing of the species).

Category	Fish receptors
(1) Fish with swim bladder or other air cavities to aid hearing.	Atlantic herring European sprat Allis and Twaite shad Anchovy European cod
(2) Fish with swim bladder that does not aid hearing.	European seabass Whiting Thin-lipped grey mullet European smelt* Sea trout Atlantic salmon European eel

Category	Fish receptors
(3) Fish without a swim bladder.	Mackerel Horse mackerel Dover sole (swimbladder larval stages) European plaice Dab European flounder Sand gobies (swimbladder larval stages) Thornback ray Tope River and sea lamprey

22.8.146 Although fish are not expected to remain stationary during the noise-generating activities, we are not aware of direct empirical evidence to support fleeing behaviour in fish. Therefore, the assessment approaches for fish do not include assumptions of fleeing behaviour.

22.8.147 The detection of particle motion is thought to help fish gain information on the surrounding seascape, notably with directional hearing. There is particle motion associated with sound waves in the water column, acoustic waves traveling through the seabed substrate, and also waves travelling along the interface between the seabed substrate and seawater (Ref. 22.52). Human activities such as dredging and impact piling, can result in particle motion transmission through the seabed substrate.

22.8.148 A full assessment of particle motion and related effects, is hampered by few published measurements of the sensitivity of different fishes to particle motion (including high levels of particle motion), limited knowledge of fish behavioural responses in a natural environment and responses to vibration through the seabed (Ref. 22.52; 358). There are also no agreed exposure criteria for particle motion at the time of writing for use in modelling. Within the assessments, particle motion has been recognised in the consideration of receptor sensitivity.

Underwater noise: navigational dredging

22.8.149 Underwater noise modelling has been conducted for instantaneous effects (peak noise level) and for continuous effects over a 24-hour period (SEL). Underwater noise modelling utilised the Popper criteria (Ref. 22.53) shown in **Table 22.71**, for the three hearing categories. The auditory effects zone predicted in the underwater noise modelling have informed the spatial extent of impacts. The modelling is reported in full in **Appendix 22L** of this volume.

22.8.150 The Popper criteria do not provide quantitative thresholds for continuous sources of noise such as dredging. Given that impulsive sounds such as piling noise are likely to have a greater effect on fish than continuous sources at the same level (Ref. 22.359), the Popper thresholds (**Table 22.71**) for impact piling have been applied in the assessment of sound exposure from continuous sources as a precautionary approach.

Table 22.71: Popper criteria (piling). "dB peak" denotes peak-to-peak sound pressure levels in units of dB re 1 µPa. "dB SEL" denotes sound exposure levels (SEL) in units of dB re 1 µPa² s.

Category	Mortality /potential mortal injury	Recoverable injury	TTS
(1) Fish with swim bladder or other air cavities to aid hearing.	207 dB SEL_{cum} or > 207 dB peak.	203 dB SEL_{cum} or > 207 dB peak.	186 dB SEL_{cum}.
(2) Fish with swim bladder that does not aid hearing.	210 dB SEL_{cum} or > 207 dB peak.	203 dB SEL_{cum} or > 207 dB peak.	> 186 dB SEL_{cum}.
(3) Fish without a swim bladder.	> 219 dB SEL_{cum} or > 213 dB peak.	> 216 dB SEL_{cum} or > 213 dB peak.	>> 186 dB SEL_{cum}.

22.8.151 Dredging near the BLF is required to allow a navigable access channel and planar surface for delivery barges to come aground. Dredging is anticipated to take 2.1 days to complete, with 742 cycles of 1 minute of dredging, followed by 3 minutes of transit. Source levels for dredging were taken from a study by Robinson *et al.,* (2012) (Ref. 22.360) and the underwater noise modelling assumed precautionary source terms from a large trailing suction hopper dredger for all dredging activities, provided in **Appendix 22L**.

22.8.152 The Popper *et al.,* (2014) (Ref. 22.53) thresholds for effects from cumulative noise are exceeded, yet the modelled impact zone for recoverable injury is limited to 6ha and from dredging, and navigational dredging during each campaign would be short-lived, although multiple dredging events per campaign are predicted during construction years. Therefore, the magnitude of impact is low.

Sensitivity assessments of effects at the sea-area or regional stock/population level: underwater noise from navigational dredging

Fish with swim bladder or other air cavities to aid hearing (Category 1): sensitivity to underwater noise from navigational dredging

22.8.153 No instantaneous effects are predicted from continuous noise sources.

22.8.154 Category 1 fish would be susceptible to mortality and recoverable injury should they remaining within close proximity of the dredging activity within a 24-hour period. This is predicted to be 70m (2ha) and 158m (6ha) for mortality and recoverable injury, respectively shown in **Table 22.72**.

22.8.155 All hearing groups have the same thresholds for TTS, which is predicted over a range of 1.8km, or an area of 435ha, shown in **Table 22.72**. Recoverable injury and TTS may reduce the survival and fitness of individuals through hearing impairment; physical and/or physiological effects could lower fitness levels until recovery occurs.

22.8.156 The lower magnitude impact of maintenance dredging would result in smaller cumulative effect ranges, due to the shorter duration of the dredge activity, provided in **Table 22.73**. Category 1 fish are the most sensitive hearing group and would only incur mortality within 25m of the dredger if they remained there for full during of dredging. Recoverable injury is restricted to 70m (1ha), whilst the cumulative TTS threshold is exceeded for fish within 69ha (629m) of the dredger for the full activity, provided in **Table 22.73**.

22.8.157 The dredging noise would be present in an existing soundscape in the GSB, where the baseline is characterised by operational noise from Sizewell B, surf noise (waves breaking on the beach), and noise from passing fishing vessels (Ref. 22.361). Recovery is considered possible in fish that remain in the zone of TTS. If individuals moved away to avoid dredging noise, it is anticipated they could return to the area in a matter of hours to days. However, it is recognised that this may be influenced by motivational state and exposure to predation in areas where fish have been displaced.

22.8.158 No changes in stock/population viability are predicted. The sensitivity of 'fish with swim bladder or other air cavities to aid hearing' to underwater noise associated with BLF dredging activities is predicted to be low.

22.8.159 The impact of underwater noise from dredging for the BLF is predicted to have a minor adverse effect on the most acoustically sensitive fish. Effects are **not significant** at the sea area and regional stock/population levels.

Table 22.72: Auditory impact zones (expressed in hectares) and/or maximum ranges (expressed in metres) from BLF dredging activities for the three hearing categories in fish. N/A indicates source level below threshold.

Activity	Hearing category.	Threshold	Instantaneous	Cumulative
Dredging BLF.	(1) Fish with swim bladder or other air cavities to aid hearing.	Mortality.	N/A.	70m; 2ha.
		Recoverable injury.	N/A.	158m; 6ha.

Activity	Hearing category.	Threshold	Instantaneous	Cumulative
		Temporary Threshold Shift.	N/A.	1,843m; 435ha.
	(2) Fish with swim bladder that does not aid hearing.	Mortality.	N/A	50m; 1ha.
		Recoverable injury.	N/A.	158m; 6ha.
		Temporary Threshold Shift.	N/A.	1,843m; 435ha.
	(3) Fish without a swim bladder.	Mortality.	N/A.	<25m.
		Recoverable injury.	N/A.	<25m.
		Temporary Threshold Shift.	N/A.	N/A.

Table 22.73: Auditory impact zones (expressed in hectares) and/or maximum ranges (expressed in metres) from BLF maintenance dredging activities for the three hearing categories in fish. N/A indicates source level below threshold.

Activity	Hearing category.	Threshold	Instantaneous	Cumulative
Maintenance Dredging BLF.	(1) Fish with swim bladder or other air cavities to aid hearing.	Mortality.	N/A.	<25m
		Recoverable injury.	N/A.	70m; 1ha.
		Temporary Threshold Shift.	N/A.	629m; 69ha.
	(2) Fish with swim bladder that does not aid hearing.	Mortality.	N/A	<25m
		Recoverable injury.	N/A.	70m; 1ha.
		Temporary Threshold Shift.	N/A.	629m; 69ha.
	(3) Fish without a swim bladder.	Mortality.	N/A.	<25m.
		Recoverable injury.	N/A.	<25m.
		Temporary Threshold Shift.	N/A.	N/A.

Fish with a swim bladder that does not aid hearing (Category 2): sensitivity to underwater noise from navigational dredging

22.8.160 No instantaneous effects are predicted from continuous noise sources.

22.8.161 Predicted zones of mortality and recoverable injury are very localised: 50m (1ha) and <25m, respectively. TTS is predicted over a range of 1.8km, or an area of 435ha, provided in **Table 22.72**. Recoverable injury and TTS may reduce the survival and fitness of individuals through hearing impairment; physical and/or physiological effects could lower fitness levels until recovery occurs.

22.8.162 No changes in stock/population viability are predicted. The sensitivity Category 2 fish to underwater noise, associated with BLF dredging activities, is predicted to be low.

22.8.163 The impact of underwater noise is predicted to have a minor adverse effect on fish with swim bladder that does not aid hearing. Effects are **not significant** at the sea area and regional stock/population levels.

Fish without a swim bladder (Category 3): sensitivity to underwater noise from navigational dredging

22.8.164 No instantaneous effects are predicted from continuous noise sources.

22.8.165 Fish species lacking a swim bladder would be exposed to mortality/mortal injury and recoverable injury in highly localised areas (<25m) around the sound source, provided in **Table 22.72**. This assumes fish remained in the vicinity of the dredging for 24 hours.

22.8.166 No changes in stock/population viability are predicted. The sensitivity of Category 3 fish to underwater noise, associated with BLF dredging activities, is predicted to be not sensitive.

22.8.167 The impact of underwater noise is predicted to have a negligible effect on Category 3 fish. Effects are **not significant** at the sea area and regional stock/population levels.

Eggs and larvae: sensitivity to underwater noise from navigational dredging

22.8.168 Given the limited mobility, motility, small size and possible vulnerability to underwater noise, exposure of eggs and larvae has been assessed. **Table 22.65** provides information on the potential effects of eggs/larval exposure to continuous noise sources like dredging.

22.8.169 In the case that insufficient data exists to provide specific guidelines for effects of noise, Popper *et al.* (2014) adopt an approach to determine relative risk at distances from the source – near, intermediate and far. These distances may nominally be considered as tens of metres (near), hundreds of metres (intermediate) and thousands of metres (far). For continuous noise sources, the relative risk of fish eggs and larvae is considered to be low for mortality/potentially mortal injury, recoverable injury and TTS at the near, intermediate and far-field distance (Ref. 22.53). In the case of masking, a high, moderate and low risk has been assigned at the near, intermediate and far-field distance, respectively. A moderate risk is assigned at the near and intermediate fields and low risk at the far-field distance.

22.8.170 The sensitivity of eggs and larvae to underwater noise from navigational dredging, is predicted to be low.

22.8.171 As a precautionary assessment, minor adverse effects are predicted for demersal and pelagic fish eggs and larvae. Reductions in ichthyoplankton abundance is considered negligible compared to the size and persistence of populations within the GSB and wider area of the North Sea. Therefore, effects are **not significant** at the sea area and regional stock/population levels.

Assessments of effects of localised displacement: underwater noise from navigational dredging

22.8.172 Behavioural response thresholds have not been formally assigned and assessment thresholds are based on behavioural responses to instantaneous noise sources reported in the literature. The applied threshold for behavioural effects is based on observations of a startle response in sprat (135 db re 1 $\mu Pa^2 s$) and in mackerel (142 db re 1 $\mu Pa^2 s$) (Ref. 22.362). These criteria have been applied as thresholds for potential behavioural responses in fish with a swim bladder (Categories 1 and 2; 135 db re 1 $\mu Pa^2 s$) and without a swim bladder (Category 3: 142 db re 1 $\mu Pa^2 s$). It should be noted that behavioural responses do not necessitate displacement from the ensonified area, provided in **Appendix 22L** of this volume.

22.8.173 In the case of Category 1 and 2 fish, behavioural effects are predicted within 2.35km (682ha) of dredging. In the case of Category 3 fish behavioural effects are predicted within 761m (98ha) of dredging, provided in **Table 22.74**. The effects zones are of a small extent, for a limited duration and the reversibility of the effects would be high.

22.8.174 The applied behavioural thresholds are based on literature evidence for impulsive noise sources and as such, are subject to a lower degree of confidence than established criteria for injury and auditory damage assessments. This is particularly true in the case of continuous noise sources e.g. dredging and drilling. Whilst the limitations of the approach should be recognised, the approach is considered to be a conservative indicator for the risk of behavioural responses and potential displacement, provided in **Appendix 22L** of this volume. However, lower levels of confidence are introduced with the application across species with different hearing sensitivities, auditory mechanisms and application to continuous noise sources. Also, it is acknowledged that the response thresholds should be applied with caution for species that do not occupy the same habitat or have the same physiology as the two pelagic species, sprat and mackerel.

Table 22.74: Behavioural impact zones for dredging, with the area (expressed in hectares) and maximum range (expressed in metres). Precautionary assessment based on evidence from impulsive noise sources.

Activity	Threshold	Behavioural zone.
Dredging BLF.	135 dB re 1 µPa²·s Applicable to herring, shad, sprat, seabass; cod, whiting, mullet.	2,352m; 682ha.
	142 dB re 1 µPa²·s. Applicable to makerel. Horse mackerel, flatfish e.g. Dover sole, sand gobies, tope, thornback ray.	761m; 98ha.

22.8.175 Fish considered to be more acoustically sensitive, such as herring, sprat, and cod, have nursery grounds intersecting the GSB. They are also prey species for designated seabirds and marine mammals, as detailed in **Section 22.8.b)** of this chapter. Herring and cod are regarded as important species for local fisheries, provided in **Appendix 22F** of this volume. Allis and Twaite shad are key conservation species, as discussed in the current baseline, provided in **Section 22.8.b)** of this chapter.

22.8.176 In the case of Category 2 fish, seabass and whiting nursery grounds intersect the GSB. Except for seabass, whiting and thin-lipped grey mullet, all species in this category are key conservation species, provided in **Table 22.61**. Seabass and whiting are prey species for designated seabirds and marine mammals, provided in **Section 22.8.b)** of this chapter. Seabass is regarded as important for local fisheries, whiting forms part of regional, North Sea landings, and thin-lipped grey mullet is regarded as an important recreational angling species, provided in **Appendix 22F** of this volume.

22.8.177 In the case of Category 3 fish, the GSB intersects with Dover sole and plaice spawning and nursery grounds as well as nursery grounds for thornback ray and mackerel. Also, sea and river lamprey are key conservation species, provided in **Table 22.61**. Dover sole, dab and sand gobies are prey species for designated seabirds and marine mammals, provided in **Section 22.8.b)** of this chapter. Dover sole and thornback ray are regarded as important species for local fisheries. Other species in the category forming part of regional, North Sea landings are plaice; flounder; dab; mackerel, and horse mackerel, provided in **Appendix 22F** of this volume.

22.8.178 The dredging noise would be present in an existing soundscape in the GSB, where the baseline is characterised by operational noise from Sizewell B, surf noise (waves breaking on the beach), and noise from passing fishing vessels (Ref. 22.361). The duration of dredging within the annual campaigns is short-lived and sound levels from plough dredging are expected to be substantially less than a trailing suction hopper dredger (basis of the modelling). Where individuals move away to avoid the dredging noise, it is anticipated they could return to the area in a matter of hours to days. However, it is recognised that this may be influenced by motivational state and exposure to predation in areas where fish may have been displaced. Fish are precautionarily assessed as having low sensitivity to displacement from dredging activities.

22.8.179 Localised displacement of fish receptors due to underwater noise from navigational dredging, is predicted to have a minor adverse effect on the availability of prey items for designated features and as fisheries resources. Effects are deemed to be **not significant**. Short-term behavioural effects (not necessarily displacement) could cause temporary reductions in feeding efficiency. The implications for bird and cetacean feeding are considered further in the **Shadow HRA** (Doc Ref. 5.10).

Underwater noise: impact piling

22.8.180 The BLF would consist of a total of 12 piles within the marine environment (below MHWS). The BLF would require installation of four pairs of ca. 1m diameter piles, two ca. 1.5m fenders and two ca, 1.5 m mooring dolphins.

22.8.181 The noise from the piling could lead to potential mortality, mortal injury, recoverable injury as well as behavioural effects, which may impact upon individuals and stocks/populations locally or regionally. Egg and larval stages have been considered, as they may be subject to barotrauma and swim bladders may develop during the larval stages.

22.8.182 Two hammer energies have been modelled; a 90kJ and a 200kJ strike energy. The 90kJ hammer energy is considered the most likely, but 200kJ has been included as a worst-case for the assessment. Indicative piling specifications (based on the 90kJ scenario) are:

- Maximum hammer energy of 90kJ.
- Strike rate of 46 strikes per minute.

- Each pile would require approximately 1,500 hammer blows to install (lasting 33 minutes).

- A maximum of five piles would be installed in each 24-hour period (applied in cumulative assessment).

22.8.183 In the case a 20-minute soft start is implemented, it is anticipated that each pile would take approximately 53 minutes to install. Therefore, 12 piles would result in a total of 10.6 hours of piling.

22.8.184 The source level estimate for pile driving was calculated using an energy conversion model, whereby a proportion of the expected hammer energy is converted to acoustic energy, provided in **Appendix 22L** of this volume. The source levels in terms of single-pulse SEL were determined to be 205.2 and 208.7 dB re 1 μPa^2 s for the 90kJ and 200kJ hammer energy, respectively.

22.8.185 The construction scenario assessed for the 24-hour cumulative exposure consisted 5 piles per day being installed. It is assumed that piling would not occur concurrently (piles will be installed one at a time). The worst-case scenario for the modelled cumulative noise levels is impact piling. Underwater noise modelling utilised the Popper criteria (Ref. 22.53) applicable to piling, provided in **Table 22.71**, for the three hearing categories summarised in **Table 22.70**. The modelling is reported full in **Appendix 22L** of this volume.

22.8.186 For the assessment of the 90kJ hammer energy and the 200kJ hammer energy, the modelled PTS zones are each spatially limited in **Table 22.75** and the duration of piling is anticipated to be short-term with the installation of 12 piles. Therefore, the magnitude of impact is low.

22.8.187 It is acknowledged that vibration from piling can propagate through the seabed. At the time of writing evidence of underwater vibration of fish receptors is still developing, accordingly there is a high degree of uncertainty over vibration and direct and indirect physical, physiological and behavioural effects to fish at all life stages. With the uncertainty and limited scientific evidence currently available, it is not considered appropriate to quantitatively assess the effects of vibration to fish receptors; therefore, the pressure has been scoped out. It should be recognised that the piling hammer energy for installing BLF deck piles and thus the resulting vibration, may be limited compared with larger scale OWF developments occurring in the region.

Sensitivity assessments of effects at the sea-area or regional stock/population level: underwater noise from impact piling

Fish with swim bladder or other air cavities to aid hearing (Category 1): sensitivity to underwater noise from navigational dredging

22.8.188 Thresholds were used to assess the potential for mortality, recoverable injury and TTS from impact piling, provided in **Table 22.71**. **Table 22.65** provides information on the potential effects of fish exposure to impulsive noise sources like piling.

22.8.189 In the case Category 1 fish, instantaneous noise levels are sufficient to cause mortality/potentially mortal injury and recoverably injury at a range of 66m in the case of a 200kJ hammer energy and 45m for a 90kJ hammer energy, provided in **Table 22.75**.

22.8.190 In the case of the cumulative noise assessment, fish in Category 1 would incur mortality or recoverable injury if they remained within 158m (5ha) and 206m (9ha), respectively for the duration of piling (90kJ hammer energy). The predicted zone of TTS would be limited to approximately 1.49km (228ha) from the piling activity, provided in **Table 22.75**. Cumulative noise modelling predicts that piling with a 200kJ hammer energy would result in mortality and recoverable injury within approximately 206m (8ha) and 303m (16ha), respectively. In the case of TTS, the zone would be approximately 1.96km (443ha) from the sound source, provided in **Table 22.75**.

22.8.191 The use of soft-start procedures, where technically feasible, should encourage the movement of fish away from the piling activity, thereby minimising the potential for cumulative auditory effects. Exposure within the zones of recoverable injury and TTS may reduce the survival and fitness of individuals through hearing impairment, while physical and/or physiology effects may lower fitness levels until recovery.

22.8.192 Given the limited cumulative effect ranges of 303m and 1.96km for recoverable injury and TTS (200kJ hammer energy), a limited proportion of the stocks/populations are likely to be exposed to mortality and hearing impairment. There may be temporary displacement as a behavioural response to the piling, with movement incurring an energetic cost which may affect individual fitness. The mobility of the species should facilitate recovery and thus a return to the affected areas after impact piling has ceased. However, it is recognised that this may be influenced by motivational state and exposure to predation.

22.8.193 The sensitivity of Category 1 fish to underwater noise from impact piling is predicted to be medium.

22.8.194 A minor adverse effect is predicted for fish receptors in Category 1. Effects are **not significant** at the sea area and regional stock/population levels.

Fish with a swim bladder that does not aid hearing (Category 2): sensitivity to underwater noise from navigational dredging

22.8.195 Instantaneous noise levels for mortality/potentially mortality injury occur up to 45m from the sound source in the case of a 90kJ hammer energy and 66m for a 200kJ hammer energy, provided in **Table 22.75**.

22.8.196 Assuming fish in Category 2 remained for within the vicinity of piling with a 90kJ hammer for the duration of piling mortality is predicted in a zone of 3ha (111m). Recoverable injury and TTS zones are 206m (9ha) and 1.49km (228ha), respectively. In the case of the 200kJ hammer energy modelling predicts mortality would occur if fish remained within 158m (5ha) of the piling activity for the cumulative assessment period, provided in **Table 22.75**. Recoverable injury and TTS are the same as Category 1 receptors; predicted within 303m (16ha) and 1.96km (443ha), respectively provided in **Table 22.75**.

22.8.197 In addition to mortality and acoustic injury, masking and changes in behaviour may have further consequences for energy expenditure, foraging, distribution, growth and survival. However, recoverability of fish in the category is considered high. The sensitivity of Category 2 receptors to underwater noise from impact piling is predicted to be low.

22.8.198 A minor adverse effect is predicted for fish receptors in Category 2. Effects are **not significant** at the sea area and regional stock/population levels.

Fish without a swim bladder (Category 3): sensitivity to underwater noise from navigational dredging

22.8.199 For Category 3 fish, modelling of the 90kJ hammer energy indicates potential for mortality/potentially mortality injury and recoverable injury very close (25m or <25m) from the sound source for instantaneous and cumulative noise levels. For cumulative noise assessments, TTS is predicted at a range of 1.49km (228ha), provided in **Table 22.75**.

22.8.200 In the case of the 200kJ hammer energy, modelling indicates there is the potential for instantaneous mortality/potentially mortality injury and recoverable injury 40m from the sound source, provided in **Table 22.75**. For cumulative noise levels, mortality would occur if fish remained <25m from the piling activity. Recoverable injury is predicted if fish were 111m (2ha) distance from the piling, while TTS is predicted if fish remain within 1.96km (443ha) from the piling, provided in **Table 22.75**.

22.8.201 In addition to mortality and acoustic injury, masking and changes in behaviour may have further consequences for energy expenditure, foraging, distribution, growth and survival. The sensitivity of Category 3 receptors to underwater noise from impact piling is predicted to be low.

22.8.202 A minor adverse effect is predicted for fish receptors in Category 3. Effects are **not significant** at the sea area and regional stock/population levels.

Table 22.75: Auditory impact zones areas (expressed in hectares) and/or Auditory impact zone maximum ranges (expressed in metres) for the three hearing categories in fish, based on a 90kJ and 200kJ piling hammer energy. The grey shaded boxes indicate that TTS is not defined for instantaneous noise exposure for fish.

Activity	Hearing category.	Threshold	Instantaneous	Cumulative
Impact piling BLF (90kJ).	(1) Fish with swim bladder or other air cavities to aid hearing.	Mortality.	45m.	158m; 5ha.
		Recoverable injury.	45m.	206m; 9ha.
		Temporary Threshold Shift.		1,493m; 2,28ha.
	(2) Fish with swim bladder that does not aid hearing.	Mortality.	45m	111m; 3ha
		Recoverable injury.	45m.	206m; 9ha.
		Temporary Threshold Shift.		1,493m; 2,28ha.
	(3) Fish without a swim bladder.	Mortality.	25m.	<25m.
		Recoverable injury.	25m.	<25m.
		Temporary Threshold Shift.		1,493m; 2,28ha.
Impact piling BLF (200kJ).	(1) Fish with swim bladder or other air cavities to aid hearing.	Mortality.	66m.	206m; 8ha.
		Recoverable injury.	66m.	303m; 16ha.
		Temporary Threshold Shift.		1,955m; 443ha.
		Mortality.	66m	158m; 5ha

Activity	Hearing category.	Threshold	Instantaneous	Cumulative
	(2) Fish with swim bladder that does not aid hearing.	Recoverable injury.	45m.	303m; 16ha
		Temporary Threshold Shift.		1.96km; 443ha
	(3) Fish without a swim bladder.	Mortality.	40m.	<25m.
		Recoverable injury.	40m.	111m; 2ha.
		Temporary Threshold Shift.		1,955m; 443ha.

Demersal and pelagic fish eggs and larvae: sensitivity to underwater noise from impact piling

22.8.203 Given the limited motility, small size and possible vulnerability to underwater noise, exposure of eggs and larvae has been assessed.

22.8.204 For pile driving, Popper *et al.,* (2014) guidelines utilise the same criteria for eggs and larvae as fish with swim bladder not involved in hearing (Category 2). Therefore, based on the mortality effects zone for Category 2 receptors as provided in **Table 22.75**, there is potential for mortality of eggs and larvae but within a limited range from the BLF piling. Popper *et al.,* (2014) assigned relative risk for other effects. Moderate relative risk is assigned at the near-field distance for recoverable injury, TTS and masking (Ref. 22.53). Low relative risk is assigned at all other distances from the sound source.

22.8.205 There is potential for mortality and for fitness and survival to be affected. Mortality of eggs and larvae is not considered to be significant given losses to natural mortality at this early life history stage of fish. The sensitivity of demersal and pelagic fish eggs and larvae to underwater noise from impact piling is predicted to be low.

22.8.206 As a worst-case, a minor adverse effect is predicted for demersal and pelagic fish eggs and larvae. Reductions in ichthyoplankton abundance is considered negligible compared to the size and persistence of populations within the GSB and wider area of the North Sea. Therefore, effects are **not significant** at the sea area and regional stock/population levels.

Assessments of effects to migratory species and localised displacement: underwater noise from impact piling

22.8.207 Behavioural response thresholds have not been formally assigned and assessment thresholds are based on behavioural responses to instantaneous noise sources reported in the literature. As such they are subject to a lower degree of confidence than established criteria for injury and auditory damage assessments.

22.8.208 The applied threshold for behavioural effects is based on observations of a startle response in sprat (135 db re 1 μPa^{2}s) and in mackerel (142 db re 1 μPa^{2}s). The response thresholds do not necessarily mean that displacement would occur. Also, it is acknowledged that the response thresholds should be applied with caution for species that do not occupy the same habitat or have the same physiology as the two pelagic species, sprat and mackerel.

22.8.209 In the case of fish in Category 1 and Category 2, there are predicted to be behavioural effects at a range of 5.60km (3,816ha) and 4.12km (1,951ha) from the piling with a 200kJ and 90kJ hammer energy, respectively provided in **Table 22.76**.

22.8.210 In the case of fish in Category 3, behavioural effects are predicted at a range of 3.10km (1,093ha), and 2.26km (614ha) from the piling with a 200kJ and 90kJ hammer energy, provided in **Table 22.76**.

22.8.211 The effects of behavioural responses may have consequences for distribution, foraging, growth and survival. Playback of piling noise impaired the startle response of seabass and it was suggested this may compromise the species' anti-predator response in the wild (Ref. 22.354; 355). Controlled experiments using playback of piling noise recordings on cod and sole observed changes in swimming behaviour in response to received sound pressure and particle motion (Ref. 22.353).

Table 22.76: Behavioural impact zones for impact piling using a 90kJ and 200kJ hammer energy. The area (expressed in hectares) and maximum range (expressed in metres) are shown. The applied threshold is based on observations of a startle response in sprat (135dB re 1 μPa^{2}s) and in mackerel (142dB re 1 μPa^{2}s).

<table>
<tr><th>Activity</th><th>Threshold</th><th>Behavioural zone</th></tr>
<tr><td>Impact piling BLF (90kJ).</td><td rowspan="2">135dB.
Applicable to herring, sprat, seabass; cod, whiting, mullet.
Migratory species: shads, eel, slamonids, and smelt.</td><td>4,119m.
1,951ha.</td></tr>
<tr><td>Impact piling BLF (200kJ).</td><td>5,597m.
3,816ha.</td></tr>
<tr><td>Impact piling BLF (90kJ).</td><td>142dB.</td><td>2,259m.
614ha.</td></tr>
</table>

Activity	Threshold	Behavioural zone
Impact piling BLF (200kJ).	Applicable to makerel, horse mackerel, flatfish e.g. Dover sole; sand gobies, tope; and, thornback ray. Migratory species: Lampreys.	3,104m; 1,093ha.

22.8.212 Shads, eel, salmonids, smelt and lampreys are migratory species. The potential for coastal noise has the potential to cause migratory barriers should piling coincide with periods of migratory behaviour. However, the total duration of impulsive underwater noise from piling is anticipated to be short-term consisting of 12 events (piles) lasting, in-combination, a total of less than 11 hours including soft starts. As such, the impacts represent a very small proportion of the migratory window, provided in **Table 22.60**. Displaced species would be able to return to the ensonified area and no barriers to migration are anticipated.

22.8.213 Underwater noise from piling, is predicted to cause localised behavioural responses in prey species resulting in localised displacement and changes in swimming behaviour. Such behavioural effects are likely to be short-lived and do not necessitate displacement from the whole ensonified area. The sensitivity of fish to displacement from piling noise is predicted to be low.

22.8.214 The potential for behavioural responses due to impact piling is predicted to have a minor adverse effect on the availability of prey items for designated species or fisheries resources. The short duration of the effects and alternative foraging areas indicated effects would be **not significant**.

22.8.215 It is acknowledged that fish in active migration may not avoid the ensonified area and the assessment considers the worst-case scenario in terms of disruption to migratory pathways. In terms of migratory species that do not avoid the ensonified area, mortality, recoverable injury and TTS would be the same as for the assessments described in **Table 22.75**.

22.8.216 Indirect-food web effects are considered in more detail in **Section 22.10** of this chapter. The **Shadow HRA** (Doc Ref. 5.10) considers the spatial intersection between behavioural impact zones and the foraging ranges of SPA and SAC designated species in further detail.

Underwater noise: unexploded ordnance clearance

22.8.217 In the case UXOs were identified on site, and alternative disposal methods or relocation are not possible, underwater detonations may be required. Appropriate management actions and mitigation measured would be implemented to minimise impacts. Such measures would be highly dependent on the location of the UXO and would require review on a case-by-case basis. The underwater noise modelling results are considered as indicative, worst-case scenarios for unmitigated impact ranges, provided in **Appendix 22L** of this volume.

22.8.218 Underwater explosions generate some of the highest peak sound pressures of all anthropogenic underwater sound sources (Ref. 22.363), and are considered a high energy, impulsive sound source, provided in **Appendix 22L** of this volume.

22.8.219 At the time of writing UXOs are not known to occur at the site and a hypothetical assessment is made. Noise propagation modelling has, therefore, been conducted for three different explosive charges: 250-pound (lb), 500lb and 1,500lb of dynamite (TNT) equivalent.

22.8.220 The Popper criteria provide guideline quantitative thresholds for mortality and potential mortal injury for fish exposed to explosive sound sources of 229 to 234 dB re 1 µPa. As a precautionary approach, assessments adopted the lower limit of this interval, namely 229 dB peak pressure, for the assessment of mortality and potential mortal injury effects from UXO detonation, provided in **Appendix 22L** of this volume. The maximum predicted impact zone where mortality and potentially mortal injury are predicted, would be 897m for a hypothetical UXO detonation of a 1,500lb charge, 622m for a 500lb charge and 493m for a 250lb charge, provided in **Table 22.77**. UXO detonation would be produce high energy impulsive noise to a maximum sea area of 126ha to 252ha, based on a circle with a radius of 897m, depending on the proximity to the coast. The modelled impact zone for unmitigated mortality for the worst-case detonation represents a moderate area of the GSB used by fish for foraging, shelter and reproductive requirements. Changes in noise levels would be very short term. The magnitude of impact is low.

Table 22.77: Fish species auditory effect ranges (expressed in metres) for UXO detonation works.

Charge mass (pound, lb)	Threshold (metres)	All fish species.
250	Mortality and potential mortal injury.	493m.
500	Mortality and potential mortal injury.	622m.
1,500	Mortality and potential mortal injury.	897m.

22.8.221 Detonations produce a rapid rise to a high peak pressure followed by a rapid decay (Ref. 22.364). The degree of damage in fish is thought to be related to several factors, including; the explosive type, size and pattern of the charge(s), water depth, species, size and life stage of fish (Ref. 22.365). Masking effects are thought to only occur during the brief duration of the sound and startle responses to the explosion are likely. However, the evidence base for hearing impairment and behavioural effects in wild fish, due to underwater explosions is limited (Ref. 22.53).

22.8.222 At the individual level, unmitigated UXO detonations represent a high risk of mortality in the intermediate field; however, injorous and behavioural risks are low in the far field (Ref. 22.53). Fish receptors are assessed as having medium sensitivity to unmitigated UXO detonations. The low impact magnitude and medium sensitivity of fish results in minor adverse effects. Effects would **not be significant** at the sea area and regional stock/population levels.

22.8.223 Should UXOs be identified on site, a full assessment would be completed considering the exact UXO specifications and location in line with Marine Licence conditions. Alternative disposal methods or relocation would be considered as well as appropriate management actions and mitigation measures in order to minimise the risk of potential impacts. As described in **Section 22.3.i)** of this chapter, should UXOs be identified on site regulatory authorities would be consulted and appropriate assessments made.

iii. Combined Drainage Outfall

22.8.224 This section describes the impacts associated with the installation and operation of the combined drainage outfall during the construction phase. Scoping identified the pressures arising from activities at the combined drainage outfall with the potential for effects on ecological receptors, provided in **Appendix 22M** of this volume. Pressures with the potential to affect fish receptors are presented in **Table 22.78.**

Table 22.78: Pressures associated with CDO activities during the construction phase that have the potential to affect fish.

Pressure	Activities resulting in pressure.	Justification
Physical change to another seabed type.	Presence of structure.	Potential to affect fish receptors through habitat change.
Habitat change - Reprofiling of substratum (extraction).	Capital dredging.	Dredging for the installation of the CDO headworks resulting in substrate extraction and potential loss of fish or eggs/egg cases.
Changes in suspended sediments.	Capital dredging.	Increases in SSC have the potential to result in a range of physical and physiological effects on different life history stages and species of fish. Behavioural effects, notably avoidance behaviour, could displace species from preferred

Pressure	Activities resulting in pressure.	Justification
		habitat or influence the passage of migratory species.
Sedimentation rate changes.	Capital dredging.	The deposits of sediment could smother eggs/egg cases/larvae, juveniles and small bodied fish. Smothering may result in stress and potential for mortality.
Underwater noise and vibration.	Capital dredging.	Dredging for the CDO would generate underwater noise. The potential effects of underwater noise on fish receptors (eggs, larvae and juvenile and adult stages), range from mortality and injury at close range to the activity, to hearing impairment, masking, behavioural effects and barrier to movement further away from the sound source.
Pollution and other chemical changes.	Construction discharges of un-ionised ammonia and heavy metals.	Potential to affect fish receptors through toxicological stress.
Synthetic compound contamination.	Construction discharges of tunnelling chemicals.	Tunnel boring machine (TBM) chemicals may be used during drilling of the cooling water intakes and outfall tunnels. Drilling wastewater containing small volumes of drilling chemical leachate would be discharged via the CDO. The potential toxicological effects are assessed
Synthetic compound contamination.	Commissioning discharges of hydrazine.	Commissioning discharges of hydrazine during cold-flush testing would be discharged through the CDO. The potential toxicological effects are assessed

22.8.225 Construction pressures scoped out of further assessment as they have been deemed to have negligible effects on fish include:

- During construction and commissioning relatively small quantities of nitrate and phosphate; primarily from the use of conditioning chemicals in the various circuits but also from treated sewage may be discharged. Negligible changes in gross primary productivity and no indirect food web effects are predicted. Nutrient discharges are, therefore, scoped out in relation to fish receptors.

- Bentonite is a clay mineral regularly used in construction and offshore drilling operations. A bentonite recovery system would be utilised; however, bentonite is assessed due to the potential to increase the SSC in the receiving waters. Bentonite is included on the OSPAR list of substances that pose little or no risk to the environment. Modelling accounted for a tunnelling wastewater discharge rate of 34.4l/s and a discharge of 8.8mg/l bentonite. The predicted concentration of bentonite in suspension would be orders of magnitude lower than baseline SSC, provided in **Section 22.4** of this chapter, with 95th percentile concentrations of 10µg/l restricted to sea surface areas of <11ha and mean concentrations of 10µg/l less than 1.5ha, provided in **Appendix 21E** of this volume. In the tidally dominated environment characterised by high resuspension rates, the potential for sedimentation of fine materials to cause ecological effects during normal tunnelling processes is negligible. No further assessment is made.

Physical change to another seabed type: presence of structure

22.8.226 The installation of the CDO head and scour protection would result in a change in seabed type from soft sediment (fine to medium sand) to a hard surface. Changing the seabed from a soft sediment habitat to a hard surface constitutes a large amount of change based on the Marine Evidence-Based Sensitivity Assessment benchmark threshold for changes in EUNIS classification (one Folk class for > ten years). The spatial extent of habitat change is very small (<0.1ha) in relation to the area of the GSB (>4,000ha). This change to seabed type would last for the lifetime of the proposed development. The very small spatial extent but long duration of the pressure constitutes a low impact magnitude.

Sensitivity assessments of effects at the sea-area or regional stock/population level: physical change (to another seabed type)

22.8.227 The sensitivity of the marine and migratory fish sub-groups to physical change in seabed is described in the assessment of the BLF. For the CDO, sensitivity is not sensitive for all sub-groups, as provided in **Table 22.79**, based on the small area affected relative to available habitat. Negligible effects are concluded and are **not significant** at the sea area and regional stock/population levels.

Table 22.79: Summary of assessment for physical change in seabed from the CDO and scour protection installation.

Sub-group	Sensitivity
Demersal fish and elasmobranch eggs /cases and larvae.	Not Sensitive.
Demersal fish and elasmobranch juveniles and adults (and small bodied fish).	

Sub-group	Sensitivity
Pelagic fish eggs and larvae.	
Pelagic fish juveniles and adults.	
Migratory fish juveniles and adults.	

Habitat structure changes - removal of substratum (extraction)

22.8.228 Installation of the CDO head would result in the removal of approximately 0.13ha of surficial sediment. Dredging is expected to occur once and last for less than 24 hours per head. Following dredging, 0.02ha of soft sediment habitat (16% of the dredged area) would be replaced by a hard habitat due to the installation of infrastructure and scour protection. The CDO would be installed in a soft-sediment environment, common within the GSB and southern North Sea.

22.8.229 Impact magnitude is assessed as very low based on the limited spatial extent of dredging relative to the extent of the affected habitat (subtidal sand) in the GSB.

Sensitivity assessments of effects at the sea-area or regional stock/population level: removal of substratum

Demersal fish and elasmobranch eggs /cases and larvae: sensitivity to removal of substratum

22.8.230 Substrate removal can reduce the available habitat for larval settlement or removes larvae and eggs atop the substrate. The removal represents a minimal change to the area of available seabed within the GSB and any losses would be indiscernible. No declines in abundance and distribution of the respective stocks/populations is expected. The sensitivity of demersal fish and elasmobranch eggs/cases and larvae to removal of substratum from dredging, is predicted to be not sensitive.

22.8.231 Negligible effects are predicted for demersal fish and elasmobranch eggs/cases and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Demersal fish and elasmobranchs: sensitivity to removal of substratum

22.8.232 Substrate removal for the CDO represents a very small spatial area in terms of the available seabed habitat for foraging or shelter. The mobility of most of the demersal species enables alternative seabed to be exploited within or beyond the GSB. Sand gobies are considered less mobile than other species in the sub-group, yet they are abundant within the GSB area and wider area of the North Sea, as provided in **Appendix 22D** of this volume. Whilst there maybe energy expended to change habitat for foraging or shelter, no impacts to fitness or survival are anticipated. The sensitivity of demersal juveniles and adults (and small bodied fish) to removal of substratum from dredging, is predicted to be not sensitive.

22.8.233 Negligible effects are predicted for demersal juveniles and adults (and small bodied fish) due to substrate removal for the CDO. Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish eggs and larvae: sensitivity to removal of substratum

22.8.234 The removal represents a negligible change to the area of available seabed within and outside of the GSB. There is also the possibility that dredging removes larvae and eggs atop the substrate. If eggs/larvae were present, then very localised mortality is possible, but the losses would be negligible in the context of natural mortality and in view of the abundances of eggs/larvae occurring within the extensive spawning and nursery grounds. The sensitivity of pelagic fish eggs and larvae to removal of substratum from dredging is not sensitive.

22.8.235 Negligible effects are predicted for pelagic fish eggs and larvae due to substrate removal for the CDO. Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish juveniles and adults: sensitivity to removal of substratum

22.8.236 The use of the water column habitat minimises the direct interaction with the area of substrate removed by dredging. The sensitivity of pelagic fish juveniles and adults to removal of substratum (0.15ha) from dredging is predicted to be not sensitive.

22.8.237 Negligible effects are predicted for pelagic fish juveniles and adults. Effects are **not significant** at the sea area and regional stock/population levels.

Migratory fish juveniles and adults: sensitivity to removal of substratum

22.8.238 The sensitivity of migratory fish juveniles and adults to removal of substratum from dredging is predicted to be not sensitive due to the limited spatial extent relative to the available habitat.

22.8.239 Negligible effects are predicted for migratory fish juveniles and adults. Effects are **not significant** at the sea area and regional stock/population levels.

Assessments of effects of localised displacement: removal of substratum

22.8.240 Displacement of fish receptors to alterative areas, due to removal of substratum, would occur over a very limited area and effect a very small proportion of fish within the GSB. Fish are not sensitive to the pressure. Substrate removal is predicted to have a negligible effect on the distribution of fish within the GSB. No significant changes in the availability of fish as prey items for designated features or as fisheries resources are predicted.

Changes in suspended sediment concentration

22.8.241 The construction dredging and disposal could temporarily increase suspended sediment concentrations, with potential to effect early life stages and older life stages of fish.

22.8.242 Dredging and local dredge disposal for the installation of the CDO head would lead to elevated suspended sediment concentrations (SSC). Plumes with instantaneous SSC of >100mg/l above daily maximum background levels are expected to form over instantaneous areas of up to 89ha at the surface (28ha depth averaged). A small area of 1ha is expected to experience an instantaneous SSC of >1,000mg/l above background at the sea surface, as provided in **Section 22.3.i)** of this chapter.

22.8.243 Ambient conditions at the site are highly variable, provided in **Section 22.4** of this chapter, and the surface waters are considered as *'intermediate turbidity'* according to WFD criteria provided in **Appendix 21E** of this volume. Dredging would temporarily increase the classification to '*turbid'*. However, SSC would return to background levels several days after dredging activity ceases. The increase in SSC would occur once for the installation of the CDO head.

22.8.244 While increases in SSC would be relatively large relative to baseline conditions, the transient nature of the plume and its intermediate spatial footprint result in an impact magnitude of medium.

Sensitivity assessments of effects at the sea-area or regional stock/population level: increases in suspended sediment

Demersal fish and elasmobranch eggs /cases and larvae: sensitivity to increases in suspended sediment

22.8.245 The evidence for effects of the eggs and larval stages of demersal fish is presented in **Table 22.65**. Spawning/nursery grounds in the GSB area encompass Dover sole, plaice, cod, seabass and thornback ray. Increases in SSC have the potential for direct mortality and sub-lethal effects. While localised egg/larvae mortality may occur, the losses are generally considered minimal compared to natural mortality. The GSB is not considered to be the only spawning or nursery grounds for species in the sub-group and as such, the presence of the taxa could be maintained through natural influxes of eggs and larvae.

22.8.246 Predicted changes in suspended solids are expected to be transient and short lived (in the order of days). Daily maximum SSC in the range 357-609mg/have been recorded 0.3m above the seabed, while background SSC at the surface in the inshore waters range between 9 and 436mg/l, provided in **Section 22.4** of this chapter. Therefore, receptors may experience this turbidity in the existing environment.

22.8.247 The sensitivity of demersal fish and elasmobranch eggs /cases and larvae to increases in suspended sediment from dredging, is predicted to be low.

22.8.248 The impact of increases in suspended sediment is predicted to have a minor adverse effect on demersal fish and elasmobranch eggs /cases and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Demersal fish and elasmobranchs: sensitivity to increases in suspended sediment

22.8.249 The evidence for effects to the juvenile/adult stages of demersal fish is presented in **Table 22.65**. The increases in SSC relative to background are modest over the area of the GSB potentially utilised by juveniles and adults. The species in the sub-group exhibit the ability to compensate for increases SSC or may be able to avoid areas with elevated SSC and return once SSC is back to ambient levels. The sensitivity of demersal fish and elasmobranch juveniles and adults (and small bodied fish) to increases in suspended sediment from dredging, is predicted to be low.

22.8.250 The impact of increases in suspended sediment is predicted to have a minor adverse effect on demersal fish and elasmobranch juveniles and adults (and small bodied fish). Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish eggs and larvae: sensitivity to increases in suspended sediment

22.8.251 According to indicative maps in Ellis *et al.* (2012), herring nursery grounds overlap with the GSB. Low intensity mackerel nursery grounds are thought to be present across the entire North. Indicative nursery grounds for horse mackerel are offshore of the North Sea. Mackerel and sprat nursery grounds also overlap with the GSB Sea, provided in **Figure 22.13**.

22.8.252 While localised egg/larvae mortality may occur, the losses are considered minimal compared to natural mortality. The GSB is not considered to be the only spawning or nursery grounds for species in the sub-group and as such, the presence of the taxa could be maintained through natural influxes of eggs and larvae. The sensitivity of pelagic fish eggs and larvae to increases in suspended sediment from dredging of the CDO, is predicted to be not sensitive.

22.8.253 The impact of increases in suspended sediment is predicted to have a minor adverse effect on pelagic fish eggs and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish: sensitivity to increases in suspended sediment

22.8.254 There is potential for physiological compensation in fish remaining in an exposed area. Fish may also behaviourally avoid the plume and be locally displaced; localised displacement effects are considered separately.

22.8.255 There is the possibility of sub-lethal effects increasing the likelihood of mortality. The mobility of the pelagic species provides access to habitat within and outside the GSB, during the dredging and to return to an area once SSC decrease. Declines in abundance and distribution of the respective stocks/populations are thus unlikely. The sensitivity of pelagic fish juveniles and adults to increases in suspended sediment from dredging, is predicted to be low.

22.8.256 The impact of increases in suspended sediment is predicted to have a minor adverse effect on pelagic fish juveniles and adults. Effects are **not significant** at the sea area and regional stock/population levels.

Migratory fish: sensitivity to increases in suspended sediment

22.8.257 Suspended sediment plumes have the potential to cause lethal and sub-lethal effects on migratory species and potentially influence migratory behaviour due to plume avoidance. This section considers the potential for direct effects and effects on migratory behaviour.

22.8.258 The known migration periods for key migratory taxa of conservation importance are summarised in **Table 22.60**. The migratory taxa assessed are smelt, European eel, river and sea lamprey.

22.8.259 Considering the timings of the respective migration periods, it is unlikely that smelt, European eel and river lamprey would be exposed to the SSC plume from the end of May to end of July. If dredging occurred during other months of the year (August-May) then the potential exists for a temporal coincidence of the SSC plume and migratory taxa.

22.8.260 The transient plume, with a narrow east-west profile, is unlikely to block the route of the migratory species. The plume is anticipated to dissipate within days, thereby limiting the presence of the plume. The migratory fish may choose to move freely around the plume, although in the case of the parasitic lamprey, this would be influenced by the host's behaviour.

22.8.261 The plume is unlikely to inhibit foraging ability in the smelt and European eel (lampreys are parasitic) and no barrier to the migratory movement of smelt, European eel, river and sea lamprey is predicted. The sensitivity of migratory fish juveniles and adults to increases in suspended sediment from construction dredging, is predicted to be not sensitive.

22.8.262 The impact of increases in suspended sediment is predicted to have a minor adverse effect on migratory fish juveniles and adults. Effects are **not significant** at the sea area and regional stock/population levels. The SSC plume would be of a limited magnitude and the passage of migratory fish would be unhindered.

Assessments of effects of localised displacement: increases in suspended sediment

22.8.263 The avoidance of fish to SSC plumes, notably pelagic fish, would be influenced by factors such as motivation, mobility and condition. Thus, fish may exhibit limited movements away from the areas of SSC, remaining in proximity to the plume and utilising the area once the plume dissipates. Should the passage of the plume influence fish behaviour, particularly those of ecological value as prey species of designated sea birds the potential exists for temporary reductions in foraging success. However, given the limited persistence and transitory nature of the plume, the scope for fish to be displaced entirely from the plume area and not return is very limited. Fish are predicted to have low sensitivity with only localised and temporary displacement of sensitive taxa likely to occur. Displacement of fish is predicted to have a minor adverse effect. No significant changes in the availability as prey items for designated features and as fisheries resources are predicted.

Changes in sedimentation rates

22.8.264 Sediment suspended by dredging and dredge disposal for the installation of the CDO would subsequently be deposited onto the seabed. Sediment deposition would be classified as 'light' throughout the plume footprint, with sediment thickness not expected to exceed 50mm and only expected to exceed 20mm over 1ha, provided in **Section 22.3.i)** of this chapter. It is predicted that all suspended sediment would be deposited within hours of dredging and then dispersed by natural resuspension, leaving no area where sediment thickness remains >20mm thicker than it was prior to dredging after 15 days, provided in **Section 22.3.i)** of this chapter. These levels of sediment deposition would occur once for the installation of the CDO head.

22.8.265 As no area would be exposed to more than 'light' deposition and deposited sediments would be rapidly dispersed, impact magnitude is assessed as very low.

Sensitivity assessments of effects at the sea-area or regional stock/population level: changes in sedimentation rates

Demersal fish and elasmobranch eggs /cases and larvae: sensitivity to changes in sedimentation rates

22.8.266 The sensitivity of demersal fish and elasmobranch eggs /cases and larvae to changes in sedimentation rates is described in the assessment of the BLF and is predicted to be not sensitive.

22.8.267 The impact of siltation rate changes resulting from dredging activities associated with the CDO, is predicted to have a negligible effect on demersal fish and elasmobranch eggs /cases and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Demersal fish and elasmobranchs: sensitivity to changes in sedimentation rates

22.8.268 The sensitivity of demersal fish and elasmobranch juveniles and adults (and small bodied fish) to changes in sedimentation rates is described in the assessment of the BLF and is predicted to be not sensitive.

22.8.269 The impact of siltation rate changes resulting from dredging activities associated with the CDO, is predicted to have a negligible effect on demersal fish and elasmobranch juveniles and adults (and small bodied fish). Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish eggs and larvae: sensitivity to changes in sedimentation rates

22.8.270 The sensitivity of pelagic fish eggs and larvae to changes in sedimentation rates is described in the assessment of the BLF and is predicted to be *Not sensitive*.

22.8.271 The impact of siltation rate changes resulting from dredging activities associated with the CDO, predicted to have a negligible effect on pelagic fish eggs and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish: sensitivity to changes in sedimentation rates

22.8.272 The sensitivity of pelagic fish juveniles and adults to changes in sedimentation rates is described in the assessment of the BLF and is predicted to be not sensitive.

22.8.273 The impact of siltation rate changes resulting from dredging activities associated with the CDO, is predicted to have a negligible effect on pelagic fish juveniles and adults. Effects are **not significant** at the sea area and regional stock/population levels.

Migratory fish: sensitivity to changes in sedimentation rates

22.8.274 The sensitivity of migratory fish to changes in sedimentation rates from dredging activities associated with the CDO, is predicted to be not sensitive.

22.8.275 The impact of siltation rate changes resulting from dredging activities associated with the CDO, is predicted to have a negligible effect on migratory fish juveniles and adults. Effects are **not significant** at the sea area and regional stock/population levels.

Assessments of effects of localised displacement: changes in sedimentation rates

22.8.276 Changes in sedimentation rates associated with dredging for the CDO is not predicted to affect the distribution of fish within the GSB. No indirect food web effects or changes in the availability of fish as prey items for designated features or as fisheries resources are expected. Fish are not sensitive to displacement resulting from sedimentation rate changes. Effects are predicted to be negligible and **not significant**.

Underwater noise

22.8.277 Prior to the installation of the CDO, dredging would be required, and a cutter suction dredger is proposed. The sources of noise from a cutter suction dredger include: the draghead, sediment moving up the pipe from the draghead into the dredger and thruster, engine/mechanical, pump and propeller sounds (Ref. 22.357). **Table 22.70** summarise the hearing categories of fish receptors that are the subject of the assessment.

22.8.278 Modelling reported in **Appendix 22L** of this volume, utilised noise levels generated by a large trailing suction hopper dredger, measured at 100m distance. Broadband source levels were back-propagated under the assumption of spherical sound spreading, yielding a level of 186 dB re 1 µPa in the range 0.1-1 kHz, with acoustic energy evenly distributed across this range and peaking slightly at 125 Hz. The dredging noise modelling assumed 9.5 hours to complete, with 12 cycles of 19 minutes of dredging, followed by a 30-minute interval for repositioning, provided in **Appendix 22L** of this volume. Applying the source noise levels from a trailing suction hopper dredger to cutter suction dredging is considered precautionary for the purposes of this assessment.

22.8.279 There are no agreed exposure criteria for particle motion at the time of writing for use in modelling. Within the assessments, particle motion has been recognised in the consideration of receptor sensitivity.

22.8.280 Thresholds for effects from cumulative noise are exceeded, yet the modelled zone for recoverable injury is limited to 2ha from dredging, provided in **Table 22.80,** which is predicted to be 9.5 hours within each 24-hours. Therefore, the magnitude of impact is low.

Sensitivity assessments of effects at the sea-area or regional stock/population level: underwater noise

Fish with swim bladder or other air cavities to aid hearing (Category 1): sensitivity to underwater noise from construction dredging

22.8.281 Instantaneous auditory effects would not occur from continuous noise sources associated with dredging for the CDO.

22.8.282 Modelling of cumulative noise exposure indicates the potential for mortality/potential mortality is very low. **Table 22.80** shows that impact zones are within 25m (or 0.25ha) from the dredging source for Category 1 fish.

22.8.283 There is the potential for recoverable injury at a range of 70m (or 2ha) from the CDO, while there is the potential for TTS at a range of 1.0km (or 162ha) from the CDO dredging, provided in **Table 22.80**. Exposure of fish may reduce survival and fitness through hearing impairment, while physical and/or physiological effects could lower fitness levels until recovery. High recoverability from TTS is anticipated.

22.8.284 Dredging is anticipated for 9.5 hours in a 24-hour period and where individuals have experienced minor disturbances and moved away from the dredging, it is anticipated they would return to the area in a matter of hours to days. The sensitivity of Category 1 receptors to underwater noise from construction dredging is predicted to be low.

22.8.285 The impact of underwater noise is predicted to have a minor adverse effect on Category 1 receptors. Effects are **not significant** at the sea area and regional stock/population levels.

Fish with a swim bladder that does not aid hearing (Category 2): sensitivity to underwater noise from construction dredging

22.8.286 In the case of Category 2 fish, there are predicted to be limited impact zones with cumulative noise. The sensitivity of Category 2 receptors to underwater noise from construction dredging is predicted to be low.

22.8.287 The impact of underwater noise is predicted to have a minor adverse effect on Category 2 receptors. Effects are **not significant** at the sea area and regional stock/population levels.

Fish without a swim bladder (Category 3): sensitivity to underwater noise from construction dredging

22.8.288 Cumulative auditory impact ranges are predicted to be limited in the case of Category 3 fish. The sensitivity of Category 3 receptors to underwater noise from construction dredging is predicted to be not sensitive.

22.8.289 The impact of underwater noise is predicted to have a negligible effect on Category 3 receptors. Effects are **not significant** at the sea area and regional stock/population levels.

Demersal and pelagic fish eggs and larvae: sensitivity to underwater noise from construction dredging

22.8.290 The sensitivity of demersal and pelagic fish eggs and larvae to underwater noise from dredging, is described in the assessment of the BLF and is precautionarily assessed as low.

22.8.291 The impact of underwater noise is predicted to have a minor adverse effect on demersal and pelagic fish eggs and larvae. Effects are **not significant** at the sea area and regional stock/population levels. Given the limited magnitude of the dredging, potential losses of eggs and larvae are considered negligible in comparison to natural mortality.

Table 22.80: Auditory impact zones areas (expressed in hectares) and/or Auditory impact zone maximum ranges (expressed in metres) from dredging of the CDO. These are based on the most sensitive category, 'fish with swim bladder or other air cavities to aid hearing'. N/A indicates source level below threshold.

Activity	Hearing category.	Threshold	Instantaneous	Cumulative
Dredging CDO.	(1) Fish with swim bladder or other air cavities to aid hearing.	Mortality	N/A.	25m; 0.25ha.
		Recoverable injury.	N/A.	70m; 2ha.
		Temporary Threshold Shift.	N/A.	1,000m; 162ha.

Assessments of effects of localised displacement: underwater noise from construction dredging

22.8.292 For Category 1 and Category 2 receptors, behavioural effects are predicted at a range of 2.21km, or an area of 640ha, provided in **Table 22.81**. In the case of Category 3 receptors, behavioural effects are limited to 778m (118ha) from the dredging.

22.8.293 The applied behavioural thresholds are based on the best available evidence, from peer-reviewed literature (Ref. 22.362), and the thresholds are a conservative indicator for the risk of behavioural responses and do not necessitate displacement. Indeed evidence indicates that habituation to impulsive sound sources occurs in fish whereby responses lessen with repeated exposure (Ref. 22.353). This indicates that applying impulsive thresholds to continuous noise sources is likely to be highly conservative. However, a precautionary approach is applied given the lower levels of confidence introduced with the application of thresholds across species with different hearing sensitivities, auditory mechanisms and the application of impulsive thresholds to continuous noise sources. Furthermore, it is acknowledged that the response thresholds should be applied with caution for species that do not occupy the same habitat or have the same physiology as the two pelagic species, sprat and mackerel.

22.8.294 The dredging noise would be present in an existing soundscape in the GSB, where the baseline is characterised by operational noise from Sizewell B, surf noise (waves breaking on the beach), and noise from passing fishing vessels (Ref. 22.361). The duration of dredging is short-lived and with limited sound levels. Should individuals move away to avoid the dredging noise, it is anticipated they could return to the area in a matter of hours to days. However, it is recognised that this may be influenced by motivational state and exposure to predation in areas where fish have been displaced. Fish are precautionarily assessed as having low sensitivity to displacement from dredging activities.

22.8.295 Localised displacement of fish receptors due to underwater noise from dredging for the CDO, is predicted to have a minor adverse indirect effect on the availability of prey items for designated features and as fisheries resources. Effects are not deemed to be significant. Short term behavioural effects (not necessarily displacement) could cause temporary reductions in feeding efficiency. The implications for bird and cetacean feeding will be considered further in the **Shadow HRA** (Doc Ref. 5.10).

Table 22.81: Behavioural impact zone for dredging the CDO, with the area (expressed in hectares) and maximum range (expressed in metres).

Activity	Threshold	Behavioural zone
Dredging CDO.	135 dB re 1 µPa²s	2,213m; 640ha.
	142 dB re 1 µPa²s	778m; 118ha.

Construction discharges: Heavy metal contamination

22.8.296 During construction of the main development site, groundwater discharges would be made via the CDO. Exploratory boreholes across the main development site quantified the concentrations of dissolved metals within the groundwater. The worst-case construction discharges for trace metals would be during the 28-day dewatering of the cut-off wall around the main construction site, as in Case A: **Plate 22.1**. The dewatering phase would result in an estimated 300,000m^3 of groundwater being discharged at a rate of 124l/s. After the initial dewatering phase nominal discharges of 15l/s would continue throughout the construction phase to remove rainwater and seepage through the cut-off wall, provided in **Appendix 21E** of this volume.

22.8.297 In the dewatering phase two groundwater metals, zinc and chromium failed initial EQS screening and General Estaurine Transport Modelling was undertaken to determine the mixing rates and spatial extent of the impacts.

22.8.298 The mean background concentration of zinc in the environment is 15.12µg/l whilst the EQS is 6.8µg/l as an annual average. Since the background levels are in exceedance of the EQS, zinc discharges could not be assessed under standard procedures. Modelling predicted the point at which zinc concentrations would be indiscernible from background based on analytical detection limits of 0.4µg/l. Therefore, the threshold value for zinc was set at 15.52µg/l. Thus, the amount of change relative to baseline is approximately 2.5%. Modelling demonstrated that zinc concentrations would only be discernible above background over a mean sea surface area of 0.11ha. At the seabed, zinc concentrations are not predicted to exceed background concentrations.

22.8.299 Chromium has a mean EQS concentration of 0.6 µg/l and a 95th percentile EQS concentration of 32µg/l. Chromium background concentrations of 0.4-0.57µg/l are reported for the site. As a precautionary measure the higher background concentration was applied to give a mean EQS threshold of 0.03µg/l. A sea surface area of 5.49ha exceeded the mean EQS, at the seabed chromium did not exceed EQS concentrations. The 95th percentile

EQS concentration (32µg/l) was not exceeded as provided in **Appendix 21E** of this volume.

22.8.300 The initial dewatering drawdown phase is a short-term activity (28 days). Areas impacted extend over a very limited spatial area and the amount of change is small relative to the baseline conditions. The impact magnitude is assessed as very low.

Sensitivity assessments of effects at the sea-area or regional stock/population level: Heavy metal contamination

Marine fish: sensitivity to heavy metal contamination

22.8.301 Existing studies indicate potentially sub-lethal and lethal effects at concentrations in mg/l, higher than the discharge plume during the dewatering (28 days) period. Speckled sanddab (*Citharichthys stigmaeus*) have been exposed to chromium solution under experimental conditions for a period of up to 21 days (Ref. 22.366). The derived median lethal concentration of chromium VI (LC_{50}) for a shorter exposure of 4 days was 30mg/l, whereas for the 21-day exposure, acute responses were observed above 5mg/l. Adult dab (*Limanda limanda*) and grey mullet (*Chelon labrosus*) have been experimentally exposed to a chromium solution for just 96 hours (Ref. 22.367). The derived median lethal concentration of chromium (LC_{50}) was 47.0mg/l and 47.2mg/l for dab and mullet, respectively. For mullet only, an LC_{50} of 21.5mg/l was determined for exposure to zinc (Ref. 22.367).

22.8.302 The acute toxicity of chromium is reported to elicit behavioural changes, effects on haematology, endocrine processes as well as possibly survival (Ref. 22.368). However, available evidence applies to concentrations exceeding the predicted metal concentrations in the discharge plume.

22.8.303 Existing studies indicate potentially lethal effects at concentrations in mg/l, higher than the discharge plume during the dewatering (28 days) period. Freshwater rainbow trout (*Oncorhynchus mykiss*) exposed to chromium for 72 hours, incurred mortality at a concentration of 0.22mg/l (Ref. 22.369). Rainbow trout have been also shown to avoid chromium at concentrations of 28µg/l (Ref. 22.370).

22.8.304 Within the EQS standard, evidence for the effects of chromium and zinc are based on studies of marine invertebrates and for NOEC concentrations of the heavy metals in the mg/l range (Ref. 22.21). These effect concentrations higher than anticipated in the discharge plume, and fish are likely to be less sensitive to short-term exposure of chromium and zinc, compared to marine invertebrates.

22.8.305 The juveniles and adults of mobile species may choose to avoid the area and move elsewhere in the GSB, while others may remain. There is potential for behavioural effects and sub-lethal effects with consequences for fitness, reproduction and survival. However, discharges of heavy metals exceed background concentrations of relevant EQS values over a very limited spatial scale and for a temporary period during dewatering (28 days), resulting in minimal exposure. The sensitivity of marine fish to zinc and chromium contamination is predicted to be not sensitive.

22.8.306 The impact of chromium and zinc contamination resulting from construction discharges, is predicted to have a negligible effect on marine fish. Effects are **not significant** at the sea area and regional stock/population levels.

Migratory fish: sensitivity to heavy metal contamination

22.8.307 Exceedance of the chromium EQS (32µg/l maximum allowable concentration) is predicted to occur over a limited area (1.91ha) of sea surface, while at the seabed, chromium did not exceed EQS concentrations. The zinc concentrations would only be discernible above background over a very limited mean sea surface area (0.11ha). While at the seabed, zinc concentrations are not predicted to exceed background concentrations. Exposure of migratory fish to heavy metal contamination is predicted to be minimal during the worst-case 28-day dewatering phase, and there are predicted to be small impact zones below concentrations known to cause an effect.

22.8.308 The sensitivity of migratory fish adults and juveniles to heavy metal contamination is predicted to be low.

22.8.309 The impact of chromium and zinc contamination resulting from construction discharges, is predicted to have a negligible effect on migratory fish. Effects are **not significant** at the sea area and regional stock/population levels.

Assessments of effects of localised displacement: heavy metal contamination

22.8.310 Any displacement behaviour due to discharges of heavy metals is predicted to be highly localised and exposure would represent a negligibly small proportion of fish in the GSB. Fish are not sensitive to this pressure. Heavy metal contamination is predicted to have a negligible effect on fish displacement. Therefore, no significant changes in the availability as prey items for designated features and as fisheries resources are predicted.

Un-ionised ammonia: treated sewage discharges

22.8.311 Ammonia is a commonly occurring pollutant that enters waterbodies from diffuse and point sources including sewage effluents, industrial and agricultural activities and decomposition of organic matter. Ammonia exists in the toxic un-ionised phase (NH_3) and as ionised ammonium (NH_4^+). The relative proportion of each form depends on the temperature, salinity and pH of the water. Higher temperatures and pH favour ammonia, whilst higher salinity favours ammonium (Ref. 22.21). Treated sewage discharges from the CDO have the potential to exert toxicological effects on plankton receptors should ammonia levels exceed EQS values of 21µg/l.

22.8.312 The highest routine sewage discharges are anticipated during Case D (**Plate 22.1**) and a worst-case un-ionised ammonia discharge would occur in the unlikely event of a sewage only discharge. In this situation dilution modelling predicts exceedance of EQS concentrations up to 6.3m from the point of discharge. EQS exceedance is within 4m of the discharge for all other construction scenarios, provided in **Appendix 21E** of this volume.

22.8.313 The magnitude of impact is assessed as low as discharges could occur throughout the construction phase.

Sensitivity assessments of effects at the sea-area or regional stock/population level: un-ionised ammonia

Demersal fish and elasmobranch eggs /cases and larvae: sensitivity to nutrient enrichment (un-ionised ammonia)

22.8.314 For marine fish eggs and larvae, existing studies indicate potentially lethal effects at concentrations in mg/l, higher than the discharge concentration. A median lethal concentration (LC_{50}) of 0.04mg/l for larval striped bass (*Morone saxatilis*), based on 96 hours exposure (Hazel *et al.* (1971) (referenced in (Ref. 22.371). The maximum un-ionised ammonia prior to mixing with seawater is approximately ≤50µg/l. Concentrations of un-ionised ammonia regarded as acutely toxic greatly exceed the concentrations predicted during the construction phase. Mortality of developing embryos in the eggs, larvae/post-larvae is therefore unlikely. The sensitivity of demersal fish and elasmobranch eggs /cases and larvae to un-ionised ammonia is predicted to be not sensitive.

22.8.315 The impact of nutrient enrichment with un-ionised ammonia from the CDO, is predicted to have a negligible effect on demersal fish and elasmobranch eggs /cases and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Demersal fish and elasmobranchs: sensitivity to nutrient enrichment (un-ionised ammonia)

22.8.316 Nutrient enrichment from un-ionised ammonia has the potential to affect health and condition of older life stages. But the maximum un-ionised ammonia prior to mixing with seawater is approximately ≤50µg/l.

Concentrations of un-ionised ammonia regarded as acutely toxic greatly exceed the concentrations predicted during the construction phase.

22.8.317 A median LC_{50} of un-ionised ammonia at 0.36mg/l and 0.46mg/l has been reported for white seabream (*Dipiodus sargus*) and Cape rockling (*G. capensis*), respectively, based on 24 hours exposure (Ref. 22.372; 373). The chronic effects of ammonia exposure in juvenile turbot (*Scophthalmus maximus*) over 4-6 weeks, have been studied under experimental conditions of 16.5-17.5°C, pH 7.92-8.03, salinity 34.5 ppt., and 80% oxygen saturation (Ref. 22.374). There were no observed mortalities for a un-ionised ammonia at concentrations of 0.4mg/l following 4-6 week exposure. An averaged LC_{50} of 0.95mg/l was reported for 28-day exposure. Growth in juveniles was stunted at an un-ionised ammonia concentration of 0.85mg/l, after chronic (34 day) exposure (Ref. 22.374).

22.8.318 Juvenile Dover sole (*S. solea*) exposed for 42 days to elevated ammonia, displayed no growth at a concentration of 0.77mg/l (Ref. 22.375). Juvenile cod (*G. morhua*) exposed for 96 days to elevated ammonia, displayed significantly reduced growth at a concentration >0.06mg/l, likely due to reduced food intake (Ref. 22.376). However, fish still grew during the prolonged exposure and fish had appeared to acclimate to the elevated ammonia concentrations (Ref. 22.376).

22.8.319 There is scope for tolerance of elevated ammonia with biological responses including detoxifying ammonia to glutamine, conversion to urea, and reduced ammonia production (Ref. 22.377). It is acknowledged that the toxicity of un-ionised ammonia and effects are influenced by a complex interaction of factors; age, stress, activity level, food consumption and environmental parameters i.e. pH, salinity, temperature (Ref. 22.378).

22.8.320 The maximum un-ionised ammonia concentration prior to 100% mixing with seawater, is approximately ≤50µg/l and the resulting affected area would be minimal. Potential lethal effects are reported for concentrations of at least an order of magnitude above source concentrations to be discharged. Potential mortality of juveniles and adults is unlikely, though sublethal effects such as reduced growth could affect the fitness of individuals, however impacted areas are spatially limited. The sensitivity of demersal fish and elasmobranch juveniles and adults (and small bodied fish) to nutrient enrichment predicted to be not sensitive.

22.8.321 The impact of nutrient enrichment with un-ionised ammonia from the CDO, is predicted to have a negligible effect on demersal fish and elasmobranch juveniles and adults (and small bodied fish). Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish eggs and larvae: sensitivity to nutrient enrichment (un-ionised ammonia)

22.8.322 As per the assessment for demersal fish and elasmobranch eggs/larvae, the sensitivity of pelagic fish eggs and larvae to un-ionised ammonia is predicted to be not sensitive. The impact of nutrient enrichment with un-ionised ammonia from the CDO, is predicted to have a negligible effect on pelagic fish eggs and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish: sensitivity to nutrient enrichment (unionised ammonia)

22.8.323 As per the assessment for demersal fish and elasmobranch juveniles and adults (and small bodied fish), the sensitivity of pelagic fish juveniles and adults to un-ionised ammonia, is predicted to be not sensitive. The impact of nutrient enrichment with un-ionised ammonia from the CDO, is predicted to have a negligible effect on pelagic fish juveniles and adults. Effects are **not significant** at the sea area and regional stock/population levels.

Migratory fish: sensitivity to nutrient enrichment (un-ionised ammonia)

22.8.324 Concentrations of un-ionised ammonia regarded as acutely toxic greatly exceed the concentrations predicted during the construction phase. Elvers and yellow eels exposed to un-ionised ammonia at a concentration of 22mg/l for 10 days, exhibited a median period of survival in excess of 10 days, at concentrations <1.0mg/l. However, there was increased mortality above 1.0mg/l (Ref. 22.379).

22.8.325 The maximum un-ionised ammonia prior to 100% mixing with seawater, is approximately ≤50µ/l and the resulting affect area would be minimal. Potential lethal effects are reported for concentrations of at least an order of magnitude above source concentrations to be discharged.

22.8.326 The sensitivity of migratory fish juveniles and adults to un-ionised ammonia, is predicted to be not sensitive. The impact of nutrient enrichment with un-ionised ammonia from the CDO, is predicted to have a negligible effect on migratory fish. Effects are **not significant** at the sea area and regional stock/population levels.

Assessments of effects of localised displacement: nutrient enrichment (un-ionised ammonia)

22.8.327 Any displacement behaviour due to discharges of un-ionised ammonia is predicted to be highly localised and exposure would represent a negligibly small proportion of fish in the GSB. Fish are not sensitive to this pressure. Un-ionised ammonia is predicted to have a negligible effect on fish displacement. Therefore, no significant changes in the availability as prey items for designated features and as fisheries resources.

Tunnelling chemical discharges

22.8.328 Based on current understanding of the underlying geology a TBM slurry method with bentonite is the most likely scenario for tunnelling. Spoil from the cutting face would be transported to a temporary stockpile for onward management. Groundwater would be generated from digging the galleries allowing access to the tunnels and tunnelling itself. During the transport and processing of spoil material, groundwater and potentially residual TBM chemicals would be produced in wastewater that would be transported landward, treated as required and discharged from the CDO.

22.8.329 To envelope alternative tunnelling methods, assessments considered the use of indicative ground conditioning TBM chemicals. Representative chemicals from those applied for Hinkley Point C assessments are used to envelope potential tunnelling options at this stage. These include the anti-clogging agent BASF Rheosoil 143 and the soil conditioning additive CLB F5 M, provided in **Chapter 21** of this volume. The potential worst-case tunnelling scenario would occur when two cooling water tunnels are being excavated simultaneously as in Case E; **Plate 22.1**.

22.8.330 Modelling predicted that the mean sea surface area in exceedance of the BASF Rheosoil 143 PNEC was restricted to 1ha (95^{th} percentile 5.8ha). The seabed is never exposed to concentrations above the PNEC (**Table 22.82**). The sea surface area exposed to CLB F5 M in exceedance of the PNEC was restricted to 3.1ha as a mean concentration (95^{th} percentile 25ha). The seabed is never exposed to concentrations above the PNEC, provided in **Appendix 21E** of this volume.

22.8.331 Tunnelling is predicted to be a medium-term impact lasting several years in total. The use of TBM surfactants in the tunnelling process remains to be confirmed and assessments present a precautionary approach enveloping worst-case representative chemicals. A small spatial area is predicted to exceed the PNEC at the sea surface whilst the seabed would not be exposed to concentrations above the PNEC.

22.8.332 The impact magnitude is assessed to be low.

Table 22.82: Areas of PNEC exceedance for different TBM discharges.

TBM chemical and active substance.	PNEC (mean).	Discharge conditions (concentration and flow rate).	Mean surface exceedance (and 95th percentile).	Mean seabed exceedance (and 95th percentile).
BASF Rheosoil 143: sodium lauryl ether sulphate.	40µg/l	23.13mg/l at 34.4l/s	1.01ha (5.83ha)	0ha
CLB F5 M: mono- alkyl sodium sulphates[51]	4.5µg/l	7.71mg/l at 34.4l/s	3.14ha (25.0ha)	0ha

Sensitivity assessments of effects at the sea-area or regional stock/population level: Tunnel Boring Machine contamination

Marine fish ichthyoplankton: sensitivity to tunnelling chemicals

22.8.333 Much of the early research into the toxicity of surfactants focussed on linear alkylbenzene sulfonate concentrations leading to mortality of the embryos and larvae of freshwater species. These were mainly bluegills (*Lepomis macrochirus*), fat head minnow (*Pimephales promelas*) and smallmouth bass (*Micropterus dolomieu*). Previous studies with these freshwater species typically found that the larval stages were most vulnerable (Ref. 22.380–382). For example, Holman and Macek (1980) reported that the NOEC, as measured in life-cycle tests or estimated from embryo-larval tests, depended on the mean alkyl chain length of the linear alkyl benzene sulphonates and was 0.11–0.25mg/l for the most toxic chain length (Ref. 22.382).

22.8.334 The acute toxic effects of the anionic surfactant alkyl benzene sulphonate on gilthead seabream (*Sparus aurata*) eggs have been studied (Ref. 22.383). The time required for 50% mortality was measured for concentrations of 0.3, 3, 6, 15 and 30mg/l respectively. In general, the time to 50% mortality decreased with increasing concentration; from 535 minutes at 0.3mg/l through to 45 minutes at 30mg/l. Decreases in surface tension, destruction of biological membranes and enzyme disruption were hypothesised to be the causes of mortality (Ref. 22.383).

22.8.335 Concentrations of the anionic surfactants AS and AES regarded as acutely toxic, greatly exceed the concentrations predicted within the worst-case envelope for the development. As a 95th percentile, a very limited area

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[51] Ethoxylated sulphates are another active substance considered but have a less precautionary PNEC (35µg/l).

(6.6ha) at the surface would exceed the PNEC. Eggs and larvae may experience acute (lethal) effects with a very small area of sea compared with the rest of the GSB. Potential mortality of eggs and larvae would be insignificant when compared with the high natural mortality experienced in early life stages.

22.8.336 The sensitivity of marine fish ichthyoplankton to TBM contamination is predicted to be not sensitive.

22.8.337 The impact of TBM contamination resulting from construction discharges, is predicted to have a negligible effect on marine fish ichthyoplankton. Effects are **not significant** at the sea area and regional stock/population levels.

Marine fish juveniles and adults: sensitivity to tunnelling chemicals

22.8.338 There have been studies regarding marine adult fish and exposure to anionic surfactants. For example, exposure of juvenile Senegalese sole (*Solea senegalensis*) to alcohol polyethoxylate has been reported to generate metabolic disturbance, yet depuration led to rapid elimination of the surfactant and normalization of metabolites (Ref. 22.384).

22.8.339 For the juvenile and adult stages, bioconcentration and bioaccumulation are the main issues that have been investigated. For example, bioaccumulation studies for various lengths of alkyl sulfates homologs (C_{12}–C_{16}), identified the bioconcentration factor (l/kg) was in the range of 1.5 to 3 (C_{12} and C_{16} respectively), with chains up to C_{16} not predicted to bioaccumulate (Ref. 22.385). Deterioration in the gill epithelial cell membranes was observed in the freshwater rainbow trout (*Oncorhynchus mykiss*), when exposed to surfactants (Ref. 22.386).

22.8.340 Physiological responses of fish are reported to generally occur at concentrations greater than 0.1mg/l, according to (Ref. 22.387). Concentrations of the anionic surfactants, AS and AES, regarded as acutely toxic, greatly exceed the concentrations predicted within the worst-case envelope for the development.

22.8.341 As a 95th percentile, a very limited area (6.6ha) at the surface would exceed the PNEC, hence the area of exposure to acute effects would be very limited. Fish are considered capable of metabolising and eliminating AS/AES and this would limit potential for bioconcentration and bioaccumulation of the chemicals.

22.8.342 The sensitivity of marine fish to TBM contamination is predicted to be not sensitive.

22.8.343 The impact of TBM contamination resulting from construction discharges, is predicted to have a negligible effect on marine fish. Effects are **not significant** at the sea area and regional stock/population levels.

Migratory fish: sensitivity to tunnelling chemicals

22.8.344 For a short-term duration, a limited area (6.6ha) at the surface would exceed the PNEC. Therefore, no barrier to the movement of migratory species is anticipated.

22.8.345 Existing studies for migratory fish focussed on the physiological effects of the anionic surfactant, Linear alkyl benzene sulphonates. For instance, inhibited vasodilation in the gills of the European eel (*A. anguilla*) and brown trout (*S. trutta*) has been identified (Ref. 22.388).

22.8.346 Concentrations of the anionic surfactants AS and AES that are acutely toxic, greatly exceed the concentrations predicted within the worst-case envelope for the development. Whilst there is the potential for functional and physiological attributes of migratory species to be affected by surfactants, no mortality is anticipated.

22.8.347 The sensitivity of migratory fish to TBM contamination is predicted to be not sensitive.

22.8.348 The impact of TBM contamination resulting from construction discharges, is predicted to have a negligible effect on migratory fish. Effects are **not significant** at the sea area and regional stock/population levels.

Assessments of effects of localised displacement: sensitivity to tunnelling chemicals

22.8.349 Any displacement behaviour due to discharges of TBM chemicals is predicted to be highly localised and exposure would represent a negligibly small proportion of fish in the GSB. Fish are not sensitive to this pressure. TBM contamination is predicted to have a negligible effect on fish displacement. Therefore, no significant changes in the availability as prey items for designated features and as fisheries resources are predicted.

Commissioning discharges: Hydrazine

22.8.350 During cold flush testing a number of chemicals would be released that required further investigation for potential water quality issues. Of these, hydrazine used to prevent corrosion of the reactor units, failed the initial screening and is considered in more detail. Based on the Rochdale envelope approach, modelling took the precautionary position of both reactors being commissioned simultaneously with hydrazine discharged into the receiving waters via the CDO. The worst-case discharge scenario is assessed.

Background concentration for hydrazine for modelling purposes was assumed to be zero.

22.8.351 There is no established EQS for hydrazine. The marine chlorophyte *Dunaliella tertiolecta* has been shown to have the lowest acute toxicity to hydrazine with a six-day EC_{50} for growth inhibition of 0.4µg/l (Ref. 22.59). These results form the basis for precautionary PNEC thresholds, provided in **Appendix 21E** of this volume. A chronic PNEC of 0.4 ng/l has been calculated for long term discharges (calculated as the mean of the concentration values) and an acute PNEC of 4 ng/l for short term discharges (represented by the 95th percentile). These thresholds are considered as precautionary triggers for further ecological investigation.

22.8.352 Assessments used in support of Canadian Federal Water Quality Guidelines for hydrazine indicate concentrations below 0.2µg/l (200ng/l) have a low probability of adverse effects for marine life. In the freshwater environment, where more data is available, a threshold of 2.6µg/l has been applied (Ref. 22.60). **Table 22.83** shows the areas of exceedance for different hydrazine release scenarios.

22.8.353 Commissioning is likely to last several years; however simultaneous discharges of hydrazine are considered unlikely and the assessment is precautionary. The impact magnitude is assessed as medium.

Table 22.83: Areas of PNEC exceedance for hydrazine discharges during commissioning of both reactors.

Model run.	Effect category.	Conc-entration (ng/l).	95th percentile surface (ha).	95th percentile seabed (ha).	Mean surface (ha).	Mean seabed (ha).
15µg/l at 83.3l/s.	Chronic	0.4			30.5	2.92
	Acute	4	12.9	2.92		
		200	0.34	0		

Sensitivity assessments of effects at the sea-area or regional stock/population level: hydrazine discharges

Demersal fish and elasmobranch eggs /cases and larvae: sensitivity to hydrazine discharges

22.8.354 Embryos of freshwater rainbow trout (*O. mykiss*) have been experimentally exposed to hydrazine nominal concentrations of 0, 1 and 5mg/l for 48 hours (Ref. 22.389). At 1mg/l, a lack of body movement was observed in the embryos, but no effects were observed on hatching rate, period or mortality.

Larvae were observed to have poor muscular development. At 5mg/l, the embryos perished (Ref. 22.389).

22.8.355 Exposure of eggs/larvae could result in morphological abnormalities, altered growth and hatching and ultimately, survival of the eggs and larvae. However, response concentrations (1-5mg/l) in rainbow trout embryos are a million-fold higher than the acute PNEC (Ref. 22.389). It is recognised that there is limited evidence for mortality of early life stages of marine species. e Potential losses are considered negligible relative to natural mortality. Also, the likelihood of mortality is minimised where species and seasonal eggs/larvae may have minimal interaction with the plume in a given year.

22.8.356 The sensitivity of demersal fish and elasmobranch eggs /cases and larvae to hydrazine discharges from the cooling water outfalls, is predicted to be not sensitive.

22.8.357 The impact of hydrazine discharges is predicted to have a minor adverse effect on demersal fish and elasmobranch eggs /cases and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Demersal fish and elasmobranchs: sensitivity to hydrazine discharges

22.8.358 The toxicity of hydrazine has predominately been studied in freshwater/migratory species, under different experimental conditions and using concentrations of hydrazine substantially higher (i.e. mg/l rather than ng/l) compared with the predicted plume concentration.

22.8.359 There is limited data on the toxicity of hydrazine to marine fish, however, freshwater examples indicate the most sensitive species have a 96h LC_{50} value of 0.61mg/l (Ref. 22.62). A nominal concentration of 3.6mg/l resulted in an LC_{50} in adult largemouth bass (*Micropterus salmoides*), after 48 hours exposure to hydrazine in static tanks (Ref. 22.390). While a hydrazine concentration of 1.08mg/l resulted in an LC_{50} in bluegills (*L. macrochirus*), after 96 hours exposure to hydrazine in static tanks. However, these concentrations are significantly (>10^5-fold) higher than the applied acute PNEC (4ng/l) for the proposed development.

22.8.360 Juveniles and adults of mobile species may choose to avoid the area and move elsewhere in the GSB, while less mobile species e.g. gobies and juvenile stages may remain. There is potential for sublethal physical and physiological effects. For example, one study into the sublethal effects of hydrazine on fish identified evidence of behavioural reposes including an increase in aggressive behaviours in laboratory trials with freshwater bluegill (*L. macrochirus*), which the authors attributed to the irritant effects of hydrazine (Ref. 22.391). However, behavioural responses occurred at concentrations of 0.1mg/l and above.

22.8.361 The sensitivity of demersal fish and elasmobranchs to hydrazine discharges is predicted to be not sensitive*.*

22.8.362 The impact of hydrazine discharges is predicted to have a minor adverse effect on demersal fish and elasmobranchs. Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish eggs and larvae: sensitivity to hydrazine discharges

22.8.363 As per the assessment for demersal fish and elasmobranch eggs/cases and larvae, the sensitive of pelagic fish eggs and larvae, to hydrazine discharges from the cooling water outfalls, is predicted to be not sensitive*.*

22.8.364 The impact of hydrazine discharges is predicted to have a minor adverse effect on pelagic fish eggs and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish juveniles and adults: sensitivity to hydrazine discharges

22.8.365 As per the assessment for demersal fish and elasmobranchs, the sensitive of pelagic fish to hydrazine discharges from the cooling water outfalls, is predicted to be not sensitive*.*

22.8.366 The impact of hydrazine discharges is predicted to have a minor adverse effect on pelagic fish. Effects are **not significant** at the sea area and regional stock/population levels.

Migratory fish juveniles and adults: sensitivity to hydrazine discharges

22.8.367 There is the potential for commissioning discharges to act as a chemical barrier to migratory eels entering/exiting the Minsmere Sluice (the closest freshwater source to the CDO). In the UK, glass eels enter river systems from the sea in March and April whilst yellow eels migrate from the rivers back to sea in September to December. Commissioning discharges could coincide with the period of eel migration, as such the concentration of hydrazine at the Minsmere sluice was investigated (Ref. 22.65). European eel is listed as a Priority Species in Section 41 of the NERC Act 2006.

22.8.368 Results from modelling hydrazine discharges show that the hydrazine plume forms a long narrow shore parallel plume leaving a narrow corridor 270m wide between the shoreline and the edge of acute PNEC. Furthermore, the northern tip of the 95th percentile surface plume is approximately 1,235 m south of the east-west axis of the Minsmere sluice. Eels would be able to migrate both north-south along the coastline and enter/exit the Minsmere sluice travelling into the North Sea without passing through a hydrazine plume at levels above the chronic PNEC. The peak instantaneous concentration at the sluice opening is 0.12ng/l at the surface and 0.11ng/l at the seabed (Ref. 22.65).

22.8.369 There are limited data on the toxicity of hydrazine to marine fish, however, freshwater examples indicate the most sensitive species have a 96h LC_{50} value of 610µg/l (Ref. 22.62). This acute toxic threshold is over 40-fold higher than the source concentration from the proposed CDO commissioning discharge and over 10^6 higher than the maximum instantaneous concentration at the sluice.

22.8.370 One study into the sublethal effects of hydrazine on fish identified evidence of behavioural reposes including an increase in aggressive behaviours in laboratory trials with freshwater bluegill (*L. macrochirus*), which the authors attributed to the irritant effects of hydrazine (Ref. 22.391). However, behavioural responses occurred at concentrations of 0.1mg/l and above, over 800,000 times higher than the instantaneous maximum concentration would be at the sluice (0.12ng/l). It is considered highly unlikely that commissioning discharges of hydrazine would affect eel migration into/out of the sluice given the low concentration and limited potential for exposure (Ref. 22.65). As such, there would be no effects on eels as a marine prey item for bittern (*Botaurus stellaris*) within the Minsmere to Walberswick SPA and Ramsar site, as in see **Table 22.1**.

22.8.371 No studies have investigated hydrazine exposure and effect to European smelt, lampreys and shad. However, lethal effects are highly unlikely[52] and given the limited persistence of the hydrazine plume at ecologically relevant concentrations, minor behaviour effects may occur in the most sensitive taxa. No barrier to migration is predicted.

22.8.372 The sensitivity of migratory fish to hydrazine from the cooling water outfalls, is predicted to be not sensitive.

22.8.373 The impact of hydrazine chlorination by-product is predicted to have a minor adverse effect on migratory fish juveniles and adults. Effects are **not significant** at the sea area and regional stock/population levels.

Unit 2 cold flush commissioning discharges and Unit 1 FRR returns

22.8.374 Once Unit 1 is operational, commissioning discharges from Unit 2, discharged via the CDO have the potential to intersect fish returned from the southern (Unit 1) FRR, approximately 340m south of the CDO. Model results show that at the southern FRR, the instantaneous hydrazine plume exceeds

[52] The lethal concentration of hydrazine to adult fathead minnow (*P. promelas*) tested in flow-through tanks, is reported to be 7.63mg/l after 24 hours exposure, and 6.19mg/l and 5.98mg/l after 48 and 96 hours, respectively (Ref. 22.63).

the acute PNEC at the surface and seabed. At a release concentration of 15µg/l, the transitory peak concentration at the surface is predicted to be 176.4ng/l. The average concentration of the plume at the surface above the PNEC (only including the times above the PNEC) is 15ng/l. Whilst the plume regularly exceeds the acute PNEC, the duration of the exceedance is short, with concentrations exceeding the acute PNEC for no longer than 3.25 hours at a time. The total time above the acute PNEC represents 5.1% of the modelled month and concentration never exceeds 200ng/l (Ref. 22.65). Given the limited sensitivity of fish to hydrazine, whereby lethal responses occur at concentrations orders of magnitude higher than the peak concentrations predicted at the southern FRR and the transitory nature of the plume, fish exposure to toxicological concentrations is minimal.

22.8.375 The potential for interrelationships of hydrazine affecting stressed fish that have already been exposed to impingement pressures is considered in **Section 22.8.c)v** of this chapter.

Assessments of effects of localised displacement: hydrazine discharges

22.8.376 Some species may be temporarily displaced from the area of the plume through avoidance behaviour. Or individual fitness compromised by sublethal or lethal effects, if unable to move away from the decaying hydrazine. However, given the limited magnitude of the hydrazine plume and the limited sensitivity of fish to the concentrations predicted, there are unlikely to be substantial avoidance behaviours and a very small proportion of fish in the GSB would be exposed. Fish are considered to have *Low* sensitivity to hydrazine discharges. Commissioning discharges of hydrazine are predicted to have a minor adverse effect on fish displacement. No significant changes in the availability as prey items for designated features and as fisheries resources are predicted.

iv. Fish Recovery and Return systems

22.8.377 This section describes the impacts associated with the installation of the fish recovery and return (FRR) systems during the construction phase. Scoping identified the pressures arising from activities at the fish recovery and return systems with the potential for effects on ecological receptors, provided in **Appendix 22M** of this chapter. Pressures with the potential to affect fish receptors are presented in **Table 22.84.**

Table 22.84: Pressures associated with FRR activities during the construction phase that have the potential to affect fish receptors.

Pressure	Activities resulting in pressure	Justification
Physical change to another seabed type.	Presence of structure.	Potential to affect fish receptors through habitat change.
Habitat change - Reprofiling of substratum (extraction).	Capital dredging.	Dredging for the installation of the FRR headworks resulting in substrate extraction and potential loss of fish or eggs/egg cases.
Changes in suspended sediments.	Capital dredging.	Increases in SSC have the potential to result in a range of physical and physiological effects on different life history stages and species of fish. Behavioural effects, notably avoidance behaviour, could displace species from preferred habitat or influence the passage of migratory species.
Sedimentation rate changes.	Capital dredging.	The deposits of sediment could smother eggs/egg cases/larvae, juveniles and small bodied fish. Smothering may result in stress and potential for mortality.
Underwater noise and vibration.	Capital dredging.	Dredging for the FRR headworks would generate underwater noise. The potential effects of underwater noise on fish receptors (eggs, larvae and juvenile and adult stages), range from mortality and injury at close range to the activity, to hearing impairment, masking, behavioural effects and barrier to movement further away from the sound source.

Physical change (to another seabed type)

22.8.378 The FRR outfalls and scour protection would replace soft sediment in the subtidal. This would result in a change in seabed type (from soft to hard substrata). The two FRR outfalls are predicted to occupy 18m^2 of seabed. The installation of scour protection would collectively result in 414m^2 hard substrate installed on the seabed.

22.8.379 The spatial extent of physical change to another seabed type is very low in relation to the available habitat in the GSB. The change from sandy sediment to hard structure results in a high score for amount of change based on the Marine Evidence-Based Sensitivity Assessment benchmark threshold for changes in EUNIS classification (1 Folk class > 10 years). The FRR outfalls and scour protection would be present for the operational lifetime. The magnitude of impact is low.

Sensitivity assessments of effects at the sea-area or regional stock/population level: physical change (to another seabed type)

22.8.380 The sensitivity of the marine and migratory fish sub-groups to physical change in seabed is described in the assessment of the BLF. For the FRR outfall systems, sensitivity is not sensitive for all sub-groups as of **Table 22.85**. This based on the small area affected relative to available habitat. Negligible effects are concluded and are **not significant** at the sea area and regional stock/population levels.

Table 22.85: Summary of assessment for physical change in seabed from FRR outfalls and scour protection installation.

Sub-group	Sensitivity
Demersal fish and elasmobranch eggs /cases and larvae.	Not Sensitive.
Demersal fish and elasmobranch juveniles and adults (and small bodied fish).	
Pelagic fish eggs and larvae.	
Pelagic fish juveniles and adults.	
Migratory fish juveniles and adults.	

Habitat structure changes - removal of substratum (extraction)

22.8.381 Installation of the two FRR systems would result in the combined removal of approximately 0.26ha of surficial sediment. Dredging is expected to occur once and last for less than 24 hours per, provided in **Section 22.3.i)** of this chapter.

22.8.382 Impact magnitude is assessed as very low based on the limited spatial extent of dredging relative to the extent of the affected habitat (subtidal sand) in the GSB.

Sensitivity assessments of effects at the sea-area or regional stock/population level: removal of substratum

22.8.383 The sensitivity of the marine and migratory fish sub-groups to removal of substratum is described in the assessment of the CDO. For the FRR outfall systems, sensitivity is not sensitive for all sub-groups, provided in **Table 22.86**. This based on the small area affected relative to available habitat. Negligible effects are concluded and are **not significant** at the sea area and regional stock/population levels.

Table 22.86: Summary of assessment for substratum removal from FRR outfalls.

Sub-group	Sensitivity
Demersal fish and elasmobranch eggs /cases and larvae.	Not Sensitive.
Demersal fish and elasmobranch juveniles and adults (and small bodied fish).	
Pelagic fish eggs and larvae.	
Pelagic fish juveniles and adults.	
Migratory fish juveniles and adults.	

Assessments of effects of localised displacement: removal of substratum

22.8.384 Displacement of fish receptors to alterative areas, due to removal of substratum, would occur over a very limited area and effect a very small proportion of fish within the GSB. Fish are not sensitive to the pressure. Substrate removal is predicted to have a negligible effect on the distribution of fish within the GSB. No significant changes in the availability of fish as prey items for designated features or as fisheries resources are predicted.

Changes in suspended sediment concentration

22.8.385 Dredging and local dredge disposal for the installation of the FRR system would lead to elevated suspended sediment concentrations (SSC). Plumes with instantaneous SSC of >100mg/l above daily maximum background levels are expected to form over instantaneous areas of up to 89ha at the surface (28ha depth averaged). A small area of 1ha is expected to experience an instantaneous SSC of >1,000mg/l above background at the sea surface, provided in **Table 22.10**.

22.8.386 Ambient conditions at the site are highly variable, provided in **Section 22.4** of this chapter, and the surface waters are considered as *'intermediate turbidity'* according to WFD criteria, provided in **Appendix 21E** of this volume. Dredging would temporarily increase the classification to '*turbid'*. However, SSC would return to background levels several days after dredging activity ceases. These increases in SSC would occur twice for the installation of the FRR system (once for each head). The timings of the SSC plumes associated with the installation of each head would not overlap.

22.8.387 While increases in SSC would be relatively large relative to baseline conditions, the transient nature of the plumes and their intermediate spatial footprint result in an impact magnitude of medium.

Sensitivity assessments of effects at the sea-area or regional stock/population level: increases in suspended sediment

22.8.388 The sensitivity of the marine and migratory fish sub-groups to increases in suspended sediment from construction dredging, is described in the assessment of the CDO. For the FRR outfall systems, sensitivity is low to not sensitive, provided in **Table 22.87**.

22.8.389 The impact of increases in suspended sediment is predicted to have a minor adverse effect on all sub-groups. Given the limited magnitude of the modelled plume, the effects are **not significant** at the sea area and regional stock/population levels.

Table 22.87: Summary of assessment for increased suspended sediment from dredging and disposal for the FRR outfalls.

Sub-group.	Sensitivity
Demersal fish and elasmobranch eggs /cases and larvae.	Low.
Demersal fish and elasmobranch juveniles and adults (and small bodied fish).	Low.
Pelagic fish eggs and larvae.	Low.
Pelagic fish juveniles and adults.	Low.
Migratory fish juveniles and adults.	Not Sensitive.

Assessments of effects of localised displacement: increases in suspended sediment

22.8.390 The avoidance of fish, notably pelagic fish, would be influenced by factors such as motivation, mobility and condition of the fish. Thus, fish may exhibit limited movements away from the areas of highest SSC, remaining in proximity to the plume and utilising the area once the plume dissipates. Given that the limited magnitude of the plume, the scope for fish to be displaced entirely from the plume area and not return is very limited. Fish are predicted to have *Low* sensitivity with only localised and temporary displacement of sensitive taxa likely to occur. Displacement of fish is predicted to have a minor adverse effect**.** No significant changes in the availability as prey items for designated features and as fisheries resources are predicted.

Changes in sedimentation rates

22.8.391 Sediment suspended by dredging and dredge disposal for the installation of the two FRR systems would subsequently be deposited onto the seabed. Sediment deposition would be classified as 'light' throughout the plume footprint, with sediment thickness not expected to exceed 50mm and only expected to exceed 20mm over 1ha. It is predicted that all suspended sediment would be deposited within hours of dredging and then dispersed by natural resuspension, leaving no area where sediment thickness remains >20mm thicker than it was prior to dredging after 15 days, provided in **Table 22.10**. These levels of sediment deposition would occur for each of the two FRR headwork installations.

22.8.392 As no area would be exposed to greater than 'light' deposition and deposited sediments would be rapidly dispersed. Impact magnitude is assessed as very low.

Sensitivity assessments of effects at the sea-area or regional stock/population level: changes in sedimentation rates

22.8.393 The sensitivity of the marine and migratory fish sub-groups to sedimentation is described in the assessment of the BLF. For the FRR outfall systems, sensitivity is not sensitive for all sub-groups, provided in **Table 22.88**. This is based on the small area affected relative to available habitat. Negligible effects are concluded and are **not significant** at the sea area and regional stock/population levels.

Table 22.88: Summary of assessment for sedimentation rate changes from dredging and disposal for the FRR outfalls.

Sub-group.	Sensitivity
Demersal fish and elasmobranch eggs /cases and larvae.	Not Sensitive.
Demersal fish and elasmobranch juveniles and adults (and small bodied fish).	
Pelagic fish eggs and larvae.	
Pelagic fish juveniles and adults.	
Migratory fish juveniles and adults.	

Assessments of effects of localised displacement: changes in sedimentation rates

22.8.394 Changes in sedimentation rates associated with dredging for the FRRs is not predicted to affect the distribution of fish within the GSB. No indirect food web effects or changes in the availability of fish as prey items for designated features or as fisheries resources are expected. Fish are not sensitive to displacement resulting from sedimentation rate changes. Effects are predicted to be negligible and **not significant**.

Underwater noise

22.8.395 Prior to the installation of the FRR outfalls, dredging with a cutter suction dredger is proposed. Dredging for the FRRs outfalls would be similar to that of the CDO, with only minor changes in auditory impact ranges resulting from changes in location and bathymetry. As such the same approach applied for the CDO is maintained. Noise modelling assumed 9.5 hours to complete dredging activities, with 12 cycles of 19 minutes of dredging, followed by a 30-minute interval for repositioning, provided in **Appendix 22L** of this volume. Applying the source noise levels from a trailing suction hopper dredger to cutter suction dredging is considered precautionary for the purposes of this assessment.

22.8.396 The thresholds for effects from cumulative noise (Ref. 22.53) are exceeded, however, the modelled zone for mortality is restricted to 25m whilst recoverable injury is limited to just 3ha from dredging. The duration of dredging activities is predicted to be 9.5 hours for each headwork, provided in **Table 22.89**. The magnitude of impact is low.

Sensitivity assessments of effects at the sea-area or regional stock/population level: underwater noise from construction dredging

Fish with swim bladder or other air cavities to aid hearing (Category 1): sensitivity to underwater noise from construction dredging

22.8.397 Instantaneous auditory effects would not occur from continuous noise sources associated with dredging for the CDO. Modelling of cumulative noise indicates the potential for mortality/potential mortality within 25m (or 0.25ha) from dredging activities with recoverable injury limited to 100m (3ha). The maximum potential for TTS extends to a range of 1.06km (or 173ha), provided in **Table 22.89**. The sensitivity of Category 1 fish to underwater noise from FRR dredging is predicted to be low.

22.8.398 The impact of underwater noise is predicted to have a minor adverse effect on Category 1 receptors. Effects are **not significant** at the sea area and regional stock/population levels.

Fish with a swim bladder that does not aid hearing (Category 2): sensitivity to underwater noise from construction dredging

22.8.399 In the case of Category 2 fish, there are predicted to be limited impact zones with cumulative noise. The sensitivity of Category 2 receptors to underwater noise from FRR dredging is predicted to be low.

22.8.400 The impact of underwater noise is predicted to have a minor adverse effect on Category 2 receptors. Effects are **not significant** at the sea area and regional stock/population levels.

Fish without a swim bladder (Category 3): sensitivity to underwater noise from construction dredging

22.8.401 Cumulative auditory impact ranges are predicted to be limited in the case of Category 3 fish. The sensitivity of Category 3 receptors to underwater noise from construction dredging is predicted to be not sensitive.

22.8.402 The impact of underwater noise is predicted to have a negligible effect on Category 3 receptors. Effects are **not significant** at the sea area and regional stock/population levels.

Demersal and pelagic fish eggs and larvae: sensitivity to underwater noise from construction dredging

22.8.403 The sensitivity of demersal and pelagic fish eggs and larvae to underwater noise from dredging, is described in the assessment of the BLF and is precautionarily assessed as low.

22.8.404 The impact of underwater noise is predicted to have a minor adverse effect on demersal and pelagic fish eggs and larvae. Effects are **not significant** at the sea area and regional stock/population levels. Given the limited magnitude of the dredging, potential losses of eggs and larvae are considered negligible in comparison to natural mortality.

Table 22.89: Auditory impact zones areas (expressed in hectares) and/or auditory impact zone maximum ranges (expressed in metres) from dredging of the two FRR outfalls. Results are based on the most sensitive hearing group Category 1 'fish with swim bladder or other air cavities to aid hearing' and apply to all receptor categories. N/A indicates source level below threshold.

Activity	Threshold	Instantaneous	Cumulative
Dredging FRR1.	Mortality.	N/A	25m; 0.25ha.
	Recoverable injury.	N/A	100m; 3ha.
	Temporary Threshold Shift.	N/A	1,063m; 173ha.
Dredging FRR2.	Mortality.	N/A	25m; 0.25ha.
	Recoverable injury.	N/A	100m; 3ha.
	Temporary Threshold Shift.	N/A	1,015m; 163ha.

Assessments of effects of localised displacement: underwater noise from construction dredging

22.8.405 For Category 1 and 2 species, behavioural effects are predicted at a range of 2.31km (or an area of 674ha) for FRR1 and at a range of 2.20km (or an area of 647ha) for FRR2, provided in **Table 22.90**. For Category 3 receptors, behavioural effects are predicted at a maximum range of 810m (123ha) for FRR1, provided in **Table 22.90**.

22.8.406 The assessment of displacement effects from FRR dredging is consistent with that of the CDO. Fish are precautionarily assessed as having low sensitivity to displacement from dredging activities. Should displacement occur the impact is temporary, and fish could return within hours to days of the impact ceasing.

22.8.407 Localised displacement of fish receptors due to underwater noise from dredging for the FRR, is predicted to have a minor adverse effect on the displacement of fish. Effects are not deemed to be significant. Short term behavioural effects (not necessarily displacement) could cause temporary reductions in feeding efficiency. The implications for bird and cetacean feeding will be considered further in the **Shadow HRA** (Doc Ref. 5.10).

Table 22.90: Behavioural impact zone for dredging the FRR outfalls, with the area (expressed in hectares) and maximum range (expressed in metres).

Activity	Threshold	Behavioural zone.
Dredging FRR1.	135 dB re 1 µPa^{2}s.	2,312m; 674ha.
	142 dB re 1 µPa^{2}s.	810m; 123ha.
Dredging FRR2.	135 dB re 1 µPa^{2}s.	2,203m; 647ha.
	142 dB re 1 µPa^{2}s.	788m; 119ha.

v. Cooling Water Infrastructure

22.8.408 This section describes the impacts associated with the installation of the cooling water infrastructure during the construction phase. Scoping identified the pressures arising from activities at the cooling water infrastructure with the potential for effects on ecological receptors, provided in **Appendix 22M** of this volume. Pressures with the potential to affect fish receptors are presented in **Table 22.91.**

Table 22.91: Pressures associated with cooling water infrastructure activities during the construction phase that have the potential to affect fish receptors.

Pressure	Activities resulting in pressure.	Justification
Physical change to another seabed type.	Presence of structure.	Potential to affect fish receptors through habitat change.

Pressure	Activities resulting in pressure.	Justification
Habitat change - Reprofiling of substratum (extraction).	Capital dredging.	Dredging for the installation of the cooling water headworks resulting in substrate extraction and potential loss of fish or eggs/egg cases.
Changes in suspended sediments.	Capital dredging.	Increases in SSC have the potential to result in a range of physical and physiological effects on different life history stages and species of fish. Behavioural effects, notably avoidance behaviour, could displace species from preferred habitat or influence the passage of migratory species.
Sedimentation rate changes.	Capital dredging.	The deposits of sediment could smother eggs/egg cases/larvae, juveniles and small bodied fish. Smothering may result in stress and potential for mortality.
Underwater noise and vibration.	Capital dredging and drilling.	Dredging for the cooling water headworks and drilling the vertical connecting shafts would generate underwater noise. The potential effects of underwater noise on fish receptors (eggs, larvae and juvenile and adult stages), range from mortality and injury at close range to the activity, to hearing impairment, masking, behavioural effects and barrier to movement further away from the sound source.

22.8.409 Construction pressures scoped out of further assessment as they have been deemed to have negligible effects on fish include:

- Drilling has the potential to change suspended sediments and sedimentation rates – The sediment plume resulting from drilling would increase SSC by <10mg/l and would not be detectable above background levels, while sedimentation of the SSC plume would be insignificant (fractions of a millimetre), provided in **Appendix 22J** of this volume. Spoil heaps consisting of relatively coarse particles would form in the immediate vicinity of the drill sites. Effects on fish receptors would be negligible.

Physical change (to another seabed type)

22.8.410 The installation of the two northern CWS intake headworks and two outfall headworks, along with scour protection, would result in a permanent change of seabed type from soft sediment (muddy sand) to a hard surface. The installation of the two southern CWS intake heads and scour protection would result in a change in seabed type from a Coralline Crag habitat to a concrete structure.

22.8.411 Scour protection for the two northern intake headworks (Unit 2) and the outfall headworks would be located in soft sediment environments and amount to a total habitat change of 5,368m^3, provided in **Appendix 20A** of this volume. In total, the northern intakes and outfalls would cause a small amount (<1ha) of soft sediment habitat to be replaced by hard structures in relation to the area of soft sediment habitat in the GSB (>4,000ha).

22.8.412 The installation of the two southern CWS intake headworks (Unit 1) and scour protection would result in a change in seabed type from a Coralline Crag habitat to a concrete structure. The area of permanent habitat loss constitutes approximately 0.1ha for both intake headworks (worst-case LVSE headwork dimensions 50 x 10m with nose ramps). The area of exposed offshore Coralline Crag habitat (where the southern intakes would be installed) is 57.5ha, with a further 365ha of exposed Coralline Crag present inshore.

22.8.413 For soft sediment habitat, the degree of habitat change is large based on the Marine Evidence-Based Sensitivity Assessment benchmark threshold for changes in EUNIS classification (one Folk class for > ten years). However, with respect to both soft sediment habitat and Coralline Crag habitats, the spatial extent of habitat change is very low. These changes to habitat type would last for the lifetime of the proposed development.

22.8.414 The very small spatial extent but permanent loss of habitat constitutes a low impact magnitude.

Sensitivity assessments of effects at the sea-area or regional stock/population level: physical change in seabed type

22.8.415 The sensitivity of the marine and migratory fish sub-groups to physical change in seabed type, is described in the assessment of the BLF. For the cooling water infrastructure, sensitivity is not sensitive for all sub-groups, provided in **Table 22.92**. This based on the small area affected relative to available habitat. Negligible effects are concluded and are **not significant** at the sea area and regional stock/population levels.

Table 22.92: Summary of assessment for physical change in seabed from the cooling water infrastructure and scour protection installation.

Sub-group	Sensitivity
Demersal fish and elasmobranch eggs /cases and larvae.	Not Sensitive.
Demersal fish and elasmobranch juveniles and adults (and small bodied fish).	
Pelagic fish eggs and larvae.	
Pelagic fish juveniles and adults.	
Migratory fish juveniles and adults.	

Habitat structure changes - removal of substratum (extraction)

22.8.416 Installation of the four CWS intake heads and two outfall heads would result in the removal of approximately 2.77ha of surficial sediment. Dredging is expected to occur once and last for less than 24 hours in total per head, provided in **Section 22.3.i)** of this chapter. Following dredging, installation of infrastructure and scour protection would replace existing habitat.

22.8.417 The proposed location of the two intakes and outfalls headworks is within a soft-sediment environment, which are commonly occurring within the GSB and wider southern North Sea. Following installation of the headworks and scour protection, soft-sediment would be back-filled.

22.8.418 Impact magnitude is assessed as low based on the limited spatial extent of dredging relative to the extent of the affected habitat (subtidal sand) in the GSB.

Sensitivity assessments of effects at the sea-area or regional stock/population level: removal of substratum

22.8.419 The sensitivity of the marine and migratory fish sub-groups to removal of substratum, is described in the assessment of the BLF. For the cooling water infrastructure, sensitivity is not sensitive for all sub-groups, provided in **Table 22.93**. This based on the small area affected relative to available habitat. Negligible effects are concluded and are **not significant** at the sea area and regional stock/population levels.

Table 22.93: Summary of assessment for removal of substratum from dredging and disposal for the cooling water infrastructure.

Sub-group	Sensitivity
Demersal fish and elasmobranch eggs /cases and larvae.	Not Sensitive.
Demersal fish and elasmobranch juveniles and adults (and small bodied fish).	
Pelagic fish eggs and larvae.	
Pelagic fish juveniles and adults.	
Migratory fish juveniles and adults.	

Assessments of effects of localised displacement: removal of substratum

22.8.420 Displacement of fish receptors to alterative areas, due to removal of substratum, would occur over a very limited area and effect a very small proportion of fish within the GSB. Fish are not sensitive to the pressure. Substrate removal is predicted to have a negligible effect on the distribution of fish within the GSB. No significant changes in the availability of fish as prey items for designated features or as fisheries resources are predicted.

Changes in suspended sediment concentration

22.8.421 Dredging and local dredge disposal for the installation CWS intake and outfall headworks would lead to elevated SSC. Plumes with instantaneous SSC of >100mg/l above daily maximum background levels are expected to form over an instantaneous depth averaged area of up to 373ha (291ha at the sea surface), provided in **Table 22.10**. A smaller area of up to 14ha is expected to experience a depth averaged instantaneous SSC of >1,000mg/l above background levels, with 34ha at the sea surface, provided in **Table 22.10**.

22.8.422 Ambient conditions at the site are highly variable, provided in **Section 22.4** of this chapter, and the surface waters are considered as '*intermediate turbidity*' according to WFD criteria, provided in **Appendix 21E** of this volume. Dredging would temporarily increase the classification to '*turbid*'. However, SSC would return to background levels several days after dredging activity ceases. The increase in SSC would occur a total of six times for the installation of CWS infrastructure (once for each intake and outfall head). The timings of the SSC plumes associated with the installation of each head would not overlap.

22.8.423 While increases in SSC would be relatively large relative to baseline conditions and occur multiple times, the transient nature of the plumes and their intermediate spatial footprint result in an impact magnitude of medium.

Sensitivity assessments of effects at the sea-area or regional stock/population level: increases in suspended sediment

22.8.424 The sensitivity of the marine and migratory fish sub-groups to increases in suspended sediment from construction dredging, is described in the assessment of the CDO. For the cooling water infrastructure, sensitivity is low to not sensitive, provided in **Table 22.94**. The impact of increases in suspended sediment is predicted to have a minor adverse effect on all sub-groups. Given the limited magnitude of the modelled plume, the effects are **not significant** at the sea area and regional stock/population levels.

Table 22.94: Summary of assessment for increased suspended sediment from dredging and disposal for the cooling water infrastructure.

Sub-group	Sensitivity
Demersal fish and elasmobranch eggs /cases and larvae.	Low.
Demersal fish and elasmobranch juveniles and adults (and small bodied fish).	Low.

Sub-group	Sensitivity
Pelagic fish eggs and larvae.	Low.
Pelagic fish juveniles and adults.	Low.
Migratory fish juveniles and adults.	Not Sensitive.

Assessments of effects of localised displacement: increases in suspended sediment

22.8.425 The avoidance of fish, notably pelagic fish, would be influenced by factors such as motivation, mobility and condition of the fish. Thus, fish may exhibit limited movements away from the areas of highest SSC, remaining in proximity to the plume and utilising the area once the plume dissipates. The mean SSC baseline conditions are approximately 450-500mg/l during Winter in the location of the offshore infrastructure beyond the Sizewell-Dunwich Bank, maximum SSC up to 2000mg/l, provided in **Section 22.4** of this chapter. Hence, the limited magnitude of the plume relative to baseline conditions indicates that fish displaced from the plume area is unlikely. Given that the limited magnitude of the plume, the scope for fish to be displaced entirely from the plume area and not return is very limited. Fish are predicted to have low sensitivity with only localised and temporary displacement of sensitive taxa likely to occur. Displacement of fish is predicted to have a minor adverse effect. No significant changes in the availability as prey items for designated features and as fisheries resources are predicted.

Changes in sedimentation rates

22.8.426 Sediment suspended by dredging and dredge disposal for the installation of the CWS intake and outfall headworks would subsequently be deposited onto the seabed. Sediment deposition would be classified as 'light' over most of the plume footprint, with sediment thickness expected to exceed 50mm over a maximum of 7ha per head. Larger areas of 106ha for CWS intakes and 40ha for CWS outfalls are expected to experience sediment deposition of >20mm, while up to 2ha may experience >300mm of deposition per head. It is predicted that all suspended sediment would be deposited within hours of dredging and then dispersed by natural resuspension, leaving no area where sediment thickness remains >20mm thicker than it was prior to dredging after 15 days, provided in **Section 22.3.i)** of this chapter. These levels of sediment deposition would occur six times for the installation of CWS infrastructure (once for each intake and outfall head).

22.8.427 As a limited area would be exposed to greater than 'light' deposition and deposited sediments would be rapidly dispersed, the impact magnitude is assessed as low.

Sensitivity assessments of fish receptors to changes in sedimentation rates

22.8.428 The sensitivity of the marine and migratory fish receptors to sedimentation is described in the assessment of the BLF. For the cooling water infrastructure, all fish sub-groups are assessed as not sensitive, provided in **Table 22.95**. This is based on the small area affected relative to available habitat. Negligible effects are concluded and are **not significant** at the sea area and regional stock/population levels.

Table 22.95: Summary of assessment for sedimentation rate changes from dredging and disposal for the cooling water.

Sub-group	Sensitivity
Demersal fish and elasmobranch eggs /cases and larvae.	Not Sensitive.
Demersal fish and elasmobranch juveniles and adults (and small bodied fish).	
Pelagic fish eggs and larvae.	
Pelagic fish juveniles and adults.	
Migratory fish juveniles and adults.	

Assessments of effects of localised displacement: changes in sedimentation rates

22.8.429 Changes in sedimentation rates associated with dredging for the cooling water infrastructure is not predicted to affect the distribution of fish within the GSB. No indirect food web effects or changes in the availability of fish as prey items for designated features or as fisheries resources are expected. Fish are not sensitive to displacement resulting from sedimentation rate changes. Effects are predicted to be negligible and **not significant**.

Underwater noise: Dredging

22.8.430 Prior to the installation of the intake and outfall heads, dredging would be required, and a cutter suction dredger is proposed. The Popper criteria (Ref. 22.53) do not provide quantitative thresholds for continuous sources of noise, such as dredging. Given that pulse sounds such as piling noise are likely to have a greater effect on fish than continuous sources at the same level (Ref. 22.359), the Popper thresholds for impact piling have been applied in the assessment of sound exposure from continuous sources on a precautionary approach, and are based on the thresholds for Category 1 fish. The criteria are shown in **Table 22.71** for all functional hearing categories and the modelling is reported fully in **Appendix 22L** of this volume.

22.8.431 **Table 22.70** summarises the hearing categories of fish receptors. It is acknowledged that fish in Category 2 and Category 3, primarily use particle motion instead of sound pressure. There are, however, recognised knowledge gaps concerning the use of particle motion by fish, the effects arising from exposure to high levels of particle motion, and the measurement and modelling of particle motion (Ref. 22.52).

22.8.432 Egg and larval stages have also been considered, as they may be subject to barotrauma and swim bladders may develop during the larval stage

22.8.433 Dredge noise modelling assumed 8.5 hours of dredging within a given day to install each intake headwork and 7 hours for the outfall. Intakes would require nine cycles of 30 minutes of dredging, followed by a 30-minute interval for repositioning whilst the outfall assessments are based on nine cycles of 20 minutes of dredging, followed by a 30-minute interval for repositioning, provided in **Appendix 22L** of this volume. Applying the source noise levels from a trailing suction hopper dredger to cutter suction dredging is considered precautionary for the purposes of this assessment.

22.8.434 Thresholds for effects from cumulative noise are exceeded during dredging activities. Cumulative mortality thresholds are exceed but within 25m of the source, the modelled zone for recoverable injury during dredging, is limited to a maximum of 1ha for the cooling water intakes and 0.25ha cooling water outfalls. Dredging is predicted to be 9.5 hours within each 24-hour period with a total of six headworks to be installed. The magnitude of impact is low.

Sensitivity assessments of effects at the sea-area or regional stock/population level: underwater noise (dredging)

Fish with swim bladder or other air cavities to aid hearing (Category 1): sensitivity to underwater noise from construction dredging outfalls

22.8.435 Instantaneous auditory effects would not occur from continuous noise sources associated with dredging for the cooling water infrastructure. Modelling of cumulative noise indicates the potential for mortality/potential mortal injury of Category 1 receptors at a range of <25m from the sound source. Equally, for the most sensitive fish, recoverable extends to a maximum range of 50m (1ha), provided in **Table 22.96**. The impact zone is spatially limited, and any avoidance behaviours would negative the potential for mortal injury.

22.8.436 The largest predicted zone of TTS is 1.08km or an area of 300ha, provided in **Table 22.96**. Fish in the zone of TTS exposure may suffer reduced fitness due to influences on communication and predator detection. Receptors in Category 1 are from regional stocks/populations occurring over much greater areas than the GSB alone. The population effects of reductions in fitness due to TTS are low. High recoverability from TTS is anticipated. The sensitivity of Category 1 receptors to underwater noise from construction dredging is predicted to be low.

22.8.437 The impact of underwater noise is predicted to have a minor adverse effect on Category 1 receptors. Effects are **not significant** at the sea area and regional stock/population levels.

Fish with a swim bladder that does not aid hearing (Category 2): sensitivity to underwater noise from construction dredging

22.8.438 For Category 2 receptors, limited impact zones are predicted for cumulative noise, provided in **Table 22.96**. The sensitivity of Category 2 receptors to underwater noise from construction dredging is predicted to be low.

22.8.439 The impact of underwater noise is predicted to have a negligible effect on Category 2 receptors. Effects are **not significant** at the sea area and regional stock/population levels.

Fish without a swim bladder: sensitivity to underwater noise from construction dredging

22.8.440 Cumulative auditory impact ranges are predicted to be limited in the case of Category 3 fish. The sensitivity of Category 3 receptors to underwater noise from construction dredging is predicted to be not sensitive.

22.8.441 The impact of underwater noise is predicted to have a negligible effect on Category 3 receptors. Effects are **not significant** at the sea area and regional stock/population levels.

Demersal and pelagic fish eggs and larvae: sensitivity to underwater noise from construction dredging

22.8.442 The sensitivity of demersal and pelagic fish eggs and larvae to underwater noise from dredging, is described in the assessment of the BLF and is predicted to be low.

22.8.443 As a worst-case, a minor adverse effect is predicted for eggs and larvae. Limited reductions in fitness and survival may occur, but should there be mortality, the potential losses are considered insignificant in the context of high natural mortality experienced by the early life history stages. Therefore, no decline in the stock/regional population viability is expected and no significant effects are concluded.

Table 22.96: Auditory impact zones areas (expressed in hectares) and/or Auditory impact zone maximum ranges (expressed in metres) from dredging of the cooling water infrastructure. These are based on fish with a swim bladder and apply to all receptor categories. N/A indicates source level below threshold.

Activity	Threshold	Instantaneous	Cumulative
Dredging north intake.	Mortality.	N/A	<25m.
	Recoverable injury.	N/A	50m; 1ha.
	Temporary Threshold Shift.	N/A	1,048m; 293ha.
Dredging south intake.	Mortality.	N/A	<25m.
	Recoverable injury.	N/A	50m; 1ha.
	Temporary Threshold Shift.	N/A	1,078m; 300ha.
Dredging outfall.	Mortality.	N/A	<25 m.
	Recoverable injury.	N/A	25m; 0.25ha.
	Temporary Threshold Shift.	N/A	982m; 241ha.

Assessments of effects of localised displacement: underwater noise (dredging)

22.8.444 The applied threshold for behavioural effects is based on observations of a startle response in sprat (135 db re 1 µPa^{2}s) and in mackerel (142 db re 1 µPa^{2}s). The response thresholds do not necessarily mean that displacement would occur. Also, it is acknowledged that the response thresholds should be applied with caution for species that do not occupy the same habitat or have the same physiology as the two pelagic species, sprat and mackerel.

22.8.445 For Category 1, and Category 2 receptors, the largest behavioural impact zone is associated with dredging the south intake. This is predicted to be a zone of 2.32km (or an area of 1,191ha) from the dredging source, provided in **Table 22.97**. For Category 3 receptors, the largest behavioural impact zone is 957m (or an area of 244ha), provided in **Table 22.97**.

22.8.446 The applied behavioural thresholds are based on the best available evidence, from peer-reviewed literature (Ref. 22.362), and the thresholds are a conservative indicator for the risk of behavioural responses and do not necessitate displacement. Indeed evidence indicates that habituation to impulsive sound sources occurs in fish whereby responses lessen with repeated exposure (Ref. 22.353). This indicates that applying impulsive thresholds to continuous noise sources is likely to be highly conservative. However, a precautionary approach is applied given the lower levels of confidence introduced with the application of thresholds across species with different hearing sensitivities, auditory mechanisms and the application of impulsive thresholds to continuous noise sources. Furthermore, it is acknowledged that the response thresholds should be applied with caution for species that do not occupy the same habitat or have the same physiology as the two pelagic species, sprat and mackerel.

22.8.447 The dredging noise would be present in an existing soundscape in the GSB, where the baseline is characterised by operational noise from Sizewell B, surf noise (waves breaking on the beach), and noise from passing fishing vessels (Ref. 22.361). The duration of dredging is short-lived and with limited sound levels. Should individuals move away to avoid the dredging noise, it is anticipated they could return to the area in a matter of hours to days. However, it is recognised that this may be influenced by motivational state and exposure to predation in areas where fish have been displaced. Fish are precautionarily assessed as having *Low* sensitivity to displacement from dredging activities.

22.8.448 Localised displacement of fish receptors due to underwater noise from dredging for the cooling water infrastructure, is predicted to have a minor adverse effect on the displacement of fish. Effects are not deemed to be significant. Short term behavioural effects (not necessarily displacement) could cause temporary reductions in feeding efficiency. The implications for bird and cetacean feeding will be considered further in the **Shadow HRA** (Doc Ref. 5.10).

Table 22.97: Behavioural impact zone for dredging the cooling water infrastructure, with the area (expressed in hectares) and maximum range (expressed in metres).

Activity	Threshold (dB re 1 μPa^{2}s)	Behavioural zone.
Dredging north intake.	135 dB.	2,271m; 1,156ha.
	142 dB	927m; 237ha.
Dredging south intake.	135 dB.	2,324m; 1,191ha.
	142 dB	957m; 244ha.
Dredging outfall.	135 dB.	2,213m; 1,191ha.
	142 dB	961m; 239ha.

Underwater noise: Drilling

22.8.449 Drilling would be required for the four vertical connection shafts between the subterranean cooling water tunnels and the four intake heads and two outfall heads. Depending on the ground conditions and geotechnical calculations, seismic qualification may be required and would be achieved through the installation of piles into the bedrock by drilling.

22.8.450 Drilling at Sizewell is expected to be via a jack-up rig. Given that the drilling machinery would, therefore, be out of the water, noise levels are likely to be similar to those generated by a drilling platform. Source levels from an acoustic study of a drilling platform were used for the assessment. The broadband source level was approximately 160 dB re µPa at 1 m in the range 10 Hz to 20 kHz. The underwater noise modelling assumed 24-hours of continuous drilling per day from 1 rig, provided in **Appendix 22L** of this volume.

22.8.451 Noise levels arising from drilling activities are predicted to be too low to generate instantaneous auditory impact zones for fish. The spatial extent of the cumulative impact zones for drilling are limited (<25m or <0.25ha). It is predicted that the thresholds for effects from cumulative noise (Ref. 22.53) would be exceeded. Drilling is predicted to take approximately 3 weeks per connection tunnel. Therefore, based on the six headworks (two outfalls and four intakes) a total of 12 weeks drilling would be required. Drilling is unlikely to be continuous with approximately 12 months between completion of each Unit, provided in **Plate 22.1** and **Section 22.5** of this chapter, as such drilling would occur for an estimated total of 12 weeks over a period of several years. The magnitude of seismic qualification underwater noise falls within the magnitude of the drilling associated with the connecting shafts. The impact magnitude is very low.

Sensitivity assessments of effects at the sea-area or regional stock/population level: underwater noise (drilling)

22.8.452 Noise levels arising from drilling activities are predicted to be too low to generate instantaneous auditory impact zones for Category 1 fish. The predicted ranges and affect areas for mortality, recoverable injury and TTS, due to cumulative noise, are very limited (<25m or <0.25ha) as of **Table 22.98**. Furthermore, behavioural effects thresholds are are restricted to within 0.25m from of the drilling activity as of **Table 22.99**.

22.8.453 The sensitivity of Category 1 fish (as a proxy for all species) to underwater noise from drilling is predicted to be not sensitive.

22.8.454 The impact of underwater noise is predicted to have a negligible effect on fish within the GSB. Effects are **not significant** at the sea area and regional stock/population levels.

Table 22.98: Auditory impact zones areas (expressed in hectares) and/or Auditory impact zone maximum ranges (expressed in metres) from drilling associated with the cooling water infrastructure. These are based on fish with a swim bladder and apply to all receptor categories. N/A indicates source level below threshold.

Activity	Threshold	Instantaneous	Cumulative
Drilling.	Mortality.	No Effect	<25m; <0.25ha.
	Recoverable injury.	No Effect	<25m; <0.25ha.
	Temporary Threshold Shift.	No Effect	<25m; <0.25ha.

Table 22.99: Behavioural impact zone for drilling the cooling water infrastructure, with the area (expressed in hectares) and maximum range (expressed in metres).

Activity	Threshold (dB re 1 μPa^{2}s)	Behavioural zone.
Drilling.	135 dB.	<25m.
	142 dB	<25m.

vi. Inter-relationship effects

22.8.455 This section provides a description of the identified inter-relationship effects that are anticipated to occur on fish ecology receptors between the individual environmental effects arising from construction of the proposed development. Pressures with the potential to affect fish receptors are assessed in detail in the following sections and include:

- In combination effects of physical change in seabed type from the infrastructure and scour protection. Changes in seabed has the potential to affect fish that would use the habitat for shelter, foraging and reproductive functions.

- In combination effects of removal of substratum by dredging for the installation of offshore infrastructure. Substratum removal has the potential to affect fish that would use the habitat for shelter, foraging and reproductive functions.

- Combined increases in suspended sediment concentration from dredging associated with capital dredging for infrastructure. Increases in SSC could affect fish that would use the seabed and water column for shelter, foraging and reproductive functions.

- Combined changes in sedimentation rates from dredging associated with the infrastructure. Increases in sediment could affect fish that would use the seabed for shelter, foraging and reproductive functions.

- Combined underwater noise from dredging associated with the infrastructure. There is potential for fish exposure to mortality, injury and for behavioural effects (avoidance) to lead to displacement.

- In combination effects of underwater noise and increases in suspended sediment from dredging associated with the infrastructure. There is potential for fish exposure to mortality, injury and for behavioural effects (avoidance) to lead to displacement.

Physical change (to another seabed type)

22.8.456 The area occupied by the components and thus area of change in seabed type is summarised in **Table 22.46**. The presence of the BLF, CDO, FRR, and northern CWS intakes and outfalls, together with the scour protection, would occupy a total area of <1ha and represent a long-term change in subtidal habitat. The presence of the components would result in a combined change in seabed type (soft to hard). This has the potential to impact on species using the area for example, as foraging and spawning/nursery habitat.

22.8.457 The spatial extent of physical change from a soft to a hard seabed type from the development components combined (<1ha subtidal habitat), is very low in relation to the available seabed habitat in the GSB. The development components would be long-term/permanent changes throughout during the construction phase and throughout operation. The impact magnitude is low.

Sensitivity assessments of effects at the sea-area or regional stock/population level: combined physical change (to another seabed type)

Fish receptors: sensitivity to combined physical change (to another seabed type)

22.8.458 Although there would be a permanent change from soft to hard substrata within the combined footprint of the development components, alternate sedimentary habitat would be available within and beyond the GSB area for foraging, shelter and reproductive requirements. Therefore, it is unlikely that this inter-relationship would increase the significance of these effects beyond the effects predicted for development components alone. Physical changes in seabed type, arising from the combined infrastructure, is predicted to have negligible effects on fish receptors. Effects are **not significant** at the sea or regional stock/population level.

Assessments of effects of localised displacement: combined physical change (to another seabed type)

22.8.459 It is unlikely that this inter-relationship would increase the significance of the effects of localised displacement, beyond the effects predicted for development components alone. Negligible effects on fish receptors assessed are concluded and effects are **not significant** at the sea or regional stock/population level.

Changes in suspended sediment concentration: dredging and dredge disposal (combined components)

22.8.460 During the construction phase, sediments would be suspended by navigational dredging for access to the BLF and by dredging and dredge disposal for the installation of CDO, CWS and FRR infrastructure. There is the potential that suspended solids/suspended sediment from the dredging and disposal could elicit behavioural, physical, physiological and morphological effects to different life history stages and species of fish.

22.8.461 Maintenance dredging for the BLF is anticipated to occur at approximately monthly intervals during the campaign period. As a worst-case, it is assumed there is temporal and spatial coincidence of the plumes from maintenance dredging for the BLF (plough dredger) and dredging (cutter suction dredger) and disposal for the installation of the CWS infrastructure and the southern FFR head.

22.8.462 The suspended sediment plumes from BLF maintenance dredging and dredging to install CWS infrastructure would not intersect, forming two discrete plumes. Therefore, the concurrent activities result in a greater spatial extent of the pressure rather than interactive effects. Increases in the total size of the instantaneous SSC plume at ecologically relevant levels are minimal. The total area with SSC above 100mg/l at the sea surface would be 308ha, provided in **Section 22.3.i)** of this chapter. This area is only slightly larger than the area that would have an SSC above 100mg/l due to dredging for CWS installation alone (291ha).

22.8.463 The suspended sediment plumes from BLF maintenance dredging and dredging to install the FRR head would intersect. At the sea surface, the maximum instantaneous area exceeding 100mg/l would be 111ha. This increase is greater than the sum of the two individual activities (106ha). However, the plume is highly transient, and the total duration of elevated SSC would be reduced due to the temporal overlap. Moreover, the affected area is not substantially larger than the area where SSC would exceed 100mg/l due to dredging for FRR installation alone (89ha).

22.8.464 The possible co-occurrence of maintenance dredging of the navigational channel with dredging for infrastructure installation would not significantly increase the spatial extent of SSC plumes. The SSC plumes associated with dredging activities for different components of the infrastructure would not overlap temporally. Therefore, the combined impact of dredging activities on SSC would not exceed that of the components alone. Impact magnitude is medium.

Sensitivity assessments of effects at the sea-area or regional stock/population level: combined increases in suspended sediment concentration

Fish receptors: sensitivity to combined changes in suspended sediment concentration

22.8.465 After dredging and disposal, the resultant plumes are temporally and spatially limited. The elevated SSC in the plumes would be within the range of concentrations recorded at the site. In the inshore waters, daily maximum SSC in the range of 266 to 459mg/l have been recorded at 1m above the seabed. Beyond the Sizewell-Dunwich Bank the mean SSC baseline conditions are approximately 450-500mg/l during Winter in the location of the offshore infrastructure, with maximum concentrations up to 2000mg/l, provided in **Section 22.4** of this chapter.

22.8.466 Considering the combined increase in SSC in the context of background conditions and acknowledging the potential for direct mortality, sub-lethal effects and avoidance behaviour, it is unlikely that this inter-relationship would increase the significance of these effects. The conclusion of minor adverse effects applies to all fish receptor sub-groups. Effects are **not significant** at the sea or regional stock/population level.

Assessments of effects of localised displacement: combined increases in suspended sediment concentration

22.8.467 It is unlikely that this inter-relationship would increase the significance of the effects of localised displacement due to avoidance, beyond the effects predicted for development components alone. The conclusion of minor adverse effects applies to all fish receptor sub-groups. Effects are **not significant** at the sea or regional stock/population level.

Changes in sedimentation rates

22.8.468 During the construction phase, sediments suspended by navigational dredging for access to the BLF and by dredging and dredge disposal for the installation of CDO, CWS and FRR infrastructure may act in-combination to increase sedimentation rates. Sedimentation rate changes have the potential to cause mortality of eggs/egg cases, larvae, juveniles and small bodied fish with limited mobility close to and on the seabed due to smothering.

22.8.469 There is potential that with concurrent dredging and drilling for the cooling water infrastructure, FFR outfalls and CDO, areas of sedimentation would overlap. The area of overlap between the dredging and drilling plumes for the development components would be limited and high resuspension rates occur. The impact magnitude is medium.

Sensitivity assessments of effects at the sea-area or regional stock/population level: combined changes in sedimentation rates

Fish receptors: sensitivity to combined changes in sedimentation rates

22.8.470 After the dredging and disposal, the resultant changes in sedimentation rates is predicted to be temporally and spatially limited. Considering the sedimentation increase and acknowledging the potential for direct mortality and sub-lethal effects, it is unlikely that this inter-relationship would increase the significance of these effects beyond the those predicted for development components alone. The conclusion of minor adverse effects applies to all fish receptor sub-groups. Effects are **not significant** at the sea or regional stock/population level.

Assessments of effects of localised displacement: combined changes in sedimentation rates

22.8.471 It is unlikely that this inter-relationship would increase the significance of the effects of localised displacement (avoidance), beyond the effects predicted for development components alone. The conclusion of minor adverse effects applies to all fish receptor sub-groups. Effects are **not significant** at the sea or regional stock/population level.

Underwater noise

22.8.472 Underwater noise changes could occur with the coincidence of navigational dredging, using a plough dredger for the BLF and construction dredging, using a cutter-suction hopper dredger, for FRR outfalls and CDO or CW infrastructure. The in-combination effects of dredging the BLF and CW has been selected as this represents the largest individual effect ranges and, therefore, the worst-case scenario.

22.8.473 Instantaneous noise thresholds are not exceeded. However, simultaneous dredging at the BLF and cooling water intakes, results in a cumulative (24-hour) TTS zone of 939ha, covering ~30% more than the sum of the TTS zones predicted for the single source BLF (435ha) and southern cooling water intake (300ha). The predicted mortality and recoverable injury zones for the separate components, are not increased with simultaneous dredging, provided in **Appendix 22L** of this volume.

22.8.474 The construction dredging is of a limited duration while navigational dredging during each campaign would be short-lived, although multiple dredging events per campaign are predicted during construction years. As a worst-case, the impact magnitude for the concurrent dredging is medium.

Sensitivity assessments of effects at the sea-area or regional stock/population level: underwater noise from combined dredging (BLF and CW intakes)

Fish receptors: sensitivity to underwater noise from combined dredging (BLF and CW intakes)

22.8.475 Whilst the inter-relationship increases the individual TTS zones by 30% no increases in mortality or recoverable injury are predicted. Fish exposed in the TTS zone may experience reductions in fitness and including reductions in the ability to detection predators, provided in **Table 22.65**. However, significant changes to the viability of the stocks/populations at the wider sea and regional levels, is unlikely for the most sensitive of the hearing categories (Category 1).

22.8.476 It is unlikely that this inter-relationship would increase the significance of the impacts beyond the effects predicted for development components alone (minor adverse effects). This conclusion applies to the hearing functional groups and eggs and larvae. Effects are **not significant** at the sea or regional stock/population level.

Assessments of effects of localised displacement: underwater noise from combined dredging (BLF and CW intakes)

22.8.477 Consecutive dredging has the potential to result in fish behavioural responses and potentially displaced from a larger area of the GSB. However, behavioural response thresholds are highly precautionary and do not necessarily infer displacement. It is unlikely that the inter-relationship would increase the significance of localised displacement from avoidance behaviour, beyond the effects predicted for development components alone. A conclusion of minor adverse effects applies to all the hearing functional groups. Effects are **not significant** at the sea or regional stock/population level.

Underwater noise and changes in suspended sediment concentrations

22.8.478 The pressure of underwater noise and changes in suspended sediment would occur with all dredging events. There is the potential for fish to suffer auditory impairment (from underwater noise changes) and stress and behavioural effects from the underwater noise and sediment plume arising from dredging. Exposure to these pressures could affect individuals and stocks/populations. Furthermore, given the potential vulnerability of fish eggs and larvae to underwater noise and suspended sediment, the life history stages are considered.

Sensitivity assessments of effects at the sea-area or regional stock/population level: combined underwater noise and changes in suspended sediment concentrations

Fish receptors: sensitivity to combined underwater noise and changes in suspended sediment concentrations

22.8.479 Of the key taxa, the most sensitive of the receptors is the Clupeids (Atlantic herring, sprat and shad), as hearing and vision are used in predator and prey detection and appraisal of the surrounding environment.

22.8.480 Where the instantaneous SSC plume and TTS zone overlap, fitness and potentially survival of fish may be temporarily affected through temporary reductions in hearing sensitivity, coupled with physiological and physical stress from increased turbidity. However, reduced fitness of individuals is likely to be insignificant in the context of the wider stocks and populations.

22.8.481 For migratory fish in the category, there is unlikely to be a barrier to migration due to the temporary nature of the in-combination SSC increases and TTS.

22.8.482 In conclusion, this inter-relationship is considered unlikely to increase the significance of these effects, beyond the effects predicted for development components alone (minor adverse effects). This conclusion applies to all the fish receptor sub-groups. Effects are **not significant** at the sea or regional stock/population level.

Demersal and pelagic fish eggs and larvae: sensitivity to combined underwater noise and changes in suspended sediment concentrations

22.8.483 Exposure to the instantaneous plume could result in minor physiological damage, such as damage to clogging of the gills (particularly in larvae and smaller fish); physiological changes such as reduced growth rates and even increased mortality (Ref. 22.392). However, the instantaneous SSC plume is of a limited magnitude and thus effects to fish eggs and larvae would be limited.

22.8.484 In conclusion, this inter-relationship is considered unlikely to increase the significance of these effects, beyond the effects predicted for development components alone in relation to eggs and larvae. Effects are **not significant** at the sea or regional stock/population level.

Assessments of effects of localised displacement

22.8.485 For the separate components of dredging-related underwater noise and SSC increase, a minor adverse indirect effect was concluded for localised displacement. It is unlikely that this inter-relationship would increase the significance of the effects of localised displacement, beyond the effects predicted for development components alone. This conclusion applies to all fish receptor sub-groups. Effects are **not significant** at the sea or regional stock/population level. The implications for bird and cetacean foraging will be considered further in the **Shadow HRA** (Doc Ref. 5.10).

d) Operation

22.8.486 The indicative timeline for the proposed development to become fully operation is 2034, with the earliest operational date assumed to be 2030 for assessment purposes as of **Plate 22.1**. This section considers the potential effects on fish receptors during the operational phase of the proposed development.

i. Beach landing facility

22.8.487 Pressures with the potential to affect fish are the same as those identified for the construction phase, provided in **Table 22.64**. For navigational dredging, pressures reoccur less frequently than during the construction phase as dredge activities are expected once every 5-10 years rather than annually. As a precautionary assumption, the impact magnitude applied during the construction phase is applied during the operation phase. Fish sensitivity and, therefore, the predicted effects are also precautionarily maintained for the operational phase assessment. The predicted effects of BLF activities on fish receptors during the operation phase is summarised in **Table 22.100**. The full impact assessment is consistent with that presented for the construction phase in **Section 22.8.c)** of this chapter.

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Table 22.100: Summary of impact magnitude, sensitivity of fish receptors and the effects and significance of pressures associated with BLF activities during the operation (and construction) phase.

Pressure	Activities resulting in pressure.	Impact magnitude.	Groupings	Sensitivity	Effect and significance.
Physical change to another seabed type.	Presence of structure.	Low	All fish receptors.	Not Sensitive.	negligible (**not significant**)
Removal of substratum (extraction).	Navigational dredging.	Low	All fish receptors.	Not Sensitive.	negligible (**not significant**)
Changes in suspended sediments.	Navigational dredging.	Medium	All fish receptors.	Not Sensitive / Low.	minor adverse effects (**not significant**)
Sedimentation rate changes.	Navigational dredging.	Low	All fish receptors.	Not Sensitive.	negligible (**not significant**)
Underwater noise and vibration.	Navigational dredging.	Low	Category 1 and 2 fish	Low	minor adverse (**not significant**)
			Category 3 fish	Not Sensitive.	negligible (**not significant**)

ii. Combined Drainage Outfall

22.8.488 Operational discharges are not anticipated from the CDO. The headwork is not expected to be decommissioned following the construction phase and would remain in place.

iii. Cooling water system

22.8.489 This section describes the impacts associated with the operation of the cooling water system during the operation phase. Scoping identified the pressures arising from activities at the fish recovery and return systems with the potential for effects on ecological receptors, provided in **Appendix 22M** of this volume. Operation phase pressures with the potential for effects on ecological receptors are presented in **Table 22.101**.

Table 22.101: Pressures associated with CWS activities during the operation phase that have the potential to affect fish receptors.

Pressure	Activities resulting in pressure	Justification
Entrainment	Cooling water abstraction.	Seawater will be abstracted from the marine environment to cool critical plant, and the abstracted water will contain ichthyoplankton and juvenile fish that would be entrained in the cooling water system. During entrainment, ichthyoplankton and juveniles would be exposed to increases in temperature, mechanical stress and chemical contaminants including chlorine and hydrazine. Exposure may have for sub-lethal effects and lethal effects on ichthyoplankton and juvenile fish. The effects of future climate change and warming sea temperatures in relation to entrainment mortality is also considered
Impingement	Cooling water abstraction.	The cooling water intakes would be protected by coarse screens to prevent the intake of biota and large items of debris, fish would inevitably enter the cooling water intake. The larger individuals must be removed before the water enters the power station cooling system to prevent them blocking the condenser tubes. Fish would be removed through impingement on drum screens. Impingement mortality may arise, while some fish would survive impingement and be returned through the FRR back to sea. There is potential for sub-lethal effects and lethal effects on fish receptors as a result of impingement

Pressure	Activities resulting in pressure	Justification
Temperature changes.	Cooling water discharges.	The discharge of heated cooling water from the outfalls, as a buoyant surface plume and seabed plume, could expose ichthyoplankton and older life history stages of fish to temperature increases. Reported effects of temperature rises range from changes in metabolism, immunology and growth through to food availability, spawning and recruitment. Also, changes in community structure and presence (Ref. 22.393). The effects of future climate change and warming sea temperatures in relation to thermal discharges is also considered.
Synthetic compound contamination.	Discharges of total residual oxidants (TRO), chlorination by-products and hydrazine.	The discharge from the outfalls of TROs, chlorination by-products and discharge of daily hydrazine discharges in the waste stream. Seabed and water column plumes of the contaminants may interact with ichthyoplankton and older life history stages of marine fish and migratory fish. Biological effects encompass sub-lethal and lethal effects and avoidance behaviours. Sub-lethal effects may, for example, consist of damage to eggs, reduced hatching success, delayed larval development, gill damage and reduced respiration (Ref. 22.106).
Abrasion / physical disturbance.	Maintenance operations.	Vessel anchoring and chain drag have the potential to affect benthic ecology receptors through the direct disturbance of organisms.

22.8.490 Operation pressures that have been scoped out of further assessment as they are considered to have negligible effects on fish receptors include:

- Nutrient enrichment – The small quantities of nitrate and phosphate that may be discharged into the GSB via the CWS outfalls during the operation phase are expected to influence annual gross primary production by orders of magnitude below the natural variation in chlorophyll *a* biomass, provided in **Section 22.6.b)** of this chapter. Such small-scale changes to primary production would have negligible indirect effects on fish.

Cooling water abstraction: Entrainment

22.8.491 Large volumes of water will be abstracted from the marine environment by the cooling water intakes to cool critical plant. The abstracted water containing ichthyoplankton, juvenile fish and adults of small species, may be too small to be impinged by the drum or band screens and would be entrained in the cooling water system. During entrainment, ichthyoplankton and juveniles would be exposed to increases in temperature and mechanical stress. Exposure to chemical contaminants including chlorine and hydrazine would occur. Exposure to contaminants would be limited by the seasonal chlorination strategy and limited duration of the daily hydrazine releases.

22.8.492 During the operational phase of the proposed development, four cooling water intakes will abstract water at a rate of 132m^3/s. Of the 132m^3/s between 10-12m^3/s will be diverted at the forebay through band screens and be for auxilliary and essential cooling systems). This water will be chlorinated but under normal operating procedures is not heated greatly. The remaining water (ca.120m^3/s) would pass over the drum screens before becoming the main cooling water flow for the condensers where it will be heated (ΔT 11.6°C) and chlorinated (seasonally).

22.8.493 The physico-chemical pressures represent a high degree of change and the duration of the pressures would last throughout the operational life of the plant, however, the volume of water abstracted in the open coastal system is small relative to the tidal exchange.

22.8.494 The impact magnitude is assessed as medium. It should be noted that entrainment predictions apply specific assessments to determine population level effects. The assessments therefore incorporate both receptor sensitivity and impact magnitude.

22.8.495 The following fish species have been screened into the assessment as either the eggs, larvae or juveniles were reported during the one-year Comprehensive Entrainment Monitoring Programme , provided in **Table 22.102**:

Table 22.102: Key taxa by early life history stages entrained at Sizewell B.

Species	Egg stage present.	Larvae stage present.	Juvenile stage present.
European seabass	✓	×	×
Gobies	×	✓	✓
Dover sole	✓	✓	×
Dab	×	×	✓
European flounder	×	✓	×
Anchovy	✓	×	×
European sprat	✓	✓	✓
Atlantic herring	×	✓	✓

22.8.496 A summary of the considerations and assumptions used in the entrainment predictions is given in **Table 22.103**.

Table 22.103: Considerations and assumptions used in predictions of entrainment estimates. Source: Appendix 22G.

Entrainment predictions: considerations and assumptions.	
Flow rate.	131.86m^3/s.
Mesh size	10mm (as at Sizewell B).
24-h sampling.	Assumption that sampling for 24 hours reduces tidal biases in abundance
Distribution of (ichthyo)plankton.	Plankton is assumed to be similarly distributed throughout the GSB, and that entrainment estimates from the intakes at Sizewell B can be used to provide predictions for Sizewell C by raising on the ratio of pumping rates.
Station annual pumping capacity.	Station runs at full load all year, with all four cooling water pumps running all year.
Survival of entrained fish eggs.	From avaliable studies, 20% survival of sole eggs and 40% survival of bass eggs is assumed in the estimates of entrainment mortality, prior to converting to the number of "equivalent spawning females". All other species precautionarily assume 100% mortality.
Female annual egg and larvae production and mortality.	Within published literature are variations in estimates of annual egg production for a given species. Therefore, where a range is given in the literature, the lower value has been used to give a precautionary evaluation.
Entrainment of fish eggs.	For calculating the numbers of eggs produced by an "average" female, it has been assumed that all eggs are fertilised and recently spawned and are thus viable.
Entrainment of fish larvae.	For calculating the numbers of larvae produced by an "average" female, it has been assumed that all eggs are fertilised and recently spawned.
Entrainment of juvenile fish.	Limited numbers of some species were entrained; therefore, scaled-up numbers to be treated with caution.
	It has been assumed that juvenile fish are 30mm at time of entrainment, based upon average size distribution data for fish impinged on Sizewell B drum screens.
Equivalent Adult Value (EAV)[53] calculation.	A precautionary EAV of 1 has been assumed where required biological information to calculate an EAV is unavaliable.

[53] The EAV calculation is a method to determine the proportion of a known size distribution of juvenile fish that will survive to adulthood and spawn. The method uses growth and natural mortality at length as its basis.

22.8.497 To calculate the numbers of entrained biota, the following steps were involved:

- Calculate mean abundance of each species in each month (number / m^3).
- Calculate monthly total numbers entrained at Sizewell B at full pumping capacity.
- Calculate annual total numbers entrained at Sizewell B.
- Calculate annual total numbers entrained at the proposed development using the ratio of pumping rates (i.e. the difference in volume of water abstracted).

22.8.498 A final dataset was obtained with the unadjusted numbers of entrained fish eggs, larvae and juveniles at the proposed development. Due to high natural mortality rates, the loss of each egg, larva or juvenile does not equate to the loss of an adult from the spawning population. Therefore, entrainment numbers were adjusted to account for this.

22.8.499 Egg losses through entrainment and the impact on fish populations, has been expressed in context of the number of eggs produced by an “average” or typical spawning female (“equivalent spawning female”). This information was based on evidence from published sources. Where a range was given then the lower, conservative estimate was used.

22.8.500 This “adult reproductive equivalent” approach may underestimate the population loss due to egg mortality before hatching, because it assumes all the eggs were viable and newly laid. Therefore, to mitigate this, the lower estimate of the number of eggs spawned has been used wherever a range was present in relevant literature, provided in **Appendix 22G** of this volume.

22.8.501 A precautionary survival rate of 0% was assumed for eggs of all species, except for Dover sole and seabass, which applied 20% and 40% survival rates, respectively based on experimental evidence from the Entrainment Mimic Unit).

22.8.502 Larval loss through entrainment and the impact on fish populations, has been expressed in the context of the numbers of larvae produced by an “average” or typical spawning female (“equivalent spawning females”). For this assessment, the estimated numbers of larvae produced was based on the number of eggs spawned from an average female that would survive to become larvae, assuming upper (97%) and lower (70%) levels of natural egg mortality. This approach provides upper and lower estimates of the impact of larval loss through entrainment.

22.8.503 For juvenile fish, an equivalent adult value (EAV) method, developed by BEEMS has been utilised (Ref. 22.394). This method is a valuable tool for determining the number or weight of juvenile fish that would have survived to adulthood and become part of the fishery had they not been abstracted (Ref. 22.395). Species length distribution data is gathered from CIMP sampling and the EAV method applies growth and natural mortality at length to determine adult values. To be precautionary, entrainment EAVs are based on the maximum length of 3cm juveniles, as few individuals below this length were recorded in the CIMP dataset. In the absence of data, a worst-case EAV value of 1 has been assumed, which will considerably over-estimate adult numbers for such species (Ref. 22.394). Estimates of EAV allow losses to be contextualised against a stock, reference population or fishery.

22.8.504 The estimated entrainment losses (unadjusted for entrainment survival or equivalent adults) by life history stage for Sizewell B and the proposed development, are detailed in **Table 22.104** and **Table 22.105**, respectively. Values for sole and bass eggs are unadjusted for entrainment survival.

22.8.505 For larvae and juveniles, the gobies could not be identified for genus or species. However, only gobies of the genus *Pomatoschistus* (the sand gobies) are considered key taxa. The calculated numbers of gobies entrained was therefore separated into sand gobies and 'other gobies' on the proportion of these groups in impingement samples. Only the losses of the sand goby component were assessed.

22.8.506 Some eggs, larvae or juveniles could not be assigned to a species due to rupture of the egg or its oil globule, or due to damage. In this case, the losses of the 'unidentified species' portion of the entrained samples was re-allocated proportionally to those species that were identified in a given sampling month. The estimated numbers entrained reflect these re-allocations**,** provided in **Appendix 22G** of this volume.

Table 22.104: Summary of estimated entrainment losses (unadjusted for entrainment survival or equivalent adult values) by life history stage at Sizewell B.

Species	Eggs	Larvae	Juveniles	Total
Seabass	4,694,916			4,694,916
Sand gobies.		52,073,218	7,602,995	59,676,213
Dover sole.	124,143,767	217,835		124,361,602
Dab			1,969,535	1,969,535
Flounder.		35,845		35,845

Species	Eggs	Larvae	Juveniles	Total
Anchovy	123,239,720			123,239,720
Sprat	12,352,555	17,434,255	7,584,699	37,371,509
Atlantic herring.		6,999,619	34,114	7,033,733

Table 22.105: Summary of estimated entrainment losses (unadjusted for entrainment survival or equivalent adult values) by life history stage for the proposed development (scaled based on abstraction volumes).

Species	Eggs	Larvae	Juveniles	Total
Seabass	12,020,809			12,020,809
Sand gobies.		133,327,662	19,466,620	152,794,282
Dover sole.	317,856,254	557,742		318,413,996
Dab			5,042,775	5,042,775
Flounder		91,776		91,776
Anchovy	315,541,543			315,541,543
Sprat	31,627,339	44,638,462	19,419,776	95,685,577
Atlantic herring.		17,921,743	87,346	18,009,089

22.8.507 To determine annual losses from entrainment, the total number of equivalent adults was calculated by summing eggs, larvae and juveniles. To be precautionary, the worst-case for larvae (assumption of 97% egg mortality) was used.

22.8.508 Thin-lipped grey mullet, Atlantic cod, thornback ray, and horse mackerel were not detected during entrainment nor plankton sampling at Sizewell (Ref. 22.219). Tope does not have egg or larval stages and the juveniles are too large to be entrained, provided in **Appendix 22G** of this volume. Therefore, the population of these species are not considered at risk of entrainment.

22.8.509 Whiting, plaice and mackerel were not detected in entrainment sampling but were detected during offshore plankton surveys (Ref. 22.219). However, the species were present in such low densities as to have negligible effect on the species at the population level should they be entrained at such densities.

22.8.510 Smelt, twaite and Allis shad, river and sea lamprey, sea trout and Atlantic salmon are not present at the vulnerable life stage/size and do not enter the marine environment until they are too large to be entrained. Therefore, the population of these species are not considered at risk of entrainment.

22.8.511 European eel, including glass eels, were not detected in entrainment sampling, but glass eels are known to migrate past the Sizewell site in very small numbers (Ref. 22.321). No glass eels were sampled during extensive offshore plankton surveys between 2008 and 2017. Therefore, negligible effects on the species at the population level are concluded.

Contextualising entrainment losses

22.8.512 To put predicted entrainment losses of fish eggs, larvae and juveniles from the proposed development, into the context of populations, the estimated equivalent adult numbers were converted to weights using mean weight values for each species.

22.8.513 The weights of entrainment losses are shown as a percentage of the spawning stock biomass (SSB), or if this is not available, with the international landings of each species, based on its stock assessment area, provided in **Appendix 22G** of this volume. Each species has a different defined stock area based on its life history, population distribution and fishery. The results are summarised in **Table 22.106**.

22.8.514 In the case of commercially important key species at Sizewell that are all species except sand goby, provided in **Table 22.106**, predicted entrainment losses of less than 1% of SSB are considered to be ecologically negligible. The assessment threshold is considered against natural variability in recruitment and natural mortality of the species populations, provided in **Table 22.106**; **Appendix 22G** of this volume. In the case of sand goby, predicted entrainment losses of less than 10 % of the population are considered to be ecologically negligible, as the population is unexploited.

Table 22.106: Predicted entrainment losses by life history stage at the proposed development. Values have been adjusted to give equivalent numbers of spawning females and equivalent numbers of adults (where species data are available to allow such estimates to be made). For commercially important species, the losses are shown in relation to stock landings and SSB. *Goby values show the number, not weight, of individuals.

Species	Entrainment loss (equivalent spawning females or EAV)				Total entrainment loss (as adults)		Individual fish wt (kg) (2010 value)	Total wt (t) upper estimate	Stock landings (t)	Stock SSB (t)	% of landing	% of SSB	Source of fishery data
	Eggs	Larvae (97% egg mortality)	Larvae (70% egg mortality)	Juvenile	Lower estimate	Upper estimate							
European seabass	36				36	36	1.365	0.049	4,768	20,780	0.001	0.000	(Ref. 22.397)
Sand gobies		1,929,768	192,977	962,430	1,155,406	2,892,198				205,882,353*		1.40	(Ref. 22.398)
Dover sole.	588	43	4		592	631	0.227	0.143	12,603	31,358	0.001	0.000	(Ref. 22.399)
Dab.				21,810	21,810	21,810	0.040	0.872	8,279	N/A	0.011	N/A	(Ref. 22.399)
European flounder.		2	0		0	2	0.082	0.000	3,365	N/A	0.000	N/A	(Ref. 22.399)
Anchovy	2,869				2,869	2,869	0.021	0.060	727	N/A	0.008	N/A	ICES catch download
European sprat.	3,635	171,029	17,103	25,052	45,790	199,715	0.010	1.997	143,500	225,041	0.001	0.001	(Ref. 22.400)
Atlantic herring		23,992	2,399	0	2,399	23,992	0.174	4.175	187,600	2,023,720	0.002	0.000	(Ref. 22.400)

Sensitivity assessments of effects at the sea-area or regional stock/population level: entrainment

22.8.515 The key fish taxa are not predicted to be sensitive to entrainment losses of ichthyoplankton or juvenile life history stages, which are orders of magnitude below the 1% SSB threshold, provided in **Table 22.106**. With the exception of sand gobies, the key taxa assessed are not sensitive to entrainment, as provided in **Table 22.107** Summary of key taxa sensitivity to entrainment, and negligible effects at the stock levels is predicted. Contextualised against high natural variability in abundance and considerable natural mortality of early life history stages, entrainment effects are **not significant** at the sea area and regional stock/population levels.

Table 22.107: Summary of key taxa sensitivity to entrainment

Species	Sensitivity
European seabass.	Not Sensitive.
Dover sole.	
Dab.	
European flounder.	
Anchovy.	
European sprat.	
Atlantic herring.	
Sand goby.	Low

22.8.516 The estimated number of sand gobies that would be entrained by Sizewell C represents approximately 1.4% of the abundance. Sand gobies are not a commercially exploited species and as such, a precautionary harvesting rate threshold of 10% SSB is considered appropriate as a screening threshold for potentially significant effects that may affect the sustainability of the stock, provided in **Appendix 22G** of this volume. Sand gobies have been precautionarily assigned low sensitivity, due to the slight exceedance of the initial 1% SSB threshold.

22.8.517 Entrainment is predicted to have a minor adverse effect on sand gobies. Effects are **not significant**.

Assessments of effects of localised displacement: entrainment

22.8.518 Ichthyoplankton are widely dispersed and seasonally abundant, provided in **Appendix 22B** of this volume. Entrainment is predicted to have negligible effects on the distribution and abundance of early life history stages of fish.

The effects of climate change on entrainment predictions

22.8.519 This section considers the influence of climate change on entrainment predictions for the proposed development. The proposed development has a long operational life cycle and the potential for warming sea temperatures could have implications for entrainment mortality.

22.8.520 Mortality due to temperature shock for the egg and larval life stages of many fish species increases rapidly once maximum temperatures exceed 30°C (Ref. 22.86; 87). With the exception of Dover sole and seabass, egg mortality is assumed to be 100% in entrainment predictions. Therefore, only Dover sole and seabass egg entrainment mortality prediction are subject to change. However, both species entrainment losses were <0.001% of SSB. Accordingly, changes in egg mortality rates are not considered to have a significant effect.

22.8.521 Warming sea temperatures have the potential to result in entrainment temperatures (ambient + 11.6ºC uplift) exceeding upper incipient lethal temperature limits for longer periods of the year. Future entrainment temperatures were considered for the following scenarios accounting for predicted future warming (based on UKCP09[54]; SRES A1B see **Appendix 21E** of this volume:

- **2030:** The decade during which the proposed development is expected to be operational (with operation anticipated to be from approximately 2034). The scenario includes both stations running simultaneously.
- **2055:** The hypothetical last likely date for Sizewell B to be operational. The scenario includes both stations running simultaneously and Sizewell C running alone.
- **2085:** Towards the end of the operational life of Sizewell C.
- **2110:** The hypothetical extreme date for Sizewell C to remain operational prior to decommissioning.

22.8.522 Mean daily entrainment temperatures are predicted to exceed 30ºC for 57 days in July-September by 2030. Temperatures peak in early August reaching 31.3ºC. By 2055, entrainment temperatures exceed 30ºC for 100 days in much of July, August and September and continue into October, provided in **Table 22.30** and in **Section 22.6.d)** of this chapter.

[54] Future sea temperatures are not included in the current UKCP18 marine climate predictions.

22.8.523 Once Sizewell B is decommissioned, entrainment temperatures exceeding 30ºC occur for fewer days, 92 in 2085 and maximum temperatures remain below 33ºC. In the extreme scenario of 2110, entrainment temperatures are predicted to exceed 30ºC for 105 days per annum between the beginning of July and mid-October as provided in **Table 22.30** in **Section 22.6.d)** of this chapter.

22.8.524 High entrainment mortality rates for longer periods of time, would likely be observed under future climate change. However, thermal lethality is highly species-specific and adaptation to future climate conditions and potential species distribution shifts may influence the ability to tolerate thermal stress (Ref. 22.87), thus influencing entrainment mortality.

22.8.525 Furthermore, the peak in abundance of ichthyoplankton occurs prior to the hottest periods of the year, between May and July, with May being the peak for invertebrate zooplankton, provided in **Appendix 22B** of this volume. The most abundant component of the ichthyoplankton off Sizewell was anchovies, which are becoming increasingly abundant in the southern North Sea. Anchovy eggs and larvae peak in June and July. The timings of the commercially important finfish species with high egg and larvae abundance at Sizewell are as follows:

- Dover sole; eggs and larvae peak in May.
- Seabass; eggs peak in May, larvae peak in June.
- Plaice; eggs peak in May, larvae peak in June.
- Herring; eggs and larvae peak in May.

22.8.526 Increases in temperature may also result in small increases in chlorination duration. The seasonal chlorination strategy for the proposed development involves chlorination during the period of the year when water temperatures exceed 10ºC. In 2030, predicted water temperatures at the intakes of the proposed development would exceed 10ºC for 219 days per annum, from the beginning of May until the start of December. Towards the end of the operational life-cycle of the proposed development in the year 2085, climate change is predicted to result in temperatures exceeding 10ºC from late April until late December, for a total of 244 days per annum, as provided in **Appendix 21E** of this volume. However, light limitation would limit the duration of the potential growing season and increases in the duration of annual chlorination is likely in the order of weeks at most.

22.8.527 Current entrainment estimates predict negligible effects at the sea-area or regional stock/population level, with the exception of minor adverse effects on sand gobies. Whilst these values may increase slightly due to increases in entrainment temperature and prolonged seasonal chlorination, the assessment of effects would remain unchanged. Abstraction rates represent approximately 1.35% of the volume of water that passages past the station and exchange rates with the wider North Sea are ca. 10%. Therefore, even with 100% mortality of ichthyoplankton, there is expected to be a minimal effect at the stock/population level, especially with high natural mortality experienced in the early life stages. The impact of entrainment at future climate related sea temperatures remains as a negligible effect on the key taxa assessed, with the exception of minor adverse effects on sand gobies. Effects are **not significant** at the sea area and regional stock/population levels.

Cooling water abstraction: Impingement

22.8.528 Fish that enter the cooling water system will be transported to the forebays where larger individuals would be impinged by the fine-mesh drum and band screens.

22.8.529 Fish abstracted by power station cooling water intakes chiefly involve the juvenile part of a population, owing to their presence in inshore nursery areas[55] and their lower swimming capability compared to adult fish. Each species has a different body shape and maximum size; therefore, the size at which an individual will be able to pass through the drum or band screen mesh depends is species specific. The proportion of the total number of a given species that is impinged by the drum screens depends on the size distribution of the species abstracted in the cooling water systems.

22.8.530 Up to $12m^3/s$ would supply auxiliary and essential cooling water systems and would be filtered by band screens. The remaining $120m^3/s$ passes through four drum screens for the main cooling water system. Both band and drum screens will be integrated within the FRR system.

22.8.531 Chlorination would occur after the drum and band screens. Therefore, impinged fish and the FRR system would not be exposed to chlorine.

22.8.532 Impingement predictions for the proposed development are based on the species composition and abundance data from the Comprehensive Impingement Monitoring Programme (CIMP) impingement monitoring studies at Sizewell B, scaled for the increase in abstraction rate for

[55] The proposed developed is in an area of low nursery intensity for most of the key taxa, with the exception of Atlantic herring, provided in **Figures 22.11** to **22.13**.

Sizewell C (Ref. 22.304–307). , The assessment is based on the following assertions, provided in **Appendix 22I** of this volume:

- Statistical analyses have demonstrated that the fish community is the same at the location of the proposed intakes (approximately 3km offshore) as at the Sizewell B intakes (approximately 700m offshore); and

- The proposed intakes are assumed to abstract the same quantity of fish per unit volume as Sizewell B, allowing volumetric scaling.

22.8.533 Predictions are based on a 10mm drum screen mesh size. The drum and band screens would be protected by trash racks with 75mm bar spacing which may block the passage of some of the largest fish and marine mammals. A summary of the considerations and assumptions used in the impingement predictions is given in **Table 22.108**.

22.8.534 During standard operating procedures, a volume of greater than 1% of the tidal volume would pass through the power station per day. Water abstractions is a long-term activity occurring throughout the operational lifecycle of the station.

22.8.535 Impingement assessments are specifically designed to account for the magnitude of impact (annual abstraction) and sensitivity of the impinged species (age-dependent mortality). Given these assessment criteria are intrinsically linked they are considered together.

Table 22.108: Considerations and assumptions used in predictions of impingement. Source: Appendix 22I.

Impingement predictions: considerations and assumptions.	
Flow rate.	132m^3/s.
24-h sampling.	Impingement sampling at Sizewell B was 24-hours - reduces tidal biases in abundance estimates.
Distribution of fish.	In general (seabass being the exception), fish are assumed to be similarly distributed throughout the GSB, and with similar size distributions. Consequently, impingement estimates from Sizewell B can be used to provide predictions for Sizewell C by raising to the ratio of pumping rates.
Station annual pumping capacity.	Impingement predictions assume the stations run at full load all year, with all four cooling water pumps running continously.
Drum screens.	A 10mm mesh size is applied allowing a direct comparison with the current mesh size employed at Sizewell B. Environment Agency (2005) recommends *“mesh size should be as small as is practical, and of no more than 6 mm aperture”* (Ref. 22.15). However, Environment Agency (2010) acknowledge that at coastal sites a 6mm mesh may lead to the risk of ctenophore blockage during summer months. Gelatinous ctenophores would more readily distort under drum screen conditions and squeeze

Impingement predictions: considerations and assumptions.	
	through a 10mm mesh screen (Ref. 22.16). A 10mm screen is therefore considered appropriate for Sizewell C.
Forebay trash rack.	A 75mm bar spacing is assumed.
Statistical method to derive annual impingement estimates.	Upper modelled confidence intervals (95th percentile) are considered as extremely precautionary, and are based on the assumption that upper value of numbers impinged is attained on every day of the year.
Forebay trash rack mortality.	It is assumed that all fish that cannot pass through the primary trash rack (75mm bar spacing) will suffer 100% mortality.
	It is assumed that if the width of the largest observed individual of a species is ≤75mm then it was unlikely to be retained by the trash racks.
FRR survival rate.	Conservative FRR recovery rates based on Environment Agency figures are applied (Ref. 22.15). The final estimates of FRR survival have been modified to account for the Sizewell C location and station design. The Sizewell C FRR system will discharge inside the Sizewell-Dunwich Bank and there is potential for fish discharged from the Sizewell C FRR to be subsequently taken up by the Sizewell B intake. Modelling suggests that this risk is negligible (<1%), but it has beeen assumed that these fish will suffer 100 % mortality during their passage through Sizewell B. The Sizewell C mortality estimates have been adjusted accordingly, see **Appendix 22I** of this volume.
	Survival percentages for epibenthic species are assumed to be the same for drum screen and band screen FRR routes. Survival of benthic species are assumed to be different in the band and drum screens, as fish will be held for a longer time period in the former. Survival of pelagic species in the band and drum screens is assumed to be 0%.
Equivalent Adult Value calculation.	A precautionary EAV of 1 has been assumed where required biological information to calculate an EAV is unavaliable.
Evaluating impingement losses.	Where absolute spawning stock biomass (SSB) cannot be estimated, impingent losses have been compared with the international landings of the stock area. This is a highly conservative estimate of population size. A 1% threshold has been applied to determine the potential for significant effects from impingement losses for commercially-exploited species; a 10% threshold has been applied for unexploited species. A 1% effect screening threshold for annual impingement provides a precautionary level. It is considered negligible compared with fishing mortality on exploited stocks. The 1% threshold is much less than the natural variability of any species at Sizewell which the ecosystem is adapted to and hence would have no significant effects on predator-prey relationships.

22.8.536 Full information on the methods and data sources used for the impingement calculations is presented in **Appendix 22I** of this volume. A summary has been presented in this section of the **ES**.

22.8.537 Equivalent Adult Values (EAVs) are used to adjust the number of lost juveniles to a corresponding number of lost adults. This adjustment is required because juveniles suffer higher natural mortality when compared with adults of the same species, and the loss of one juvenile does not result in the loss of one adult from the spawning stock. Conversion of the predicted numbers impinged to the equivalent number of adults is a simple matter of converting EAV equivalent numbers to weights using the mean individual weight per species, then multiplying the total impingement mortality with the appropriate EAV value for each species. The EAV values used were calculated using a method developed as part of the BEEMS programme (Ref. 22.394).

22.8.538 The EAVs represent the proportion of the impinged juvenile fish that would be expected to reach adulthood based upon natural mortality and growth estimates. For species where the required population parameters are not available, an EAV of 1 has been assumed as a conservative estimate (i.e. it is assumed that every individual would have otherwise reach adulthood). The EAV for key taxa from the Sizewell fish community are shown in **Table 22.109**. Refer to **Appendix 22I** of this volume for the method and full EAV calculations.

22.8.539 Impingement losses (by weight for the key taxa) (with and without mitigation) were compared with either the spawning stock biomass (SSB) or, if these are not available, the international landings for a species (relevant stock units shown in **Table 22.110**. The threshold used to assess the significance of impingement losses of the assessed species is 1% of the SSB or fishery landings for exploited species and 10% for unexploited species. Assessments are based on annual losses relative to SSB or landing thresholds, in the same manner as fisheries stock assessments. This approach represents the most meaningful assessment for a stock or population that is appropriately managed. Whilst the **ES** approach recognises the long-term nature of the impact, a well managed stock/population has the ability to be resilient to mortality, as such cumulative, year on year effects are not appropriate for a 'renewable' stock.

22.8.540 Given the scale of the fish stock assessment areas and the potential for other developments with similar activities to act cumulatively on fish stocks, a dedicated cumulative effects assessment (CEA) has been completed. Specifically, the effects of entrainment and impingement from the development of NNBs on fish stocks with overlapping geographic ranges has been assessed **Volume 10 Chapter 4** of the **ES**.

Table 22.109: Equivalent Adult Value metrics and mean weight of individuals used to convert the numbers impinged to adult equivalent numbers and weights at the proposed development.

Species (common name).	Equivalent Adult Value annual impingement.	Mean weight per individual (kg).
Sole	0.213	0.214
Whiting	0.356	0.286
Atlantic cod	0.359	2.602
Dab	0.445	0.041
European flounder	0.462	0.082
European plaice	0.345	0.246
European seabass	0.224	1.531
Thin-lipped grey mullet	0.083	0.520
Sand goby	1.000	0.002
Thornback ray	0.193	3.193
Tope	1.000	6.900
European sprat	0.751	0.011
Atlantic herring	0.715	0.189
Anchovy	0.974	0.021
Mackerel	1.000	0.319
Horse mackerel	1.000	0.140
European smelt	0.761	0.017
European eel	1.000	0.329
Allis shad	1.000	0.572
Twaite shad	1.000	0.313
Sea lamprey	1.000	1.212
River lamprey	1.000	0.079
Sea trout	1.000	1.734
Atlantic salmon	1.000	3.684

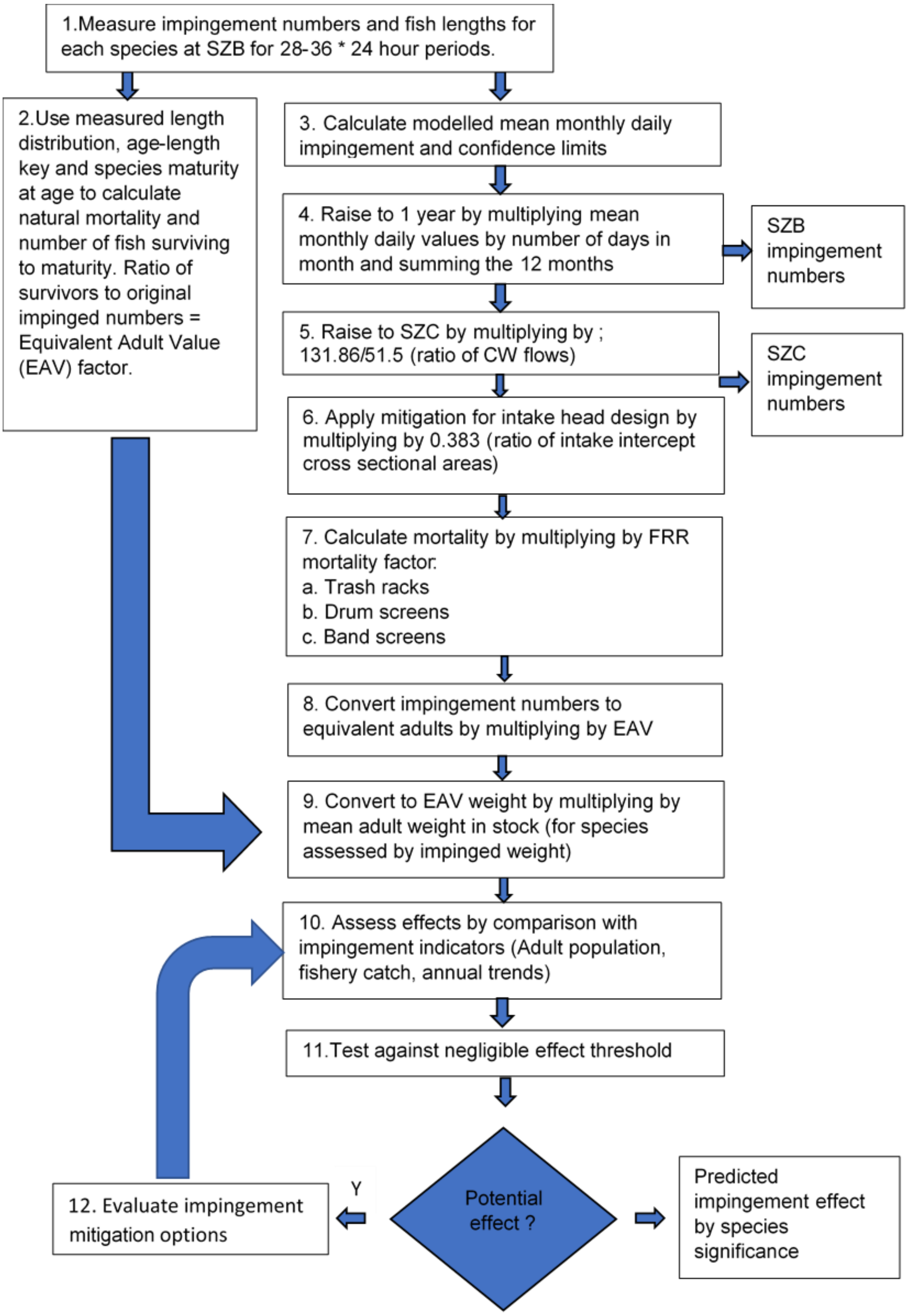
Table 22.110: Summary of ICES relevant stock units, where defined, for key taxa (see Appendix 22I for further details).

Species (common name).	Stock Unit.
Sole.	Subarea 4 (North Sea).
Whiting	Subarea 4, Division 7.d (North Sea, Eastern Channel).
Atlantic cod.	Subarea 4 and Subdivisions 7.d and 20 (North Sea, Eastern Channel, Skagerrak and Kattegat).
Dab.	Subarea 4 and Division 3.a (North Sea, Skagerrak and Kattegat).
European flounder.	Subarea 4 and 3.a (North Sea and Skagerrak and Kattegat).
European plaice.	Subarea 4 IV and Subdivision 20 (North Sea and Skagerrak).
European seabass.	Divisions 4.b-c, 7.a, and 7.d-h (Central and southern N Sea, Irish Sea, English Channel, Bristol Channel and Celtic Sea).
Thin-lipped grey mullet.	Stock unit not defined. Alternative sources for catches or landings were used; ICES' Official Nominal Catches 2006 – 2017, downloaded from the ICES website.
Sand goby.	Stock unit not defined. Population abundance from (Ref. 22.401).
Thornback ray.	Subarea 4 and Divisions 3.a and 7.d (North Sea, Skagerrak, Kattegat and eastern English Channel).
Tope.	North east Atlantic.
European sprat.	Subarea 4 (North Sea).
Atlantic herring.	Subarea 4 and Divisions 3.a and 7.d (North Sea, Skagerrak and Kattegat, Eastern Channel).
Anchovy.	Northerly anchovy unit.
Mackerel.	Subareas 1–8 and 14, and in Division 9.a (the Northeast Atlantic and adjacent waters).
Horse mackerel.	Divisions 3.a, 4.b,c and 7.d (North Sea).
European smelt.	Not defined. Includes the East Anglian coast and rivers on the European coast from the Elbe to the Scheldt.
European eel.	Silver eel biomass estimated from Anglian River Basin District (RBD).
Allis shad.	Garonne.
Twaite shad.	Stock unit not defined but includes the River Elbe and Belgian river Scheldt. A separate spawning population on the river Weser has not been included in the assessment.
Sea lamprey.	Not defined.
River lamprey.	Estimated numbers from Humber catchment.
Sea trout.	Not defined. EA catch numbers used.
Atlantic salmon.	Working Group on North Atlantic Salmon.

22.8.541 The full process for determining impingement estimates is illustrated in **Plate 22.6**.

22.8.542 To allow transparency of the predicted effectiveness of embedded mitigation predictions of impingement losses are presented as two assessments: one assessment without mitigation, and one assessment with full mitigation (FRR system, low-velocity side-entry intake heads). For further reference, **Appendix 22I** of this volume, provides assessment tables for each individual mitigation step. The relative effectiveness of each individual mitigation measure is given, in terms of numbers/weight and losses relative to relevant stock, as provided in **Table 22.114** and **Table 22.115**.

Plate 22.6: The impingement assessment process.



Impingement losses with embedded mitigation

22.8.543 This assessment includes the embedded mitigation of the FRR system and low-velocity side-entry (LVSE) intake heads.

22.8.544 Well-designed FRR systems have been reported to achieve 80−100% survival rates for robust epibenthic species, such as plaice and flounder, and moderate rates (~50−60%) for demersal species such as the robust gadoids (e.g. cod), provided in **Appendix 22I** of this volume. Conservative FRR survival rate for demersal fish like seabass, is reported in the range of 50-80% (Ref. 22.15). However, survival rates for delicate pelagic species such as herring, sprat and shad are usually low (<10%) (Ref. 22.15).

22.8.545 The conservative FRR recovery rates given in the EA science report (Ref. 22.15) have been used as the basis for FRR survival rates, provided in **Appendix 22I** of this volume. However, the final estimates of FRR survival have been modified to account for the location and station design of the proposed development. The FRR system would discharge inside the Sizewell-Dunwich Bank and there is potential for fish discharged from the FRR to be subsequently taken up by the Sizewell B intake. Particle tracking modelling has shown that the risk of re-impingement is negligible with the proposed easterly location resulting is less than 1% re-impingement (Ref. 22.14). Whilst this is a very minor additional impact it has been assumed that any fish re-impinged by Sizewell B would incur 100% mortality during passage through Sizewell B. As such, a minor additional mortality term has been applied for the proposed development to compensate for re-impingement potential, provided in **Appendix 22I** of this volume.

22.8.546 In addition to using drum screens for the main cooling water flow, the proposed development will be equipped with band screens to protect the essential and auxiliary cooling water system. The normal operating mode of such band screens is to be stationary and to only rotate intermittently at six hourly intervals unless significant clogging occurs. However, a very slow ('creep') mode would be employed to provide low velocity continuous operation.

22.8.547 As a conservative estimate, it has been assumed that the same FRR survival estimates from the HPC band screens are applicable. This is that the fish survival percentages for epibenthic species would be the same for drum screen and band screen FRR systems, but the survival of demersal and pelagic species in the band screens will be 0%.

22.8.548 LVSE intake heads will be fitted approximately 3 km from shore. The proposed intake heads will be capped structures with the intake surfaces orthogonal to the direction of the tidal flows. This design is calculated to reduce the cross-sectional area available to intercept any fish being transported in the tidal flows. The reduction in cross-sectional area and the low intake velocity is expected to reduce the number of fish abstracted per cumec of water compared with Sizewell B, provided in **Appendix 22I** of this volume. Modelling indicates that the proposed development will abstract, per cumec, 38% of the fish abstracted by Sizewell B, because of the intake head design (Ref. 22.24).

Gelatinous zooplankton and fish inundations on FRR survival

22.8.549 There is potential for overloading of the FRR system by dead fish that do not survive the recovery process (mostly pelagic fish such as sprat and herring) causing fatal oxygen depletion in parts of the system where fish densities are the highest (the drum and band screen buckets). The drum screens would rotate at a normal rate of 2.5m min^{-1}, but during periods of heavy load, this can be increased to 10m min^{-1} and then 20m min^{-1}. Similarly, the band screens would be designed to achieve a significant increase in filtration capacity by increasing the rotation rate from the normal 'creep' speed to fast.

22.8.550 At such speeds, any dead fish would be quickly moved through the system and discharged though the FRR outfall. The risk to fish survival from dead fish in the fish buckets is, therefore, expected to be negligible, as provided in **Appendix 22I** of this volume.

22.8.551 There is the potential for clogging of FRR systems during ctenophore blooms. Ctenophores are present at Sizewell year-round, but only occur in dense blooms in summer (typically in June). Following assessment of ctenophore impingement at Sizewell B, a 10mm mesh is proposed to be fitted at Sizewell C. Consequently, most abstracted ctenophores will be entrained rather than impinged. There have not been any shutdowns at Sizewell B which also uses 10mm mesh filtration due to gelatinous species. The risk of clogging of the FRR by ctenophores is expected to be minimal, as provided in **Appendix 22I** of this volume.

22.8.552 The potential of reduced fish survival in the FRR due to ctenophore blooms has also been assessed. Data from impingement studies at Sizewell B show that the weight of fish impinged during summer ctenophore blooms is extremely small (in some cases ctenophores constituted 100 % of the weight of material passing through the cooling water system). Smaller peaks in ctenophore abundance occur at other times of the year, but the additional biomass is much smaller than the maximum fish biomass that the FRR system can handle with negligible risk to fish survival. The risk to fish survival from the abundance of ctenophores in the fish buckets is, therefore, expected to be negligible, as provided in **Appendix 22I** of this volume.

Assessment of impingement losses

22.8.553 The impingement predictions without mitigation, for the 24 key taxa, are shown in **Table 22.111**.

22.8.554 The impingement predictions with full mitigation (FRR system and LVSE intake heads), for the 24 key taxa, are shown in **Table 22.112**.

22.8.555 Impingement predictions corrected for seabass distribution within the Greater Sizewell Bay and contexutilised for thin lipped grey mullet against an estimated SSB are provided in **Table 22.113**.

22.8.556 The impingement predictions, with species-specific effectiveness of different embedded mitigation measures, are shown in **Table 22.114**. The LVSE intake head has a 61.7% effectiveness in relation to unmitigated losses, across all key taxa (the LVSE is predicted to abstract 0.383 per cumec of the fish that the Sizewell B intake abstracts).

22.8.557 The effectiveness of the FRR system is determined by FRR survival and by the proportion of each species that will pass through the trash racks. The FRR system has a 0% effectiveness in relation to unmitigated losses of pelagic key taxa, including clupeids, mackerel, and smelt as well as demersal taxa (sea trout). The effectiveness of the FRR system increases, in the range of 40%-46%, for epibenthic taxa (dab) and several demersal taxa i.e. seabass, thin-lipped grey mullet, whiting and cod). FRR effectiveness is highest (range of 77%-80%) for key epibenthic taxa i.e. sand goby, sole, flounder, plaice, tope, thornback ray, sea and river lamprey, and European eel.

Table 22.111: Annual mean impingement predictions with no mitigation. Losses have been converted to adult equivalent value (EAV) numbers and weights (t) and calculated as a percentage of the relevant mean stock SSB (t) or mean international landings (t) where SSB information is not available. Species where the impingement weight exceed 1% of the relevant stock comparator are shaded in red. Values in red font are estimates of the population numbers (sand goby) or reported catch numbers (salmon and sea trout).

Species	Mean prediction.	EAV number.	EAV weight (t).	Mean SSB (t).	% of SSB	Mean landings (t).	% of landings
Sprat	7,125,393	5,352,978	56.23	220,757	0.03	151,322	0.04
Herring	2,555,783	1,827,944	344.87	2,198,449	0.02	400,244	0.09
Whiting	1,865,492	664,261	189.86	151,881	0.13	17,570	1.08
Seabass	575,367	128,861	197.26	14,897	1.32 [56]	3,051	6.47
Sand goby.	381,612	381,612	0.73	205,882,353	0.19	NA	NA
Sole	250,059	53,233	11.40	43,770	0.03	12,800	0.09
Dab	148,921	66,211	2.70	NA	NA	6,135	0.04
Anchovy	73,865	71,952	1.49	NA	NA	1,625	0.09
Thin-lipped grey mullet.	67,684	5,642	2.93	NA	NA	120	2.45
Flounder	38,180	17,631	1.44	NA	NA	2,309	0.06
Plaice	25,288	8,734	2.15	690,912	0.00	80,367	0.00
Smelt	23,863	18,170	0.30	105,733,825	0.02	8	3.56

[56] Seabass are not uniformly distributed across the site with evidence demonstrating that juvenile seabass are attracted to the warm water effluents of Sizewell B in Winter. Accounting for the significantly greater distribution of seabass in the inshore waters away from the Sizewell C intakes (Ref. 22.402), impingement predictions reduce to **12,886** individuals (EAV number) or **0.13% of SSB**, provided in **Appendix 22I** of this volume.

Species	Mean prediction.	EAV number.	EAV weight (t).	Mean SSB (t).	% of SSB	Mean landings (t).	% of landings
Cod	16,845	6,049	15.74	103,025	0.02	34,701	0.05
Thornback ray.	10,802	2,082	6.65	NA	NA	1,573	0.42
River lamprey.	6,720	6,720	0.53	62	0.86	1	47.65
Eel	4,516	4,516	1.49	79	1.89	14	10.70
Twaite shad.	3,601	3,601	1.13	7,519,986	0.05	1	84.60
Horse mackerel.	4,077	4,077	0.57	NA	NA	21,442	0.00
Mackerel	628	628	0.20	3,888,854	0.00	1,026,828	0.00
Tope	64	64	0.44	NA	NA	498	0.09
Sea trout.	10	10	0.02	NA	NA	39,795	0.02
Allis shad.	5	5	0.00	27,397	0.018	0	1.79
Sea lamprey.	5	5	0.01	NA	NA	NA	NA
Salmon	0	0	0.00	NA	NA	38,456	0.00

Table 22.112: Annual mean Sizewell C predictions of impingement for the 24 key species assuming full mitigation (FRR and LVSE intake heads). Losses have been converted to adult equivalent value (EAV) numbers and weights (t) and calculated as a percentage of the relevant mean stock SSB (t) or mean international landings (t) where SSB information is not available. Values in red font are estimates of the population numbers (sand goby) or reported catch numbers (salmon and sea trout).

Species	Mean Sizewell C prediction.	Sizewell C prediction after intake head adjustment.	FRR mortality.	EAV number.	EAV weight (t).	mean SSB (t).	% of SSB	Mean landings (t).	% of landings
Sprat	7,125,393	2,729,025	2,729,025	2,050,190	21.53	220,757	0.01	151,322	0.01
Herring	2,555,783	978,865	978,865	700,103	132.08	2,198,449	0.01	400,244	0.03
Whiting	1,865,492	714,484	393,295	140,044	40.03	151,881	0.03	17,570	0.23
Seabass	575,367	220,366	121,326	27,172	41.60	14,897	0.28 [57]	3,051	1.36
Sand goby.	381,612	146,157	30,108	30,108	0.06	205,882,353	0.01	NA	NA
Sole	250,059	95,773	19,729	4,200	0.90	43,770	0.00	12,800	0.01
Dab	148,921	57,037	30,715	13,656	0.56	NA	NA	6,135	0.01
Anchovy	73,865	28,290	28,290	27,558	0.57	NA	NA	1,625	0.04
Thin-lipped grey mullet.	67,684	25,923	14,273	1,190	0.62	NA	NA	120	0.52

[57] Seabass are not uniformly distributed across the site (Ref. 22.402). **Table 22.113** presents impingement predictions accounting for the significantly greater distribution of seabass in the inshore waters away from the Sizewell C intakes, further details are provided in **Appendix 22I** of this volume.

Species	Mean Sizewell C prediction.	Sizewell C prediction after intake head adjustment.	FRR mortality.	EAV number.	EAV weight (t).	mean SSB (t).	% of SSB	Mean landings (t).	% of landings
Flounder	38,180	14,623	3,377	1,559	0.13	NA	NA	2,309	0.01
Plaice	25,288	9,685	1,995	689	0.17	690,912	0.00	80,367	0.00
Smelt	23,863	9,139	9,139	6,959	0.12	105,733,825	0.01	8	1.36
Cod	16,845	6,451	3,884	1,395	3.63	103,025	0.00	34,701	0.01
Thornback ray.	10,802	4,137	852	164	0.52	NA	NA	1,573	0.03
River lamprey.	6,720	2,574	530	530	0.04	62	0.07	1	3.76
Eel	4,516	1,730	356	356	0.12	79	0.15	14	0.84
Twaite shad.	3,601	1,379	1,379	1,379	0.43	7,519,986	0.02	1	32.40
Horse mackerel.	4,077	1,561	1,561	1,561	0.22	NA	NA	21,442	0.00
Mackerel	628	241	241	241	0.08	3,888,854	0.00	1,026,828	0.00
Tope	64	24	5	5	0.03	NA	NA	498	0.01
Sea trout.	10	4	4	4	0.01	NA	NA	39,795	0.01
Allis shad.	5	2	2	2	0.00	27,397	0.01	0	0.68
Sea lamprey.	5	2	0	0	0.00	NA	NA	NA	NA
Salmon	0	0	0	0	0.00	NA	NA	38,456	0.00

Table 22.113: Annual mean Sizewell C predictions of impingement for seabass and thin lipped grey mullet assuming full mitigation (FRR and LVSE intake heads). Losses have been converted to adult equivalent value (EAV) numbers and weights (t) and calculated as a percentage of the relevant mean stock SSB (t) or mean international landings (t) where SSB information is not available. Seabass estimates account for differences in distribution within the GSB. Grey mullet estimates apply a calculated SSB. Further details provided in Appendix 22I of this volume.

Species	Mean Sizewell C prediction.	Sizewell C prediction after intake head adjustment.	FRR mortality.	EAV number.	EAV weight (t).	mean SSB (t).	% of SSB	Mean landings (t).	% of landings
European Seabass[58].	57,537	22,037	12,133	2,717	4.16	14,897	0.03	3,051	0.14
Thin lipped grey mullet[59]	67,684	25,923	14,273	1,190	0.62	600	0.10	120	0.52

[58] Seabass are not uniformly distributed across the site with evidence suggesting juvenile seabass are attracted to the warm water effluents of Sizewell B in Winter. Sampling was undertaken inside and outside of the Sizewell-Dunwich Bank, and close to and distant from the current and proposed intake/outfall locations of Sizewell B and C, respectively. The survey identified that 95% of seabass were recorded inside the Sizewell-Dunwich Bank. The assessment accounts for the reduction in impingement due to the offshore location of the intake headworks. Further details are provided in **Appendix 22I** of this volume.

[59] There is not a directed commercial fishery for grey mullet in the southern North Sea and therefore the landings data (120 t) are considered highly likely to represent less than 20% SSB. Therefore, the predicted impingement at 0.52% of landings is equivalent to approximately 0.1% of a conservative SSB estimate. Further details are provided in **Appendix 22I** of this volume.

Table 22.114: Species-specific effectiveness of different embedded mitigation measures. Comparison shows annual mean Sizewell C predictions of impingement for the 24 key species expressed in adult equivalent value (EAV) numbers and weights (t). Effectiveness is presented in relation to unmitigated losses.

Species	Unmitigated		LVSE mitigation only.			FRR mitigation only.			Full mitigation (LVSE and FRR).		
	EAV number.	EAV weight (t).	EAV number.	EAV weight (t).	% effect-iveness	EAV number.	EAV weight (t).	% effect-iveness	EAV number.	EAV weight (t).	% effect-iveness
Sprat	5,352,978	56.23	2,050,190	21.53	61.7%	5,352,978	56.23	0.0%	2,050,190	21.53	61.7%
Herring	1,827,944	344.87	700,103	132.08	61.7%	1,827,944	344.87	0.0%	700,103	132.08	61.7%
Whiting	664,261	189.86	254,412	72.72	61.7%	365,649	104.51	45.0%	140,044	40.03	78.9%
Seabass	128,861	197.26	49,354	75.55	61.7%	70,946	108.61	44.9%	27,172	41.60	78.9%
Sand goby.	381,612	0.73	146,157	0.28	61.7%	78,612	0.15	79.4%	30,108	0.06	92.1%
Sole	53,233	11.40	20,388	4.36	61.7%	10,966	2.35	79.4%	4,200	0.90	92.1%
Dab	66,211	2.70	25,359	1.03	61.7%	35,656	1.46	46.1%	13,656	0.56	79.4%
Anchovy	71,952	1.49	27,558	0.57	61.7%	71,952	1.49	0.0%	27,558	0.57	61.7%
Thin-lipped grey mullet.	5,642	2.93	2,161	1.12	61.7%	3,106	1.62	44.9%	1,190	0.62	78.9%
Flounder	17,631	1.44	6,753	0.55	61.7%	4,071	0.33	76.9%	1,559	0.13	91.2%
Plaice	8,734	2.15	3,345	0.82	61.7%	1,799	0.44	79.4%	689	0.17	92.1%
Smelt	18,170	0.30	6,959	0.12	61.7%	18,170	0.30	0.0%	6,959	0.12	61.7%
Cod	6,049	15.74	2,317	6.03	61.7%	3,642	9.48	39.8%	1,395	3.63	76.9%

Species	Unmitigated		LVSE mitigation only.			FRR mitigation only.			Full mitigation (LVSE and FRR).		
	EAV number.	EAV weight (t).	EAV number.	EAV weight (t).	% effect-iveness	EAV number.	EAV weight (t).	% effect-iveness	EAV number.	EAV weight (t).	% effect-iveness
Thornback ray.	2,082	6.65	797	2.55	61.7%	429	1.37	79.4%	164	0.52	92.1%
River lamprey.	6,720	0.53	2,574	0.20	61.7%	1,384	0.11	79.4%	530	0.04	92.1%
Eel	4,516	1.49	1,730	0.57	61.7%	930	0.31	79.4%	356	0.12	92.1%
Twaite shad.	3,601	1.13	1,379	0.43	61.7%	3,601	1.13	0.0%	1,379	0.43	61.7%
Horse mackerel.	4,077	0.57	1,561	0.22	61.7%	4,077	0.57	0.0%	1,561	0.22	61.7%
Mackerel	628	0.20	241	0.08	61.7%	628	0.20	0.0%	241	0.08	61.6%
Tope	64	0.44	24	0.17	61.7%	13	0.09	79.7%	5	0.03	92.2%
Sea trout.	10	0.02	4	0.01	61.7%	10	0.02	0.0%	4	0.01	60.0%
Allis shad.	5	0.00	2	0.00	61.7%	5	0.00	0.0%	2	0.00	60.0%
Sea lamprey.	5	0.01	2	0.00	61.7%	1	0.00	80.0%	0	0.00	100.0%
Salmon	0	0.00	0	0.00	61.7%	0	0.00	NA	0	0.00	NA

Table 22.115: Comparison of impingement losses for different mitigation measures in relation to the relevant mean stock SSB (t) or mean international landings (t) where SSB information is not available. Species where the impingement weight exceed 1% of the relevant stock comparator are shaded in red. Values in red font are estimates of the population numbers (sand goby) or reported catch numbers (salmon and sea trout).

Species	Mean SSB (t).	Mean landings (t).	Unmitigated		LVSE mitigation only.		FRR mitigation only.		Full mitigation (LVSE and FRR).	
			% of SSB	% of landings	% of SSB	% of landings	% of SSB	% of landings	% of SSB	% of landings
Sprat	220,757	151,322	0.03	0.04	0.01	0.01	0.03	0.04	0.01	0.01
Herring	2,198,449	400,244	0.02	0.09	0.01	0.03	0.02	0.09	0.01	0.03
Whiting	151,881	17,570	0.13	1.08	0.05	0.41	0.07	0.59	0.03	0.23
Seabass	14,897	3,051	1.32	6.47	0.51	2.48	0.73	3.56	0.28	1.36
Sand goby.	205,882,353	NA	0.19	NA	0.07	NA	0.04	NA	0.01	NA
Sole	43,770	12,800	0.03	0.09	0.01	0.03	0.01	0.02	0.00	0.01
Dab	NA	6,135	NA	0.04	NA	0.02	NA	0.02	NA	0.01
Anchovy	NA	1,625	NA	0.09	NA	0.04	NA	0.09	NA	0.04
Thin-lipped grey mullet.	NA	120	NA	2.45	NA	0.94	NA	1.35	NA	0.52
Flounder	NA	2,309	NA	0.06	NA	0.02	NA	0.01	NA	0.01
Plaice	690,912	80,367	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Smelt	105,733,825	8	0.02	3.56	0.01	1.36	0.02	3.56	0.01	1.36

Species	Mean SSB (t).	Mean landings (t).	Unmitigated		LVSE mitigation only.		FRR mitigation only.		Full mitigation (LVSE and FRR).	
			% of SSB	% of landings	% of SSB	% of landings	% of SSB	% of landings	% of SSB	% of landings
Cod	103,025	34,701	0.02	0.05	0.01	0.02	0.01	0.03	0.00	0.01
Thornback ray.	NA	1,573	NA	0.42	NA	0.16	NA	0.09	NA	0.03
River lamprey.	62	1	0.86	47.65	0.33	18.25	0.18	9.82	0.07	3.76
Eel	79	14	1.89	10.70	0.72	4.10	0.39	2.20	0.15	0.84
Twaite shad.	7,519,986	1	0.05	84.60	0.02	32.40	0.05	84.60	0.02	32.40
Horse mackerel.	NA	21,442	NA	0.00	NA	0.00	NA	0.00	NA	0.00
Mackerel	3,888,854	1,026,828	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tope	NA	498	NA	0.09	NA	0.03	NA	0.02	NA	0.01
Sea trout.	NA	39,795	NA	0.02	NA	0.01	NA	0.02	NA	0.01
Allis shad.	27,397	0	0.018	1.79	0.01	0.68	0.02	1.79	0.01	0.68
Sea lamprey.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Salmon	NA	38,456	NA	0.00	NA	0.00	NA	0.00	NA	0.00

Sensitivity assessments of effects at the sea-area or regional stock/population level: impingement (without and with embedded mitigation)

Dover sole without mitigation

22.8.558 In the absence of mitigation, the proposed development is predicted to result in the equivalent loss of ca. 53,250 adult fish per annum representing 0.03% of the SSB, provided in **Table 22.111**. Such losses would have a negligible effect on the stock viability. The sensitivity of Dover sole to impingement is predicted to be low.

22.8.559 Reflecting the long-term impact of the proposed development and the mortality of impinged individuals, minor adverse effects on Dover sole are predicted due to impingement. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Dover sole with full mitigation

22.8.560 With full mitigation, the estimated equivalent loss of adult fish reduces to ca. 4,200 per annum representing 0.00% (<0.01%) of the SSB, and 0.01% of fishery landings, provided in **Table 22.112**. Such losses would have a negligible effect on the stock viability. The sensitivity of Dover sole to impingement with full mitigation is place is predicted to be not sensitive.

22.8.561 Negligible effects on Dover sole are predicted due to impingement with full mitigation in place. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Whiting without mitigation

22.8.562 Without mitigation the proposed development is predicted to result in the equivalent loss of ca. 664,250 adult fish per annum, accounting for 0.13% of the whiting SSB, provided in **Table 22.111**. Such losses would have a negligible effect on the stock viability. The sensitivity of whiting to impingement is predicted to be low.

22.8.563 Minor adverse effects on whiting are predicted due to impingement. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Whiting with full mitigation

22.8.564 With full mitigation in place, the estimated equivalent loss of adult fish reduces to 140,044 per annum representing 0.03% of the SSB, provided in

Table 22.112. Such losses would have a negligible effect on the stock viability. The sensitivity of whiting to impingement with full mitigation is place is predicted to be low.

22.8.565 Minor adverse effects on whiting are predicted due to impingement with the full mitigation in place. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Atlantic cod without mitigation

22.8.566 Without mitigation the proposed development is predicted to result in the equivalent loss of ca.6,050 adult fish per annum representing 0.02% of the SSB, provided in **Table 22.111**. Such losses would have a negligible effect on the stock viability. The sensitivity of Atlantic cod to impingement is predicted to be low.

22.8.567 Reflecting the long-term impact of the proposed development and mortality of impinged individuals, minor adverse effects on cod are predicted due to impingement. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Atlantic cod with full mitigation

22.8.568 With full mitigation in place, the estimated equivalent loss of adult fish reduces to approximately 1,395 per annum representing 0.00% (<0.01%) of the SSB, provided in **Table 22.112**. Such losses would have a negligible effect on the stock viability. The sensitivity of cod to impingement with full mitigation is place is predicted to be not sensitive.

22.8.569 Negligible effects on cod are predicted due to impingement with full mitigation in place. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

European plaice without mitigation

22.8.570 Without mitigation the proposed development is predicted to impinge less than 0.01% of the plaice SSB, provided in **Table 22.111**. The sensitivity of plaice to impingement is predicted to be not sensitive. The impact of impingement from cooling water abstraction is predicted to have a negligible effect on plaice. Effects are **not significant** at the sea area and regional stock/population levels.

European plaice with full mitigation

22.8.571 Adult losses are predicted to be 689 fish per annum representing less than 0.01% of the SSB, provided in **Table 22.112**. The sensitivity of plaice to impingement with full mitigation is predicted to be not sensitive. The impact of impingement from cooling water abstraction with full mitigation in place is predicted to have a negligible effect on plaice. Effects are **not significant** at the sea area and regional stock/population levels.

Dab without mitigation

22.8.572 Without mitigation the proposed development is predicted to impinge 0.04% of the dab international landings, provided in **Table 22.111**. The sensitivity of dab to impingement is predicted to be not sensitive. The impact of impingement from cooling water abstraction is predicted to have a negligible effect on dab. Effects are **not significant** at the sea area and regional stock/population levels.

Dab with full mitigation

22.8.573 With full mitigation, adult losses are predicted to be 13,656 fish per annum representing less than 0.01% of international landings, provided in **Table 22.112**. The sensitivity of dab to impingement with full mitigation is predicted to be not sensitive. The impact of impingement from cooling water abstraction with full mitigation is predicted to have a negligible effect on dab. Effects are **not significant** at the sea area and regional stock/population levels.

European flounder without mitigation

22.8.574 Without mitigation the proposed development is predicted to impinge 0.06% of the flounder international landings, provided in **Table 22.111**. The sensitivity of flounder to impingement is predicted to be not sensitive. The impact of impingement from cooling water abstraction is predicted to have a negligible effect on flounder. The predicted impingement losses are a negligible proportion of the stock (<1.0% threshold). Effects are **not significant** at the sea area and regional stock/population levels.

European flounder with full mitigation

22.8.575 Adult losses are predicted to be 1,559 fish per annum representing 0.01% of international landings, provided in **Table 22.112**. The sensitivity of flounder to impingement with full mitigation is predicted to be not sensitive. The impact of impingement from cooling water abstraction with full mitigation is predicted to have a negligible effect on flounder. Effects are **not significant** at the sea area and regional stock/population levels.

European seabass without mitigation

22.8.576 Without impingement mitigation, losses of seabass are predicted to equated to 128,861 adults (EAV) per annum representing 1.32% of the SSB, provided in **Table 22.111**.

22.8.577 Unmitigated losses exceed the effect threshold. However, seabass are not uniformly distributed across the site with evidence suggesting juvenile seabass are attracted to the warm water effluents of Sizewell B in Winter. In February 2016, a survey was undertaken to investigate the distribution of seabass in the GSB area. Sampling was undertaken inside and outside of the Sizewell-Dunwich Bank, and close to and distant from the current and proposed intake/outfall locations of Sizewell B and C, respectively. The survey identified that 95% of seabass were recorded inside the Sizewell-Dunwich Bank (Ref. 22.402). Once operational, the proposed development would generate a thermal plume offshore, however, in the deeper water the thermally buoyant plume has reduced interaction with the seabed but would enhance the warming effect within the Sizewell-Dunwich Bank. Therefore, should the distribution of seabass remain similar to currently observed impingement predictions represent a marked overestimate. Accounting for the distribution of seabass, unmitigated losses are predicted to account for 12,886 fish or 0.13% of SSB. Further details are provided in **Appendix 22I** of this volume.

22.8.578 The sensitivity of seabass to impingement is predicted to be low.

22.8.579 Minor adverse effects on seabass are predicted due to impingement. Predicted losses are within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

European seabass with full mitigation

22.8.580 With the full mitigation in place the estimated equivalent loss of adult fish reduces to approximately 27,172 per annum, representing 0.28% of the SSB, provided in **Table 22.112**.

22.8.581 Accounting for the greater distribution of seabass in the inshore waters away from the Sizewell C intakes (Ref. 22.402) impingement predictions are estimated to be as low as 2,717 individuals or 0.03% of SSB (**Table 22.113)**, further details provided in **Appendix 22I** of this volume. The sensitivity of seabass to impingement with full mitigation is place is predicted to be low.

22.8.582 Minor adverse effects on seabass are predicted due to impingement with the full mitigation in place. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Thin-lipped grey mullet without mitigation

22.8.583 The 1% threshold of fishery landings is exceeded for thin-lipped grey mullet, provided in **Table 22.111**; but as this stock is unexploited a 10% threshold is more appropriate. The limited landings data that are available are considered to represent a small fraction of the SSB. The resultant predicted impingement effects are, therefore, likely to be grossly overestimated. The sensitivity of thin-lipped grey mullet to impingement is predicted to be not sensitive. The impact of impingement from cooling water abstraction is predicted to have a negligible effect on thin-lipped grey mullet. Effects are **not significant** at the sea area and regional stock/population levels.

Thin-lipped grey mullet with full mitigation

22.8.584 Adult losses are predicted to be approximately 1,190 fish per annum representing 0.52% of international landings, provided in **Table 22.112**. The lack of a directed fishery means there is limited landings data. For an undirected fishery it is highly unlikely that the landings represent more than 20% of the SSB. Therefore, the predicted loss of mullet relative to an estimated SSB is predicted to be 0.1%, below the 1% threshold and negligible for stock viability (**Table 22.113**), further details provided in **Appendix 22I** of this volume. For such a species without a directed fishery, a 1% threshold is overly precautionary, and a 10% threshold is indicated by proven international fisheries assessment methodology, further reducing the significance of the predicted impingement effect. Given the small number of fish impinged each year effects on the SSB are considered negligible. The sensitivity of grey mullet to impingement with full mitigation is predicted to be not sensitive.

22.8.585 The impact of impingement from cooling water abstraction with full mitigation is predicted to have a negligible effect on mullet. Effects are **not significant** at the sea area and regional stock/population levels.

Sand goby without mitigation

22.8.586 Without mitigation the proposed development is predicted to impinge approximately 0.19% of the sand goby population estimate annually, provided in **Table 22.111**. Such losses would have a negligible effect on the stock viability. Furthermore, the population size for sand goby used in the assessment is likely an underestimate and so the assessment is highly precautionary. Sand gobies are a short-lived species, whilst adults have relatively restricted ranges, losses would be replaced by recruitment of ichthyoplankton. The sensitivity of sand gobies to impingement is predicted to be low.

22.8.587 Minor adverse effects on sand goby are predicted due to impingement. Effects are **not significant** at the sea area and regional stock/population levels.

Sand goby with full mitigation

22.8.588 With full mitigation in place, the estimated equivalent loss of adult fish reduces to approximately 30,108 per annum, representing 0.01% of the population estimate, provided in **Table 22.112**. Such losses would have a negligible effect on the stock viability. The sensitivity of sand gobies to impingement with full mitigation is place is predicted to be low.

22.8.589 Minor adverse effects on sand goby is predicted due to impingement with the full mitigation in place. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Thornback ray without mitigation

22.8.590 The impact of impingement from cooling water abstraction is predicted to result in the loss of 2,082 fish or 0.42% of the fishery landings being lost per annum in the absence of mitigation, provided in **Table 22.111**. The sensitivity of thornback ray to impingement is predicted to be low. Minor adverse effects on thornback ray are predicted. Effects are **not significant** at the sea area and regional stock/population levels.

Thornback ray with full mitigation

22.8.591 With full mitigations, adult losses are predicted to be 164 fish per annum representing 0.03% of international landings. The sensitivity of thornback ray to impingement with full mitigation is predicted to be not sensitive. The impact of impingement from cooling water abstraction with full mitigation is predicted to have a negligible effect on thornback ray. Effects are **not significant** at the sea area and regional stock/population levels.

Tope without mitigation

22.8.592 The sensitivity of tope to impingement is predicted to be not sensitive. The impact of impingement from cooling water abstraction is predicted to have a negligible effect on tope at 64 individuals per annum, as provided in **Table 22.111**. The predicted impingement losses are a negligible proportion of the estimated population and only 0.09% of fishery landings. Effects are **not significant** at the sea area and regional stock/population levels.

Tope with full mitigation

22.8.593 The sensitivity of tope to impingement with full mitigation is predicted to be not sensitive. Adult losses are predicted to be 5 fish per annum representing 0.01% of international landings, provided in **Table 22.112**. The impact of impingement from cooling water abstraction with full mitigation is predicted to have a negligible effect on tope. Effects are **not significant** at the sea area and regional stock/population levels.

European sprat without mitigation

22.8.594 Without mitigation the proposed development is predicted to result in the equivalent loss of over 5.35 million adult fish per annum representing 0.03% of the SSB, provided in **Table 22.111**. The sensitivity of sprat to impingement is predicted to be low.

22.8.595 Minor adverse effects on sprat are predicted due to impingement. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

European sprat with full mitigation

22.8.596 Adult losses are predicted to 2,050,190 fish per annum representing 0.01% of SSB, provided in **Table 22.112**. Such losses would have a negligible effect on the stock viability. The sensitivity of sprat to impingement with full mitigation is predicted to be low.

22.8.597 Minor adverse effects on sprat are predicted due to impingement with the full mitigation in place. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Atlantic herring without mitigation

22.8.598 Without mitigation the proposed development is predicted to result in the equivalent loss of 1.83 million adult fish per annum representing 0.02% of the SSB, provided in **Table 22.111**. Such losses would have a negligible effect on the stock viability. The sensitivity of Atlantic herring to impingement is predicted to be low.

22.8.599 Minor adverse effects on herring are predicted due to impingement. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Atlantic herring with full mitigation

22.8.600 Adult losses are predicted to 700,103 fish per annum representing 0.01% of SSB, provided in **Table 22.112**. The sensitivity of herring to impingement with full mitigation is predicted to be low.

22.8.601 Minor adverse effects on herring are predicted due to impingement with the full mitigation in place. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Anchovy without mitigation

22.8.602 Without mitigation the proposed development is predicted to result in the equivalent loss of 72,000 adult fish per annum representing 0.09% of the landings, provided in **Table 22.111**. Such losses would have a negligible effect on the stock viability. The sensitivity of anchovy to impingement is predicted to be low.

22.8.603 Minor adverse effects on anchovy are predicted due to impingement. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Anchovy with full mitigation

22.8.604 Adult losses are predicted to 27,558 fish per annum representing 0.04% of international landings, provided in **Table 22.112**. The sensitivity of anchovy to impingement with full mitigation is predicted to be low.

22.8.605 Minor adverse effects on anchovy are predicted due to impingement with the full mitigation in place. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Mackerel without mitigation

22.8.606 Without mitigation the proposed development is predicted to result in the equivalent loss of 628 adult fish per annum representing <0.01% of the SSB, provided in **Table 22.111**. Such losses would have a negligible effect on the stock viability. The sensitivity of mackerel to impingement is predicted to be not sensitive.

22.8.607 Negligible effects on mackerel are predicted due to impingement. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Mackerel with full mitigation

22.8.608 Adult losses are predicted to 241 fish per annum representing 0.00% of SSB, provided in **Table 22.112**. The sensitivity of mackerel to impingement with full mitigation is predicted to be not sensitive.

22.8.609 The impact of impingement from cooling water abstraction with full mitigation is predicted to have a negligible effect on mackerel. Effects are **not significant** at the sea area and regional stock/population levels.

Horse mackerel without mitigation

22.8.610 Without mitigation the proposed development is predicted to result in the equivalent loss of 4,100 adult fish per annum representing <0.01% of landings (**Table 22.111**). Such losses would have a negligible effect on the stock viability. The sensitivity of horse mackerel to impingement is predicted to be not sensitive.

22.8.611 Negligible effects on horse mackerel are predicted due to impingement. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Horse mackerel with full mitigation

22.8.612 Adult losses are predicted to 1,561 fish per annum representing 0.00% of international landings (**Table 22.112**). The sensitivity of horse mackerel to impingement with full mitigation is predicted to be not sensitive.

22.8.613 The impact of impingement from cooling water abstraction with full mitigation is predicted to have a negligible effect on horse mackerel. Effects are **not significant** at the sea area and regional stock/population levels.

European smelt without mitigation

22.8.614 Given the genetic information on the smelt at Sizewell, it is probable that the smelt impinged are from multiple locations on the east coast of the UK and from European estuaries including (but not limited to) the Scheldt (Belgium) and the Elbe in Germany, provided in **Appendix 22I** of this volume. Smelt are widely dispersed in the southern North Sea for summer feeding. As such the likelihood of their migration routes to freshwater rivers intersecting with the abstraction risk zones of either the Sizewell B or Sizewell C intakes is considered very low and there is no reason to consider that the species would be more at risk of impingement at either Sizewell B or Sizewell C.

22.8.615 Considering only UK populations and given the limited number of licences issued for commercial exploitation, the size of fishery landings will be a substantial underestimate of the stock size. Therefore, comparisons have been made against estimates of population size for the River Elbe. Between 2009 and 2017, an estimated annual average 105.7 million adult smelt passed through the River Elbe (Ref. 22.403). In the absence of mitigation, the losses of smelt by the proposed development represent 0.02% of these population numbers, provided in **Appendix 22I** of this volume.

22.8.616 The sensitivity of smelt to impingement is predicted to be low.

22.8.617 Minor adverse effects on smelt are predicted due to impingement without mitigation. Predicted losses are within levels of natural variability in population sizes. Effects are **not significant** at the sea area and regional stock/population levels.

European smelt with full mitigation

22.8.618 With full mitigation, predicted losses reduce to 0.01% of estimated population size for the River Elbe. The sensitivity of smelt to impingement with full mitigation is predicted to be low.

22.8.619 Minor adverse effects on smelt are predicted due to impingement with full mitigation. Predicted losses are within levels of natural variability in population sizes. Effects are **not significant** at the sea area and regional stock/population levels.

European eel without mitigation

22.8.620 Without mitigation the proposed development is predicted to result in the equivalent loss of 4,516 adult fish per annum representing 1.89% of the estimated silver eel biomass of the Anglian River Basin District (RBD)[60] (**Table 22.111**). The predicted impingement losses, without mitigation, exceed the 1% threshold of fishery landings. However, the estimated impingement loss for eels is considered to be overestimated as an EAV of 1 was used for this species. Samples of eels obtained from the Sizewell B site show that all eels impinged are yellow eels and therefore immature. An EAV of 1 will therefore result in an overestimate of the impingement losses. The sensitivity of European eel to impingement is predicted to be low.

22.8.621 Minor adverse effects on eel are precautionarily predicted due to impingement. Effects are **not significant** at the sea area and regional stock/population levels.

[60] 1% of the RBD SSB is a highly precautionary measure that may equate to approximately 0.005% SSB. Further details of eel population assessments are provided in **Appendix 22I.**

European eel with full mitigation

22.8.622 With the full mitigation in place the estimated equivalent loss of adult fish reduces to approximately 356 per annum (**Table 22.112**). The estimated 356 eels equate to 0.12t, equivalent to 0.15% of the estimated biomass (silver eel) of the Anglian RDB, provided in **Appendix 22I** of this volume. Such losses would have a negligible effect on the stock viability. The sensitivity of eel to impingement with full mitigation is place is predicted to be low.

22.8.623 Minor adverse effects on eel are predicted due to impingement with the full mitigation in place. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Allis shad without mitigation

22.8.624 A single Allis shad was recorded in the CIMP dataset in 2009 and is considered a straggler from the Garonne population (Ref. 22.403). The predicted unmitigated impingement of Allis shad is very low; 5 fish per annum (**Table 22.111**). The sensitivity of Allis shad to impingement is predicted to be not sensitive. Such losses would have a negligible effect on the stock viability.

22.8.625 Negligible effects on Allis shad are predicted due to impingement. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Allis shad with full mitigation

22.8.626 With the full mitigation in place the estimated equivalent loss of adult fish reduces to just 2 fish, representing 0.01% of the estimated population number (**Table 22.112**). Such losses would have a negligible effect on the stock viability. The sensitivity of Allis shad to impingement with full mitigation is place is predicted to be not sensitive.

22.8.627 Negligible effects on Allis shad are predicted due to impingement. Predicted losses are well within levels of natural variability in stock size. Effects are **not significant** at the sea area and regional stock/population levels.

Twaite shad without mitigation

22.8.628 There is currently no SSB for the North Sea twaite shad population and no directed fishery, so comparison with landings data does not provide a meaningful assessment. There are no spawning populations of twaite shad on the east coast of the UK, the only known spawning populations are in the Welsh Rivers and the River Severn network. Young from the west coast remain in the local area or move across to Ireland. It is therefore likely that the twaite shad found at Sizewell are from populations from European rivers.

22.8.629 Losses have been compared with the population estimates available from Spring monitoring surveys conducted on the Rivers Elbe and Scheldt (Ref. 22.403). Between 2009 and 2017, an average estimated 7.5 million adult twaite shad pass through these two river systems each year. In the absence of mitigation, the losses of twaite shad (3,601 fish) represent 0.05% of these population numbers (Ref. 22.403). The sensitivity of Twaite shad to impingement is predicted to be low.

22.8.630 Minor adverse effects on twaite shad are predicted due to impingement. Predicted losses are well within levels of natural variability in stock size. Effects are **not significant** at the sea area and regional stock/population levels.

Twaite shad with full mitigation

22.8.631 With the full mitigation in place the estimated equivalent loss of adult fish reduces to 1,379 fish, representing 0.02% of the population numbers (**Table 22.112**). Such losses would have a negligible effect on the stock viability. The sensitivity of twaite shad to impingement with full mitigation in place is predicted to be low.

22.8.632 Negligible effects on twaite shad are predicted due to impingement. Predicted losses are well within levels of natural variability in stock size. Effects are **not significant** at the sea area and regional stock/population levels.

Sea lamprey without mitigation

22.8.633 The predicted unmitigated impingement of sea lamprey is very low; 5 fish per annum (**Table 22.111**). Such losses would have a negligible effect on the stock viability. The sensitivity of sea lamprey to impingement is predicted to be not sensitive.

22.8.634 Negligible effects on sea lamprey are predicted due to impingement. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Sea lamprey with full mitigation

22.8.635 Adult losses are predicted to be two fish per annum with the FRR and <1 fish with the full mitigation (**Table 22.112**). The sensitivity of sea lamprey to impingement with full mitigation is predicted to be not sensitive.

22.8.636 The impact of impingement from cooling water abstraction with full mitigation is predicted to have a negligible effect on sea lamprey. Effects are **not significant** at the sea area and regional stock/population levels.

River lamprey without mitigation

22.8.637 Losses of river lampreys have been compared with the run size of adult fish returning to spawn in the Humber catchment area in 2019, provided in **Appendix 22I** of this volume. The predicted impingement losses, without mitigation (6,720 fish), represent 0.86% of the 62t of adults in the 2018 spawning run. The sensitivity of river lamprey to impingement is predicted to be low.

22.8.638 Minor adverse effects on river lamprey are predicted due to impingement with no mitigation. Effects are **not significant** at the sea area and regional stock/population levels.

River lamprey with full mitigation

22.8.639 Adult losses are predicted to be 530 fish per annum (**Table 22.112**), which is 0.07% of the 2018 spawning population estimate. The sensitivity of river lamprey to impingement with full mitigation is predicted to be not sensitive.

22.8.640 The impact of impingement from cooling water abstraction with full mitigation is predicted to have a negligible effect on river lamprey. Effects are **not significant** at the sea area and regional stock/population levels.

Atlantic salmon and sea trout without mitigation

22.8.641 No Atlantic salmon were recorded within the CIMP dataset 2008-2017. Therefore, salmon is not expected to be impinged. Just two sea trout were recorded in 2010 within the CIMP dataset. As such, a highly conservative assessment of impingement losses has been made.

22.8.642 The predicted unmitigated impingement of sea trout is very low; precautionarily assessed as 10 fish per annum (**Table 22.111**), which is 0.02% of the catch numbers for the English east coast. Such losses would have a negligible effect on the stock viability. The sensitivity of Atlantic salmon and sea trout to impingement is predicted to be not sensitive.

22.8.643 Negligible effects on salmonid species are predicted due to impingement. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Atlantic salmon and sea trout with full mitigation

22.8.644 Negligible effects on salmonid species are predicted due to impingement with full mitigation in place. Predicted losses are well within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Assessments of effects of localised effects: impingement

22.8.645 ICES (International Council for the Exploration of the Seas) derived SSB represents the international best practice approach for determining effects on a stock and is applied for fishing stock assessments at either a fleet or individual boat level are assessed. The potential for the proposed development to have local level effects has been raised during consultation. **Appendix 22I** of this volume, considers the potential for such local effects in relation to the occurrence of spatially distinct sub-stocks and local reductions in terms availability of fish as a prey item.

22.8.646 There is no conclusive evidence of local sub-stocks at Sizewell. The fish impinged reflect the seasonal migrations of fish into and out of the area. Impingement *per se* is not predicted to result in localised reductions in abundance of fish due to the open coastal situation of the proposed development. Fish mobility, tidal exchange and larval supply would act to dampen localised reductions in abundance. Therefore, on the open coastal waters at Sizewell, the proposed development would cause no discernible local effects on the local fish assemblage, provided in **Appendix 22I** of this volume.

22.8.647 The return of dead and moribund fish via the FRR system has the potential to locally increase abundance of some taxa with limited/no resistance to impingement pressures. This is considered further in the FRR assessment in **Section 22.8.d)iv** and in a food webs context in **Section 22.10**, both of this chapter. Fish that survive impingement may display behavioural responses leading to displacement although this may be influenced by the condition of the surviving fish and potentially, subsequent exposure to cooling water discharges. A minor adverse effect on the distribution of fish within the GSB is predicted. However, **no significant** reductions in prey availability for designated features or fish as fisheries resources are predicted.

Cooling water abstraction: Entrapment

22.8.648 Impingement and entrainment together are considered as a single entrapment impact for the proposed development. However, differences between the two datasets should be acknowledged. For impingement the dataset spans nine years, and the predictions are based on modelled mean monthly impingement values, using all year’s data. Impingement losses are considered against a mean SSB or landings value for the years 2009 – 2017 (the years of sampling). For entrainment, the predictions are based on a single year's sampling (2010), and the losses were compared against the SSB and landings data for that year, provided in **Appendix 22G** of this volume.

22.8.649 Entrapment has been estimated by summing the % losses of impingement and entrainment. A more direct comparison between individual sampling years cannot be made due to the nature of the datasets. However, with the exception of sand goby, the entrainment losses of key taxa are extremely low, and it would require annual changes in SSBs or landings of 2 or 3 orders of magnitude to significantly affect the combined total losses, provided in **Appendix 22I** of this volume. Such significant changes in SSB are not seen from year to year for those key taxa during the period 2009-2017, so the methodology is regarded as appropriate. For sand goby, the opposite is true in that impingement losses are at such a low level compared to the entrainment losses that it would require similarly large annual changes in population abundance to significantly affect the outcome.

22.8.650 Entrapment estimates have been made without mitigation (**Table 22.116**); and with full mitigation (**Table 22.117**).

Entrapment losses without mitigation

22.8.651 Results are similar to those obtained for impingement alone; without mitigation it is only seabass, thin-lipped grey mullet, and European eel that exceed the 1% threshold, as a result of impingement. These species are joined by the sand goby for combined entrapment (**Table 22.116**), coming from the entrainment losses.

Entrapment losses with embedded mitigation

22.8.652 With full mitigation, only sand goby out of the key taxa exceeds 1% of the stock comparator (**Table 22.117**). However, sand goby is an unexploited short-lived stock; therefore, the appropriate comparator for negligible effects is 10% of the SSB.

22.8.653 As a worst-case, Minor adverse effects on the key taxa are predicted due to entrapment (combined entrainment and impingement), with full mitigation in place. Predicted losses are within levels of natural variability in stock sizes. Effects are **not significant** at the sea area and regional stock/population levels.

Table 22.116: Annual mean Sizewell C entrapment predictions (impingement + entrainment) with no impingement mitigation. Corrections for seabass and thin-lipped grey mullet are incorporated into the assessment. For impingement, losses have been converted to adult equivalent value (EAV) numbers and weights (t) and calculated as a % of either the mean stock SSB (t) or mean international landings (t) for the period 2009-2017. For entrainment, the worst-case losses have been converted to EAV numbers and weight and calculated as a % of the SSB and landings in 2010 only. Species where the entrapment weight is >1% of the relevant stock comparator (either SSB or landings – given in bold) are shaded red. Numbers in red font are estimates of the population numbers (e.g. sand goby) or reported catch numbers (salmon & sea trout).

Species	Impingement						Entrainment						Entrapment			
	EAV number.	EAV weight.	Mean SSB.	% of SSB	Mean Land-ings.	% of land-ings.	EAV number.	EAV weight.	SSB 2010	% of SSB	Landings 2010	% of land-ings	EAV number.	EAV weight.	% of SSB	% of land-ings.
Sprat	5,352,978	56.23	220,757	0.03	151,322	0.04	199,715	2.00	225,041	0.00	143,500	0.00	5,552,693	58.23	**0.03**	0.04
Herring	1,827,944	344.87	2,198,449	0.02	400,244	0.09	23,992	4.18	2,023,720	0.00	187,600	0.00	1,851,936	349.05	**0.02**	0.09
Whiting	664,261	189.86	151,881	0.13	17,570	1.08	-	-	-	-	-	-	664,261	189.86	**0.13**	1.08
Seabass	12,886	19.73	14,897	0.13	3,051	0.65	36	0.05	20,780	0.00	4,768	0.00	12,922	19.78	**0.13**	0.65
Sand goby.	381,612	0.73	205,882,353	0.19	NA	NA	2,892,198	-	205,882,353	1.40			3,273,810		**1.59**	NA
Sole	53,233	11.40	43,770	0.03	12,800	0.09	631	0.14	31,358	0.00	12,603	0.00	53,864	11.54	**0.03**	0.09
Dab	66,211	2.70	NA	NA	6,135	0.04	21,810	0.87	NA	NA	8,279	0.01	88,021	3.57	NA	**0.05**
Anchovy	71,952	1.49	NA	NA	1,625	0.09	2,869	0.06	NA	NA	727	0.01	74,821	1.55	NA	**0.10**
Thin-lipped grey mullet.	5,642	2.93	600	0.49	120	2.45	-	-	-	-	-	-	5,642	2.93	**0.49**	2.45
Flounder	17,631	1.44	NA	NA	2,309	0.06	2	0.00	NA	NA	3,365	0.00	17,633	1.44	NA	**0.06**

Species	Impingement						Entrainment						Entrapment			
	EAV number.	EAV weight.	Mean SSB.	% of SSB	Mean Land-ings.	% of land-ings.	EAV number.	EAV weight.	SSB 2010	% of SSB	Landings 2010	% of land-ings	EAV number.	EAV weight.	% of SSB	% of land-ings.
Plaice	8,734	2.15	690,912	0.00	80,367	0.00	-	-	-	-	-	-	8,734	2.15	**0.00**	0.00
Smelt	18,170	0.30	105,733,825	0.02	8	3.56	-	-	-	-	-	-	18,170	0.30	**0.02**	3.56
Cod	6,049	15.74	103,025	0.02	34,701	0.05	-	-	-	-	-	-	6,049	15.74	**0.02**	0.05
Thornback ray.	2,082	6.65	NA	NA	1,573	0.42	-	-	-	-	-	-	2,082	6.65	NA	**0.42**
River lamprey.	6,720	0.53	62	0.86	1	47.65	-	-	-	-	-	-	6,720	0.53	**0.86**	47.65
Eel	4,516	1.49	79	1.89	14	10.70	-	-	-	-	-	-	4,516	1.49	**1.89**	10.70
Twaite shad.	3,601	1.13	7,519,986	0.05	1	84.60	-	-	-	-	-	-	3,601	1.13	**0.05**	84.60
Horse mackerel.	4,077	0.57	NA	NA	21,442	0.00	-	-	-	-	-	-	4,077	0.57	NA	**0.00**
Mackerel	628	0.20	3,888,854	0.00	1,026,828	0.00	-	-	-	-	-	-	628	0.20	**0.00**	0.00
Tope	64	0.44	NA	NA	498	0.09	-	-	-	-	-	-	64	0.44	NA	**0.09**
Sea trout.	10	0.02	NA	NA	39,795	0.02	-	-	-	-	-	-	10	0.02	NA	**0.02**

Table 22.117: Annual mean Sizewell C entrapment predictions (impingement + entrainment) with full impingement mitigation (LVSE heads and FRR). Corrections to seabass and thin-lipped grey mullet are incorporated into the assessment. For impingement, losses have been converted to adult equivalent value (EAV) numbers and weights (t) and calculated as a % of either the mean stock SSB (t) or mean international landings (t) for the period 2009-2017. For entrainment, the worst-case losses have been converted to EAV numbers and weight and calculated as a % of the SSB and landings in 2010 only. Species where the entrapment weight is >1% of the relevant stock comparator (either SSB or landings – given in bold) are shaded red. Numbers in red font are estimates of the population numbers (e.g. sand goby) or reported catch numbers (salmon & sea trout).

Species	Impingement						Entrainment						Entrapment			
	EAV number.	EAV weight.	Mean SSB.	% of SSB	Mean Land-ings.	% of land-ings.	EAV number.	EAV weight.	SSB 2010	% of SSB	Land-ings 2010	% of land-ings.	EAV number.	EAV weight.	% of SSB	% of land-ings.
Sprat	2,050,190	21.53	220,757	0.01	151,322	0.01	199,715	2	225,041	0	143,500	0	2,249,905	23.53	**0.01**	0.01
Herring	700,103	132.08	2,198,449	0.01	400,244	0.03	23,992	4	2,023,720	0	187,600	0	724,095	136.26	**0.01**	0.03
Whiting	140,044	40.03	151,881	0.03	17,570	0.23	-	-	-	-	-	-	140,044	40.03	**0.03**	0.23
Seabass	2,717	4.16	14,897	0.03	3,051	0.14	36	0	20,780	0	4,768	0	27,244	41.65	**0.03**	0.14
Sand goby.	30,108	0.06	205,882,353	0.01	NA	NA	2,892,198	-	205,882,353	1.40	0	0.00	2,922,306		**1.42**	0.00
Sole	4,200	0.9	43,770	0	12,800	0.01	631	0	31,358	0	12,603	0	4,831	1.04	**0.00**	0.01
Dab	13,656	0.56	NA	NA	6,135	0.01	21,810	1	NA	NA	8,279	0	35,466	1.43	NA	**0.02**
Anchovy	27,558	0.57	NA	NA	1,625	0.04	2,869	0	NA	NA	727	0	30,427	0.63	NA	**0.05**
Thin-lipped grey mullet.	1,190	0.62	600	0.10	120	0.52	-	-	-	-	-	-	1,190	0.62	**0.10**	0.52
Flounder	1,559	0.13	NA	NA	2,309	0.01	2	0	NA	NA	3,365	0	1,561	0.13	NA	**0.01**

Species	Impingement						Entrainment						Entrapment			
	EAV number.	EAV weight.	Mean SSB.	% of SSB	Mean Land-ings.	% of land-ings.	EAV number.	EAV weight.	SSB 2010	% of SSB	Land-ings 2010	% of land-ings.	EAV number.	EAV weight.	% of SSB	% of land-ings.
Plaice	689	0.17	690,912	0	80,367	0	-	-	-	-	-	-	689	0.17	**0.00**	0.00
Smelt	6,959	0.12	105,733,825	0.01	8	1.36	-	-	-	-	-	-	6,959	0.12	**0.01**	1.36
Cod	1,395	3.63	103,025	0	34,701	0.01	-	-	-	-	-	-	1,395	3.63	**0.00**	0.01
Thornback ray.	164	0.52	NA	NA	1,573	0.03	-	-	-	-	-	-	164	0.52	NA	**0.03**
River lamprey.	530	0.04	62	0.07	1	3.76	-	-	-	-	-	-	530	0.04	**0.07**	3.76
Eel	356	0.12	79	0.15	14	0.84	-	-	-	-	-	-	356	0.12	**0.15**	0.84
Twaite shad.	1,379	0.43	7,519,986	0.02	1	32.40	-	-	-	-	-	-	1,379	0.43	**0.02**	32.40
Horse mackerel.	1,561	0.22	NA	NA	21,442	0	-	-	-	-	-	-	1,561	0.22	NA	**0.00**
Mackerel	241	0.08	3,888,854	0	1,026,828	0	-	-	-	-	-	-	241	0.08	**0.00**	0.00
Tope	5	0.03	NA	NA	498	0.01	-	-	-	-	-	-	5	0.03	NA	**0.01**
Sea trout.	4	0.01	NA	NA	39,795	0.01	-	-	-	-	-	-	4	0.01	NA	**0.01**

Contextualising entrapment losses

22.8.654 To place the losses of commercially exploited species into context, entrapment losses (by weight) of commercially-exploited species were compared to fishery discards. Entrapment weights as a percentage of the landings are presented in **Table 22.118**, these can be compared against the percentage of discarded landed weights for each species (**Table 22.118**).

22.8.655 This approach indicates the effect of entrapment losses as a result of the proposed development, on the exploited stock in the context of fisheries landings and discards. For commercially important species, entrapment losses are lower than <1% of landings. Discards as a percentage of landings weights vary dramatically depending on the species. However, entrapment losses are at least two orders of magnitude lower than the proportion of landed fish that is discarded annually (**Table 22.118**). For example, the mean weight of cod discarded between 2009 and 2017 was 12,980t whereas the predicted mean Sizewell C entrapment loss for the same period is 3.6t, provided in **Appendix 22I** of this volume. No discard estimates are available for seabass, sprat and thornback ray.

Table 22.118: Discarded weight as a percentage of landed weight for commercially-exploited species. The calculated entrapment loss (with full mitigation) as a percentage of landed weight is provided for context. For species given in bold, the principal stock comparator for entrapment losses is SSB rather than landings.

Year	Cod	Sole	Plaice	Dab	Whiting	Flounder	Horse mackerel	Mackerel
2008	93.2	1.9	44.4	316.7	57.4	44.9	-	3.9
2009	62.8	4.3	39.5	474.7	54.5	47.9	-	3.6
2010	33.6	8.3	35.5	513.2	73.5	97.5	-	0.4
2011	27.2	7.2	33.6	599.0	66.1	55.7	-	0.6
2012	26.9	9.0	44.2	746.9	73.6	55.0	-	0.5
2013	33.8	11.2	25.2	808.9	46.4	80.9	-	0.1
2014	30.4	6.5	39.6	1064.7	66.6	59.1	-	0.1
2015	33.5	6.9	35.1	932.2	109.8	69.7	20.0	0.0
2016	32.0	5.4	30.4	881.2	107.2	35.9	11.1	0.2
2017	23.1	5.8	31.5	875.9	91.0	47.3	9.1	0.1
Sizewell C Entrapment (% of landed weight).	0.01	0.01	0.00	0.02	0.23	0.01	0.00	0.00

Cooling water discharges: Thermal discharges

22.8.656 Power stations require the abstraction of large volumes of cooling water. During the operational phase, the cooling water is discharged into the seal pit together with the main cooling water flow from the condenser, at temperatures up to 11.6°C higher than ambient, at a rate of 132m³/s. The cooling water will be discharged to the receiving waters via two outfall heads.

22.8.657 At the point of discharge the cooling water is thermally buoyant and stratification occurs. Heat is lost from the plume directly as radiation, both to the air and receiving waters. As the plume cools differences in buoyancy decrease and tidal mixing overcomes vertical stratification. At this point heat is dissipated causing a general warming effect to the receiving waters. The rate of mixing is determined by the tidal flow and the level of turbulence within the system (Ref. 22.13). Strong tides at Sizewell (>1m/s) and the interaction with the bathymetry shapes the plume profile.

22.8.658 The behaviour of the thermal plume can be characterised in three zones;

- Near-field: occurs at the point of discharge where the plume has restricted horizontal movement and mixes in a vertical profile.
- Mid-field: vertical momentum decreases and the plume begins to travel slowly with the ambient tidal flow. Shear with the seabed caused the ambient flow to be more turbulent and interact with the edge of the thermal plume causing heat losses.
- Far-field: the plume is integrated in the tidal flow and mixing is subject to differences in density gradients, wave energy and bathymetry, which can cause the plume to decrease in thickness and break into filaments and eddies.

22.8.659 Unlike chemical standards which normally have a clear evidence link to ecological effects, thermal standards are not always evidence-based due to a lack of reliable data (Ref. 22.87). To be protective of the most sensitive species thermal standards have, therefore, been set on an indicative basis. The **ES** considers relevant HRA standards applicable for European Marine Sites and WFD standards to determine potential effects for receptors.

22.8.660 BEEMS Scientific Advisory Report (2011) reviews the available evidence on thermal effects and concludes: “The available data confirms that adverse effects of CW outfalls are restricted to an area close to the plume, that temperature rises up to 3°C appear to be tolerable, and that resulting temperatures of less than 27°C have no clear deleterious impact on species in the receiving waters, but, in the longer term, changes in the local community may result as species with differing tolerances of elevated temperature show differing survival, growth and patterns of reproduction from those expressed under ambient conditions. Furthermore, populations that persist adjacent to a heated CW effluent will acclimate to those new local conditions and evolve in response to them" (Ref. 22.87).

22.8.661 The absolute temperature (**Table 22.119**) and thermal uplift thresholds (**Table 22.120**) were applied to trigger further ecological investigation for the potential for effect on fish receptors. In addition, the potential for thermal plumes to cause barriers to migratory species was considered in relation to local estuaries. It is known from laboratory thermal preference experiments, that fish species can choose to avoid areas of high temperature and so there is a possibility that thermal plumes could act as barriers to migration; principally in transitional waters.

22.8.662 However, the BEEMS Expert Panel (2011) critically reviewed the evidence for thermal barriers and concludes "there is an assumption that a CW discharge forms a thermal barrier to migratory fish, yet there is little experimental evidence to support this" (Ref. 22.87). Existing thermal standards for transitional waters specify that an estuary's cross section should not have an area larger than 25% with a temperature uplift above 2˚C, for more than 5% of the time. As such the **ES** considers the potential for thermal occlusion of migratory fish in the Alde-Ore and Blyth estuaries. Furthermore, consideration has been paid to a hypothetical coastal corridor, extending from the shore to 3km offshore applying the same criteria as an estuarine environment.

Table 22.119: Thermal thresholds applied for assessing absolute temperature increases on fish receptors.

Absolute water temperature (as a 98th percentile).					
Temperature	WFD Status.	Designated site proposed criteria.	Fish receptor groups.	Area of exceedance (Sizewell B only).	Area of exceedance (Sizewell B + Sizewell C).
> 23ºC.	Moderate	N/A[61]	Cold water species.	Surface 44.9ha.	Surface 89.6ha.
				Seabed 8.75ha.	Seabed 25.6ha.
> 28ºC.	Poor	SPA	Warm water species.	Surface 0ha.	Surface 0.11ha.
				Seabed 0ha.	Seabed 0ha.

[61] Recommended thermal thresholds exist for SACs designated for estuarine or embayment habitat and/or salmonid species, where absolute temperature thresholds of 21.5ºC as a 98th percentile apply (Ref. 22.393). These criteria are not applicable to fish assessments for the proposed development.

Table 22.120: Thermal thresholds applied for assessing thermal uplift above ambient and temperature increases on fish receptors.

Thermal uplift above ambient					
Temperature uplift.	**WFD Status.**	**Designated site proposed criteria.**	**Annual uplift percentile.**	**Area of exceedance (Sizewell B only).**	**Area of exceedance (Sizewell B + Sizewell C) (worst case for EcIA).**
> 2ºC.	Good.	N/A.	98th percentile.	Surface 2,433ha.	Surface 7,899ha.
				Seabed 2,127ha.	Seabed 6,241ha.
> 3ºC	Moderate.	N/A.	98th percentile.	Surface 1,263ha.	Surface 2,200ha.
				Seabed 668ha.	Seabed 1,553ha.
> 2ºC.	NA.	SPA /SAC.	100th percentile[62].	Surface 9,370ha.	Surface 22,455ha.
				Seabed 5,214ha	Seabed 16,443ha

22.8.663 An assessment has been made of the potential for the thermal plume to act as barrier to migration for those species moving between coastal and transitional waters (Ref. 22.13). The assessment applied a similar approach to transitional waters and applied a threshold for an offshore cross-section (running from the coast to 3km offshore), that should not have an area larger than 25% with a temperature uplift above 2°C, for more than 5% of the time (Ref. 22.13).

22.8.664 There are currently no uniform regulatory standards in place to control thermal loads in transitional and coastal waters. Consequently, an assembled Expert Panel reviewed existing legislation and the key issues relating to thermal tolerances for the New Nuclear Builds programme (Ref. 22.87). The impact of the proposed power station was evaluated through modelling, whereby the difference in temperature between a zero Reference run, which has no power station discharge and a scenario with Sizewell B and the proposed development was run. Modelling the cumulative effects of the proposed development and Sizewell B, in relation to thermal standards, was undertaken as Sizewell B will be operational until at least 2035. The

[62] The General Estaurine Transport Model used the maximum instantaneous temperature fields, saved every hour over a one-year simulation. The 100th percentile provides data on the area that exceeds 2°C excess temperature for at least 1 hour per year (1h in 8760h per annum) and has little ecological relevance.

difference is calculated for each hourly snapshot and the annual mean and the 98th percentile are calculated from this difference. The 98th percentile was chosen because it is a metric required under HRA and WFD assessment processes.

22.8.665 In 2006 WQTAG 160, "Guidance on assessing the impact of thermal discharges on European Marine Sites", recommended interim thermal standards for assessing SAC/SPA sites in estuarine and coastal sites under the Habitats Regulations, based upon standards contained within the Freshwater Fish Directive.

22.8.666 Absolute temperature uplifts of 28ºC occur over a negligible area (0.11ha) at the sea surface. Absolute thermal uplifts of >23ºC occurs over an area of 89.6ha at the surface and 25.6ha at the seabed as a 98th percentile during the operation of Sizewell B and Sizewell C, provided **Figure 21.5** of **Chapter 21** of this volume. A maximum of 89.6ha at the surface, and 25.6ha at the seabed exceed the >23°C 'Good/Moderate' threshold for Sizewell C and Sizewell B in-combination (**Table 22.119**). The temperature uplifts would occur whilst Sizewell C is operational (until at least 2035).

22.8.667 Thermal uplifts of >2ºC occur over an area of 7,899ha at the surface and 6,241ha at the seabed as a 98th percentile during the operation of Sizewell B and Sizewell C, provided in **Figure 21.4** of **Chapter 21** of this volume. Uplifts of >3ºC occur over an area of 2,200ha at the surface and 1,553ha at the seabed as a 98th percentile during the operation of Sizewell B and Sizewell C (**Table 22.120**).

22.8.668 Model runs output instantaneous thermal fields at hourly resolution for the period of one year. Accordingly, a 98th percentile represents the cumulative spatial area that individual cells (25x25m) within the model domain exceeds a threshold temperature for 7.3 days at any point during the year. The 98th percentile statistics are not necessarily consecutive and could be days or months apart.

22.8.669 The latest date Sizewell B is anticipated to remain operational is 2055. Following 2055, thermal discharges from Sizewell B would cease. The Sizewell C only plume results in smaller areas of thermal impacts (**Table 22.121**).

Table 22.121: WFD thermal standards and areas of exceedance for absolute temperature and temperature uplift during the operation of Sizewell C alone.

Absolute water temperature (as a 98th percentile).			Thermal uplift (as a 98th percentile).		
Temperature	**Status**	**Position**	**Uplift**	**Status**	**Position**
20ºC - 23ºC	Good	-	> 2ºC	Good	Surface 1,551ha

					Seabed 170.6ha
23ºC - 28ºC	Moderate	Surface 0ha	> 3ºC	Moderate	Surface 305.7ha
		Seabed 0ha			Seabed 0ha
> 28ºC	Poor	Surface 0ha			
		Seabed 0ha			

22.8.670 The impact magnitude is based on the worst-case scenario of Sizewell B and the proposed development discharging cooling water concurrently. Thermal discharges would occur throughout the operational life cycle of the proposed station and are long term impacts. Absolute thermal exceedance with the potential to cause acute effects is constrained to a very small area (<1ha). Modest thermal uplifts (2ºC) with the potential for chronic effects can extend over instantaneous areas of thousands of hectares at the sea surface within the tidal excursion.

22.8.671 Noting the detachment of thermal standards from biological thresholds and the precautionary use of the 98^{th} percentile in assessing the spatial extent of the thermal plume, the impact magnitude for fish receptors is assessed as medium. Sensitivity assessments will consider the areas (instantaneous) and thermal tolerances in more detail.

22.8.672 The effects of future climate change and warming sea temperatures in relation to thermal discharges is considered further. These assessments focus on absolute temperatures as thermal uplifts are predicted to be largely independent of ambient water temperature (Ref. 22.13) and would remain the same as assessed here.

Sensitivity of fish sub-groups to thermal discharges

22.8.673 Fish exposed to temperature elevations may experience increases in metabolism and respiration resulting in stress and increased activity and food intake. Exposure to elevated temperatures can have general and specific effects on the physiology of fish, with influences on growth and condition of ichthyoplankton and juveniles, initiating earlier reproductive phase in adults and potentially accelerating reproductive success (Ref. 22.393; 404–410).

22.8.674 Fish may exhibit attraction behaviour where the plume temperature aligns with an optimal energetic temperature or is similar to the seasonally preferred temperature of a species. There is, however, the potential for fish that aggregate in the plume to be at greater risk of predation. Additionally, enhance foraging may occur where prey items of fish are attracted to the warmer plume waters.

22.8.675 The potential interaction of fish receptors has been considered in relation to the seabed and surface plumes. Effects from temperature increases can be grouped into effects that are acute or chronic. Acute effects are lethal effects where temperatures approach the species' critical threshold. Chronic effects are long-term effects to biological processes related to an elevation in mean temperature (Ref. 22.393).

22.8.676 Potential effects of temperature increases are assessed for cold-water species and warm-water species. Cold-water species are typically of an Arctic-Boreal zoogeographic distribution, encompassing species with an Arctic distribution (>60°N), and Arctic–Boreal distribution (from the Arctic Circle through the northern temperate zone to the southern United Kingdom. Temperature increases due to the plume may particularly affect Arctic-Boreal species where the southern, warmer limit is reached and hence species may be near to the limits of their thermal niche. Warm-water species typically have Boreal–Lusitanian distributions (north of the United Kingdom down to Iberia) (Ref. 22.87).

22.8.677 The assessments specifically consider potential effects to species and respective life history stage(s) (**Table 22.122**), that were recorded in abundance within the coastal trawl surveys, zooplankton surveys, impingement and/or entrainment monitoring programmes. The species assessed include commercially and ecologically important species.

22.8.678 Available evidence indicating preferred temperature and temperature ranges and upper lethal temperatures for different life history stages of cold-water species, are shown in **Table 22.123**.

Table 22.122: Cold and warm-water species and life history stages assessed in relation to thermal discharges, via the cooling water outfalls.

Group	Species	Eggs	Larvae	Juveniles	Adults
Cold water species.	Dab	×	×	✓	✓
	Atlantic cod	×	×	✓	✓
	Whiting	×	×	✓	✓
	Atlantic herring	×	✓	✓	✓
	Mackerel	×	×	✓	✓
	River lamprey	×	×	×	✓
	European smelt	×	×	×	✓
	Sea trout and salmon	×	×	×	✓
Warm water species.	Dover sole.	✓	✓	✓	✓
	European flounder	×	✓	✓	✓
	European plaice	×	✓	✓	✓
	European seabass	✓	✓	✓	✓
	Thin-lipped grey mullet	×	×	✓	✓
	Sand gobies	×	✓	✓	✓
	Thornback ray	✓*egg cases	×	✓	✓
	Tope	×	×	✓	✓
	Anchovy	✓	✓		✓
	Horse mackerel	×	×	✓	✓
	European sprat	✓	✓	✓	✓
	European eel	×	×	✓	✓
	Sea lamprey	×	×	×	✓

Table 22.123: Summary of preferred temperature / temperature ranges (PT) and upper lethal temperature / temperature ranges (ULT) for different life history stages of assessed cold-water species.

Species	Eggs		Larvae		Juveniles		Adults	
	PT (°C)	ULT (°C)	PT (°C)	ULT (°C)	PT (°C)	ULT (°C)	PT (°C)	ULT (°C)
Dab	-	-	-	-	2-20ºC (Ref. 22.393).	>26ºC 26ºC indicates temperature tolerance range (Ref. 22.411).	2-20ºC (Ref. 22.393).	Potentially >26ºC; 26ºC indicates temperature tolerance range (Ref. 22.411).
Cod	-	-	-	-	5-15ºC (in Southern North Sea) (Ref. 22.412).	Potentially >23ºC (Ref. 22.413).	5-15ºC (in Southern North Sea) (Ref. 22.412).	Potentially >23ºC (Ref. 22.393).
Whiting	-	-	-	-	11-16ºC (modelled from Thames Estuary). (Ref. 22.414).	Potentially >24ºC (Ref. 22.393).	11-16ºC (modelled from Thames Estuary) (Ref. 22.414).	Potentially >24ºC (Ref. 22.393).
Atlantic herring.	-	-	16ºC (Ref. 22.415),	22–24ºC (Ref. 22.416), 20.5 – 23.5ºC (Ref. 22.408),	10-16ºC (Ref. 22.415).	19.5 – 21.2ºC (Ref. 22.415).	≤10ºC (Thames) (Ref. 22.417).	22–24ºC (Ref. 22.416). 19.5–21.2ºC (Ref. 22.418).
River lamprey.	-	-	-	-	-	-	3-23ºC (Ref. 22.393).	Potentially >23ºC (Ref. 22.393).

Species	Eggs		Larvae		Juveniles		Adults	
	PT (°C)	ULT (°C)	PT (°C)	ULT (°C)	PT (°C)	ULT (°C)	PT (°C)	ULT (°C)
European smelt.	-	-	-	-	-	-	8-17 ºC (Thames Estuary) (Ref. 22.414).	Potentially >20ºC (Ref. 22.393)..
Salmon and Sea trout.	-	-	-	-	-	-	8-17ºC (Ref. 22.419; 420).	Potentially >23ºC (Ref. 22.393).

PT = Preferred temperature; ULT = Upper lethal temperature; as per (Ref. 22.87), this is used as a catch-all for other terminology cited in the literature i.e. Critical thermal maximum, upper incipient lethal temperature and ultimate upper incipient lethal temperature. The dash (-) indicates where the life history stage has not been considered owing to a general absence in the GSB area.

Sensitivity assessments of effects at the sea-area or regional stock/population level: temperature changes

Cold-water ichthyoplankton: thermal discharges

22.8.679 Applying the >23ºC threshold for the absolute water temperature, the area of exceedance at the surface and seabed, as a 98th percentile, would be small; 89.6.ha and 25.6ha, respectively (**Table 22.119**). This means that even the most sensitive ichthyoplankton would experience limited exposure to acute (lethal) effects in a tidal environment.

22.8.680 Within the areas where the 2 and 3ºC uplifts are predicted to occur, there is potential for chronic, sub-lethal effects on ichthyoplankton physiology and behaviour as temperatures may exceed thermal preference (**Table 22.123**). Exposure of larvae to elevated sea surface temperatures within the plume may increase metabolic rates due to increased energy demand and swimming activity. Laboratory trials with herring larvae have shown this has the potential for indirect effects on growth and potentially survival (Ref. 22.421). The instantaneous thermal plume uplift area has a distinctly seasonal component with the larges areas observed in Winter and the smallest areas observed in summer, provided in **Section 22.6.d)** of this chapter; **Plate 22.4**. Therefore, the period of peak ichthyoplankton abundance will have a bearing on the exposure to the plume. Herring larvae are most abundant off Sizewell in May. During May the monthly average plume area above 2°C is 680ha and the average surface plume area above 3°C is 242ha (Ref. 22.13). Mean water temperature off Sizewell (centred on the year 2006) are 12.2ºC in May, therefore areas where exceedance of the thermal preference or lethal temperatures for herring larvae (**Table 22.123**) would be minimal. Therefore, any acute or chronic effects (sub-lethal) effects would be localised, exposing a very small proportion of the population. Ichthyoplankton typically experience high natural mortality and so potential losses are considered negligible relative to ichthyoplankton abundance.

22.8.681 Cold-water ichthyoplankton are predicted to be not sensitive to thermal discharges.

22.8.682 The impact of thermal discharges is predicted to have a negligible effect on cold-water ichthyoplankton. Effects are **not significant** at the sea area and regional stock/population levels.

Cold-water juveniles and adults: thermal discharges

22.8.683 Applying the >23ºC threshold for the absolute water temperature, the area of exceedance at the surface and seabed, as a 98th percentile, would be small area; 89.6ha and 25.6ha, respectively (**Table 22.119**). This means that juveniles and adults would experience limited exposure to acute (lethal) effects in a tidal environment.

22.8.684 However, exposure to lethal temperatures could be minimised by species movement vertically and/or horizontally in the water column as well as accessing alternative areas within and beyond the GSB, that are within the preferred temperature range. Some of the species also occur seasonally and so this may limit potential for interaction with the thermal plume.

22.8.685 Where the predicted 2 and 3ºC uplifts would occur, there is potential for chronic, sub-lethal effects on juvenile and adult physiology, behaviour and thus fitness as temperatures move away from the thermal niche for a species (**Table 22.123**).

22.8.686 The sensitivity of cold-water juveniles and adults to temperature changes, due to thermal discharges from the cooling water outfalls, is predicted to be low.

22.8.687 The impact of thermal discharges from the cooling water outfalls, is predicted to have a minor adverse effect on cold-water juvenile and adult fish. There is potential for avoiding the lethal temperatures and the availability of alternative habitat within and outside the GSB for fish to shelter, forage and for use during reproduction. Effects are **not significant** at the sea area and regional stock/population levels.

Warm-water ichthyoplankton and egg cases: thermal discharges

22.8.688 Applying the threshold of areas >28ºC for acute effects, indicates that the area of exceedance at the surface and seabed, as a 98th percentile, would be negligible; 0.11ha and 0ha, respectively for both stations operating (**Table 22.120**). Sizewell C operating alone does not exceed 23ºC as a 98th percentile at the surface or the seabed (**Table 22.121**), however, thermal discharges do combine with Sizewell B operating to increase the inshore areas above 23ºC to 89.6ha at the surface and 25.6ha at the seabed (**Table 22.119**). Upper lethal temperatures of Dover Sole eggs are in the range of 19–22ºC (Ref. 22.409). Therefore, there is the potential to incur acute mortality if eggs coincide with the hottest part of the plume. However, eggs are most abundant in May when water temperatures are below summer maximums and the small spatial area mean a very small proportion of planktonic eggs would be exposed. This means that warm-water ichthyoplankton would experience limited exposure to acute (lethal) effects in a tidal environment.

22.8.689 Where the predicted 2 and 3ºC uplifts would occur (**Table 22.121**), there is potential for chronic, sub-lethal effects. Exposure of larvae to elevated sea surface temperatures within the plume may increase metabolic rates due to increased energy demand and swimming activity. Exposure of eggs may influence incubation times and risk of mortality before hatching (Ref. 22.422).

22.8.690 The seasonal plume profile and abundance of ichthyoplankton has a bearing on the potential for effects. The highest number of anchovy eggs were recorded in June, the highest anchovy larvae abundances during July 2011, and the highest number of seabass and sprat eggs and larvae were collected in May and June. Dover sole eggs are most abundant in the waters off Sizewell in April and May, with larvae most abundant in May, provided in **Appendix 22B** of this volume. The preferred temperature range for Dover sole egg incubation is 7-16ºC (Ref. 22.423) and 10-16ºC for egg hatching (Ref. 22.409). In May, the monthly average instantaneous plume area above 3°C is 242ha (Ref. 22.13). Mean water temperature off Sizewell (centred on the year 2006) are 12.2ºC in May, therefore areas where exceedance of the thermal preference for Dover sole eggs would be minimal.

22.8.691 While localised egg/larvae mortality may occur, no decline in the stock/regional population viability is predicted. Temperature changes, due to thermal discharges are predicted to result in small localised changes in physiology to a negligibly small proportion of the population. Warm-water ichthyoplankton are therefore predicted to be not sensitive.

22.8.692 The impact of thermal discharges from the cooling water outfalls, is predicted to have a negligible effect on warm-water ichthyoplankton and egg cases. Effects are **not significant** at the sea area and regional stock/population levels.

Warm-water juveniles and adults: thermal discharges

22.8.693 A negligible area exceeds the 28ºC threshold for acute effects with both stations operating (**Table 22.120**). Sizewell C operating alone does not exceed 23ºC as a 98th percentile at the surface or the seabed (**Table 22.121**), however, thermal discharges do combine with Sizewell B operating to increase the inshore areas above 23ºC to 89.6ha at the surface and 25.6ha at the seabed (**Table 22.119**). This means that warm-water juveniles and adults would experience extremely limited exposure to acute (lethal) effects due to the proposed development and avoidance behaviours mean acute effects are highly unlikely.

22.8.694 Within the 2 and 3ºC uplifts plume areas, there is potential for chronic, sub-lethal effects where temperatures may be more closely associated with the thermal preference of warm-water species. In such instances, changes in physiology, behaviour and thus fitness may occur. some life stages may even exploit the warmer waters. Juvenile seabass distribution in the estuary of the River Medway has been shown to be strongly associated with the warm water discharge from the Kingsnorth power station (Ref. 22.424). It was suggested that the growth and survival of first-year seabass were enhanced so that mortality was reduced (Ref. 22.424). Juvenile Dover sole growth is reported across a temperature range of 22-28ºC, although temperature preference increases with acclimation temperature and can exceed the optimal temperature for growth (Ref. 22.425). Adult growth occurs to an optimum of 20-25ºC (Schram *et al.*, 2013) whilst temperature for spawning is lower, at approximately 7ºC (Ref. 22.87).

22.8.695 Less thermally tolerant warm-water species may experience adverse physiological effects or avoidance behaviours in close proximity to the thermal discharge at higher temperatures. However, the areas of predicted uplift as an instantaneous plume for the sea surface and seabed are limited in the tidally dominated system, provided in **Section 22.6.d)** of this chapter; **Plate 22.4**.

22.8.696 Given the range of species in the group, a precautionary approach is that the sensitivity of warm-water juveniles and adults to temperature changes, due to thermal discharges from the cooling water outfalls, is low.

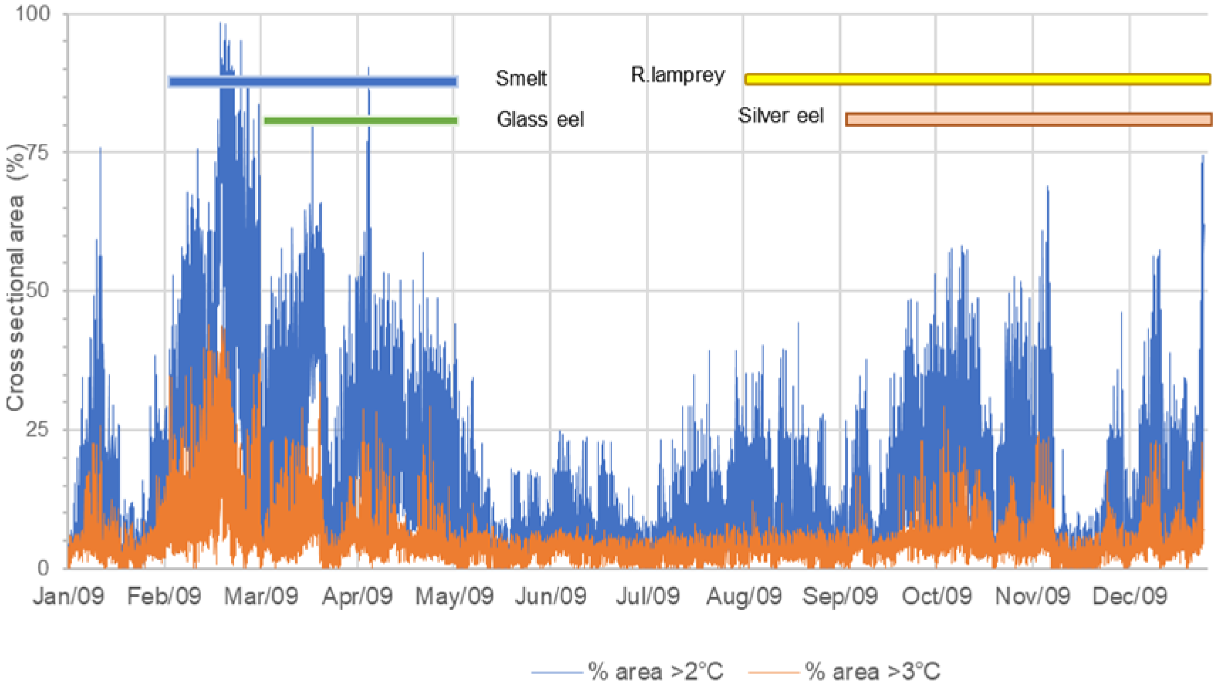
22.8.697 There is potential for avoidance behaviours in close proximity to the discharge where temperature exceed thermal optima. However, there is also the potential for attraction of warmed areas for some of the species, such as seabass, capable of exploiting the heated cooling water. Therefore, minor adverse to beneficial effects are predicted at a localised scale. Effects are **not significant** at the sea area and regional stock/population levels.

Migratory fish: thermal uplift

22.8.698 Thermal standards for transitional waters specify that an estuary's cross section should not have an area larger than 25% with a temperature uplift above 2°C, for more than 5% of the time to avoid potential barriers to migratory fish. These criteria have been applied to the Blyth and Alde-Ore Estuaries and a potential migratory corridor in the coastal waters off Sizewell (Ref. 22.13).

22.8.699 Unlike in estuarine systems, thermal standards for occlusion along open coastal systems do not exist. As a precautionary stance a migration corridor of approximately 3km wide from the coast to the Sizewell C outfalls was modelled as a potential migration route and the same criteria as an estuary were applied. Uplifts of 2°C exceed 25% of the corridor for 18.7% of the year, thereby triggering further ecological investigation. The percentage of the coastal transect predicted to experience the >2°C and >3°C uplift is shown in **Plate 22.7**, with migration periods of smelt, river lamprey, glass and silver eel indicated.

Plate 22.7: Percentage of Sizewell transect with >2°C (blue line) and >3°C (orange line) uplift shown against fish migration periods (From: BEEMS Technical Report TR302 (Ref. 22.13)**).**



22.8.700 Minimal evidence supports thermal avoidance of modest thermal uplifts causing avoidance behaviours and temperature increases of >2°C may not be a significant deterrent to the movement of a number of important species (Ref. 22.13). Experimental studies have shown that salmonids and smelt will tolerate temperature increases of up to 4°C above background (Ref. 22.426). Juvenile chinook salmon (*Oncorhynchus tshawytscha*) tested under three discharge conditions (no plume, ambient plume and heated plume) avoided plume temperatures greater than 9-11°C above ambient. Given the choice of a base temperature averaging 12.3°C (9.5°C in the case of eels), or water incrementally raised by 2–12°C, only juvenile smelt and dace exhibited an avoidance reaction, initially observed at a ΔT of +4°C and +8°C, respectively, relative to the base temperature (Ref. 22.87; 427). Choice chamber results do not reflect real world behavioural imperatives which in practice may drive fish to ignore thermal uplifts.

22.8.701 Based on the available evidence for thermal avoidance of migratory species off Sizewell a precautionary 3°C thresholds may be applied for smelt, sea trout, glass eel and silver eel. For these species, modelling results show that potential avoidance thresholds would occur over 25% of the coastal corridor for less than 5% of the time during their migratory periods (Ref. 22.13). Therefore, no occlusion effects are predicted.

22.8.702 The thermal avoidance threshold for river and sea lampreys is unknown. Therefore a 2°C uplift criteria has been adopted as a precautionary approach. River lamprey migration periods are of August to December. During which time the percentage of the cross section that would exceed 2°C uplift is a maximum of 75% (for 1h only) with a mean of 12%. More than half the transect would be available for 99% of the time. However, the route that lampreys would take to return to a suitable river is determined by the location of their host when the lamprey decides to detach itself and considering the location of the nearest potential spawning locations in the Blyth and the Alde-Ore, statistically very few fish would seem likely to follow a path that takes them through the Sizewell thermal plumes. Given the high percentage of the transect that would be available for a Sizewell transit and the low likelihood that such a transit would take place, the Sizewell thermal plumes are not considered to present a barrier to migration for sea and river lampreys (Ref. 22.13).

22.8.703 At the mouth of the Alde-Ore Estuary, excess temperatures in the order of 0°C to 1°C occur as 98th percentiles (Ref. 22.13). As such, no occlusion effects are predicted.

22.8.704 The thermal plume intersects over 25% of the Blyth estuary cross section at 98th percentile temperatures above 2°C for 3.5% of the annual model simulation (307 hours per annum), less than the 5% threshold. However, the temporal components of the plume were investigated further in relation to migratory species of interest. The period from November to January, inclusive, represents the time of year with the greatest potential for thermal occlusion. Adult river lamprey migrate into estuaries from August to December (**Table 22.60**). During river lamprey migratory periods, a total of 124 hours is predicted to exceed 2°C across at least 25% of the estuary cross section (3.4% of the time). During a subset of the migration period (from October to December), a 2°C uplift is predicted to occur over 25% of the estuary mouth for 5.6% of the time, however, thermal barriers are not predicted to last for more than 1 day.

22.8.705 Other migratory species are predicted to be less sensitive to thermal occlusion at the mouth of the River Blyth due to existing evidence of a higher tolerance for thermal uplifts. For example, European smelt[63] migrate into estuaries from February to April, inclusive (**Table 22.60**). Smelt have been shown to exhibit an avoidance reaction at a ΔT of +4°C relative to base

[63] Surveying using fyke nets and kick sampling methods was carried out in the tidal and estuarine areas of the Blyth in April and May 2016 when high density spawning migrations would have been expected if smelt were undertaking spawning migrations in the Blyth river. No smelt were found in the area. Furthermore, there was an absence of suitable spawning substrate and a physical barrier to migration further upstream (Ref. 22.314). It is therefore highly unlikely that a spawning population exists in the Blyth (**Appendix 22D** of this volume).

temperatures (Ref. 22.87; 427). As such, the cross-sectional area of the Blyth exposed to a 3°C uplift was calculated. During the migration period, a 3ºC uplift is predicted to occur over 25% of the Blyth estuary mouth for 1.3% of the time. No thermal barriers are predicted for migratory species in the Blyth estuary.

22.8.706 The sensitivity of migratory fish to thermal occlusion from the operational thermal discharge of both stations, is assessed as not sensitive with only minor behavioural changes likely.

22.8.707 No barriers to migration are predicted and minor adverse effects are predicted for migratory fish. Effects are **not significant** at the sea area and regional stock/population levels.

Assessments of effects of localised displacement: temperature changes

22.8.708 Thermal plumes can potentially elicit behavioural avoidance and attraction. Little evidence indicates that 2°C or 3°C temperature increases above ambient would cause avoidance. Cucumber Smelt (a locally common herring-like pelagic species) has shown avoidance at a ΔT of +4°C (Ref. 22.87; 427). Acoustic surveys of sprat at Sizewell have shown no apparent avoidance of the Sizewell B 2ºC uplift chlorinated plume (Ref. 22.303). Juvenile seabass were found to more abundant inshore within the existing Sizewell B thermal plume in Winter (Ref. 22.402).

22.8.709 These species form components of the diet of designated species and there is, therefore, the potential for behavioural effects to have implications for the availability of fish as a prey species. However, plume areas at temperatures likely to have foraging consequences on designated seabirds and marine mammals are small relative to the foraging range (Ref. 22.428).

22.8.710 Localised displacement of fish receptors due to the thermal discharges from the cooling water outfalls, is predicted to have a minor adverse to minor beneficial effect on the local distribution of fish. Effects are not deemed to be significant. The potential indirect effects of localised displacement of fish species that form prey for designated birds and marine mammals is considered further as part of the **Shadow HRA** (Doc Ref. 5.10).

Effects of climate changes and thermal discharges on fish receptors

22.8.711 Absolute exceedances of contemporary thermal standards (SAC, SPA and WFD) has been considered in relation to the influence of climate change in order to ascertain absolute temperatures in the future, provided in **Appendix 21E** of this volume. The method considered Sizewell B and the proposed development operating in 2030 and 2055, as a worst-case. The proposed development operating alone is also considered in 2055, 2085 and 2110 to represent an extreme hypothetical scenario.

22.8.712 Future climate change is not predicted to significantly increase the absolute areas in exceedance of 28ºC, which remain under 1ha for all scenarios tested. Following the end of operation of Sizewell B, 28ºC as an absolute temperature, is not predicted to be exceeded as a 98th percentile even under the extreme climate case of operations in 2110.

22.8.713 In the unlikely event both stations are operational in 2055 an area of 506.2ha at the surface would exceed 23ºC. At the seabed absolute temperatures of 23ºC are reached over an area of 92.3ha and 264.4ha in 2030 and 2055, respectively.

22.8.714 In the extreme 2110 scenario, climate warming resulted in larger areas exceeding 23ºC as a 98th percentile (7,080ha at the surface), and 6,540ha at the seabed. However, climate change is estimated to be +3.045 across the model domain by 2110, hence a station uplift of just 0.56ºC is sufficient to exceed contemporary thermal standards[64], provided in **Appendix 21E** of this volume. Applying future climate predictions to thermal assessments should be treated with a degree of caution due to the inherent uncertainties in predicting future climate. Furthermore, contextualising future climate scenarios to contemporary thermal standards should be regarded as indicative as regulatory standards would need to be readdressed to account for climate change.

22.8.715 In 2085, towards the end of the likely operational life-cycle, seabed areas in exceedance of 23ºC are predicted to occur over just 0.2ha, whereas surface exceedance occurs over an area of 69.1ha. The total area of the thermal plume above 23ºC in 2085 is, therefore, smaller and further offshore than the contemporary predictions for the two power stations.

22.8.716 With both Sizewell B and the proposed development operating, predicted changes in absolute seabed and sea surface temperatures, exposure of cold-water taxa to acute (lethal) effects may increase. Furthermore, the station may contribute to climate driven effects with elevated temperatures exceeding thermal preferences of sensitive species resulting in further localised chronic effects or changes in distribution. However, taxa exposure would be influenced by climate-related shifts including higher background temperatures. Acclimation and/or adaptation to elevated background temperatures and changes in geographic distribution, described in the future baseline in **Section 22.8.b)** of this chapter, would occur as a response to climate change. Furthermore, thermal tolerance and thermal preference in fish varies with acclimation temperature (Ref. 22.393). This infers that taxa within the GSB exposed to future temperature scenarios would have

[64] 98th percentile temperature for the five-year period from 2009-2013 is 19.4°C and forms the basis for absolute temperature calculations.

differential sensitivities to absolute thermal thresholds applied in current standards. Furthermore, once Sizewell B ceases to operate the combined effects of climate change and thermal discharges from Sizewell C (2055 simulation) would be considerably smaller and further offshore than the contemporary absolute thermal exceedance of Sizewell B alone, provided in **Appendix 21E** of this volume.

22.8.717 Thermal uplifts above ambient are predicted to be largely independent of the background sea temperature (Ref. 22.13). Therefore, predicted thermal uplift areas would remain similar under future climate scenarios, provided in **Appendix 21E** of this volume. Fish (including migratory species) adapted to future thermal baselines, would experience the same relative temperature differences as in the contemporary assessment. It is feasible that the elevated background temperatures may interplay with thermal uplifts to greater effect in cold-water species with potential implication for migration. However, as thermal uplifts from Sizewell C operating alone are predicted to cover a smaller spatial extent further offshore than the existing Sizewell B plumes, disruption to migratory routes is considered unlikely, provided in **Appendix 22E** of this volume.

22.8.718 The impact of thermal discharges under the future climate scenario, is predicted to have a minor adverse effect on cold-water taxa**.** Effects are **not significant** at the sea area and regional stock/population levels.

22.8.719 The impact of thermal discharges under the future climate scenario on warm water species is predicted to be similar as the contemporary assessment. The operation of the proposed development may locally exacerbate a general trend of a shift in northerly distribution of warm-water species. Minor adverse to minor beneficial effects are predicted. Effects are **not significant** at the sea area and regional stock/population levels.

Cooling water discharges: Chlorinated discharges

22.8.720 To control biofouling of critical sections of the plant during operation, cooling water will be chlorinated by the addition of sodium hypochlorite. EDF Energy's operational policy for its existing UK fleet is to continuously dose during the growing season to achieve a total residual oxidant (TRO) dose of 0.2mg/l in critical sections of the plant and at the inlet to the condensers (after the FRR drum screens). Chlorination would be applied when water temperatures exceed 10ºC (Ref. 22.102).

22.8.721 The primary biocidal effects of seawater chlorination result from oxidants associated with water chemistry. These oxidants are measured and expressed as the TRO concentration. Accordingly, the sum of TROs, rather than simply chlorine, are measured. The TRO discharge concentration would be 0.15mg/l, discharged at a rate of 132m^3/s in the cooling water at a temperature of 11.6 °C above ambient, provided in **Appendix 21E** of this volume.

22.8.722 The total residual oxidants (TRO) result from the combination of chorine and organic material in the water, furthermore chlorination compounds are broken down to form chlorination by-products. This section considers the impact magnitude of TRO and chlorination by-product discharges.

Total residual oxidants: Impact magnitude

22.8.723 Experimental studies at Sizewell were used to model the TRO plume based on the seawater chemistry and applying an empirical demand/decay formulation coupled into the General Estaurine Transport Model forSizewell. The EQS for TROs is 10µg/l as a 95th percentile concentration. The TRO plumes from Sizewell C and Sizewell B are spatially distinct at ecologically relevant concentrations and follow a long narrow trajectory parallel to the coast. Therefore, Sizewell C is considered separately with Sizewell B part of the baseline.

22.8.724 The Sizewell C TRO plume is highly stratified and concentrations exceed the EQS over a sea surface area of 338ha and a seabed area of 2.1ha, provided in **Figure 21.6** of **Chapter 21** of this volume.

22.8.725 The impact magnitude for TRO discharges has been assessed as medium.

22.8.726 TRO discharges would occur for the operational life-cycle of the proposed development and would be continuous throughout the growing season when water temperatures exceed 10ºC. In 2030, water temperatures at the Sizewell C intakes are predicted to exceed 10ºC from the beginning of May until the start of December. Future climate change may extend the period of the year seawater temperatures exceed 10ºC, and by proxy, the seasonal duration of chlorination under the current strategy.

Chlorination by-products: Impact magnitude

22.8.727 Depending on the water chemistry an array of chlorination by-products (CBPs) can be formed in addition to TROs. Seawater is rich in bromide, which reacts with chlorination compounds to produce chlorination by-products.

22.8.728 The most abundant chlorination by-product in discharges from coastal power stations, and the only product detected in the waters off Sizewell is bromoform (Ref. 22.103), provided in **Appendix 21E** of this volume. Bromoform is lost through volatilization to the atmosphere. Loss rates were incorporated into the General Estaurine Transport Model forSizewell to predict the extent of the bromoform plume.

22.8.729 EQS concentrations for bromoform do not exist and a PNEC of 5µg/l as a 95th percentile is applied as the recommended standard (Ref. 22.103). The bromoform plume is predicted to follow a similar trajectory to the TRO plume with a narrow, tidally transported plume forming parallel to the shore. The plume is highly stratified with PNEC concentrations exceeding 5µg/l over an area of 52ha at the surface and 0.15ha at the seabed. The Sizewell C plume is discrete from the Sizewell B plume.

22.8.730 Bromoform discharges would occur for the operational life-cycle of the proposed development and would be continuous throughout the growing season when water temperatures exceed 10°C.

22.8.731 The impact magnitude for bromoform discharges has been assessed as medium.

Sensitivity assessments of effects at the sea-area or regional stock/population level: total residual oxidants

22.8.732 In the near-field of the TRO plume, exposure could result in acute effects (lethal) over spatially restricted areas, for life stages and species unable to avoid the plume. In the wider field area where the TRO plume occurs, there is potential for chronic effects (sub-lethal).

22.8.733 A summary of exposure studies with TRO discharges and fish receptors is provided in **Table 22.124**.

Table 22.124: Summary of TRO exposure studies and potential effects on fish receptors.

Pressure	Receptor	Potential effect
TRO.	Demersal fish and elasmobranch eggs/egg cases and larvae.	A range of ichthyoplankton survival studies have been conducted. For instance, ichthyoplankton survival studies have been conducted with an Entrainment Mimic Unit designed to imitate the passage of water through cooling water systems at the Sizewell A/B power stations (Ref. 22.222). A residual concentration (0.20ppm at the condenser) typically applied by UK coastal power stations was used, which was considered to decay to around half of this concentration at the discharge point. Significant mortalities of sole post-larvae were observed, but adverse effects on the eggs were not observed. Seabass eggs were not harmed by the chlorine levels typical of entrainment, but significant larvae mortality, ranging from 30% to 70%, was observed at levels ≥0.2ppm (Ref. 22.222). This is noted as a much higher concentration that would be in TRO plume from the proposed development. With the Entrainment Mimic Unit, the exposure and survival rates of entrained plaice larvae has been investigated. This was for a profile consistent with conditions at the Entrainment Mimic Unit studies, designed to replicate entrainment conditions at the proposed development (pressure, ΔT of 11.6°C, with an intake and outfall maximum exposure concentration of 0.2mg/l) investigated survival of larval plaice. Yolk sac larvae survival was predicted to be 0.57% and it was determined that where chlorination occurred with temperature and pressure, there was high mortality (Ref. 22.79). Further experiments with plaice larvae found that effects of chlorination compounded those from elevated temperature. When focussing just at chlorination effects, survival of yolk sac larvae was predicted to be 11.2% at TRO of 0.2mg/l (Ref. 22.79). The effect of chlorine exposure on plaice eggs was investigated using the Entrainment Mimic Unit. Fertilised eggs were exposed at two different low-dose TRO concentrations of 0.02 and 0.07mg/l and mortality was monitored for the developing eggs. At a mean measured TRO concentration of 0.01mg/l (EQS concentration) over an 8-day period, there is no significant increase in mortality relative to the control. However, at a mean measured concentration of 0.04mg/l there was an additional mortality of 47% relative to the control (Ref. 22.108). An increase in mortality at a measured concentration of 0.04mg/l TRO occurred at the time of hatching and it was implied that even at higher exposure concentrations, mortality may not be as high if the timing of exposure does not coincide with the hatching period (Ref. 22.108). The effect of temperature and chlorine exposure on cod eggs and larvae were investigated using the Entrainment Mimic Unit. The experimental results were modelled to predict survival at the designed ΔT of 11.6°C, with an outfall maximum

Pressure	Receptor	Potential effect
		exposure concentration of 0.2mg/l TRO during periods of chlorine dosing. The predicted survival rates were 3.48%, 76.12% and 51.61% for cod early eggs, late eggs and yolk sac larvae, respectively (Ref. 22.79).
	Demersal fish and elasmobranch.	Choice chamber experiments were carried out at the Cefas laboratory, Lowestoft to determine the potential avoidance of juvenile seabass to TROs. The results suggested that the fish initially were able to detect the presence of TRO and preferred unchlorinated water; however, possibly due to acclimatisation this initial avoidance response reduced over time (Ref. 22.429). Furthermore, it was suggested that local seabass populations at Sizewell may adapt to variable, low TRO concentrations predicted in the majority of the plume area of the planned Sizewell C cooling water discharge (e.g.~0.04mg/l) (Ref. 22.429). In 2015, experiments were run at the Cefas laboratory, Lowestoft to simulate the exposure of fish in the Sizewell C FRR system. Ten individual fish of a species (seabass, plaice, turbot) were added to a holding tank containing seawater chlorinated to achieve a concentration of 0.2mg/l TRO. A group of 10 fish were also added to a similar sized control tank to compare behavioural responses. TROs were maintained for 100 minutes of exposure and this duration reflected transit time through the power station. However, there was also the consideration of a period (up to two subsequent hours), during which fish remain in the TRO discharge plume which gradually mixes with new seawater (Ref. 22.108). To simulate this exposure profile, after 100 minutes the seawater flow to the holding tank was started at a rate of 3-10 litres/minute to reflect more rapid mixing with new seawater following discharge from the FRR. All fish were regularly monitored for 24 hours after exposure and throughout the test, observations were made for any changes in behaviour, particularly in comparison to the control treatment. The initial TRO concentration in each test varied slightly, but in each case then followed a similar pattern of initial rapid decay preceding a slower decline. In general, the TRO concentration was below the detection limit after around 180 minutes (i.e. <0.02mg/l). No mortality was observed in any of the control treatments. Seabass were the only species which experienced mortality because of exposure to chlorinated seawater. Mortality of 3-year old seabass was 40% compared to 90% for the 2-year old seabass. Plaice, sole and turbot suffered no mortality in any treatment (Ref. 22.108). In this series of brief exposure studies, the sensitivity of fish to TRO following the chlorination of seawater varied with species and potentially with age (Ref. 22.108).
	Pelagic fish eggs and larvae.	Herring post-larvae survival to TRO has been investigated and when exposed to initial concentrations of 0.25 parts-per-million, post-larvae suffered no mortalities (Ref. 22.430). The study did not, however, determine post-exposure effects.

Pressure	Receptor	Potential effect
	Migratory fish.	Experiments were run at the Cefas laboratory, Lowestoft to simulate the exposure of European eels (amongst other species) to TRO. Fish were added to a holding tank containing seawater chlorinated to achieve a concentration of 0.2mg/l TRO. TROs were maintained for 100 minutes of exposure and this duration reflected transit time through the power station. All fish were regularly monitored for 24 hours after exposure and throughout the test. In general, the TRO concentration was below the detection limit after around 180 minutes (i.e.<0.02mg/l). No mortality was observed in any of the control treatments. European eels suffered no mortality in any treatment (Ref. 22.108). In this series of brief exposure studies, the sensitivity of fish to TRO following the chlorination of seawater varied with species and potentially with age. In 2016, studies were conducted in the Cefas laboratory to investigate glass eel exposure to chlorination. A 100% survival rate was identified for glass eels exposed to a single chlorination dose to achieve a target concentration of 0.2mg/l TRO (at ambient sea water temperature) (Ref. 22.431).

Demersal fish and elasmobranch eggs/cases and larvae: sensitivity to total residual oxidants

22.8.734 Eggs and larvae drift inshore into the GSB area and consequently, could be exposed to the buoyant surface plume. The exposure of eggs and larvae to the seasonal TRO plume would depend on the timing of their seasonal occurrence in the water column. Results from the 2008-2012 zooplankton sampling identified the highest number of sole eggs in May 2010, while the highest number of larvae was collected in May 2011. The highest number of seabass eggs was caught in May 2011 while the highest number of larvae was caught in June 2011, provided in **Appendix 22B** of this volume.

22.8.735 High mortalities of sole post-larvae exposed to TRO concentrations of 0.20ppm (0.2mg/l) has been reported, yet adverse effects on the eggs were not observed (Ref. 22.222). Seabass eggs were not harmed by the chlorine levels typical of entrainment, but significant larvae mortality, ranging from 30% to 70%, was observed at levels ≥0.2ppm (Ref. 22.15). It is acknowledged that this is a much higher concentration that would be in TRO plume from the proposed development.

22.8.736 Compared to larvae, pelagic eggs are likely to have a higher resistance to TROs because of the presence of the membrane, though the eggs may display morphological impairments (Ref. 22.106).

22.8.737 A very small proportion of the stock of pelagic eggs and larvae would be exposed to TROs and no decline in the stock/regional population viability, due to mortality, is expected. The sensitivity of demersal fish and elasmobranch eggs/cases and larvae, to TRO discharges from the cooling water outfalls, is predicted to be not sensitive.

22.8.738 The impact of TRO discharges from the cooling water outfalls is predicted to have a negligible effect on demersal fish and elasmobranchs early life stages. Effects are **not significant** at the sea area and regional stock/population levels.

Demersal fish and elasmobranch juveniles and adults: sensitivity to total residual oxidants

22.8.739 Following discharge, rapid dilution of the TRO plume results in a concentration gradient. Whereby TROs with the potential to elicit acute effects are limited to a small spatial area near the discharge head. For example, the TRO plume above 20µg/l occurs over 98ha and 0.34ha at the surface and seabed, respectively. While the plume over a concentration of 50µg/l is predicted for <9ha at the surface with no areas in exceedance of 50µg/l at the seabed, provided in **Appendix 21E** of this volume.

22.8.740 Survival studies with sole, plaice, seabass and cod are summarised in **Table 22.124**. From these studies, it is inferred that juvenile flatfish, including sole, are generally tolerant of TRO from chlorination. For example, plaice, sole and turbot suffered no mortality during studies with exposure to a TRO concentration of 0.2mg/l (Ref. 22.108). However, it is recognised that the experiments did not necessarily account for post-exposure sub-lethal effects.

22.8.741 For mobile juveniles and adults, avoidance behaviour may mitigate exposure to toxic effects from the TROs. The TRO concentrations initiating an avoidance response is likely to vary between species and life history stages, as evident in experimental trials with Californian estuarine fish (Ref. 22.432). Juveniles and adults of mobile species may choose to avoid the area and move elsewhere in the GSB, while others may remain and acclimate to decaying TRO concentration. Choice chamber experiments suggested that seabass are able to detect the presence of TROs at a nominal concentration of 40µg/l and preferred unchlorinated water. However, initial avoidance responses reduced over time (Ref. 22.429). Furthermore, it was suggested that local seabass populations at Sizewell may adapt to variable, low TRO concentrations predicted in the majority of the plume area (Ref. 22.429), and concentrations of 50µg/l. occur over areas of <9ha at the surface as a 95th percentile. Suggesting avoidance behaviours are likely to be highly restricted.

22.8.742 The TRO seabed plume above EQS concentrations (10µg/l) covers a very small extent of seabed (2.1ha) in the GSB potentially used by species for foraging and spawning/nursery functions. For species that exhibit diurnal or seasonal movements into/out of the area, there would be access to seabed habitat outside of the GSB to support reproductive and foraging requirements.

22.8.743 The sensitivity of demersal fish and elasmobranchs to TRO discharges from the cooling water outfalls, is predicted to be low.

22.8.744 The impact of TRO discharges from the cooling water outfalls is predicted to have a minor adverse effect on demersal fish and elasmobranchs. Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish eggs and larvae: sensitivity to total residual oxidants

22.8.745 Eggs and larvae drift inshore into the GSB area and consequently, could be exposed to the buoyant surface plume. The exposure of eggs and larvae to the seasonal TRO plume would depend on the timing of their seasonal occurrence in the water column. The highest number of herring larvae were collected during May 2012 and would be exposed to the plume. The highest number of sprat eggs was collected in March 2011 (outside the chlorination season), while the highest number of sprat larvae was collected in June

2010. The highest number of mackerel eggs were caught in May 2011. The highest number of anchovy eggs and larvae were collected in June and July 2012, provided in **Appendix 22B** of this volume.

22.8.746 Herring larvae have been shown to survive exposure to TRO concentrations of 0.25mg/l (Ref. 22.430) (**Table 22.124**). Limited evidence is available regarding chlorination exposure and survival rates for anchovy, sprat and mackerel eggs and larvae.

22.8.747 A very small proportion of the seed-stock of pelagic eggs and larvae would be exposed to TROs and no decline in the stock/regional population viability, due to mortality, is expected. The sensitivity of pelagic fish eggs and larvae to TRO discharges from the cooling water outfalls, is predicted to be not sensitive.

22.8.748 The impact of TRO discharges from the cooling water outfalls, is predicted to have a negligible effect on pelagic fish eggs and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish juveniles and adults: sensitivity to total residual oxidants

22.8.749 There may be very localised acute effects in the near-field of the plume; however, there is predicted to be a rapid dilution of the plumes. There is the potential for sub-lethal effects in the far-field of the plume, and considering evidence for demersal fish, there is potential for effects on physiology, behaviour and thus fitness of pelagic species.

22.8.750 For mobile juveniles and adults, avoidance behaviour may mitigate exposure to toxic effects from the TROs. The TRO concentrations initiating an avoidance response are likely to vary between species and life history stages. Juveniles and adults of mobile species may choose to avoid the area and move elsewhere in the GSB, while others may remain and acclimate to decaying TRO concentration. Also, for species that exhibit seasonal movements into/out of the area, there would be access to habitat outside of the GSB to support reproductive and foraging requirements.

22.8.751 The TRO seabed plume covers a very small extent (2.1ha above EQS) of seabed in the GSB potentially used as herring nursery grounds. The TRO surface plume is also covers a small extent in relation to the available habitat in the GSB (338ha above EQS), with the mobility of pelagic species enabling access to alternative habitat in the GSB.

22.8.752 The sensitivity of pelagic fish juveniles and adults to TRO discharges from the cooling water outfalls, is predicted to be low.

22.8.753 The impact of TRO discharges from the cooling water outfalls is predicted to have a minor adverse effect on pelagic fish juveniles and adults. Effects are **not significant** at the sea area and regional stock/population levels.

Migratory fish juveniles and adults: sensitivity to total residual oxidants

22.8.754 Chlorination would be applied when water temperatures exceed 10ºC between May and November (Ref. 22.102). This period does not coincide with the migration periods of smelt and glass eel, however some of the species of interest at Sizewell may passage past the proposed development during periods of seasonal chlorination (**Table 22.60**). It should be noted that TRO plumes do not intersect the Alde-Ore or Blyth estuaries at ecologically meaningful concentrations.

22.8.755 There is experimental evidence of European eels, including glass eels, surviving exposure to TRO concentrations representative of operational discharges from the proposed development (Ref. 22.431; 433). In the case of salmonids, rainbow trout and Atlantic salmon are reported as avoiding TRO concentrations of 0.001, 0.01 and 1.0mg/l, but exhibited attraction towards a concentration of 0.1mg/l (Ref. 22.434).

22.8.756 The Sizewell C TRO plume is highly stratified and concentrations exceed the EQS (10µg/l) over a sea surface area of 338ha and a seabed area of 2.1h, provided in **Appendix 21E** of this volume. Avoidance behaviour could mitigate exposure to toxic effects, but the TRO concentrations initiating an avoidance response are likely to vary between species and occur over limited areas. Whilst avoidance behaviours may occur, no barriers to migration are predicted.

22.8.757 The sensitivity of migratory fish juveniles and adults to TRO discharges from the cooling water outfalls, is predicted to be low.

22.8.758 The impact of TRO discharges from the cooling water outfalls is predicted to have a minor adverse effect on migratory fish juveniles and adults. Effects are **not significant** at the sea area and regional stock/population levels.

Assessments of effects of localised displacement: total residual oxidants

22.8.759 Localised displacement through avoidance behaviour towards the TRO plume may occur in some species. Seabass, for example, have been shown to avoid TRO concentrations that would occur near the point of discharge, but may acclimate to the plume with responses diminishing following exposure (Ref. 22.429). Chlorinated discharges would be seasonal, therefore during the Winter when some species such as clupeids are most abundant there would be no TRO plumes.

22.8.760 Localised displacement of fish receptors due to the TRO discharges is predicted to have a minor adverse effect on the local distribution of fish. Effects are not deemed to be significant. The potential indirect effects of localised displacement of fish species that form prey for designated birds and marine mammals is considered further as part of the **Shadow HRA** (Doc Ref. 5.10).

Synthetic compound contamination: Bromoform from chlorination

22.8.761 Bromoform is a chlorination by-product that also occurs naturally in the marine environment due to benthic and planktonic alga production (Ref. 22.113). Seawater is rich in bromide, which reacts with the chlorination compounds used in the anti-fouling process. Depending on the water chemistry a vast array of chlorination by-products can be formed in addition to TROs. The chlorination by-products that evolve following the chlorination of seawater were tested as part of the BEEMS Programme at Sizewell.

22.8.762 The dominant chlorination by-products are bromoform, dibromochloromethane bromodichloromethane, monobromaceitic acid, dibromoaceitic acid, dibromoacetonitrile and 2,4,6 tribromophenol. Only bromoform was detected in seawater samples following additions of chlorine at a range of concentrations (Ref. 22.435); therefore, modelling of the bromoform plume was undertaken in the case of Sizewell B operating and the cumulative impact of Sizewell B and Sizewell C. The bromoform plume followed the same trajectory as the TRO plume with a narrow band running parallel to the shore, provided in **Appendix 21E** of this volume.

22.8.763 EQS concentrations for bromoform do not exist and a PNEC of 5µg/l as a 95th percentile is applied as the recommended standard (Ref. 22.103). The bromoform plume is predicted to follow a similar trajectory to the TRO plume with a narrow, tidally transported plume forming parallel to the shore. The plume is highly stratified with PNEC concentrations exceeding 5µg/l over an area of 52ha at the surface and 0.67ha at the seabed. The Sizewell C plume is discrete from the Sizewell B plume.

22.8.764 Bromoform discharges would occur for the operational life-cycle of the proposed development and would be continuous throughout the growing season when water temperatures exceed 10ºC. The effects from future climate change and increased annual chlorination period is discussed in the climate change and entrainment prediction section. The impact magnitude for bromoform discharges has been assessed as medium.

Assessments of effects at the sea-area or regional stock/population level: bromoform

Demersal fish and elasmobranch eggs /cases and larvae: sensitivity to bromoform chlorination by-product

22.8.765 There is limited published literature on the ecotoxicity of bromoform to ichthyoplankton. A study of freshwater carp embryo exposure to a range of chlorination by-products, including bromoform, determined that the 96h LC_{50} was 52mg/l (Ref. 22.436). This median lethal concentration is substantially (10,000-fold) greater than the target 5µg/l EQS for the proposed development, which is exceeded over a very limited area (52ha at the surface and 0.67ha at the seabed).

22.8.766 The sensitivity of demersal fish and elasmobranch eggs /cases and larvae to bromoform from the cooling water outfalls, is predicted to be not sensitive.

22.8.767 The impact of bromoform is predicted to have a negligible effect on demersal fish and elasmobranch eggs /cases and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Demersal fish and elasmobranch: sensitivity to bromoform chlorination by-product

22.8.768 No observed effect concentrations for bromoform on a range of marine organisms including bivalve gill tissue and larvae, echinoderm larvae and bacteria ranged from 0.5 to 3.4mg/l (Ref. 22.113). The 96-h LC_{50} for the sheepshead minnow (*C. variegatus*) is reported to be 17.9mg/l; which is orders of magnitude above concentrations observed in the field (Ref. 22.113). Bromoform has been shown to bioaccumulate in the fat tissue of farmed seabass raised in the chlorinated discharges of the Gravelines power station in France. The bromoform burden disappeared rapidly once seasonal chlorination ceased and did not accumulate in muscle tissue. Long-term, low-level exposure to chlorinated discharges did not reduce growth rates or damage liver tissues as such, seabass incurred very limited ecotoxicological stress (Ref. 22.103).

22.8.769 Lethal effects are unlikely given the limited persistence of bromoform, which is expected to diminish over time because of anaerobic degradation and volatilization. As such, the nature of exposure would be limited temporally and spatially. No decline in the stock/regional population viability, due to mortality, is expected.

22.8.770 The sensitivity of demersal fish and elasmobranchs to bromoform from the cooling water outfalls, is precautionarily assessed to be low.

22.8.771 The impact of bromoform is predicted to have a minor adverse effect on demersal fish and elasmobranchs. Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish eggs and larvae: sensitivity to bromoform chlorination by-product

22.8.772 Published literature on the ecotoxicity of bromoform and pelagic fish ichthyoplankton is limited in availability. The U.S. Environmental Protection Agency (Ref. 22.437) set the toxicity of bromoform based upon toxicity to sheepshead minnow (*C, variegatus*). Lethal effects applied to a concentration of 2.9mg/l after 96 hours of exposure. For a generic application to other fish, lethal effects were established at 7mg/l of bromoform after 96 hours of exposure (Ref. 22.437).

22.8.773 There is a low likelihood of chronic effects such as altered growth and potentially the survival of eggs and hatched larvae/post larvae. No decline in the stock/regional population viability, due to mortality, is expected.

22.8.774 The sensitivity of pelagic fish eggs and larvae to bromoform from the cooling water outfalls, is predicted to be *Not Sensitive.*

22.8.775 The impact of bromoform chlorination by-product is predicted to have a negligible effect on pelagic fish eggs and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish juveniles and adults: sensitivity to bromoform chlorination by-product

22.8.776 Published literature on the ecotoxicity of bromoform and pelagic fish is limited in availability. The pelagic nature of the species in the water column minimises potential interaction with the seabed bromoform plume. Juveniles and adults of mobile species may choose to avoid the area and move elsewhere in the GSB, while others may remain. Lethal effects are unlikely given the limited persistence of bromoform, which is expected to diminish over time because of anaerobic degradation and volatilization.

22.8.777 The sensitivity of pelagic fish juveniles and adults to bromoform from the cooling water outfalls, is predicted to be not sensitive.

22.8.778 The impact of bromoform is predicted to have a negligible effect on pelagic fish juveniles and adults. Effects are **not significant** at the sea area and regional stock/population levels.

Migratory fish juveniles and adults: sensitivity to bromoform chlorination by-product

22.8.779 Given the limited persistence of the bromoform plume, no barrier to migration is predicted.

22.8.780 Migratory fish may choose to avoid the area and move elsewhere in the GSB, though some may remain. Parasitic lamprey would, however, be controlled by the host's movements. Lethal effects are unlikely given the limited persistence of bromoform, which is expected to diminish over time because of anaerobic degradation and volatilization. As such, the nature of exposure would be limited temporally and spatially.

22.8.781 The sensitivity of migratory fish to bromoform from the cooling water outfalls, is predicted to be not sensitive.

22.8.782 The impact of bromoform chlorination by-product is predicted to have a negligible effect on migratory fish juveniles and adults. Effects are **not significant** at the sea area and regional stock/population levels.

Assessments of effects of localised displacement

22.8.783 Some species may be temporarily displaced from the area of the plume through avoidance behaviour. As such, minor changes in localised abundance and distribution could occur. However, given the limited magnitude of the bromoform plume, the seasonal chlorination strategy, and acknowledging the seasonal presence of some of the species, there are unlikely to be substantial changes in availability of fish prey items for designated features and fisheries resources. Therefore, localised displacement of fish receptors, due to the bromoform plume from the proposed development, is predicted to have a negligible effect which is **not significant**.

Synthetic compound contamination: Daily hydrazine discharges in the waste stream

22.8.784 Hydrazine (N_2H_4) is an ammonia-derived compound with strong anti-oxidant properties, regularly used as a corrosion inhibitor in cooling water circuits of nuclear power stations. Worst-case daily discharges from Sizewell C have been modelled based on hydrazine discharges of 24kg per annum into the cooling water flow. Conservative decay rates were incorporated into the General Estaurine Transport Model to consider two release strategies based on different pulses of 69ng/l for 2.32h a day and 34.5ng/l for 4.63h a day culminating in the same total annual load (24kg/yr).

22.8.785 The plume simulations showed that both strategies gave similar results. The hydrazine plume follows a narrow trajectory parallel to the shore. At the seabed, less than 1ha exceeds the chronic PNEC, irrespective of the release strategy. At the surface the area that exceeds the chronic PNEC is 158 and 157ha for the 69ng/l and 34ng/l releases, respectively.

22.8.786 The acute thresholds were only exceeded in the 69ng/l release strategy over a very small area of the seabed (0.13ha). Surface exceedance extended to 17.4ha and 13.8ha in the 34.5ng/l and 69ng/l strategy, respectively, provided in **Appendix 21E** of this volume; **Table 22.125**.

22.8.787 Daily discharges of hydrazine will occur throughout the lifetime of the power station, although the hydrazine plume would be present for hours within a day. As the PNEC would be exceeded over a small area of the seafloor and somewhat larger area of the sea surface during this period, under both hydrazine release scenarios, impact magnitude is assessed as medium. This assessment is highly precautionary, given the conservative nature of the PNECs used.

Table 22.125: Area of the hydrazine plume in exceedance of concentration thresholds.

Hydrazine release strategy	PNEC threshold	Area of exceedance (ha)	
		Surface	Seabed
69ng/l for a duration of 2.32h a day.	Chronic 0.4ng/l (mean)	158.1	0.56
	Acute 4ng/l (95th percentile)	13.8	0.22
34.5ng/l for a duration of 4.63h a day.	Chronic 0.4ng/l (mean)	156.9	0.34
	Acute 4ng/l (95th percentile)	17.4	0

Assessments of effects at the sea-area or regional stock/population level: hydrazine discharges

22.8.788 A summary of exposure studies with hydrazine and fish receptors is provided in the construction CDO assessment, provided in **Section 22.8.c)** in this chapter, for commissioning discharges.

Demersal fish and elasmobranch eggs /cases and larvae: sensitivity to hydrazine discharges

22.8.789 In the near-field of the hydrazine plume, exposure could result in acute effects (lethal) over very spatially restricted areas, for life stages and species unable to avoid the plume. In the wider field area where the hydrazine plume occurs, there is potential for chronic effects (sub-lethal).

22.8.790 Exposure of eggs/larvae could result in morphological abnormalities, altered growth and hatching and ultimately, reduced survival of the eggs and larvae. However, concentrations (1-5mg/l) for mortality of freshwater rainbow trout embryos in the study by Henderson *et al.* (1983), are 10^6-fold higher than the acute PNEC (Ref. 22.389). Whilst it is recognised that there is limited evidence for mortality of early life stages of marine species, potential losses of eggs/larvae are considered negligible relative to natural mortality.

22.8.791 The sensitivity of demersal fish and elasmobranch eggs/cases and larvae to hydrazine discharges from the cooling water outfalls, is predicted to be not sensitive.

22.8.792 The impact of hydrazine discharges is predicted to have a negligible effect on demersal fish and elasmobranch eggs /cases and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Demersal fish and elasmobranchs: sensitivity to hydrazine discharges

22.8.793 The toxicity of hydrazine has predominately been studied in freshwater/migratory species, under different experimental conditions and using concentrations of hydrazine substantially higher compared with the predicted plume concentration (i.e. mg/l rather than ng/l).

22.8.794 Juveniles and adults of mobile species may choose to avoid the area and move elsewhere in the GSB, while less mobile species e.g. gobies and juvenile stages may remain. There is potential for sublethal physical and physiological effects, based on studies outlined the CDO construction assessment, provided in **Section 22.8.c)** of this chapter. One study identified evidence of behavioural reposes including an increase in aggressive behaviours in laboratory trials with freshwater bluegill (*L. macrochirus*), which the authors attributed to the irritant effects of hydrazine. However, behavioural responses were reported at concentrations of 0.1mg/l and above (Ref. 22.391).

22.8.795 A very small extent of the GSB seabed and small area of sea surface is likely to be exposed to the hydrazine plume compared with foraging habitat and spawning/nursery habitat within and outside the GSB and concentrations are orders of magnitude below observed effect thresholds.

22.8.796 The sensitivity of demersal fish and elasmobranchs to hydrazine discharges is predicted to be not sensitive.

22.8.797 The impact of hydrazine discharges is predicted to have a negligible effect on demersal fish and elasmobranchs. Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish eggs and larvae: sensitivity to hydrazine discharges

22.8.798 Consistent with the assessment for demersal fish and elasmobranch eggs/cases and larvae, the sensitive of pelagic fish eggs and larvae, to hydrazine discharges from the cooling water outfalls, is predicted to be not sensitive.

22.8.799 The impact of hydrazine discharges is predicted to have a negligible effect on pelagic fish eggs and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish juveniles and adults: sensitivity to hydrazine discharges

22.8.800 As per the assessment for demersal fish and elasmobranchs, the sensitive of pelagic fish to hydrazine discharges from the cooling water outfalls, is predicted to be not sensitive.

22.8.801 The impact of hydrazine discharges is predicted to have a negligible effect on pelagic fish. Effects are **not significant** at the sea area and regional stock/population levels.

Migratory fish juveniles and adults: sensitivity to hydrazine discharges

22.8.802 Given the limited persistence of the hydrazine plume, no barrier to migration is predicted.

22.8.803 Migratory fish may choose to avoid the area and move elsewhere in the GSB, though some may remain. Parasitic lamprey would, however, be controlled by the host's movements. Lethal effects are unlikely given the ability of fish to avoid the plume and in view of the very limited area of the surface plume, where the acute threshold would be exceeded for either release strategy.

22.8.804 The sensitivity of migratory fish to hydrazine from the cooling water outfalls, is predicted to be not sensitive.

22.8.805 The impact of hydrazine chlorination by-product is predicted to have a negligible effect on migratory fish juveniles and adults. Effects are **not significant** at the sea area and regional stock/population levels.

Assessments of effects of localised displacement: hydrazine discharges

22.8.806 The limited available evidence for behavioural responses to hydrazine, means that the assessment is precautionary, however plume concentrations are orders of magnitude below observed effect thresholds. It is feasible that some species may be temporarily displaced from the area of the plume through avoidance behaviour. As such, minor changes in localised abundance and distribution could occur.

22.8.807 Given the limited magnitude of the hydrazine surface plume and the limited duration of daily discharges (maximum 4.6 hours), avoidance is unlikely and no changes in availability of fish prey items for designated features and fisheries resources are predicted. Hydrazine discharges from the proposed development are predicted to have a negligible effect on local fish distributions. Effects are **not significant**.

iv. Fish Recovery and Return systems

22.8.808 This section describes the impacts associated with the operation of the fish recovery and return (FRR) systems during the operation phase. The FRR system is designed to minimise impacts on impinged fish and invertebrate populations. However, some pelagic species such as clupeids are highly sensitive to mechanical damage caused during passage through the cooling water intakes, drum screens and FRR channels and incur high mortality rates. Operation phase pressures with the potential for effects on fish receptors are presented in **Table 22.126**.

Table 22.126: Pressures associated with FRR activities during the operation phase that have the potential to affect fish receptors.

Pressure	Activities resulting in pressure	Justification
Organic loading.	Discharges of dead and moribund biota.	The return of dead and moribund biota is a source of organic carbon with the potential to influence secondary production at the seabed through detrital pathways and provide a source of food for fish receptors.
Increases in un-ionised ammonia.	Discharges of dead and moribund biota.	Decaying biomass would release ammonia into the surrounding waters, which has potential to affect benthic ecology receptors through toxicological stress.

22.8.809 Operation pressures that have been scoped out of further assessment as they are considered to have negligible effects on fish receptors include:

- Reductions in dissolved oxygen – Decaying biomass returned to receiving waters via the FRR would increase the biochemical oxygen demand and has the potential to reduce dissolved oxygen levels. The waters off Sizewell are well mixed vertically, thus facilitating reaeration, and the rate of water exchange within the GSB would limit the extent and duration of any oxygen reduction. Background dissolved oxygen concentrations conforms to ‘high’ status within the WFD waterbody and this includes the influence of Sizewell B. The biological oxygen demand from biomass discharged from the FRRs is predicted to have a negligible effect on water quality.

- Nutrient enrichment – The decay of organic material would release nutrients into the system. The small quantities of nitrate and phosphate that would be released are expected to influence annual gross primary production by orders of magnitude below the natural variation in chlorophyll *a* biomass, provided in **Section 22.6.b)** of this chapter. Such small-scale changes to primary production would have negligible indirect effects on benthic ecology receptors.

Organic enrichment from discharge of dead and moribund biota

22.8.810 Biota that suffer mortality as a result of the impingement process would be discharged into the receiving waters via the FRR. This activity has the potential to affect fish receptors by increasing the availability of food to scavengers/opportunists. A full food web assessment is considered in **Section 22.10** of this chapter.

22.8.811 The total biomass of dead and moribund biota to be discharged from the FRR has been estimated based on abstraction rates and information on the seasonal abundance of species, along with length-to-weight distributions of the species impinged at the existing Sizewell B station. The data show large seasonal variation in discharges. The highest discharge biomass would occur in December to April, when clupeids are most abundant, with peaks in abundance in March. During March, mean daily discharges of biomass of 1,318kg/d are predicted from the FRR systems. Between April to September, a lower mean daily discharge biomass of 155kg (wet weight) is predicted with an annual average of 408kg/d, provided in **Section 22.7.d)** in this chapter; **Table 22.57**.

22.8.812 Modelling indicates that dead and moribund biota discharged from the FRR would primarily settle onto the seabed in the vicinity of the two FRR outfalls. However, tidal and wave driven resuspension would re-distribute material. Discharges are expected throughout the year, in seasonally variable quantities, for the duration of the operation phase.

22.8.813 Impact magnitude is assessed as medium.

Sensitivity assessments of effects at the sea-area or regional stock/population level: organic enrichment

Demersal fish and elasmobranchs: sensitivity to organic enrichment (from discharge of dead and moribund biota)

22.8.814 Opportunistic foragers like seabass, scavengers like cod and detritivores, may be attracted to and forage on the dead and moribund biota. The food web impacts of elevated detrital resources caused by dead and moribund biota are discussed further in **Section 22.10** of this chapter.

22.8.815 Demersal fish, including juvenile seabass that are known to be more abundant within the warm waters within the Sizewell-Dunwich Bank during Winter, provided in **Appendix 22D** of this volume, may utilise FRR discards resulting in localised attraction. For example, gadoids including cod (*G. morhua*) and whiting (*M. merlangus*) have all been shown to be attracted to fisheries discards (Ref. 22.116).

22.8.816 The sensitivity of demersal fish and elasmobranchs to organic enrichment is predicted to be low.

22.8.817 The impact of organic enrichment is predicted to have a minor beneficial indirect effect on demersal fish and elasmobranchs. This is due to the highly connected nature of GSB to the wider North Sea, which is likely to dampen the effects of discards. Effects are not predicted to be significant at the sea area and regional stock/population levels. This is given the large changes in seasonal and interannual variability in population size/local abundance observed in many taxa.

Pelagic fish: sensitivity to organic enrichment (from discharge of dead and moribund biota)

22.8.818 There is potential for localised increases in the population size of some secondary zooplankton consumers, provided in **Section 22.6.d)** of this chapter, which may be prey for pelagic fish e.g. Atlantic herring and sprat. However, given the foraging and mobility traits of planktonic foraging fish, it is considered unlikely that taxa in this sub-group would be positively affected by the release of dead and moribund biota. The sensitivity of pelagic fish to organic enrichment is predicted to be low.

22.8.819 The impact of organic enrichment is predicted to have a negligible effect on pelagic fish. Effects are **not significant** at the sea area and regional stock/population levels.

Migratory fish juveniles and adults: sensitivity to sensitivity to organic enrichment (from discharge of dead and moribund biota)

22.8.820 There is potential for localised increases in the population size of some secondary zooplankton consumers, provided in **Section 22.6.d)** of this chapter, which may be prey of certain migratory species e.g. shad and smelt. However, given the foraging and mobility traits of migratory key taxa, it is considered unlikely that taxa in this sub-group would be positively affected by the release of dead and moribund biota. The sensitivity of migratory fish juveniles and adults to organic enrichment is predicted to be not sensitive.

22.8.821 The impact of organic enrichment is predicted to have a negligible effect on migratory fish juveniles and adults. Effects are **not significant** at the sea area and regional stock/population levels.

Assessments of effects of localised displacement: organic enrichment (from discharge of dead and moribund biota)

22.8.822 The potential for opportunistic foragers and detritivores to be attracted by dead and moribund biota exists. Some demersal species may be attracted to FRR discharges resulting in localised increases in abundance. There is predicted to be a minor beneficial effect. No significant changes in the availability as prey items for designated features and as fisheries resources are predicted.

Un-ionised ammonia from discharge of dead and moribund biota

22.8.823 The decay of biomass released from the FRR has the potential to cause increased in un-ionised ammonia above EQS concentrations. The tissue ammonia content for fish and seasonal physio-chemical conditions were incorporated into the un-ionised ammonia calculator, provided in **Appendix 21F** of this volume. Un-ionised ammonia was calculated for Summer, and Winter when fish discharges and ambient conditions differ.

22.8.824 During the period April-September, daily discharges of 405.2kg of dead or moribund biota have the potential to cause un-ionised ammonia concentrations to exceed the EQS (21µg/l) over an area of 1.2ha (under average conditions). To account for Summer conditions, 95th percentile temperature and pH, and average salinity was considered. Under this scenario the EQS is exceeded over an area of 3.8ha.

22.8.825 To account for the worst-case scenario the highest daily discharge value (3,442kg/d in March) was applied using a 5th percentile salinity, average temperature for March and average annual pH. Under these scenarios the exceedance of the EQS occurs over an area of 6.7ha, provided in**Appendix 22F** of this volume.

22.8.826 Biomass values are based on rates of impingement at Sizewell B and extrapolated to account for abstraction volumes. They do not account for the Sizewell C intake head design that will mitigate fish entrapment and is predicted to abstract ca 60% fewer fish per cumec than Sizewell B, or any losses from the system through tidal/wave transport or consumption. Furthermore, the assessments consider discharges of dead and moribund biota form a single point source. This adds a further precautionary factor to the assessment as the two FRR units, located approximately 300m apart, would allow a greater level of initial dilution with discharges split between two spatially separated points sources. Results should, therefore, be considered as highly precautionary.

22.8.827 The maximum spatial scale of the impacts is low and differs seasonally. Discharges would occur throughout the operational phase of the proposed development; therefore, the duration is high and the amount of change seasonally variable.

22.8.828 The impact magnitude is assessed as medium.

Sensitivity assessments of effects at the sea-area or regional stock/population level: un-ionised ammonia

Demersal fish and elasmobranch eggs /cases and larvae: sensitivity to un-ionised ammonia

22.8.829 Concentrations of un-ionised ammonia regarded as acutely toxic greatly exceed the concentrations predicted from dead and moribund biota discharged from the FRR systems. Mortality of developing embryos in the eggs, larvae/post-larvae is therefore unlikely and a very limited proportion of the population would be exposed to concentrations above EQS levels. The sensitivity of demersal fish and elasmobranch eggs /cases and larvae to un-ionised ammonia is predicted to be *Not Sensitive*.

22.8.830 The impact of un-ionised ammonia from the FRR systems is predicted to have a negligible effect on demersal fish and elasmobranch eggs /cases and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Demersal fish and elasmobranchs: sensitivity to un-ionised ammonia

22.8.831 The CDO construction assessment summarises studies of marine fish exposed to un-ionised ammonia, provided in **Section 22.8.c)** of this chapter. The EQS is exceeded but over a very limited i.e. maximum of 6.7ha in March, provided in **Appendix 22G** of this volume. Mortality of juveniles and adults is unlikely, though chronic effects such as reduced growth could occur in individuals in proximity to the FRR. However, a very small proportion of the population would be exposed. The sensitivity of demersal fish and elasmobranch juveniles and adults (and small bodied fish) is predicted to be not sensitive.

22.8.832 The impact of un-ionised ammonia from the FRR systems, is predicted to have a negligible effect on demersal fish and elasmobranch juveniles and adults (and small bodied fish). Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish eggs and larvae: sensitivity to un-ionised ammonia

22.8.833 As per the assessment for demersal fish and elasmobranch eggs/larvae, the sensitivity of pelagic fish eggs and larvae to un-ionised ammonia is predicted to be not sensitive.

22.8.834 The impact of un-ionised ammonia the FRR systems, is predicted to have a negligible effect on pelagic fish eggs and larvae. Effects are **not significant** at the sea area and regional stock/population levels.

Pelagic fish: sensitivity to un-ionised ammonia

22.8.835 As per the assessment for demersal fish and elasmobranch juveniles and adults (and small bodied fish), the sensitivity of pelagic fish juveniles and adults to un-ionised ammonia, is predicted to be not sensitive.

22.8.836 The impact of un-ionised ammonia the FRR systems, is predicted to have a negligible effect on pelagic fish juveniles and adults. Effects are **not significant** at the sea area and regional stock/population levels.

Migratory fish: sensitivity to un-ionised ammonia

22.8.837 The EQS is exceeded but over a very limited i.e. maximum of 6.7ha in March, provided in **Appendix 21F** of this volume. Potential lethal effects are not predicted, and chronic effect would only occur over a small area.

22.8.838 The sensitivity of migratory fish juveniles and adults to un-ionised ammonia, is predicted to be not sensitive. The impact of un-ionised ammonia from the FRR systems, is predicted to have a negligible effect on migratory fish. Effects are **not significant** at the sea area and regional stock/population levels.

Assessments of effects of localised displacement: un-ionised ammonia

22.8.839 Localised displacement of fish receptors, due to un-ionised ammonia, is predicted to have a negligible effect. Therefore, no significant changes in the availability as prey items for designated features and as fisheries resources are predicted.

v. Inter-relationship effects

22.8.840 This section provides a description of the identified inter-relationship effects that are anticipated to occur on fish receptors, arising from the combination of individual environmental impacts arising from the operation of the proposed development.

Commissioning discharges of hydrazine on fish discharged from the FRR

22.8.841 Commissioning of the two reactors is likely to be staggered. As such, Unit 1 may become operational whilst Unit 2 is still being commissioned. In such a scenario commissioning discharges from Unit 2, discharged via the CDO have the potential to intersect fish returned from the southern (Unit 1) FRR, approximately 340m south of the CDO. Fish discharged from the Unit 1 FRR would already have experienced stresses associated with impingement and may be more sensitive to exposure of hydrazine.

22.8.842 The instantaneous plume of hydrazine was modelled at the point of Unit 1 FRR. Model results show that the instantaneous hydrazine plume exceeds the acute PNEC (4ng/l 95th percentile) at the surface and seabed. At a release concentration of 15µg/l, the transitory peak concentration at the surface is predicted to be 176.4ng/l. The average concentration of the plume at the surface above the PNEC (only including the times above the PNEC) is 15ng/l. The duration of the exceedance is short, with concentrations exceeding the acute PNEC for no longer than 3.25 hours at a time. The total time above the acute PNEC represents 5.1% of the modelled month and never exceeds 200ng/l (Ref. 22.65). There is limited data on the toxicity of hydrazine to marine fish, however, freshwater examples indicate the most sensitive species have a 96h LC_{50} of 610,000ng/l (Ref. 22.62). This acute toxic threshold is orders of magnitude above the transient peak concentration predicted at the FRR. Fish exposed to impingement stress may be less tolerant, to chemical stress. However, the low concentrations and transitory nature of the plume indicated additional mortality would be minimal.

Interaction between thermal discharges and chlorine toxicity

22.8.843 During the operation of the cooling water outfalls, chlorine would seasonally be discharged into the heated cooling water stream. When seawater mixes with chlorine total residual oxidants (TRO) are produced resulting from the combination of chorine and organic material in the water, in addition chlorination compounds are broken down to form chlorination by-products. Increased temperatures may increase the rate of chlorination by-product formation (synergistic effects) but also accelerate the degradation rate. The ambient temperature fluctuations at the time of chlorination may influence the kinetics of chlorination by-product formation and survival (Ref. 22.87).

22.8.844 Elevated temperature can potentially magnify the effects of chlorine toxicity on fish (Ref. 22.438). The mechanism is summarised as a reduction in metabolic scope at higher temperatures and consequential reduction in resistance (Ref. 22.438). This means that the synergistic effects of elevated temperatures and TROs need to be considered.

22.8.845 The operation of the proposed development would result in a very small increase in the area of seabed exposed to the TRO plume above EQS concentrations (2.1ha above EQS). The total seabed area where absolute temperatures are >23ºC occurs over limited areas (25.6ha as a 98th percentile with both stations operating), whilst temperatures above 28ºC do not occur at the seabed. Therefore, no further consideration is made of the possible synergistic effects for seabed plumes.

22.8.846 During the chlorination season, the area of the surface TRO plume (338ha above EQS from Sizewell C) would overlap and exceed the predicted surface plume where the absolute temperatures are >23ºC (89.6ha as a 98th percentile). There would, however, be negligible overlap of the area of 0.11ha for the absolute temperature uplifts >28ºC and surface TRO plume. At the boundary of the surface EQS threshold, thermal uplifts (98th percentile) are less than 3ºC, provided in **Figure 21.7** of **Chapter 21** of this volume, and mean thermal uplifts are less than 1ºC.

22.8.847 Chlorination and thermal discharges would occur throughout the lifetime of the proposed development, though chlorination would be seasonal. The impact magnitude is medium.

Assessments of effects on fish receptors: thermal discharges and chlorine toxicity

22.8.848 TRO toxicity may increase with the near-field of the thermal plume. However, limited acute (lethal) effects are predicted to be localised and mobile species and life history stages may be able to demonstrate avoidance behaviours reducing exposure.

22.8.849 The inter-relationship of the TRO and thermal plumes is not predicted to increase the significance of effects concluded for the pressures alone. This conclusion applies to fish receptors assessed in **Section 22.8.d)** of this chapter. Effects are **not significant** at the sea or regional stock/population level.

Assessments of effects of localised displacement: thermal discharges and chlorine toxicity

22.8.850 It is unlikely that the inter-relationship between thermal and chlorinated discharges would increase the significance of the effects of localised displacement, beyond the effects predicted for the pressures individually. The conclusion applies to all fish receptors assessed. Effects are **not significant** at the sea or regional stock/population level.

Hydrazine and temperature changes

22.8.851 Hydrazine persistence in the marine environment is low to moderate dependent upon its concentration and the water quality, provided in **Appendix 21E** of this volume. It is relatively stable but reacts rapidly with any oxidizing agents present. Considering the decay of hydrazine, increases in water temperature were found to enhance the toxicity of the compound for fish taxa (Ref. 22.87).

Assessments of effects at the sea-area or regional stock/population level: hydrazine and temperature changes

22.8.852 The inter-relationship of the hydrazine and thermal plumes is not predicted to increase the significance of effects concluded for the pressures alone. This conclusion applies to all fish receptors assessed. Effects are **not significant** at the sea or regional stock/population level.

Assessments of effects of localised displacement: hydrazine and temperature changes

22.8.853 It is unlikely that this inter-relationship would increase the significance of the effects of localised displacement, beyond the effects predicted for the pressures. This conclusion applies to all fish receptors assessed. Effects are **not significant** at the sea or regional stock/population level.

Chlorinated discharges and treated sewage in the cooling water system

22.8.854 During operational phase, seasonal chlorination would be applied to protect critical plant from biofouling. Chlorination of seawater results in the liberation of a range of TROs and chlorination by-products depending on the water chemistry. Elevated organic content and ammonia can lead to the formation of chloramines and bromamines (Ref. 22.106). Increased ammonia levels at estuarine power stations has previously been proposed as the factor behind elevated toxicity of chlorination in comparison to the open coastal sites (Ref. 22.69).

22.8.855 Ammonia discharges from plant conditioning chemicals and the on-site sewage treatment would also be discharged via the cooling water outfalls. Whilst EQS levels are not predicted to be exceeded once the discharges mix with the receiving waters, there is the potential for ammonia to react with chlorinated discharges in the cooling water stream.

Assessments of effects at the sea-area or regional stock/population level: Chlorinated discharges and treated sewage

22.8.856 The synergistic effects of chlorination and ammonia discharges may increase the toxicity of the cooling water to entrained ichthyoplankton. However, small increases in mortality are not predicted to influence entrainment predictions. Abstraction rates represent approximately 1.35% of the volume of water that passages past the station and exchange rates with the wider North Sea are ca. 10%. Therefore, even with 100% mortality of ichthyoplankton, there is expected to be a negligible effect at the stock/population level, especially with high natural mortality experienced in the early life stages, provided in **Appendix 22G** of this volume.

22.8.857 The synergistic effects of chlorination and ammonia discharges are not predicted to alter the assessment of entrainment effects.

22.8.858 The impact of entrainment remains as a negligible effect on the key taxa assessed (**Table 22.63**). Effects are **not significant** at the sea area and regional stock/population levels.

Primary and secondary entrainment

22.8.859 During entrainment, ichthyoplankton and juveniles would be exposed to increases in temperature and mechanical stress. Survivors of entrainment through the cooling water system (primary entrainment) would, at the point of discharge, be exposed to thermo-chemical stressors (secondary entrainment).

Assessments of effects at the sea-area or regional stock/population level: primary and secondary entrainment

22.8.860 Although there is potential for increased stress, reduced fitness and increased mortality within the discharge plume the combined effect of primary and secondary entrainment would not increase the significance of the effects beyond the effects predicted for primary alone. This is due to the fact that even if 100% mortality of entrained ichthyoplankton was assumed, the volume of cooling water is sufficiently low compared to tidal exchange to dampen any effects, provided in **Appendix 22G** of this volume. Effects are **not significant** at the sea or regional stock/population level.

Entrainment and impingement in-combination (entrapment)

22.8.861 Entrainment and impingement have the potential to affect fish receptors across all life history stages and the in-combination effects of the two impacts has been considered. Minor adverse effects have been concluded. Effects are **not significant** at the sea area and regional stock/population levels, provided in **Section 22.8.d)** of this chapter.

22.9 Marine mammals

a) Introduction

22.9.1 This section presents the findings of the marine mammal assessment for the construction and operation of the proposed development. The objective of the assessment is to identify any likely effects and if required, highlight any secondary mitigation and monitoring measures in order to minimise any adverse significant effects.

b) Marine mammals baseline environment

22.9.2 This section presents a description of the baseline environmental characteristics within the footprint of the proposed development and in the surrounding area.

22.9.3 The marine mammal baseline was established using the following data and information sources (further information can be found in **Appendix 22E** of this volume:

- The Small Cetaceans in the European Atlantic and North Sea I, II and III surveys which use density surface modelling (animals/km^2) based on visual sightings
- The Special Committee on Seals reports which estimates harbour and grey seal total (at sea and hauled out) usage around the UK.
- The Atlas of Cetacean Distribution in North-west European Waters (Ref. 22.439).
- A Wildfowl and Wetlands Trust Consulting report (Ref. 22.440).
- Static acoustic monitoring for harbour porpoise and dolphins off the Sizewell site using static acoustic devices (BEEMS Technical Report TR271 (Ref. 22.441)).
- The Marine Aggregate Regional Environmental Assessment for the Outer Thames Region published by the Thames Estuary Dredging Association (Ref. 22.128).
- Wind farm EIAs for the Galloper (Ref. 22.442) and Anglian Zone (East Anglia Offshore Wind Limited (Ref. 22.443).
- Thames Estuary harbour seal tagging study by the Zoological Society of London (Ref. 22.444).

i. Current baseline

22.9.4 Three species of marine mammals are known to occur in the Greater Sizewell Bay (GSB). These include one cetacean species: harbour porpoise (*Phocoena phocoena*) and two pinniped species: harbour seal (also known as common seal) (*Phoca vitulina)* and grey seal (*Halichoerus grypus*). Other species of cetaceans are present in the southern North Sea, provided in **Appendix 22E** of this volume, although, these species are infrequently observed within the Great Sizewell Bay (GSB) and therefore scoped out of the assessment.

Harbour porpoise *(Phocoena phocoena)*

22.9.5 Harbour porpoise sighting datasets spanning over a 25-year period indicate their wide-ranging distribution around all of the UK and adjacent seas, with the fewest sightings in the English Channel and southern-most part of the North Sea (Ref. 22.439). However, more recent aerial surveys (conducted between 2001-2008) focusing on the coastline around the UK showed that concentrations of porpoises are found from Norfolk to Kent, with dense cluster of sightings off Southwold (north of the GSB) (Ref. 22.440). Large scale abundance surveys across the UK and adjacent waters provided new information on the distribution of harbour porpoise revealing that their distribution has expanded from the North Sea into the Channel (Ref. 22.445). The surveys also provided new and revised estimates for harbour porpoise in the North Sea (289,000 in 1994, 355,000 in 2005 and 345,000 in 2016) (Ref. 22.445). Data from Small Cetaceans in the European Atlantic and North Sea III survey indicate Summer harbour porpoise densities in the wider area off the southern East Anglian coast are 0.6 - 0.7 animals/km^2.

22.9.6 The Thames Regional Environmental Assessment (REA) (Ref. 22.128) and BEEMS monitoring programme (Ref. 22.441) showed that harbour porpoise are present year-round in the area local to the proposed development and that the wider area of the southern North Sea has become potentially important habitat for this species. During the surveys in the outer Thames Estuary, the majority of porpoise sightings were recorded during the Winter period. It has been suggested that the high number of sightings during this part of the year could be linked to the increase in food abundance in the area due to herring spawning, provided in **Appendix 22D** of this volume.

22.9.7 Under the BEEMS programme a static acoustic monitoring technique was used to investigate the presence of cetaceans in the proposed development area. The acoustic loggers (C-PODS) were deployed over 18 months, from September 2011 to March 2013. The data collected provided an insight into porpoise activity in the area. Porpoises were detected on 64% of monitoring days with the number of detections being consistently higher between October and March and lowest during the Summer months. Furthermore, detections rates were higher during night than day and there appeared to be a preference for offshore waters (10-20km from the coast) with lower detection rates inshore (1-2km from the coast) (Ref. 22.441).

22.9.8 The Southern North Sea Special Area of Conversation (SAC) is designated solely for the purpose of aiding the management of the Annex II[65] species harbour porpoise. The site was formally designated in February 2019. The designated area is of high importance to harbour porpoise in both the Summer and Winter months. The conservation objective of the site is to ensure site integrity making an appropriate contribution to maintaining Favourable Conservation Status (FCS) for harbour porpoise in UK waters. The site covers both inshore and offshore waters (within and beyond 12nm of the coast, respectively) and stretches from the central North Sea (north of Dogger Bank) to the Straits of Dover in the south, covering an area of 36,951km^2. As such, it includes the area of open sea adjacent to the eastern boundary of the proposed development (**Figure 22.15**).

22.9.9 Harbour porpoises are opportunistic predators feeding on a variety of fish and cephalopods. Their diet varies among regions, seasons, sexes and sizes (Ref. 22.446). Despite a wide range of prey species found in their diet, porpoises prefer small shoaling demersal or pelagic fish (Ref. 22.447). Porpoises also appear to be flexible feeders as they can easily switch to different prey species if their preferred prey is not sufficiently available (Ref. 22.448). Large spatio-temporal variations are observed in porpoise diet, but it is believed that their foraging strategy is primarily guided by the quality of the prey rather than its quantity in order to meet energy demands (Ref. 22.449). Wisniewska *et al.* (2016) reported that porpoises forage almost continuously day and night catching up to 550 small (3-10cm) fish prey per hour with a more than 90% success rate (Ref. 22.450). Taking in consideration previous studies on their prey in the North Sea, seasonality, and expected prey availability in the Sizewell area, as of **Appendix 22D** of this volume, it is considered that their main Winter prey in the proposed development area consists of sprat (*Sprattus sprattus*), herring (*Clupea harengus*), whiting (*Merlangius merlangus*), seabass (Dicentrarchus labrax), gobies (fam. *Gobiidae*) and Dover sole (*Solea solea*) while their Summer prey includes sprat, whiting, gobies, dab (*Limanda limanda*) and Dover sole (Ref. 22.335).

Harbour seal *(Phoca vitulina)*

22.9.10 In the UK, harbour seals are predominantly found around the west coast of Scotland, the Hebrides and the Northern Isles. However, smaller concentrations are also found along the east coast, in the Moray Firth, Firth of Tay, The Wash and the Thames Estuary (Ref. 22.451). The most recent estimate of the UK population in 2016 was 43,500 individuals (95%

[65] Annex II species require designation of SACs under the Habitat Directive (92/43/ECC).

confidence intervals 35,600 to 58,000), which constitutes approximately 30% of the eastern Atlantic subspecies population (Ref. 22.452).

22.9.11 The nearest sites of relevance to the proposed development area are The Wash and Blakeney Point to the north and the Thames Estuary to the south. Of these, The Wash has the largest proportion of harbour seals containing around 7% of the total UK population. Tagging studies have revealed that the harbour seals transit along the coastline between the Thames and north Norfolk (Ref. 22.444; 453) suggesting a level of at-sea usage of the area close to the proposed development. Generally, habitat use is considered to be low to moderate in the proposed development area with low haul-out usage (Ref. 22.451).

22.9.12 The Wash and North Norfolk Coast SAC is the closest SAC site designated for harbour seals and is situated approximately 120km from the proposed development area (**Figure 22.15**). The Wash is the largest embayment in the UK and the extensive intertidal flats along this stretch of the coast provide ideal habitat for harbour seal breeding and hauling-out.

22.9.13 Studies investigating the spatial distribution of harbour seals indicate that they form discrete regional populations, display heterogeneous habitat usage and generally stay close to the coast (Ref. 22.454). The typical foraging trips are usually between 40 to 50km from the haul-out site (Ref. 22.452). However, more recent tagging studies have shown that they can travel 50-100km offshore and up to 200km between haul-out sites (Ref. 22.453; 455). The location and surrounding marine habitat play a role in the range of foraging trips. The longest foraging trips have been recorded during tagging studies at The Wash where seals often foraged up to 120km offshore (average 80km) and occasionally travelled up to 220km (Ref. 22.453). Taking this into consideration, it is possible that the seals from The Wash could utilise areas adjacent to the proposed development.

22.9.14 Harbour seals are opportunistic predators feeding on a variety of prey. The most dominant prey species in the south western North Sea are whiting, Dover sole, dragonet (*Callionymus lyra*) and sand gobies (*Pomatoschistus minutus*). These prey species made up the majority (63 %) of the total of 31 species recorded in the study conducted by Selection of prey varies seasonally and regionally while the dominant pattern appears to be predation on the most abundant prey (Ref. 22.456).

22.9.15 Based on the fish availability at Sizewell, provided in **Appendix 22D** of this volume, the main prey of harbour seals within the GSB is expected to consist of whiting, Dover sole and sand gobies.

Grey seal (*Halichoerus grypus)*

22.9.16 Approximately 38% of the world's grey seal population breed in the UK and of these, 88% breed in Scotland (Ref. 22.451). The largest populations are in the Outer Hebrides and Orkney, with further breeding colonies in Shetland, SW England, Wales and the north and east coasts of mainland Britain. The latest UK estimate of grey seals in 2016 was 141,000 individuals (95% confidence intervals 117,500 to 168,500) (Ref. 22.452). Similar to the harbour seal, southern North Sea grey seal populations of relevance to the proposed development are found in The Wash, East Anglia and the Thames Estuary. Southern North Sea colonies in Lincolnshire and East Anglia have increased by more than 15% over the last ten years possibly as a result of seals from outside these regions recruiting into the breeding population (Ref. 22.451).

22.9.17 Previous surveys conducted in the wider area suggest that grey seals are present regularly around the proposed development area (Ref. 22.442; 457; 458). However, they do not utilise the area heavily and appear present mostly during Winter and Spring (Ref. 22.457). The nearest SAC to the proposed development that includes grey seal as a qualifying feature is the Humber Estuary, approximately 220km to the north (**Figure 22.15**).

22.9.18 Grey seals are wide ranging and can utilise different breeding and foraging grounds (Ref. 22.459). Typical foraging trips are within 100km from their haul-out sites, although trips of several hundred kilometres have been recorded (Ref. 22.452). They generally make trips between known foraging grounds and return to the same haul-out site but there is also evidence that they can move between different haul-out sites (Ref. 22.452). For example, seals tagged at Donna Nook and Blakeney Point used multiple haul-out sites between the Netherlands and Northern France (Ref. 22.460). Given the wide-ranging and extensive movements of grey seals there is a likelihood that seals from the Humber Estuary SAC may be present in the wider proposed development area.

22.9.19 Grey seals are generalist feeders taking a wide range of prey (i.e. fish, molluscs, cephalopods, echinoderms, crustaceans and cephalopods) (Ref. 22.452). In rare cases, grey seals are also known to predate on harbour porpoises (Ref. 22.461) and harbour seals (Ref. 22.462). Their main prey includes fish species such as sandeels (*Ammodytes marinus)*, gadoids (cod (*Gadus morhua*)), whiting, haddock (*Melanogrammus aegelfinus*), ling (*Molva molva*)) and flatfish (plaice (*Pleuronectes platessa*), sole, flounder (*Platichthys flesus*), and dab). The diet varies seasonally and from region to region. Foraging trips typically last between one and 30 days and the seals tend to forage on the seabed at depths of up to 100m (Ref. 22.452). In contrast to harbour seals, grey seals forage further offshore and the difference in their diets can be attributed to difference in fish distributions.

22.9.20 Based upon fish availabilities at Sizewell, provided in **Appendix 22D** of this volume, the prey of grey seals within the GSB is expected to largely consist of Dover sole, flounder and plaice.

ii. Future baseline

22.9.21 The harbour porpoise has a widespread distribution around the UK and is the most abundant cetacean species in the North Sea (Ref. 22.439). However, their distribution is not fixed and is driven by a variety of factors including those linked to anthropogenic pressures. More specifically, there has been a shift in porpoise distribution in recent years from northern regions of the North Sea to the southern North Sea, English Channel and Celtic Sea (Ref. 22.463). This could be attributed to recent reductions in prey availability in the north (whiting and sandeel) but sustained availability in the south (whiting and herring) (Ref. 22.464). Despite this shift in their distribution, porpoise abundance throughout the North Sea has not changed markedly in recent years (Ref. 22.445). Based on the modelling predictions of the impacts of climate change, it is expected that harbour porpoises could decline in the southern North Sea in the future with a predicted shift northwards due to their narrow habitat requirements (Ref. 22.465). Considering the location of the proposed development, it is not expected that such shifts would have a significant impact on the presence of harbour porpoises in the GSB.

22.9.22 The southern North Sea colonies of grey seals in Lincolnshire and East Anglia have increased by more than 15% over the last ten years (Ref. 22.452). By contrast, there have been declines in harbour seal populations around the UK. This decline is attributed to outbreaks of epizootic disease, interspecies competition, decrease in food resources due to overfishing and possibly due to climate-mediated changes in food supply (Ref. 22.466). It is predicted that changes in physical habitat due to the climate change induced sea-level rise may affect seal haul-out and breeding sites on low lying coasts (such as those at The Wash) leading to a loss of habitat (Ref. 22.465) and consequently leading to changes in their abundance and distribution. However, it is not expected that such changes would greatly affect the presence of these two species in the wider GSB given that there is no/little haul-out in this area.

22.9.23 Marine mammals as top predators directly respond to the changes in their prey availability and movement. A shift of the warmer water species such as short-beaked common dolphin (*Delphinus delphis*) and striped dolphin (*Stenella coeruleoalba*) further north off western Britain and the northern North Sea has been recently documented (Ref. 22.467). It is thought that their range expansion is linked to changes in the distribution of warmer water fish species such as anchovy (*Engraulis encrasicolus*) and sardines (*Sardina pilchardus*)(Ref. 22.468). Squid populations are expected to increase in the future (Ref. 22.469) which could lead to a potential increase in their predators such as Risso's dolphin (*Grampus griseus*) and striped dolphin in the North Sea. Therefore, currently rare species for this area could potentially occur in the GSB in the future.

iii. Receptor Value

22.9.24 Marine mammals are protected by a number of national and international regulations and are listed as Annex II species under the Habitat Directive and under section 41 of the NERC, for more details see **Section 22.2** of this chapter. Harbour porpoise and the two species of pinnipeds are also designated features of the SACs in the UK waters. Thus, the group as a whole is assigned high receptor value.

iv. Zone of Influence

22.9.25 The Zone of Influence (ZOI) encompasses the area within which impacts (beneficial or adverse) are expected to occur. The size of the ZOI is species (or group) specific and depends on the particular activity in question and the spatial extent of the impact.

22.9.26 Underwater noise is considered to be the activity with the largest spatial impact on marine mammals given that underwater sound propagates away from the sound source and influences marine mammals at distance.

22.9.27 Impact piling is the activity with the greatest potential to cause instantaneous auditory injury to marine mammals, while noise associated with drilling and dredging represents no risk. Underwater noise assessments (herein) consider the case of a hypothetical unexploded ordinance (UXO) detonation, thereby encompassing the full suite of potential auditory impacts. However, impact piling has been used to inform underwater assessment scenarios.

22.9.28 Considering the results of underwater noise modelling a precautionary approach is applied and the greatest ZOI is approximately 12.5km from the source. It is thought that effects from all pressures associated with the proposed development would occur within this spatial scale for marine mammals.

22.9.29 Impacts from the proposed development would not occur in isolation from activities from other developments. A Cumulative Effects Assessment (CEA) has been completed with focus on the southern North Sea SAC, provided in **Chapter 4** of **Volume 10** of the **ES**.

c) Construction

22.9.30 The construction phase, including commissioning, of the proposed development has the potential to effect marine mammal receptors.

Construction is planned to commence in 2022 and last between nine and 12 years.

22.9.31 This section considers the development components and associated activities that were identified during scoping, provided in **Appendix 22M** of this volume, to result in pressures warranting further investigation.

i. Coastal defence feature

22.9.32 Construction and maintenance of the coastal defence features would be above MHWS. No significant effects on marine mammal receptors are predicted from these activities[66].

ii. Beach landing facility

22.9.33 This section describes the impacts associated with the installation and operation of the beach landing facility (BLF) during the construction phase. Scoping identified the pressures arising from activities at the BLF with the potential for effects on ecological receptors, provided in **Appendix 22M** of this volume. Those pressures with the potential to effect marine mammal receptors are presented in **Table 22.127**.

Table 22.127: Pressures associated with BLF activities with the potential to effect marine mammal receptors.

Pressure	BLF activities resulting pressure.	Justification and evidence base.
Changes in SSC.	Navigational, dredging and piling.	Increases in SSC have the potential to affect marine mammal receptors through disruption or impairment to feeding.
Underwater noise.	Navigational, dredging and piling.	The potential effects of underwater noise on marine mammal receptors range from injury (close to the source) or to behavioural or barrier effects (at gretaer distances).
Visual disturbance from artificial lighting.	Construction activities for the BLF installation and construction phase	Introduction of artificital light can potentially cause disturbance and displacement.

[66] The only pressure associated with the construction of the coastal defence feature that could potentially affect marine mammals would be visual disturbance from artificial light. However, considering that the assessment for the same pressure associated with the construction and operation within the marine environment resulted in negligible effects on marine mammal receptors, as well as implementation of the lighting strategy, it is thought that effects in this case would be proportionally lessened. Additionally, coastal populations of marine mammals are known to occur in the vicinity of land-based man-made structures and settlements and no major deterrent effects due to artificial light have been reported. Thus, it is deemed that a detailed assessment for this pressure is not required.

Pressure	BLF activities resulting pressure.	Justification and evidence base.
	deliveries once the BLF is operational.	
Physical disturbance from vessel activity.	Construction activities for the BLF installation and construction phase deliveries once the BLF is operational.	Physical presence of vessels as well as increased vesel traffic can potentially cause disturbance and displacement.

Changes in suspended sediment concentration

22.9.34 Construction of the BLF requires dredging of a navigation channel over the outer longshore bar and creation of a planar grounding surface. The initial dredge profile requires the redistribution of 4,600m^3 of sediment by plough dredging. Such activities would temporarily increase suspended sediment concentrations (SSC).

22.9.35 Dredge plume modelling is detailed in **Appendix 22J** of this volume. Dredge areas, sediment plume characteristics and changes in sedimentation as a result of dredging activities are provided in **Section 22.3.i)** of this chapter. Following the initial capital dredging event, a plume with an instantaneous suspended sediment concentration (SSC) of >100mg/l above daily maximum background levels is expected to form inshore over an area of up to 108ha at the sea surface and 83ha as a depth averaged plume. A small area of up to 7ha would experience an instantaneous SSC of >1,000mg/l above background levels. Maintenance dredging, occurring at approximately monthly intervals during the campaign period when the majority of BLF deliveries are anticipated (31st March – 31st October each year) would result in up to 28ha of sea surface expected to experience >100mg/l, and 1ha expected to experience >1,000 mg/l above background SSC on each occasion.

22.9.36 Dredging has the potential to temporarily increase turbidity from a baseline status of '*intermediate turbidity*' to '*turbid*' according to the WFD criteria over part of the study area. However, SSC would return to background levels several days after dredging activity ceases, provided in **Appendix 22J** of this volme.

22.9.37 Given the wide foraging range of marine mammals and the spatial and temporal extent of this impact, the magnitude is considered to be low.

Marine mammal sensitivity to suspended sediment concentrations

22.9.38 Harbour porpoise and seals are well adapted to existence in turbid coastal waters (Ref. 22.470) and are therefore resistant to this pressure. A study carried out on a blindfolded captive harbour porpoise demonstrated that the animal was still able to forage successfully, using echolocation to navigate. However, it did reduce its swim speed when blindfolded (Ref. 22.471).

22.9.39 Seals are also able to forage normally despite being blind (Ref. 22.472). Harbour seals have extremely sensitive vibrissae which allow them to follow hydrodynamic trails from prey (Ref. 22.473) and discriminate between different sized or shaped objects (Ref. 22.474).

22.9.40 The GSB is situated in a region of the North Sea that has relatively shallow waters (40m maximum depth) and the hydrodynamic regime is classified as '*permanently mixed'* through continuous wave and tide action (Ref. 22.43). The baseline SSC in the GSB varies depending on seasonality, tidal state, wave energy, and the occurrence of storm events. The short duration of the dredging activities and the rapid decrease in SSC following cessation of activities suggest that impacts would be short-lived. Large natural variability in SSC occurs at the site.

22.9.41 Indirect effects due to behavioural avoidance by fish from the plume could occur but this has been assessed as minor and **not significant**, provided in **Section 22.8** of this chapter, and there would be no significant impact on marine mammals foraging in the area. Therefore, it is considered that marine mammals are not sensitive to increases in SSC associated with the BLF.

22.9.42 The impact of increased SSC resulting from dredging activities is predicted to have a negligible effect on marine mammal receptors. Effects are predicted to be short-lived, spatially limited and not significantly different to conditions in the existing marine environment. Effects are **not significant**.

Underwater noise

Piling

22.9.43 The BLF will have a piled deck that would require impact piling to install the piles. A total of 12 piles would be installed within the marine environment below MHWS, see **Appendix 20A** of this volume. Piles of ca. 1.5m in diameter will be located in shallow waters of <5m ODN. The expected hammer energy is 90kJ, but 200kJ was also modelled to envelope a wide range of engineering options. **Appendix 22L** of this volume details the underwater noise modelling for the piling associated with the BLF.

22.9.44 The low energy impact piling associated with the BLF resulted in no instantaneous Permanent Threshold Shift (PTS) or Temporary Threshold Shift (TTS) outside the standard 500m marine mammal mitigation zone (Ref. 22.23) at the onset of piling. More specifically, the maximum instantaneous

TTS impact range[67] during piling was estimated to be 67m for harbour porpoise with a 200kJ hammer strike energy. PTS was restricted to 41m of the piling activity for the 200kJ scenario and 27m for the 90kJ hammer energy scenario.

22.9.45 Seal auditory impacts zones[68] were considerably smaller, with maximum instantaneous ranges of 9m and 16m for PTS and TTS respectively for the 200kJ scenario (**Table 22.128**). Instantaneous effects from piling are considered minimal and can be effectively mitigated through compliance with JNCC (2010) protocol (tertiary mitigation) (Ref. 22.23).

22.9.46 Two techniques are used to assess total noise exposure over the duration of piling (a stationary model and a fleeing model). These models cater for the uncertainty of the animal's reaction following exposure to a high noise source. The stationary model assumes that the animal will not move at all over 24 hour period while the fleeing model takes in consideration the probability of fleeing, the swimming speed and flight path.

22.9.47 Assessments of fleeing behaviour assumed that marine mammals would flee from the source location at the onset of activity. Animals were assumed to flee out to a maximum distance of 25km after which they were assumed to remain stationary at that distance. The model assumed that the animals flee at constant speeds (1.4 m/s and 1.8 m/s for harbour porpoise and seals respectively), along straight lines away from the pile location, as long as the local water depth exceeds a minimum value (3m for harbour porpoises). In the case of harbour porpoises fleeing, if the animal encounters water shallower than the allowed minimum depth, a change is direction is calculated and effected by the model. Conversely, seals could move in any depths of water or move to the shore (within the 25 km maximum distance from the pile location), thus stopping their sound exposure.

22.9.48 Cumulative sound exposure was predicted for pile driving five consecutive piles within 24-hours using the most likely 90kJ hammer energy and the worst-case 200kJ hammer energy. The stationary cumulative auditory impact zones for harbour porpoise was predicted as 12.45km and ~2km for TTS and PTS, respectively. The 90kJ hammer energy scenario resulted in a TTS impact zone of ~6.6km and a PTS impact zone of ~1.3km (**Table 22.128**).

22.9.49 The corresponding fleeing harbour porpoise assessments resulted in no PTS impact zones, while the TTS zone extended to approximately 2.8km for the

[67] Auditory effects zone predicted in underwater noise modelling (**Appendix 22L**) inform the spatial extent of impacts.
[68] Both species of seals have the same threshold for assessment.

90kJ hammer energy scenario and to approximately 4.8km for the 200kJ scenario (**Table 22.128**).

22.9.50 The corresponding TTS and PTS zones for cumulative noise exposure were predicted to be smaller for seals than for harbour porpoise. These differences are a consequence of the differing auditory weighting (which is markedly different at low frequencies) and exposure threshold for seals. In the stationary model TTS was predicted to extend to ~ 3.1km and PTS to ~300m for the seals in the 200kJ hammer energy scenario. For the 90kJ hammer energy scenario, the corresponding maximum impact ranges were approximately 35% smaller than those predicted in the worst-case scenario (**Table 22.128**).

22.9.51 The corresponding fleeing seals assessments resulted in no PTS or TTS impact zones for either hammer energy (**Table 22.128**).

Table 22.128: Marine mammal auditory impact zones for piling activity

Activity	Threshold	Instantaneous		Stationary Cumulative.		Fleeing Cumulative.	
		Harbour porpoise.	Phocid seals.	Harbour porpoise.	Phocid seals.	Harbour porpoise.	Phocid seals.
Impact piling 90kJ.	PTS	27m	6m	1,297m; 190ha	206m; 10ha	No impact.	No impact.
	TTS	45m	10m	6,624m; 4,994ha	1,882m; 430ha	2,765m; 768ha	No impact.
Impact piling 200kJ.	PTS	41m	9m	2,081m; 561ha	303m; 20ha	No impact.	No impact.
	TTS	67m	16m	12,450m; 10,223ha	3,104m; 1,064ha	4,795m; 2,179ha	No impact.

22.9.52 Considering the short duration of the proposed piling activity, small pile sizes and the small scale of the Sizewell C Project and low corresponding hammer energies required for installation, the expected effects are predicted to be small-scale and short-term occurring within a spatially limited area. As per the Rochdale envelope, the worst case scenarios in terms of cumulative effects and temporal duration include: a) a maximum of five piles per day resulting in completion of piling within 2.5 days (worst case for cumulative assessment); and b) piling occurring as discrete events over 12 days (worst case for temporal duration, but smaller cumulative effects).

22.9.53 All the scenarios modelled for instantaneous TTS and PTS have impact ranges well within the 500m, which falls within the standard mitigation zone as per JNCC guidance (Ref. 22.23). Thus potential for injury and distrurbance can be further reduced with application of the prescribed measures. As a result, the magnitude of the impact is considered to be low.

22.9.54 A Sizewell C Project specific Marine Mammal Mitigation Protocol (MMMP) for piling, outlining the mitigation measures (tertiary mitigation), has been submitted as part of the DCO application, provided in **Appendix 22N** of this volume.

Marine mammal sensitivity to piling noise

22.9.55 The potential effects of underwater noise from piling range from direct injury and/or auditory damage at close range to short-term behavioural or barrier effects. To date, there has been no documented evidence of injury or mortality in harbour porpoises or seals as a result of pile driving noise. This could be due to employment of the avoidance strategies by animals and/or implementation of mitigation measures thus reducing the occurrence of injury and lethal effects (Ref. 22.302).

22.9.56 Changes in the behaviour of harbour porpoises in response to pile driving have been reported at multiple offshore wind farm sites. However, harbour porpoises returned to the area once the piling noise stopped. Piling duration has a large impact on harbour porpoise displacement from an area with longer pile driving durations leading to a longer displacement (Ref. 22.475). The expected number of porpoises affected during the Sizewell C Project is likely to be low given the short duration and the fact that porpoises prefer waters further away from the coast (10-20km from the coast (Ref. 22.441)).

22.9.57 Even though clear adverse short term effects on individual animals have been recorded in different studies (Ref. 22.475–479), there is currently no indication that harbour porpoises are significantly affected by construction piling at the population level (Ref. 22.480). The Marine Evidence Group tasked with assessing the population effects of spatial displacement of harbour porpoises during OWF construction concluded that despite some small, measurable population-level effects, the magnitude of the potential changes are much less significant than those related to other human activities and are unlikely to affect the long-term viability of this species in the North Sea (Ref. 22.480).

22.9.58 Behavioural changes, for example avoidance, have also been observed in harbour seals as a result of pile driving up to 25km from the sound source. However, seals returned to the area shortly after piling ceased (within two hours) (Ref. 22.481). It is suggested that the extent of spatial avoidance depends on differences in piling characteristics and the effects of bathymetry on sound propagation, resulting in various degrees of displacement between sites (Ref. 22.482). Marine mammals displaced following short-term piling activities associated with the BLF are expected to return to the area shortly after the activity ceases, affording a high degree of resilience.

22.9.59 It is commonly accepted that marine mammals follow the abundance and distribution of their prey. This is particularly the case for harbour porpoises that need to forage regularly in order to meet their high metabolic demands (Ref. 22.450). Therefore, the effect of underwater noise on prey species could have indirect effects on marine mammals. **Appendix 22L**, of this volume, presents the assessment of behavioural responses of fish to impact piling. The 90kJ hammer energy would result in maximum behavioural response ranges of ~ two km whereas the 200kJ hammer energy scenario would result in maximum response ranges of 2.8km. It should be noted that behavioural responses to instantaneous noise sources do not necessitate displacement but may have consequences for prey availability. Changes in prey availability within these ranges could decrease the likelihood of marine mammal presence in the same area. Behavioural responses or displacement of prey species from these areas has the potential to temporarily effect marine mammals. However, it is worth noting that fish impact ranges are spatially smaller than the predicted impact ranges for marine mammals in a stationary model. Therefore, the primary trigger for marine mammal displacement from the ensonified area is more likely to be fleeing behaviour than changes in prey availability.

22.9.60 Cumulative exposure to noise sources can result in auditory impacts extending over larger areas should a marine mammal remain within the auditory impact zone for the duration of the piling activities. However, such scenarios are unlikely given the high mobility of marine mammals and the documented avoidance behaviour to piling noise (Ref. 22.475–477; 479). It is assumed that both harbour porpoise and pinnipeds display high level of resistance to this pressure. Therefore, short-term avoidance by marine mammals to underwater piling noise is expected.

22.9.61 The sensitivity of marine mammal populations to underwater noise from piling at the BLF is predicted to be medium.

22.9.62 The impact of increased underwater noise resulting from piling activities is predicted to have a minor adverse effect on marine mammals. Effects would be short-lived and return to baseline conditions after piling activity ceases with no population levels effects predicted. Effects are therefore **not significant**.

Dredging

22.9.63 Dredging activities emit sounds that are continuous and comparatively low in frequency and intensity, although occasional higher frequencies can be emitted.

22.9.64 The results of the underwater noise modelling predicted no instantaneous auditory impact zones for marine mammals from dredging. However, cumulative auditory impact zones associated with the dredging for the BLF were the largest of all dredging activities planned on site. This is due to the highly precautionary (but unlikely due to operational restrictions) assumption of 24 hours continuous operations. The resulting stationary cumulative impact ranges for harbour porpoises extend to ~11.6km for TTS and ~1.7km for PTS. The corresponding dredging assessments for fleeing harbour porpoise resulted in no PTS, with the largest TTS zone extending to ~1.4km in the case of 24hour dredging associated with the BLF construction (**Table 22.129**).

Table 22.129: Marine mammal auditory impact zones for dredging activity

Activity	Threshold	Instant.	Stationary Cumulative.		Fleeing cumulative.	
		All species.	Harbour porpoise.	Phocid seals.	Harbour porpoise.	Phocid seals.
Dredging for BLF construction.	PTS	N/A	1,657m; 394ha.	111m; 5ha.	No impact.	No impact.
	TTS	N/A	11,576m; 11,33ha.	2,975m; 969ha.	1,377m; 241ham	No impact.

22.9.65 The predicted cumulative sound exposure impacts on stationary harbour seals and grey seals were much lower than the corresponding predictions for stationary harbour porpoise, as a consequence of differences in auditory weightings and noise exposure thresholds applicable to these distinct functional hearing groups. The largest seal auditory impact zones for TTS extended to ~3km and PTS to 111m in the stationary model. The corresponding dredging assessments for fleeing harbour or grey seals resulted in no PTS and no TTS effect zones (**Table 22.129**). Therefore, fleeing behaviours are predicted to prevent auditory damage in these species.

22.9.66 The largest impact ranges were for all stationary cumulative scenarios. However, the likelihood of marine mammals remaining in this proximity to the shallow subtidal dredging activity for the full 24-hour period required to cause auditory damage is very low. Despite the precautionary nature of the assessments PTS ranges can be considered modest for highly mobile species that are known to employ avoidance strategies in response to underwater noise. The impact magnitude for dredging is low.

Marine mammal sensitivity to dredging noise

22.9.67 Available literature on the effects of dredging on marine mammals is scarce but it is generally accepted that the most likely effects include short to medium-term behavioural reactions and masking of low-frequency calls, such as those produced by seals. Temporary hearing loss is possible if animals stay for extended periods near the dredger, but auditory injury is considered unlikely (Ref. 22.483). The results of the noise modelling are in line with this statement given that no instantaneous auditory effects were predicted and cumulative fleeing models indicate only modest TTS ranges, provided in **Appendix 22L** of this volume.

22.9.68 It is expected that any marine mammals in the area would retreat to a safe distance before injury could occur, therefore showing a high degree of resistance to this pressure. It has been reported that harbour porpoises exhibit short-term avoidance of the area where sand dredging was taking place. Harbour porpoises avoided the dredging vessel at a range of 600m but returned a few hours after the dredging activity ceased, showing a level of resilience to this pressure (Ref. 22.484). Grey seals in Ireland showed some level of avoidance to high construction vessel traffic (Ref. 22.485).

22.9.69 Dredging noise can potentially mask vocalisations produced by pinnipeds (Ref. 22.486), but. there are no known breeding grounds or haul-out sites for either grey or harbour seals in the vicinity of the proposed development area.

22.9.70 The sensitivity of marine mammal populations to underwater noise from dredging during the construction and maintenance of the BLF is predicted to be low.

22.9.71 The impact of increased underwater noise resulting from dredging activities is predicted to have a minor adverse effect on marine mammals. Effects are predicted to be short-lived and return to baseline conditions rapidly after dredging activity ceases. Effects are **not significant**.

Vessel noise

22.9.72 An increase in vessel traffic associated with deliveries to the BLF during the construction period would occur. The anticipated routes for deliveries to the proposed development include transhipment from the UK ports of Great Yarmouth and Harwich, and/or from the Netherlands ports of Rotterdam and Vlissingen. The highest frequency of expected deliveries is expected to occur between 31st March and 31st October each year. The most common type of the vessels would be construction vessels and vessels engaged in daily deliveries. The daily frequency of the vessels is not expected to be high, as barges can only land once during high tide and during daylight.

22.9.73 Existing marine traffic in the waters adjacent to the proposed development (out to 12nm) indicate the presence of various vessel types, with the most frequent being cargo, recreational, fishing and wind farm support vessels (22.11). During Summer an average of 72 vessels were observed per day while an average of 37 vessels were observed during Winter (Ref. 22.487; 488).

22.9.74 It is predicted that the potential increase in ambient noise levels associated with the BLF deliveries from vessel traffic during the construction period is likely to be modest and well within the natural variability at the site, provided in **Appendix 22L** of this volume, and would not significantly contribute to the existing background noise. Any increase in ambient noise levels within the development area would be relatively low in comparison to noise levels associated with the shipping lanes further offshore where harbour porpoises are more likely to occur.

22.9.75 Considering that the increase in vessel traffic is anticipated to occur during the period of the year when the least number of harbour porpoises are expected within the proposed development (Ref. 22.441) as well as the results of underwater noise modelling, provided in **Appendix 22L** of this volume, the assigned impact magnitude is low.

Marine mammal sensitivity to vessel noise

22.9.76 Marine mammals demonstrate a variable level of adverse reactions towards vessel traffic (Ref. 22.489). It is thought that animals inhabiting shallow, coastal habitats are especially vulnerable given that those areas are usually coincident with higher levels of vessel traffic (Ref. 22.490). Behavioural responses to ship noise are generally short-term, but can come at the cost of the energetic investment in moving, lost opportunities in foraging and social behaviour, as well as potential abandonment of calves (Ref. 22.491).

22.9.77 Harbour porpoises show avoidance to vessel traffic and could leave the area completely (Ref. 22.492). A study comparing densities of harbour porpoise and vessels revealed that areas with a high density of sea traffic are less frequented by porpoises than areas with a low density of sea traffic (Ref. 22.493). Porpoises have been shown to avoid vessels at substantial ranges suggesting that they may respond to low levels of vessel noise (Ref. 22.494; 495). Despite the fact that vessel noise is generally within the low frequency range, low levels of medium to high frequency components in vessel noise can elicit strong behavioural responses in harbour porpoises (Ref. 22.491). The authors suggested that such low levels can be experienced at ranges of more than 1km away from the vessels.

22.9.78 Studies on the effects of vessel noise to pinnipeds at sea are scarce. A recent study showed that passing vessels provoked an energetic response that terminated the natural resting cycle and precipitated a behavioural change that continued after the vessel had passed (Ref. 22.490).

22.9.79 The sensitivity of marine mammals to vessel noise is considered medium.

22.9.80 The impact of vessel noise from construction activities is predicted to have a minor adverse effect on marine mammal receptors. Effects are **not significant**.

Visual disturbance from artificial light

22.9.81 Artificial lighting is a likely requirement on the BLF and moored vessels would introduce light into the marine environment. The volume of vessels engaged in the construction of the BLF will be mostly related to deliveries. Most deliveries to the BLF are anticipated in a four-year period (notionally between 2025 and 2028). During this period deliveries would occur most frequently during the Spring and Summer months. However, it is possible that deliveries might be required throughout the year.

22.9.82 A lighting strategy, provided in Lighting Management Plan; **Appendix 2C, Volume 2 of the Environmental Statement**, for the construction and operational sites has been designed and is outlined in the **CoCP** (Doc Ref. 8.11). The strategy considers the following principles: a) lighting should be designed to minimise, where practicable, landscape, seascape and visual effects; b) the visual effects at night from lighting and light spill should be minimised without compromising either safety or security; c) the lighting should be designed to minimise disturbance to protected species and severance of habitats, where reasonably practicable; d) road lighting and signage should be designed to limit the impact on the surrounding landscape and wildlife where practicable. The proposed strategy takes into account environmental considerations in order to minimise light pollution. One of the proposed mitigation measures is that no lighting would be used when BLF is inactive. However, this is subject to the navigational risk assessment.

22.9.83 The magnitude of the impact is therefore considered as low.

Marine mammal sensitivity to visual disturbance

22.9.84 Marine mammals have large, well developed eyes (Ref. 22.496) and good eyesight both in water and air (Ref. 22.496; 497). Introduction of artificial light could potentially cause visual disturbance. However, vision is not their primary sense as they rely on hearing for the majority of the ecologically important activities including navigation, foraging, and communication. Harbour porpoises and seals are able to forage when blindfolded or blind (Ref. 22.471; 472), and coastal populations of marine mammals occur near urban areas and man-made structures emitting artificial light and no significant deterrent effects have been reported. Some reports suggest that seals are attracted to artificial light in order to enhance their foraging success (Ref. 22.498; 499).

22.9.85 The likelihood of any adverse effects is further decreased by application of the lighting strategy which aims to minimise light spill into the marine environment and is considered as embedded mitigation.

22.9.86 It is considered that marine mammals are not sensitive to visual disturbance from artificial light during the construction of the BLF (and construction site lighting).

22.9.87 The impact of visual disturbance from artificial light is predicted to have a negligible effect on marine mammal receptors. Effects are **not significant**.

Physical disturbance from vessel activity

22.9.88 The number of vessels engaged in the construction of the BLF will be mostly related to deliveries. Most deliveries to the BLF are anticipated in a four-year period (notionally between 2025 and 2028), and deliveries would occur most frequently during Spring and Summer. The most common type of vessels would be construction vessels and vessels engaged in daily deliveries. The daily frequency of the vessels is not expected to be high, as barges can only land once during high tide and during daylight.

22.9.89 Transit speeds of barges in the North Sea are approximately six knots. The potential for marine mammal collision with barges and construction vessels is low.

22.9.90 Considering that the increase in vessel traffic is anticipated to occur during the period of the year when the least number of harbour porpoises are expected within the proposed development area (Ref. 22.441), the assigned impact magnitude is low.

Marine mammal sensitivity to disturbance from vessel activity

22.9.91 The physical presence of vessels and its associated activity together with the noise produced could potentially disturb marine mammals or cause displacement from their habitat if the disturbance is persistent and long term. Literature suggests a certain level of impact mostly in terms of short-term behavioural reaction. Reaction of animals depends on several factors including the behavioural state of the animals, type of vessel and vessel activity (Ref. 22.500). Generally, high speed and erratic movement of the vessels elicit stronger behavioural reactions.

22.9.92 Active avoidance behaviour of harbour porpoises to vessel presence has been well documented (Ref. 22.491; 501). Incidences of avoidance within 1000m and 800m have been reported (Ref. 22.494; 495). Studies on construction activities and vessel traffic effects on marine mammals in northwest Ireland concluded that any impact on harbour porpoises is only short term given that their seasonal pattern of presence persisted regardless of the above-mentioned activities (Ref. 22.502). This could suggest a certain level of habituation to these anthropogenic activities.

22.9.93 Avoidance behaviour of construction vessels by grey seals has also been observed (Ref. 22.485). Harbour and grey seals are known to flee haul-out sites in response to approaching and passing vessels (Ref. 22.503–506) but there are no such sites in the Sizewell area.. There are some anecdotal reports of seals being attracted to approaching vessels. Despite little scientific documentation of positive interactions, such encounters are not entirely unlikely given the inquisitive nature of these animals.

22.9.94 The presence of seals and porpoises around stationary vessels and platforms is not unlikely as those pose a little threat to animals and could potentially attract sheltering prey (Ref. 22.507).

22.9.95 It is considered that the sensitivity of marine mammals to physical disturbance from vessel activity during the construction of the BLF is low.

22.9.96 The impact of disturbance from vessel activity is predicted to have minor adverse effects on marine mammal receptors. Effects are **not significant**.

iii. Combined Drainage Outfall

22.9.97 This section describes the impacts associated with the installation and operation of the combined drainage outfall during the construction phase, including commissioning. Scoping identified the pressures arising from activities at the combined drainage outfall with the potential for effects on ecological receptors, provided in **Appendix 22M** of this volume. Those pressures with the potential to affect marine mammal receptors are presented in **Table 22.130**.

Table 22.130: Pressures associated with CDO activities with the potential to affect marine mammal receptors.

Pressure	CDO activities resulting pressure.	Justification and evidence base.
Visual disturbance from artificial lighting.	Dredging vessel activity and installation of the headwork.	Introduction of artificilal light can potentially cause disturbance and displacement.
Physical disturbance from vessel activity.	Dredging vessel activity and installation of the headwork.	Physical presence of vessels as well as increased construction vessel traffic can potentially cause disturbance and displacement.
Changes in SSC.	Dredging for the installation of the headwork.	Increases in SSC have the potential to affect marine mammal receptors through disruption or impairment to feeding.
Underwater noise.	Dredging for the installation of the headwork.	The potential effects of underwater noise on marine mammal receptors range from injury (at close distances to

Pressure	CDO activities resulting pressure.	Justification and evidence base.
		the source) to behavioural or barrier effects (at greater distances).
Heavy metal contamination.	Construction discharges.	Heavy metal contamination has the potential to result in direct effects on marine mammal receptors affecting their health and fitness, or indirect effects through a reduction in prey availability or quality.
Nutrient enrichment: un-ionised ammonia.	Construction discharges.	Un-ionised ammonia in sewage discharges has the potential to exert toxicological effects and is assessed further. Marine mammals are not predicted to be directly affected by increases in macro-nutrient inputs (nitrogen and phosphate). Effects of nutrient inputs on primary producers are predicted to be well within the bounds of natural variability. Therefore, no indirect food web effects are predicted, provided in **Section 22.6.c)** of this chapter.
Hydrazine contamination.	Commissioning discharges.	Hydrazine contamination has the potential to affect marine mammal receptors directly or indireclty affecting their health and fitness.
Tunnel boring machine (TBM) chemical contamination.	Construction discharges.	TBM contamination has the potential to affect marine mammal receptors directly or indireclty affecting their health and fitness.

Visual disturbance from artificial light

22.9.98 The introduction of artificial lighting will occur during construction of CDO. The light will be introduced mainly by moored construction vessels engaged in dredging activity and installation of headworks. A single dredge event lasting 9.5 hours is expected. A lighting strategy would also be applicable for the construction of the CDO.

22.9.99 The magnitude of the impact is considered as low.

Marine mammal sensitivity to visual disturbance

22.9.100 Marine mammals have a good eyesight in air and water, but they predominantly rely on their hearing for the majority of ecologically important activities (see BLF section for more details). Marine mammals are therefore assessed as not sensitive to the introduction of artificial light during construction of CDO.

22.9.101 Artificial light will be introduced for a very short period of time during the dredging activity. Thus, any avoidance or displacement, would be short-lived with animals returning to the area after cessation of the activity. The resulting effects of this impact are expected to be negligible. Effects are **not significant**.

Physical disturbance from vessel activity

22.9.102 Vessel activity and presence during construction of the CDO will be associated with the dredging and installation of headworks. These activities are expected to have a limited temporal presence lasting only several hours.

22.9.103 Given a limited duration of these activities, the assigned impact magnitude is low.

Marine mammal sensitivity to disturbance from vessel activity

22.9.104 The physical presence of vessels and their associated activity together with the noise produced could potentially disturb marine mammals or cause displacement from their habitat if the disturbance is persistent and long term. Literature suggests a certain level of impact mostly in terms of short-term behavioural responses such as avoidance although habituation and positive responses have been reported (please see BLF section for more details).

22.9.105 It is considered that sensitivity of marine mammals to physical disturbance from vessel activity during the construction of the CDO is low.

22.9.106 The impact of disturbance from vessel activity is predicted to have minor adverse effects on marine mammal receptors. Effects are **not significant**.

Changes in suspended sediment concentration

22.9.107 The dredge volume for the CDO is approximately 1,845m^3 and the total surface footprint is 1,320m^2. A single dredge event is planned during the CDO head construction lasting ~9.5 hours. It is assumed that dredge spoil would be disposed of on-site via a pipe that transports the dredge material 500m down drift.

22.9.108 Dredge plume modelling is detailed in **Appendix 22J** of this volume. Dredge areas, sediment plume characteristics and changes in sedimentation as a result of dredging activities are provided in **Section 22.3.i)** of this chapter. Plumes with instantaneous SSC of >100mg/l above daily maximum background levels are expected to form over areas of up to 89ha at the surface. A small area of 1ha is expected to experience an instantaneous SSC of >1,000mg/l above background at the sea surface.

22.9.109 Dredging has the potential to temporarily increase turbidity from a baseline status of '*intermediate turbidity*' to '*turbid*' according to the WFD criteria over part of the study area. However, SSC would return to background levels several days after the dredging activity ceases, provided in **Appendix 21J** of this volume. The increase in SSC would occur once for the installation of the CDO head.

22.9.110 Given the wide foraging range of marine mammals and the spatial and temporal extent of this impact, the magnitude is considered to be low.

Marine mammal sensitivity to suspended sediment concentrations

22.9.111 The sensitivity of marine mammal populations to increases in suspended sediment is fully described in the assessment of the BLF. The short duration of the dredging activities and the rapid decrease in SSC following cessation of activities suggest that impacts would be short-lived. Large natural variability in SSC occur at the site depending on seasonality, tidal state, wave energy, and the occurrence of storm events. However, indirect effects due to behavioural avoidance by fish from the plume could occur but this has been assessed as minor, provided in **Section 22.8** in this chapter. Therefore, there would be no significant impact on marine mammals foraging in the area and marine mammals are not sensitive to this impact.

22.9.112 The impact of increased SSC resulting from dredging activities is predicted to have a negligible effect on marine mammal receptors. Effects are predicted to be short-lived, spatially limited and **not significant** relative to existing variation in the area.

Underwater noise

22.9.113 Noise levels from dredging were predicted as too low to generate instantaneous auditory effect zones for marine mammals. Provided in **Appendix 22L** of this volume.

22.9.114 Dredging associated with the CDO resulted in harbour porpoise cumulative auditory effect zones with TTS extending to ~6.5km and PTS to ~0.8km, where continuous exposure over 24 hours was assumed. The corresponding fleeing cumulative impact zone was reduced to ~1km for TTS. No PTS was predicted to occur under the fleeing animal assumption.

22.9.115 The predicted cumulative sound exposure effects on harbour seal and grey seal were much smaller than the corresponding predictions for harbour porpoise, TTS extending to ~1.4km and PTS of <0.025km. The corresponding dredging assessments for fleeing harbour or grey seals resulted in no PTS and no TTS impact zones (**Table 22.131**).

22.9.116 The impact magnitude is low.

Table 22.131: Marine mammal auditory impact zones for dredging activity

Activity	Threshold	Instant	Stationary cumulative		Fleeing cumulative	
		All species	Harbour porpoise	Phocid seals	Harbour porpoise	Phocid seals
Dredging CDO	PTS	N/A	849m; 135ha.	25m; <0.25ha.	No impact	No impact.
	TTS	N/A	6,421m; 4,799ha.	1,369m; 280ha.	1,025m; 173ha.	No impact.

Marine mammal sensitivity to underwater noise

22.9.117 The sensitivity of marine mammal populations to underwater noise from dredging is fully described in the assessment of the BLF. Evidence suggests that the most likely effects are short to medium-term behavioural changes in the form of temporal avoidance of the area in the immediate vicinity of the dredging site. The sensitivity of marine mammal populations to underwater noise from dredging during the construction and maintenance of the CDO is predicted to be low.

22.9.118 The impact of increased underwater noise resulting from dredging activities is predicted to have a minor adverse effect on marine mammals. Effects are **not significant** and predicted to return to baseline conditions after dredging activities cease.

Heavy-metal contamination

22.9.119 During construction of the main development site, groundwater discharges would be made via the CDO. Exploratory boreholes across the main development site quantified the concentrations of dissolved metals within the groundwater. The worst-case construction discharges for trace metals would be during the 28-day dewatering of the cut-off wall around the main construction site (Case A: **Plate 22.1**). The dewatering phase would result in an estimated 300,000m^3 of groundwater being discharged at a rate of 124l/s. After the initial dewatering phase nominal discharges of 15l/s would continue throughout the construction phase to remove rainwater and seepage through the cut-off wall, provided in **Appendix 21E** of this volume.

22.9.120 In the dewatering phase two groundwater metals, zinc and chromium failed initial EQS screening and a General Estaurine Transport Model was used to determine the mixing rates and spatial extent of the impacts.

22.9.121 The mean background concentration of zinc in the environment is 15.12µg/l whilst the EQS is 6.8µg/l as an annual average. Since the background levels are in exceedance of the EQS, zinc discharges could not be assessed under standard procedures. Modelling predicted the point at which zinc concentrations would be indiscernible from background based on analytical detection limits of 0.4µg/l. Therefore, the threshold value for zinc was set at 15.52µg/l. Thus, the amount of change relative to baseline is approximately 2.5%. Modelling demonstrated that zinc concentrations would only be discernible above background over a mean sea surface area of 0.11ha. At the seabed, zinc concentrations are not predicted to exceed background concentrations.

22.9.122 Chromium has a mean EQS concentration of 0.6 µg/l and a 95th percentile EQS concentration of 32µg/l. Chromium background concentrations of 0.4-0.57µg/l are reported for the site. As a precautionary measure the higher background concentration was applied to give a mean EQS threshold of 0.03µg/l. A sea surface area of 5.49ha exceeded the mean EQS, at the seabed chromium did not exceed EQS concentrations. The 95th percentile EQS concentration (32µg/l) was not exceeded, provided in **Appendix 21E** of this volume.

22.9.123 The initial dewatering drawdown phase is a short-term activity (28 days). Areas impacted extend over a very limited spatial area and the amount of change is small relative to the baseline conditions. The impact magnitude is assessed as very low.

Marine mammal sensitivity to heavy metal contamination

22.9.124 Marine mammals occupy the top position in the trophic system and exhibit long life spans. This, coupled with the long biological half-life of pollutants, can result in bioaccumulation of heavy metals that affect health and fitness (Ref. 22.508). There has been an increased number of marine mammal stranding events in the southern North Sea linked to the health of individuals (Ref. 22.508). In a southern North Sea study, increasing zinc levels were observed with deteriorating health condition (i.e. emaciation and bronchopneumonia) in harbour porpoise (Ref. 22.508). However, zinc is an essential metal and the link between increases in zinc concentration and disease status may result from zinc redistribution in response to infection, not necessarily exposure to the metal (Ref. 22.509). Heavy metal concentrations (high levels of cadmium) in porpoises stranded in Iceland and Norway were found to be partly diet-related, as a result of contaminated prey (Ref. 22.508).

22.9.125 In fish, the direct uptake of heavy metals occurs through the gills, and there is a potential for indirect effects through food webs. However, the fish assessment, provided in **Section 22.8** of this chapter, predicts *negligible* effects of chromium and zinc contamination on fish species due to minimal spatial and temporal exposure. No significant indirect effects through their prey are expected in marine mammals.

22.9.126 The limited spatial extent of zinc and chromium discharges in the inshore waters and the limited duration of discharges mean the probability of exposure is minimal, especially as that uptake is only possible indirectly through the consumption of prey. Marine mammal populations are predicted to be not sensitive to heavy-metal discharges.

22.9.127 The impact of heavy-metal contamination resulting from construction discharges is predicted to have a negligible effect on marine mammals. Effects are **not significant**.

Nutrient enrichment: Un-ionised ammonia

22.9.128 Ammonia is a commonly occurring pollutant that enters waterbodies from diffuse and point sources including sewage effluents, industrial and agricultural activities and decomposition of organic matter. Ammonia exists in the toxic un-ionised phase (NH_3) and as ionised ammonium (NH_4^+). The relative proportion of each form depends on the temperature, salinity and pH of the water. Higher temperatures and pH favour ammonia, whilst higher salinity favours ammonium (Ref. 22.21). Treated sewage discharges from the CDO have the potential to exert toxicological effects on plankton receptors should ammonia levels exceed EQS values of 21µg/l.

22.9.129 The highest routine sewage discharges are anticipated during Case D (**Plate 22.1**) and a worst-case un-ionised ammonia discharge would occur in the unlikely event of a sewage only discharge. In this situation dilution modelling predicts exceedance of EQS concentrations up to 6.3m from the point of discharge. EQS exceedance is within 4m of the discharge for all other construction scenarios, provided in **Appendix 21E** of this volume.

22.9.130 The magnitude of impact is assessed as low as discharges could occur throughout the construction phase.

Marine mammal sensitivity to un-ionised ammonia

22.9.131 As modelling indicates that un-ionised ammonia EQS concentrations would be exceeded within a very limited area directly adjacent to the point of discharge (i.e. the maximum extent of discharge predicted not to exceed 6.3m), it is unlikely that this would affect marine mammals which are free ranging, highly mobile species with large home ranges. Ammonia does not bioaccumulate, so if prey that had been exposed to ammonia were consumed, there would be no effect on harbour porpoise or seals. Therefore, no direct or indirect effects are expected and the sensitivity of marine mammal populations to nutrient enrichment is predicted as *Not Sensitive*.

22.9.132 The impact of un-ionised ammonia from construction discharges is predicted to have a negligible effect on marine mammals. Effects are **not significant**.

Commissioning discharges: Hydrazine contamination

22.9.133 During cold flush testing, hydrazine would be used as a corrosion inhibitor. Based on the Rochdale envelope approach, modelling took the precautionary position of both reactors being commissioned simultaneously with hydrazine discharged into the receiving waters via the CDO. The results of the modelling showing areas of exceedance for hydrazine discharges is presented in **Section 22.6.c)** of this chapter; **Table 22.22**. Considering that marine mammals are highly mobile species with wide habitat ranges, it is assumed that the acute exposure is more likely[69] than chronic. As such, the threshold concentration for acute effects (PNEC 4ng/l as a 95th percentile) was predicted to be 12.9ha and <3ha at the surface and seabed, respectively.

22.9.134 Commissioning is likely to last several years; however simultaneous discharges of hydrazine from both units is considered unlikely. A conservative magnitude score of medium is assigned applying a highly precautionary approach and taking into the account temporal and spatial element of the potential impact.

Marine mammal sensitivity to hydrazine contamination

22.9.135 There is evidence that hydrazine is harmful to aquatic organisms at low concentrations (Ref. 22.62; 510) and although its persistence is low to moderate this is dependent upon various water quality parameters. The likelihood of adverse effects to marine life is considered as low if the concentrations of hydrazine are less than 0.2µg/l (Ref. 22.60). The maximum surface area that exceeds the ecologically relevant concentrations (0.2µg/l) is <0.5ha, provided in **Section 22.6.c** of this chapter; **Table 22.22**).

22.9.136 Toxicity data exist for amphibian, fish, invertebrate and plant species but not marine mammals. However, these top predators could be potentially affected indirectly through the effects on their prey. Assessments on fish receptors indicate that toxicological effects from hydrazine discharges are highly unlikely as of **Section 22.6.c)** of this chapter. Also, the impact area

[69] For chronic effects, animals are required to remain within the area of exceedance for prolonged periods of time.

represents a very small proportion of the foraging range of highly mobile species no indirect effects are predicted.

22.9.137 The rapid degradation rates and low bioconcentration factor of hydrazine indicates that the bioaccumulation potential is low (Ref. 22.62). No indirect food webs effects from hydrazine bioaccumulation are predicted.

22.9.138 The sensitivity of marine mammal populations to hydrazine contamination is predicted to be not sensitive.

22.9.139 The impact of hydrazine contamination resulting from commissioning discharges is predicted to have a minor adverse effect on marine mammals. Effects are **not significant**.

Tunnelling chemical discharges

22.9.140 Based on current understanding of the underlying geology a TBM slurry method with bentonite is the most likely scenario for tunnelling. Spoil from the cutting face would be transported to a temporary stockpile for onward management. Groundwater would be generated from digging the galleries allowing access to the tunnels and tunnelling itself. During the transport and processing of spoil material, groundwater and potentially residual TBM chemicals would be produced in wastewater that would be transported landward, treated as required and discharged from the CDO.

22.9.141 To envelope alternative tunnelling methods, assessments considered the use of indicative ground conditioning TBM chemicals. Representative chemicals from those applied for Hinkley Point C assessments are used to envelope potential tunnelling options at this stage. These include the anti-clogging agent BASF Rheosoil 143 and the soil conditioning additive CLB F5 M, provided in **Chapter 21** of this volume. The potential worst-case tunnelling scenario would occur when two cooling water tunnels are being excavated simultaneously (Case E; **Plate 22.1**). Modelling predicted that the mean sea surface area in exceedance of the BASF Rheosoil 143 PNEC was restricted to 1ha (95th percentile 5.8ha) while the sea surface area exposed to CLB F5 M in exceedance of the PNEC was restricted to 3.1ha as a mean concentration (95th percentile 25ha) (see **Table 22.20**). The seabed is never exposed to concentrations above the PNEC, provided in **Appendix 21E** of this volume.

22.9.142 Tunnelling is predicted to be a medium-term impact lasting several years in total. The use of TBM surfactants in the tunnelling process remains to be confirmed and assessments present a precautionary approach enveloping worst-case representative chemicals. A small spatial area is predicted to exceed the PNEC at the sea surface whilst the seabed would not be exposed to concentrations above the PNEC.

22.9.143 The impact magnitude is assessed to be low.

Marine mammal sensitivity to tunnelling chemicals

22.9.144 The majority of information on effects of surfactants comes from freshwater studies and there is limited data on effects to marine organisms. Recent studies focusing on the marine environment suggest that biodegradation is considerably slower than in freshwater while ecotoxicity studies indicate that marine species are almost as sensitive as freshwater species (Ref. 22.213). There is no information related to marine mammals.

22.9.145 The primary route for toxicological effects on marine mammals would be through ingestion of contaminated fish. Laboratory studies exposing fish to anionic surfactants reported effects on olfaction, respiration and gill physiology. The effects occurred at concentrations exceeding 0.1 mg/l in most cases (Ref. 22.387). The avoidance reaction by fish has been one of the more commonly monitored effects in behavioural studies with surfactants. Avoidance of several anionic surfactants by a variety of fish species has been observed at concentrations ranging from 0.002 to 0.40 mg/l (Ref. 22.387). However, metabolism and elimination of surfactants is rapid, leading Madsen *et al.* (2001) to conclude that bioconcentration in fish does not occur (Ref. 22.58). As such food-web effects are considered to be low.

22.9.146 A very small proportion of the marine mammal within the GSB would be directly or indirectly (through contaminated prey) exposed to TBM surfactants and toxicological effects are unlikely. However, due to lack of evidence for marine mammals, a precautionary low sensitivity to the representative TBM discharges is assigned.

22.9.147 TBM discharges are predicted to have minor adverse effects on marine mammal receptors. Effects are therefore **not significant**.

iv. Fish recovery and return systems

22.9.148 This section describes the impacts associated with the installation of the fish recovery and return (FRR) systems during the construction phase. Scoping identified the pressures arising from activities at the FRR systems with the potential for effects on ecological receptors, provided in **Appendix 22M** of this volume. Those pressures with the potential to affect marine mammal receptors are presented in **Table 22.132**.

Table 22.132: Pressures associated with FRR system activities with the potential to affect marine mammal receptors.

Pressure	FRR activities resulting pressure.	Justification and evidence base.
Visual distubrance from artificial lighting.	Navigational and dredging.	Introduction of artificilal light can potentially cause disturbance and displacement.
Physical disturbance from vessel activity.	Navigational and dredging.	Physical presence of vessels as well as increased vessel traffic can potentially cause disturbance and displacement.
Changes in SSC.	Dredging for the installation of the headwork.	Increases in SSC have the potential to affect marine mammal receptors through disruption or impairment to feeding.
Underwater noise.	Dredging for the installation of the headwork.	The potential effects of underwater noise on marine mammal receptors range from injury (close to the source) to behavioural or barrier effects (at greater distances).

Visual disturbance from artificial light

22.9.149 Artificial lighting is a likely requirement during dredging and navigational activities during construction of the FRR. A single dredging event for each of the two FRR outfall heads is predicted, lasting a total of 19 hours. Therefore, any artificial light introduced will short-lived. The lighting strategy will further reduce the likelihood of light pollution.

22.9.150 The magnitude of the impact is considered as low.

Marine mammal sensitivity to visual disturbance

22.9.151 Introduction of artificial light could potentially cause visual disturbance to marine mammals. However, vision is not the primary sense of marine mammals as they rely primarily on their hearing for the majority of ecologically important activities including navigation, foraging, and communication (for more details see BLF section). They are able to fully function without depending on visual clues. Any disturbance caused by artificial lighting would not be detrimental.

22.9.152 The likelihood of any adverse effects is further decreased by application of the lighting strategy which aims to minimise light spill into the marine environment.

22.9.153 It is considered that marine mammals are not sensitive to visual disturbance from artificial light during the construction of the FRR.

22.9.154 The impact of visual disturbance from artificial light is predicted to have a negligible effect on marine mammal receptors. Effects are **not significant**.

Physical disturbance from vessel activity

22.9.155 The number of vessels engaged in the construction of the FRR will be related to dredging and navigational activities. The impacts associated with these activities will be short lived given the limited duration of the proposed activities. Thus, the assigned impact magnitude is low.

Marine mammal sensitivity to disturbance from vessel activity

22.9.156 As described in previous sections, the physical presence of vessels and their associated activity together with the noise produced could potentially disturb marine mammals or cause displacement from their habitat if such disturbance is persistent and long term. Literature suggests a certain level of impact mostly in terms of short-term behavioural responses such as avoidance although habituation and positive responses have been reported (please see BLF section for more details).

22.9.157 The sensitivity of marine mammals to physical disturbance from vessel activity during the construction of the FRR is considered as low.

22.9.158 The impact of disturbance from vessel activity is predicted to have minor adverse effects on marine mammal receptors. Effects are **not significant**.

Changes in suspended sediment concentration

22.9.159 The dredge volume is approximately 3,690m^3 per FRR system while the surface area is 2,640m^2. It is assumed that the dredge spoil would be disposed of on-site via a pipe that transports the dredge material 500m down drift.

22.9.160 The area affected by sediment disturbed during the dredging and local disposal of sediment from the FRR outfalls extends north-south along the coast, with limited offshore extent. Dredge plume modelling is detailed in **Appendix 22J** of this volume. Dredge areas, sediment plume characteristics and changes in sedimentation as a result of dredging activities are provided in **Section 22.3.i)** of this chapter. Plumes with an instantaneous SSC of >100mg/l above daily maximum background levels are expected to form over areas of up to 89ha at the surface. A small area of 1ha is expected to experience an instantaneous SSC of >1,000mg/l above background at the sea surface.

22.9.161 Dredging has the potential to temporarily increase turbidity from a baseline status of '*intermediate turbidity'* to '*turbid*' according to the WFD criteria over part of the study area. However, SSC would return to background levels several days after dredging activity ceases in **Appendix 22J** of this volume.

22.9.162 Given the wide foraging range of marine mammals and the spatial and temporal extent of this impact, the magnitude is considered to be low.

Marine mammal sensitivity to suspended sediment concentrations

22.9.163 The sensitivity of marine mammal populations to increases in suspended sediment is described in the assessment of the BLF, provided in **Section 22.9.c)** of this chapter. The short duration of the dredging activities and the rapid decrease in SSC following cessation of activities suggest that impacts would be short-lived. Large natural variability in SSC occurs at the site depending on seasonality, tidal state, wave energy, and the occurrence of storm events. However, indirect effects due to behavioural avoidance by fish from the plume could occur but this has been assessed as minor, provided in **Section 22.8** of this chapter. There would be no significant impact on marine mammals foraging in the area. It is assessed that marine mammals are not sensitive to this impact.

22.9.164 The impact of increased SSC resulting from dredging activities is predicted to have a negligible effect on marine mammal receptors. Effects are predicted to be short-lived, spatially limited and **not significant** relative to natural variation.

Underwater noise

22.9.165 Noise levels from dredging are predicted to be too low to generate instantaneous auditory effect zones for marine mammals. Dredging associated with the FRRs resulted in harbour porpoise cumulative auditory effect zones with TTS extending to ~6.5km and PTS to ~0.8km, where continuous exposure over 24 hours was assumed. When a fleeing scenario is considered, no PTS was predicted while TTS is expected within ~1km (**Table 22.17**).

22.9.166 The predicted cumulative sound exposure effects on harbour seal and grey seal were much smaller than the corresponding predictions for harbour porpoise, TTS extending to ~1.4km and PTS to ~0.05km. Fleeing cumulative scenarios did not predict any PTS or TTS impact zones (**Table 22.133**).

22.9.167 The impact magnitude is medium.

Table 22.133: Marine mammal auditory impact zones for dredging activity

Activity	Threshold	Instant.	Stationary Cumulative.		Fleeing cumulative.	
		All species	Harbour porpoise.	Phocid seals.	Harbour porpoise.	Phocid seals.
Dredging FRR1.	PTS	N/A	822m; 140ha.	50m; 1ha.	No impact.	No impact.
	TTS	N/A	6,532m; 4,920ha.	1,426m; 299ha.	1,097m; 191ha.	No impact.
Dredging FRR2.	PTS	N/A	849m; 135ha.	25m; <0.25ha.	No impact.	No impact.
	TTS	N/A	6,433m; 4,839ha.	1,376m; 285ha.	1.025m; 177ha.	No impact.

Marine mammal sensitivity to underwater noise

22.9.168 The sensitivity of marine mammal populations to underwater noise from dredging is described in the assessment of the BLF. Evidence suggests that the most likely effects are short to medium-term behavioural changes in temporal avoidance of the area in the immediate vicinity of the dredging site. The sensitivity of marine mammal populations to underwater noise from dredging during the construction of the FRR is predicted to be low.

22.9.169 The impact of increased underwater noise resulting from dredging activities is predicted to have a minor adverse effect on marine mammals. Effects are **not significant** and predicted to return to baseline conditions rapidly after dredging activities cease.

v. Cooling water infrastructure: intakes and outfalls

22.9.170 This section describes the impacts associated with the installation of the cooling water systems (CWS) (intakes and outfalls) during the construction phase. It is proposed that each intake tunnel will have two intake headworks while the outfall tunnel will have two outfall headworks. Scoping identified the pressures arising from activities at the cooling water intakes with the potential for effects on ecological receptors, provided in **Appendix 22M** of this volume. Those pressures with the potential to affect marine mammal receptors are presented in **Table 22.134**.

Table 22.134: Pressures associated with cooling water intake and outfalls activities with the potential to affect marine mammal receptors.

Pressure	Cooling water infrasctucture activities resulting pressure.	Justification and evidence base.
Visual distubrance from artificial lighting.	Navigational, dredging.	Introduction of artificial light can potentially cause disturbance and displacement.
Physical disturbance from vessel activity.	Navigational, dredging.	Physical presence of vessels as well as increased vessel traffic can potentially cause disturbance and displacement.
Changes in SSC.	Dredging, drilling for connection tunnels and installation of seismically qualified heads.	Increases in SSC have the potential to affect marine mammal receptors through disruption or impairment to feeding.
Underwater noise.	Dredging, drilling for connection tunnels and installation of seismically qualified heads.	The potential effects of underwater noise on marine mammal receptors range from injury (close to the source) to behavioural or barrier effects (at greater distances).

Visual disturbance from artificial light

22.9.171 Artificial lighting is a likely requirement during dredging and navigational activities during construction of the CWS. Four dredging events for intakes and two events for outfalls are predicted, lasting up to 24 hours. Any artificial light introduced will be short-lived. The lighting strategy will further reduce the likelihood of light pollution.

22.9.172 The magnitude of the impact is considered as Low.

Marine mammal sensitivity to visual disturbance

22.9.173 Introduction of artificial light could potentially cause visual disturbance to marine mammals. However, vision is not their primary sense as they rely on hearing for the majority of ecologically important activities including navigation, foraging, and communication (for more details see BLF section). They are able to fully function without visual clues. Any disturbance caused by artificial lighting would not be detrimental.

22.9.174 The likelihood of any adverse effects is further decreased by application of lighting strategy which aims to minimise light spill into the marine environment.

22.9.175 It is considered that marine mammals are not sensitive to visual disturbance from artificial light during the construction of the CWS.

22.9.176 The impact of visual disturbance from artificial light is predicted to have a negligible effect on marine mammal receptors. Effects are **not significant**.

Physical disturbance from vessel activity

22.9.177 The presence of vessels on site is anticipated throughout much of the years weather window with activities associated with offshore construction for the cooling water infrastructure, dredging, drilling infrastructure placement. The number of vessels engaged in the construction activities of the CWS will be related to dredging and navigational activities. The impacts associated with these activities will be short lived given the limited duration of the proposed activities. Thus, the assigned impact magnitude is low.

Marine mammal sensitivity to disturbance from vessel activity

22.9.178 As described previously, the presence of vessels and associated activity together with the noise produced could potentially disturb marine mammals or cause displacement from their habitat if such disturbance is persistent and long term. Literature suggests some impact, mostly in terms of short-term behavioural responses such as avoidance, but habituation and positive responses have also been reported (please see BLF section for more details).

22.9.179 It is considered that sensitivity of marine mammals to physical disturbance from vessel activity during the construction of the CWS is low.

22.9.180 The impact of disturbance from vessel activity is predicted to have minor adverse effects on marine mammal receptors. Effects are **not significant**.

Changes in suspended sediment concentration

22.9.181 It is assumed that the intake head foundations would be installed to the bedrock. The sediment depth is likely to vary at each head location and the assumed dredge volume is based on a worst case sediment depth of 6m. An excavated volume of 69,600m^3 per intake head has been calculated.

22.9.182 It is assumed that the outfall head foundations would be installed to the bedrock. The sediment depth is likely to vary at each head location and the assumed dredge volume is based on a worst-case sediment depth of 6m. An excavated volume of 23,500m^3 per outfall head has been calculated.

22.9.183 Dredge plume modelling is detailed in **Appendix 22J** of this volume. Dredge areas, sediment plume characteristics and changes in sedimentation as a result of dredging activities are provided in **Section 22.3.i)** of this chapter. Plumes with an instantaneous SSC of >100mg/l above daily maximum background levels are expected to form over an area of up to 373ha (depth averaged, 291ha at the sea surface). A smaller area of up to 14ha is expected to experience a depth averaged instantaneous SSC of >1,000mg/l above background levels (34ha at the sea surface).

22.9.184 Dredging has the potential to temporarily increase turbidity from a baseline status of '*Intermediate turbidity*' to '*Turbid*' according to the WFD criteria over part of the study area. However, SSC would return to background levels several days after dredging activities cease, provided in **Appendix 22J** of this volume. The increase in SSC would occur six times for the installation of CWS infrastructure (once for each intake and outfall head). The timings of the SSC plumes associated with the installation of each headwork would not overlap.

22.9.185 Given that the predicted area of the plume arising during dredging for CWS is larger than during CDO, BLF and FRR construction, the associated impact magnitude is increased to medium.

Marine mammal sensitivity to suspended sediment concentrations

22.9.186 The SSC caused by dredging for CWS is the largest impact for this pressure considering the spatial and temporal extent of elevated SSC. The impact occurs beyond the Sizewell-Dunwich Bank where harbour porpoise abundance is greater (Ref. 22.441). However, harbour porpoise, as well as seals, are well adapted to turbid coastal waters (Ref. 22.470) and are therefore resistant to this pressure. No indirect effects are expected, as no significant effects are predicted in terms of the localised displacement of fish receptors and thus prey availability, provided in **Section 22.8** of this chapter. Further details on the sensitivity of marine mammal populations to increases in suspended sediment is described in the assessment of the BLF and is predicted to be not sensitive.

22.9.187 The impact of increased SSC resulting from dredging activities is predicted to have a minor adverse effect on marine mammal receptors. This is considered very precautionary taking into account that no significant effects are predicted in relation to their prey. Effects are predicted to be short-lived and within the bounds of natural variation in the conditions already found in the area, provided in **Section 22.4** of this chapter. Effects are **not significant**.

Underwater noise

Dredging

22.9.188 Noise levels from dredging were too low to generate instantaneous auditory impact zones for marine mammals. Dredging associated with the south cooling water intake resulted in the largest harbour porpoise cumulative auditory effect zones with TTS extending to ~5.9km and PTS to ~0.7km, where continuous exposure over 24 hours was assumed. When fleeing scenarios were considered, the results indicated no PTS ranges and TTS ranges between 0.65-0.81km (**Table 22.135**), provided in **Appendix 22L** of this volume.

22.9.189 The predicted cumulative sound exposure effects on harbour and grey seal were much smaller than the corresponding predictions for harbour porpoise, TTS of ~0.9km and PTS of less than 25m. No PTS and TTS ranges were predicted for fleeing seals (**Table 22.135**), provided in **Appendix 22L** of this volume.

22.9.190 The impact magnitude is low.

Table 22.135: Marine mammal auditory impact zones for dredging activity

Activity	Threshold	Instant.	Stationary Cumulative.		Fleeing cumulative.	
		All species.	Harbour porpoise.	Phocid seals.	Harbour porpoise.	Phocid seals.
Dredging north cooling water intake.	PTS	N/A	668m; 125ha.	<25m.	No impact.	No impact.
	TTS	N/A	5,640m; 6,540ha.	989m; 246ha.	797m; 103ha.	No impact.
Dredging south cooling water intake.	PTS	N/A	718m; 131ha.	<25m.	No impact.	No impact.
	TTS	N/A	5,922m; 6856ha.	996m; 256ha.	810m; 114ha.	No impact.
Dredging cooling water outfall.	PTS	N/A	549m; 90ha.	<25m.	No impact.	No impact.
	TTS	N/A	5,074m; 5,663ha.	869m; 188ha.	654m; 88ha.	No impact.

Drilling

22.9.191 Noise levels arising from drilling activities are predicted to be too low to generate instantaneous auditory impact zones for marine mammals. Cumulative auditory effect zones for harbour porpoise were spatially limited. For all drilling scenarios PTS effect zones were predicted to extend 50m or less from the source. Cumulative exposure for harbour porpoise TTS impact zones extended to approximately 1,300m from the source (**Table 22.136**).

22.9.192 In all cases, the harbour seal and grey seal auditory impact zones were predicted to be less than 25m (**Table 22.136**).

22.9.193 In all cases, the fleeing marine mammal assessments resulted in no PTS or TTS impact zones (**Table 22.136**).

22.9.194 The impact magnitude is low.

Table 22.136: Marine mammal auditory impact zones for drilling activity

Activity	Threshold	Instantaneous		Stationary Cumulative.		Fleeing Cumulative.
		Harbour porpoise.	Phocid seals.	Harbour porpoise.	Phocid seal.	All marine mammals.
Drilling north cooling water intake shaft.	PTS	No impact.	No impact.	50m; 1ha.	<25m.	No impact.
	TTS	No impact.	No impact.	1,286m; 422ha.	<25m.	No impact.
Drilling south cooling water intake shaft.	PTS	No impact.	No impact.	50m; 1ha.	<25m.	No impact.
	TTS	No impact.	No impact.	1,286m; 431ha.	<25m.	No impact.
Drilling cooling water outfall shaft.	PTS	No impact.	No impact.	25m; 0.25ha.	<25m.	No impact.
	TTS	No impact.	No impact.	1,307m; 399ha.	<25m.	No impact.

Marine mammal sensitivity to underwater noise

22.9.195 The sensitivity of marine mammal populations to underwater noise from dredging is fully described in the assessment of the BLF and is predicted to be low. The expected sensitivity to drilling noise is considered to be similar with more restricted impact zones.

22.9.196 The impact of increased underwater noise resulting from dredging and drilling activities is predicted to have a minor adverse effect on marine mammals. Effects are predicted to be short-lived and return to baseline conditions shortly after dredging and drilling activity ceases. Effects are **not significant**.

vi. Unexploded Ordinance (UXO) detonations

22.9.197 If UXOs are discovered at the site and alternative disposal methods or relocation are not possible, underwater detonations may be required. Underwater explosions generate some of the highest peak sound pressures of all anthropogenic underwater sound sources (Ref. 22.363), and are considered a high energy, impulsive sound source.

22.9.198 At the time of writing, it has not been confirmed if any UXOs are present in the vicinity of the site, thus specific details are not available. Noise propagation modelling was conducted for three different hypothetical explosive charges: 250lb, 500lb and 1,500lb of TNT equivalent with onsite detonation. The results should be considered as indicative, worst-case scenarios for unmitigated impact ranges.

22.9.199 The thresholds for auditory effects from explosives are consistent with the peak SPL criteria for impact piling as described in **Appendix 22L** of this volume. The impact ranges illustrating the distances within which marine mammals may be exposed to potentially harmful noise levels for the UXO detonation works are presented in **Table 22.137**.

Table 22.137: Marine mammal instantaneous auditory effect ranges for UXO detonation works.

Charge mass TNT equivalent (lb).	Threshold	Harbour porpoise.	Harbour/grey seal.
250	PTS	7,726m.	1,514m.
	TTS	14,238m.	2,789m.
500	PTS	9,734m.	1,907m.
	TTS	17,939m.	3,514m.
1,500	PTS	14,039m.	2,750m.
	TTS	25,872m.	5,068m.

22.9.200 The explosive charge mass of 1,500lb had the largest impact ranges for all species. Harbour porpoises were the most sensitive receptors, unweighted PTS thresholds (202 dB re 1 µPa) are anticipated up to a range of up to 14km from the source (**Table 22.137)**. Given the auditory impact ranges for the hypothetical unmitigated UXO detonation are considerably larger than other noise generating activities associated with the proposed development, an additional assessment step whereby the number of individuals potentially exposed to PTS has been calculated. Using the effect range as a radius and accounting for the inshore setting of the development the effect area would be at least 310km^2. Small Cetaceans in the European Atlantic and North Sea III survey data predicts density of 0.67 individuals per km^2 (Ref. 22.445), as such >200 individuals could be exposed to PTS. The number of individual exposed and the high sensitivity (permanent auditory damage) results in major adverse effects for unmitigated UXO clearance. Effects would be **significant** at the population level.

22.9.201 The assessment is highly precautionary as the assessment considers the largest hypothetical explosive charge with no mitigation (a situation that would not occur). Should a UXO be identified on site, a full assessment would be completed considering the exact UXO specifications and location in relation to site-specific factors as described in **Section 22.3.i).vi** of this chapter. A dedicated marine mammal mitigation protocol would be prepared in consultation with statutory stakeholders, considering site-specific appropriate mitigation measures, **Section 22.3.i** of this chapter. Implementation of mitigation measures would reduce impacts to the point where minor adverse effects are predicted. Such measures would mean effects would be **not significant**.

22.9.202 Seals have higher thresholds for auditory impacts from explosive sources and the resultant auditory effect ranges are smaller. Unweighted PTS thresholds (peak sound pressure level; 218 dB re 1 µPa) are anticipated up to a range of up to 2.75km from the source (**Table 22.137**). Based on the latest seal at sea usage maps, the maximum density of grey seals and harbour seals has been calculated as 0.053 and 0.046, respectively (Ref. 22.536). Using the effect range as a radius and accounting for the inshore setting of the development the effect area would be at least 11.9km^2. For both grey and harbour seals (less than) one individual would be exposed to PTS. Temporary auditory effects arising from TTS would extend to greater distances. The magnitude of impacts is considered to be medium and the sensitivity medium. This results in moderate effects in the absence of mitigation. Effects would be **significant**. Implementation of mitigation measures would reduce impacts to the point where minor adverse effects are predicted. Such measures would mean effects would be **not significant**.

vii. Inter-relationship effects

22.9.203 This section provides a description of the identified inter-relationship effects that are anticipated on marine mammal receptors between the individual environmental effects arising from construction of the proposed development. These are the effects arising from construction work acting in-combination to form additive, synergetic or antagonistic effects.

Noise generating activities in-combination

22.9.204 The only construction activities generating underwater noise with the potential to cause auditory damage that may occur simultaneously is dredging at two locations. This considered as the worst-case scenario of in-combination activities related to noise.

22.9.205 Underwater noise modelling considered a precautionary assumption of a hypothetical scenario involving simultaneous dredging at the BLF and at the southern cooling water intakes, provided in **Appendix 22L** of this volume. These were assumed to represent the worst-case scenarios for underwater noise. The resulting auditory impact zones suggest a slightly larger acoustic footprint of the combined dredging than the same activity at the two constituent single locations.

22.9.206 The cumulative (24 hour) PTS impact zone for stationary harbour porpoise increased by approximately 20% of the sum of the dredge activities individually but remained relatively small (i.e. 620ha) for highly mobile species. However, TTS impact zones for stationary harbour porpoise were smaller than the sum of the individual dredge activities due to spatial overlap (i.e.14,359ha). When fleeing was included in the assessment of the in-combination dredge scenario, no PTS was predicted. A small TTS effect zone of 1,040ha was predicted for harbour porpoise.

22.9.207 For seals, the stationary PTS zone covered 5ha, while the stationary TTS zone covered 1,411ha, representing ~15% more than the combined coverage of the TTS zones predicted for the individual dredge scenarios. Incorporation of fleeing responses in the model resulted in no auditory impact zones for seals (**Table 22.138**).

Table 22.138: Marine mammal auditory impact zones for dredging activity at two locations

Activity	Threshold	Instant	Stationary Cumulative		Fleeing cumulative.	
		All species	Harbour porpoise.	Phocid seals.	Harbour porpoise	Phocid seals
In-combination scenario dredging BLF and south cooling water intake.	PTS	N/A	620ha.	5ha.	No impact.	No impact.
	TTS	N/A	14,359ha.	1,411ha.	1,040ha.	No impact.

22.9.208 The impact of increased underwater noise resulting from single dredging activity is predicted to have a minor adverse effect on marine mammals. The predicted in-combination impact zones would increase by ~20% in the worst-case scenario, and incorporation of fleeing models predicted no PTS. Therefore, it is assumed that in-combination effects would not significantly increase the outcome. Effects are predicted to be short-lived and return to baseline conditions shortly after dredging activity ceases. Effects are **not significant**.

Changes in suspended sediment concentration and underwater noise

22.9.209 The combined pressures of underwater noise and changes in suspended sediment could occur with navigational dredging.

22.9.210 There is a spatially limited area where the maximum instantaneous SSC plume potentially intersects the TTS and PTS impact zones.

22.9.211 Capital dredging is predicted to occur at least once per campaign (year) and to last 2.1 days. A certain level of maintenance dredging is expected throughout the campaign period (31st March to 31st October each year) on approximately a monthly basis depending on ambient conditions and associated infilling rates. It is predicted that SSC would return to background concentrations within several days. Dredge plume modelling is detailed in **Appendix 22J** of this volume. Dredge areas, sediment plume characteristics and changes in sedimentation as a result of dredging activities are provided in **Section 22.3.i)** of this chapter. No direct effects are expected, but there is the potential of indirect effects due to prey avoidance of the SSC plume. The SSC plume is relatively transient and baseline conditions should resume within days and no significant effects are expected on marine mammals foraging in the area. The overall effect of this impact was assessed as negligible.

22.9.212 Although stationary cumulative impact ranges for harbour porpoises extend up to ~11km for TTS, the underwater noise modelling predicts that harbour porpoises fleeing cumulative TTS zone for the dredging for BLF construction is ~1.3km with non-existent PTS. No impact zones are predicted for fleeing seals. The effects are assessed as minor adverse.

22.9.213 Considering that the underwater noise effects are greater than those associated with SSC, the underwater noise is considered as the overriding impact. The resulting in-combination effects equal the original underwater noise assessment of minor adverse effects. Effects are **not significant**.

Changes in suspended sediment concentration from combined dredging and disposal activities

22.9.214 The pressure of changes in suspended sediment could occur from dredging and disposal activities. Maintenance dredging for the BLF is planned to occur at approximately monthly intervals during the campaign period. As a worst-case, it is assumed there is a temporal and spatial coincidence of the plumes from maintenance dredging for the BLF (plough dredger) and dredging (cutter suction dredger) and disposal of a) cooling water infrastructure and, b) the southern FRR. As described in the plankton assessment **Section 22.6.c)** of this chapter, the suspended sediment plumes from the BLF maintenance dredge and the cooling water infrastructure do not interact but form two discrete plumes. Thus, the concurrent activities result in a greater spatial area of impacts rather than interactive effects. Increases in the total size of the instantaneous SSC plume and areas of sedimentation at ecologically relevant levels are considered minimal.

22.9.215 The suspended sediment plume from the BLF maintenance dredge and the FRR dredge plume do interact. At the sea surface the maximum instantaneous area exceeding 100mg/l increases to 111ha. This increase is greater than the sum of the two individual activities, however, the plume is highly transient and the total duration of increase in SSC would be reduced due to the temporal overlap.

22.9.216 The resulting effects of single pressures were assessed as negligible. Given that the temporal overlap is limited, it is unlikely that this inter-relationship would increase the significance of these effects. Effects are therefore considered to be **not significant**.

d) Operation

i. Beach landing facility

22.9.217 This section describes the impacts associated with the maintenance and operation of the beach landing facility (BLF) during the operation phase. Scoping identified the pressures arising from activities at the BLF with the potential for effects on ecological receptors, provided in **Appendix 22M** of this volume. Those pressures with the potential to affect marine mammal receptors are presented in **Table 22.139**.

Table 22.139: Pressures associated with BLF activities with the potential to affect marine mammal receptors.

Pressure	BLF activities resulting pressure.	Justification and evidence base.
Visual disturbance from artificial lighting.	Navigational, maintenance of infrastructure.	Introduction of artificial light can potentially cause disturbance and displacement.
Physical disturbance from vessel activity.	Navigational, maintenance of infrastructure.	Physical presence of vessels as well as increased vessel traffic can potentially cause disturbance and displacement.
Changes in SSC.	Navigational dredging.	Increases in SSC have the potential to affect marine mammal receptors through disruption or impairment to feeding.
Underwater noise.	Navigational dredging.	The potential effects of underwater noise on marine mammal receptors range from injury (close to the source) to behavioural or barrier effects (at greater distances).

Visual disturbance from artificial light

22.9.218 During the operational phase, the BLF would receive occasional AIL deliveries, approximately every 5-10 years. When the BLF is operational an initial capital dredging event would be required followed by maintenance dredging to maintain the planar surface during operations. The presence of delivery barges (approximately every 5-10 years) which require artificial lighting may lead to disturbance and displacement impacts. A lighting strategy designed to minimise light spill into the marine environment would be implemented. One of the proposed mitigation measures is no lighting when BLF is not in use (subject to navigational risk assessment). Nonetheless, a certain level of artificial lighting is likely to be introduced in the environment due to the requirement of lighting on the BLF and moored vessels.

22.9.219 The magnitude of the impact is therefore considered as low.

Marine mammal sensitivity to visual disturbance

22.9.220 As previously described (see construction section), marine mammals are considered not sensitive to visual disturbance from artificial light given that their vision is not their primary sense for navigation, foraging and communication. Additionally, should any displacement and avoidance occur, they are likely to be short-term and reversable.

22.9.221 The impact of visual disturbance from operational activities is predicted to have a negligible effect on marine mammal receptors.

Physical disturbance from vessel activity

22.9.222 Occasional deliveries to the BLF during the operational phase (every 5-10 years) would necessitate dredging for the BLF access channel and result in increased delivery vessel activity. Thus, small -scale vessel activity is expected during this phase. The impact magnitude is assessed as low.

Marine mammal sensitivity to physical disturbance

22.9.223 As previously described, the presence of vessels and associated activity together with the noise produced could potentially disturb marine mammals or cause displacement from their habitat if the disturbance is persistent and long term. Literature suggests impacts mostly in terms of short-term behavioural responses such as avoidance although habituation, but positive responses have been reported (please see construction section for more details).

22.9.224 It is considered that sensitivity of marine mammals to physical disturbance from vessel activity during the operation of BLF is low.

22.9.225 The impact of disturbance from vessel activity is predicted to have minor adverse effects on marine mammal receptors. Any avoidance of the area would be short-term, and animals are expected to return upon cessation of the activity. Effects are **not significant**.

Changes in suspended sediment concentration

22.9.226 Sporadic maintenance dredging of the BLF access channel would be required during the operational phase of the proposed development (approximately every 5-10 years). The requirements are the same as during the construction phase i.e. dredging of a navigation channel over the outer longshore bar and creation of a planar grounding surface. The dredge profile requires the redistribution of a total of 4,600m^3 of sediment by plough dredging. Such activities would increase SSC.

22.9.227 Dredge areas, sediment plume characteristics and changes in sedimentation as a result of dredging activities are provided in **Section 22.3.i)** of this chapter. A plume with an instantaneous suspended sediment concentration (SSC) of >100mg/l above daily maximum background levels is expected to form inshore over an area of up to 108ha at the sea surface and 83ha as a depth averaged plume. Maintenance dredging would result in up to 28ha of sea surface expected to experience >100mg/l above background SSC on each occasion, provided in **Appendix 22J** of this volume.

22.9.228 Dredging has the potential to temporarily increase turbidity from a baseline status of '*intermediate turbidity*' to '*turbid*' according to the WFD criteria over part of the study area. However, SSC would return to background levels several days after dredging activities ceases. The assigned impact magnitude is low.

Marine mammal sensitivity to suspended sediment concentrations

22.9.229 The sensitivity of marine mammal populations to increases in suspended sediment is described in the assessment of the BLF construction. The short duration of the dredging activities and the rapid decrease in SSC following cessation of activities suggest that impacts would be short-lived. Large natural variability in SSC occurs at the site depending on seasonality, tidal state, wave energy, and the occurrence of storm events. However, indirect effects due to behavioural avoidance by fish from the plume could occur but this has been assessed as minor, provided in **Section 22.8** of this chapter, and therefore there would not be a significant impact on marine mammals foraging in the area. Consequently, it is assessed that marine mammals are not sensitive to this impact.

22.9.230 The impact of increased SSC resulting from dredging activities is predicted to have a negligible effect on marine mammal receptors. Effects are predicted to be short-lived, spatially limited and **not significant**.

Underwater noise

22.9.231 Dredging at the BLF resulted in the largest impact zones for underwater noise due to the precautionary 24-hour nature of the modelled activities. Despite the precautionary nature of the assessments PTS ranges were modest for highly mobile species. Dredging activities at the locations of the BLF resulted in PTS for harbour porpoise extending to ~0.6km (76ha) following 24 hours of continuous dredging. The corresponding PTS range for seals was 25m (<0.25ha). TTS ranges for the stationary cumulative scenario extended to ~5.5km and ~0.9 km for harbour porpoises and seals, respectively. No PTS ranges were predicted for harbour porpoises under the fleeing animal assumption; TTS was predicted to occur at ~1.3km. No TTS and PTS ranges were calculated for fleeing seals, provided in **Table 22.140** and **Appendix 22L** of this volume.

22.9.232 The impact magnitude is medium.

Table 22.140: Marine mammal auditory impact zones for dredging activity

Activity	Threshold	Instant.	Stationary Cumulative.		Fleeing cumulative.	
		All species.	Harbour porpoise.	Phocid seals.	Harbour porpoise.	Phocid seals.
Dredging for BLF maintenance.	PTS	N/A	665m; 76ha.	25m; <0.25ha.	No impact.	No impact.
	TTS	N/A	5,565m; 3,650ha.	903m; 125ha.	1,308m; 225ha.	No impact.

Marine mammal sensitivity to underwater noise

22.9.233 Detailed information on marine mammal sensitivity to underwater noise from dredging is outlined in **Section 22.9.c)** of this chapter. Overall, both harbour porpoises and seals are known to exhibit short-term avoidance areas where dredging is taking place. Other effects such as masking of seal's social calls or auditory injury are unlikely considering the location of the development area and results of underwater noise modelling. The sensitivity of marine mammal populations to underwater noise from dredging during the operation and maintenance of the BLF is predicted to be low.

22.9.234 The impact of increased underwater noise resulting from dredging activities is predicted to have a minor adverse effect on marine mammals. Effects are predicted to be short-lived and return to baseline conditions rapidly after dredging activity ceases. Effects are **not significant**.

ii. Cooling water infrastructure

22.9.235 This section describes the impacts associated with water abstraction and discharges from the cooling water infrastructure during the operational phase. Scoping identified the pressures arising from cooling water abstraction and discharges with the potential for effects on ecological receptors, provided in **Appendix 22M** of this volume. Those pressures with the potential to affect marine mammal receptors are presented in **Table 22.141**.

22.9.236 The assessment has been conducted against species identified in the current baseline. Should future changes in the distribution of marine mammals species occur due to climate change and/or the availability of prey at a wider scale, see Future Baseline, **Section 22.9.b** of this chapter, the assessment against current marine mammal species baselines are considered to be reflective of the marine mammals that may occur under future baselines at large.

Table 22.141: Pressures associated with cooling water infrastructure activities with the potential to affect marine mammal receptors.

Pressure	Cooling water infrastructure activities resulting pressure.	Justification and evidence base.
Impingement.	Cooling water abstraction.	Embedded mitigation measures (i.e. coarse bar screens at the intake) are in place to prevent large marine mammals entering the cooling water system. However, there is a highly unlikely possibility of small marine mammal entering the intake system. Impingment of prey items has the potential to influence the local availablity of prey. Impingement would result in losses of fish from the system, but biomass is retained and returned via the FRR. Species with low resistance to impingement stresses would be retuned dead or moribund presenting a potential feeding opportunity for seals.
Temperature changes.	Operational discharge.	Marine mammals have well-developed homeostatic mechanisms that maintain their body temperature within a narrow range,and they are resistent to the small scale temperature changes relative to their foraging ranges. However, there is a potential for indirect food web effects due to reduction in the prey availibaility as a result of fish avoidance of the thermal plume area.
Synthetic compound contamination.	Chlorination compounds and hydrazine.	Synthetic compound contamination has the potential to affect fitness of marine mammal receptors. Direct toxicological effects will be assesed. In addition, there is the potential for indirect effects due to prey avoidance of chemical plumes or bioaccumulation of contaminants through ingestion of contaminated prey.

Impingement

22.9.237 Embedded mitigation measures in the form of coarse bar screens (bars spaced at ca. 0.26m centres) would be in place to prevent large marine mammals entering the cooling water system. Any smaller animals entering the system would be transported to the forebays. No further movement beyond the forebay would be possible due to the presence of trash racks with narrow bar spacing (75mm) placed before the drum and band screens.

22.9.238 Given that impingement would occur for the operational lifetime of the proposed development and potentially directly and indirectly affect marine mammals, the magnitude of the impact is assigned as medium.

Marine mammal sensitivity to impingement

22.9.239 Direct impingement is considered very unlikely considering that embedded mitigation would prevent the entrance of all but the smallest marine mammals. Nonetheless, there is a possibility of small marine mammals entering (and leaving) the intake system through coarse bars. If this occurs, the animal would be rescued from the forebay, which is the furthest point it can enter. This scenario is considered a very rare event based on operating experience at other operational nuclear power stations.

22.9.240 Impingement of prey items has the potential to influence the local availability of prey. Impingement would result in losses of fish from the system, but biomass is retained and returned via the FRR. Species with low resistance to impingement stresses would be returned dead or moribund presenting a potential feeding opportunity.

22.9.241 Harbour porpoises in the wild are not known to consume dead prey and fish mortality caused by impingement would not increase their food availability. However, seals are reported to consume fishery discards or dying fish entangled in fishing nets, and dead or moribund fish near the FRR could constitute a feeding opportunity. However, there is no evidence of seal aggregations around Sizewell B, which discards fish form its outfall, suggesting very limited exploitation of such opportunities.

22.9.242 Fish assessment, provided in **Section 22.8.d)** of this chapter, determined losses of fish due to abstraction (with embedded FRR and LVSE mitigation), would have negligible effects on stocks of key fish taxa. Impingement has been assessed as having a minor adverse effect on fish species. Any localised fish losses could potentially reduce foraging opportunities, but such losses would be replaced given fish mobility within the open system. Wide-ranging marine mammals would be unaffected by localised loss of prey.

22.9.243 Marine mammal sensitivity to this pressure is considered low.

22.9.244 No significant changes in the prey availability due to fish impingement are expected while direct impingement is considered very unlikely. Therefore, the predicted effects are assessed as minor adverse. Effects are **not significant**.

Cooling water discharges: temperature changes

22.9.245 Direct cooled power stations require the abstraction of large volumes of cooling water. During the operational phase, cooling water is discharged at temperatures up to 11.6°C higher than ambient, at a rate of 132m³/s. Marine mammals can be affected directly or indirectly though effects on their prey.

22.9.246 Thermal standards include criteria for absolute temperature and thermal uplifts to determine the potential for acute and chronic effects and behavioural responses. Recommended thermal standards exist for SACs, SPAs and Water Framework Directive (WFD) waterbodies. The receiving waters adjacent to the proposed development are within the Southern North Sea SAC designated for harbour porpoise. Accordingly, SAC thermal standards are considered in this instance.

22.9.247 SAC thermal recommendations include a maximum allowable 2°C thermal uplift (100th percentile) above ambient at the edge of the mixing zone. Furthermore, SACs designated for estuarine or embayment habitat and/or cold-water salmonid species, apply absolute temperature thresholds of 21.5°C as a 98th percentile (Ref. 22.393)). However, these criteria are not applicable to the Southern North Sea SAC designated only for harbour porpoise. Absolute temperature thresholds for marine mammal sensitivity assessments consider SPA thresholds (28°C as a 98th percentile). For fish species, a conservative thermal uplift of 3°C is considered a more appropriate avoidance threshold (Ref. 22.428). Thus, 3°C will be taken into account for indirect effects.

22.9.248 Thermal thresholds and areas of exceedance are provided in **Table 22.142**. Due to the plume interaction, areas of exceedance for Sizewell B and Sizewell C are included to represent the worst-case scenario.

Table 22.142: Thermal thresholds and areas of exceedance for marine mammal assessments.

Threshold	Criteria	Designated site thermal standard.	Area of exceedance (Sizewell B only).	Area of exceedance (Sizewell B + Sizewell C).	Area of exceedance (Sizewell C only)
	Thermal uplift.		Surface 9,370ha.	Surface 22,464ha.	Surface 16,775ha.

Threshold	Criteria	Designated site thermal standard.	Area of exceedance (Sizewell B only).	Area of exceedance (Sizewell B + Sizewell C).	Area of exceedance (Sizewell C only)
2ºC uplift as a 100th percentile.		SAC[70]	Seabed 5,214ha.	Seabed 16,451ha.	Seabed 12,244ha.
3ºC uplift as a 98th percentile.	Thermal uplift.	WFD	Surface 1,263ha.	Surface 2,200ha.	Surface 305.7ha.
			Seabed 667.7ha.	Seabed 1,553ha.	Seabed 0ha.
> 28ºC.	Absolute temperature	SPA	Surface 0ha.	Surface 0.11ha.	Surface 0ha.
			Seabed 0ha.	Seabed 0ha.	Seabed 0ha.

22.9.249 During the operation of the proposed development, absolute temperatures exceed 28ºC over a very restricted sea surface area (0.11ha) and do not exceed 28ºC at the seabed, provided in **Table 22.142** and **Figure 21.5** of **Chapter 21** of this volume. This suggests that there is a minimal potential for direct effects for highly mobile species such as marine mammals.

22.9.250 Uplifts of >3ºC occur over an area of 2,200ha at the surface and 1,553ha at the seabed as a 98th percentile during the operation of Sizewell B and Sizewell C, provided in **Table 22.142** and **Figure 21.4** of **Chapter 21** of this volume.

22.9.251 The environment at GSB is tidally dominated and marine mammals are highly mobile. The instantaneous plume provides further ecologically relevant information about the plume dynamics. The size of the instantaneous plume is highly seasonal and driven by meteorology and mixing conditions throughout the year. These conditions determine the relative size of the surface and seabed plume. Strong winds in Winter result in the largest instantaneous plume size. During Winter when harbour porpoises are more numerous, the average plume area exceeding 2°C at the surface is between 745ha and 2,605ha while 3°C exceedance is between 429ha and 834ha (Ref. 22.13).

22.9.252 Thermal discharges would occur throughout the operational life cycle of the proposed station. Absolute thermal exceedance with the potential to cause acute effects is constrained to a small area. Thermal uplifts with the potential

[70] It is worth noting that the absolute area of exceedance extends beyond Southern North Sea (SNS) SAC and is considered here. The area relevant to SNS SAC will be addressed within the **Shadow HRA** (Doc Ref. 5.10).

for chronic effects can extend over thousands of hectares, however instantaneous plumes are restricted to smaller areas. For highly mobile species such as marine mammals, the instantaneous plume is more dominant in eliciting any potential effects.

22.9.253 The impact magnitude is precautionarily assessed as medium.

Marine mammal sensitivity to temperature changes

22.9.254 Marine mammals have well-developed homeostatic mechanisms that maintain their body temperature within a narrow range, and they are more resistant to temperature changes than exothermal aquatic fauna (Ref. 22.511). Their physiological adaptions (i.e. low surface area-to-volume ratio and insulating blubber or fur) and ability to freely move and leave places with unsuitable temperatures, make them unlikely to be affected by the temperature changes expected to occur at the proposed development.

22.9.255 The most likely effects on marine mammals would be indirect effects through their prey, given that evidence indicates some fish may avoid thermal uplifts. Nonetheless, such effects are expected to be minor, provided in **Section 22.8** of this chapter; (Ref. 22.428)) taking into account the restricted area of impact in which prey species might be affected. In addition, as the large foraging ranges of marine mammals ensure they can compensate for a potential localised prey decline. The size of the instantaneous plume at 3°C excess temperature ranges between 179ha and 834ha at surface and between 44ha and 673ha at seabed (Ref. 22.13).

22.9.256 Seal tagging studies conducted at Sizewell B do not suggest any barrier effects caused by the thermal plume from the currently operating plant (Ref. 22.453; 512). Acoustic data confirms the presence of harbour porpoises within the area of the existing thermal plume during Winter when thermal uplifts are at their greatest (Ref. 22.441).

22.9.257 If harbour porpoises were to avoid the warmest area of the thermal plume (>28°C, 0.11ha) or incur indirect effects as a result of prey avoidance in areas above >3°C this could potentially lead to habitat loss within the Southern North Sea SAC. The worst case monthly average instantaneous plume >3°C occurs in February over an area of 834ha. This represents 0.023% of the available SAC (3,695,100ha). Therefore, no significant habitat loss is expected.

22.9.258 The sensitivity of marine mammal populations to temperature changes is predicted to be not sensitive.

22.9.259 The impact of temperature changes from operational discharges is predicted to have a minor adverse effect on marine mammal receptors. Effects are **not significant**.

Cooling water discharges: chlorinated discharges

22.9.260 To control biofouling of critical sections of the plant during operation, intake water would be chlorinated by the addition of sodium hypochlorite. The primary biocidal effects of seawater chlorination result from oxidants associated with water chemistry. These oxidants are measured and expressed as the total residual oxidant (TRO) concentration. Accordingly, the sum of TROs, rather than simply chlorine, is measured. The TRO discharge concentration would be 0.15mg/l, discharged at a rate of 132m^3/s in the cooling water at a temperature of less than 11.6 °C above ambient, provided in **Appendix 21E** in this volume.

22.9.261 TROs result from the combination of chorine and organic material in the water. Chlorination compounds are broken down to form chlorination by-products. This section considers the impact magnitude of TRO and chlorination by-product discharges.

Total residual oxidants: impact magnitude

22.9.262 The EQS for TROs is 10µg/l as a 95th percentile concentration. The TRO plumes from Sizewell C and Sizewell B are spatially distinct at ecologically relevant concentrations and follow a long narrow trajectory parallel to the coast. Therefore, Sizewell C is considered separately with Sizewell B as part of the baseline.

22.9.263 The Sizewell C TRO plume is highly stratified and concentrations exceed the EQS over a moderate area of sea surface area of 338ha and a small area of seabed, 2.1ha, provided in **Figure 21.6** of **Chapter 21** of this volume.

22.9.264 TRO discharges would occur for the operational lifecycle of the proposed development and would be continuous throughout the growing season when water temperatures exceed 10^{o}C.

22.9.265 The impact magnitude for TRO discharges has been assessed as medium.

Chlorination by-products: impact magnitude

22.9.266 Seawater is rich in bromide, which reacts with chlorination compounds to produce chlorination by-products. The most abundant chlorination by-product in discharges from coastal power stations, and the only product detected in the waters off Sizewell is bromoform (Ref. 22.103), provided in **Appendix 21E** of this volume.

22.9.267 EQS concentrations for bromoform do not exist and a PNEC of 5µg/l as a 95th percentile is applied as the recommended standard (Ref. 22.103). The bromoform plume is predicted to follow a similar trajectory to the TRO plume with a narrow, tidally transported plume forming parallel to the shore. The

Sizewell C plume is discrete from the Sizewell B plume. The Sizewell C plume is stratified with PNEC concentrations exceeding 5µg/l over an area of 52ha at the surface and 0.67ha at the seabed.

22.9.268 Bromoform discharges would occur for the operational lifecycle of the proposed development and would be continuous throughout the growing season when water temperatures exceed 10ºC. The impact magnitude for bromoform discharges has been assessed as medium.

Marine mammal sensitivity to chlorinated discharges

22.9.269 Limited evidence is available on the effects of chlorinated discharges, TROs and bromoform on marine mammals in the wild. Thus, the assessment considers evidence from marine mammals in captivity and potential food web effects.

22.9.270 Chlorine or its by-products can cause damage to the cornea in captive pinnipeds (Ref. 22.513). Skin infections have been observed in captive mammals due to chlorination destroying beneficial microflora and inactivation of antimicrobial substances secreted by the skin (Ref. 22.514). However, the concentration of chlorine in pools regularly exceeds 2.5mg/l (Ref. 22.515) and animals are continuously exposed to highly chlorinated water for prolonged periods. Such concentrations are orders of magnitude above concentrations within the Sizewell C plume. Toxicity is concentration and exposure dependant, with wild animals having less exposure due to the ability to move freely within a large, open area.

22.9.271 Chlorination by-products are rapidly degraded in the marine environment and the low bioconcentration factor of bromoform indicates that indirect effects due to bioaccumulation in the food web is limited (Ref. 22.105). Moreover, no significant declines in abundance and distribution of prey stocks is predicted ((Ref. 22.428); see also fish assessment).

22.9.272 Should harbour porpoises avoid the area of the TRO plume this could potentially lead to habitat loss within the SAC for this species. However, considering the size of the predicted plume (338ha) relative to the size of the SAC (3,695,100ha), the habitat loss would be negligible (0.009% of the SAC). It is also worth noting that, harbour porpoises are more frequent in the GSB during Winter when there would be no chlorination. Therefore, the limited utilisation of the area during this period further decreases potential habitat loss.

22.9.273 The sensitivity of marine mammal populations to chlorine contamination is predicted to be low.

22.9.274 The impact of chlorinated discharges is predicted to have a minor adverse effect on marine mammal receptors. Effects are **not significant**.

Cooling water discharges: Hydrazine

22.9.275 Hydrazine (N_2H_4) is an ammonia-derived compound with strong anti-oxidant properties, regularly used as a corrosion inhibitor in cooling water circuits of nuclear power stations. Worst-case daily discharges from Sizewell C have been modelled based on hydrazine discharges of 24kg per annum into the cooling water flow. Conservative decay rates were incorporated into the General Estaurine Transport Model to consider two release strategies based on different pulses of 69ng/l for 2.32h a day and 34.5ng/l for 4.63h a day culminating in the same total annual load (24kg/yr).

22.9.276 The plume simulations showed that both strategies gave similar results. The hydrazine plume follows a narrow trajectory parallel to the shore. At the seabed, less than 1ha exceeds the chronic PNEC, irrespective of the release strategy. At the surface the area that exceeds the chronic PNEC is 158 and 157ha for the 69ng/l and 34ng/l releases, respectively.

22.9.277 The acute thresholds were only exceeded in the 69ng/l release strategy over a very small area of the seabed (0.13ha). Surface exceedance extended to 17.4ha and 13.8ha in the 34.5ng/l and 69ng/l strategy, respectively, provided in **Appendix 21E** of this volume. The full results of the modelling are presented in **Table 22.33** and provided in **Section 22.6.d)** of this chapter.

22.9.278 There is no existing EQS value for hydrazine and PNEC values were derived for assessment purposes from a review of available toxicity data. With limited available toxicity data for marine species a high safety factor was applied resulting in an acute PNEC value of 4ng/l as a 95^{th} percentile and a mean chronic value of 0.4ng/l being applied. These thresholds are considered precautionary and Canadian Federal Water Quality Guidelines indicate a low likelihood for adverse effects below 0.2µg/l for marine life (Ref. 22.60).

22.9.279 Daily discharges would occur throughout the lifecycle of the proposed development. The magnitude of impact is medium.

Marine mammal sensitivity to hydrazine contamination

22.9.280 Toxicity data exist for amphibian, fish, invertebrate and plant species but no marine mammals. However, top predators could be potentially indirectly affected through effects on their prey. Data on fish toxicity are available only for few freshwater species indicating that 96h LC_{50} of 610µg/l for common guppy (*Lebistes rericulatus*) and the highest for fathead minnow (*Pimephales promelas*) (Ref. 22.60). Such concentrations are considerably higher than those experienced within the plume. Due to lack of evidence on effect of hydrazine contamination to marine mammals, a precautionary approach was applied and assigned sensitivity is low.

22.9.281 The impact of hydrazine contamination resulting from daily operational discharges is predicted to have a minor adverse effect on marine mammals. Effects are **not significant**.

iii. Fish recovery and return systems

22.9.282 This section describes the impacts associated with the operation of the FRR. The FRR system is designed to minimise impacts on impinged fish and invertebrate populations. However, some species such as clupeids are highly sensitive to mechanical damage from impingement on the drum for band screens and incur high mortality rates. The return of dead and moribund biota retains biomass within the system and represents a potential source of food for marine mammals. Pressures with the potential to effect marine mammals are presented in **Table 22.143**.

Table 22.143: Pressures on marine mammals associated with discharges from the FRR.

Pressure	Activities resulting in pressure.	Justification
Organic enrichment.	Discharge of dead and moribund biota.	The return of dead and moribund biota represents a potential source of food for marine mammal receptors. The effects of increased food availability is considered in this section, whilst wider food webs assessements are provided in **Section 22.10** of this chapter.

Fish recovery and return: organic enrichment

22.9.283 The total biomass of moribund biota predicted to be discharged from the FRR has been estimated based on abstraction rates and information on the seasonal abundance of species impinged for the existing Sizewell B station. The data shows seasonal variation in the discharge of moribund fish. The highest discharge biomass would occur in December to April, when clupeids are most abundant, with peaks in abundance in March. During March, mean daily discharges of biomass of 1,318kg/d are predicted from the FRR systems. Between April to September, a lower mean daily discharge biomass of 155kg (wet weight) is predicted with an annual average of 408kg/d, provided in **Section 22.7.d)** of this chapter; **Table 22.57**.

22.9.284 The pressure would occur for the operational lifetime of the proposed development. The greatest impact occurs at a time of year harbour porpoises are most abundant in the area coinciding with the highest biomass of their prey (i.e. clupeids).

22.9.285 The magnitude of the impact is assigned as medium.

Marine mammal sensitivity to organic enrichment

22.9.286 There are no reports of harbour porpoises consuming dead prey in the wild and it is widely acknowledged that they actively engage in targeting live prey. No aggregations of harbour porpoises have been reported around Sizewell B suggesting that such easy feeding opportunities are not being exploited. Harbour porpoise are considered as not sensitive to FRR discards and behavioural responses are not predicted.

22.9.287 Seals are reported to consume fishery discards or dying fish entangled in fishing nets (Ref. 22.516), and dead or moribund fish near the FRR could constitute an easy feeding opportunity. This would particularly be the case for the grey seals given that they exhibit a greater level of flexible and opportunistic feeding habits. However, there is no evidence of seal aggregations around Sizewell B which already discharges fish from its outfall. Seals are considered as not sensitive to FRR discards, but it is feasible a degree of behavioural attraction could occur.

22.9.288 The impact of organic enrichment from FRR discards is predicted to have negligible effects on harbour porpoises and minor beneficial effects on seal species. Effects are **not significant** at the population level.

iv. Inter-relationship effects

22.9.289 This section provides a description of the identified inter-relationship effects that are anticipated to occur on marine mammal receptors between the individual environmental effects arising from operation of the proposed development.

Temperature changes and synthetic compound contamination

22.9.290 Thermal discharges would occur throughout the year from the proposed development. Seasonal chlorination of critical plant would result in thermal discharges being chlorinated once water temperature exceeds 10ºC. The TRO plume occurs within the thermal plume. Increased temperature may increase the rate of chlorination by-product formation (synergistic effects) but also the rate of degradation (neutralistic effects). Furthermore, elevated temperatures can enhance the toxicity of chlorine.

22.9.291 Marine mammals are not considered to be sensitive to temperature changes and have low sensitivity to chlorine contamination. Additionally, the spatial extent of the impact relative to their range is minimal, provided in **Figure 21.7** of **Chapter 21** of this volume. Therefore, no direct effects are expected. However, indirect effects could occur given that these combined pressures affect their prey species. The fish assessment, provided in **Section 22.8** of this chapter, however did not predict an increase of the significance of effects arising from the combined pressures thus overall effects remain **not significant** (i.e. minor adverse).

Nutrient enrichment and synthetic compound contamination

22.9.292 During operation, the control of biofouling with chlorination would result in seasonal discharges of total residual oxidants (TRO) in the cooling water stream (via the cooling water outfalls). Ammonia discharge from plant conditioning chemicals and the on-site sewage treatment plant would also be discharged via the cooling water outfalls. With elevated ammonia, a variety of chloramines and bromamines can form (Ref. 22.106). The presence of these chlorination by-products, could potentially result in increased toxicity.

22.9.293 Un-ionised ammonia discharges are predicted to be limited and are predicted to mix with and react with TRO within a spatially limited area. There is predicted to be a rapid reaction of the un-ionised ammonia with TRO and chemical volatility of chloramines and bromamine. Chlorination and ammonia discharges would occur throughout the lifetime of the proposed development, but the seasonal occurrence of chlorination would limit the coincidence of the plumes.

22.9.294 No significant direct effects on marine mammal species are expected due to their lack of sensitivity to these pressures. However, there is a potential of indirect effects through their prey species. The fish assessment, provided in **Section 22.8** of this chapter, predicted minor adverse effect in a spatially limited area. Given the high mobility and foraging flexibility of marine mammals, no significant reduction in their prey availability is expected.

22.9.295 Therefore, it is unlikely that this inter-relationship would significantly increase the resulting effects i.e. the result of the assessment remains minor adverse. Effects are **not significant**.

22.10 Indirect effects and food webs

a) Introduction

22.10.1 This section characterises the Greater Sizewell Bay (GSB) food web (i.e. a network of organisms and their feeding interactions) and its features relevant to the construction and operation of the proposed development. Food web interactions and potential effects on prey availability of designated features of European Marine Sites is considered within the **Shadow HRA** that forms part of the DCO application (Doc Ref. 5.10).

22.10.2 The food web, position of the key taxa identified within each receptor assessment along with the interaction pathways with predators and their resources is presented. An understanding of the food web enables the basis for predicting the potential for effects from the proposed development.

22.10.3 Food webs reveal system-level phenomena that cannot be detected by studying focal species or assemblages alone. For instance, effects mediated via the food web can manifest within an assemblage not directly affected by the development, including changes to resources (e.g. prey populations) and to predation pressure. The food web therefore represents a synthesis of baseline information (species populations) supported by published feeding interaction data which can help to predict how an ecosystem could respond to environmental change.

b) Method summary

22.10.4 The food web is constructed based on the key taxa identified within the receptor specific sections of this chapter. Surface feeding and diving seabirds, as well as detrital resources are also included.

22.10.5 Important basal resources, intermediate taxa and top predators whose populations are important components of the food web are identified.

22.10.6 Potential pathways for indirect effects to propagate through the food web are depicted. However, alternative energy pathways can serve to dampen food web level effects following changes in the distribution and/or local abundance of a given taxa due to environmental change associated with the proposed development. As such the resistance and resilience of the food web to perturbation are discussed.

22.10.7 Sizewell Bay is a geographically small non-delineated area, which connects to the wider southern North Sea. Thus, transfer of water causes exchange of taxa at the base of the food web (e.g. planktonic organisms), and large mobile taxa, including marine mammals, fish and seabirds can both import and export resources from the site. Furthermore, mobile taxa especially those with large foraging ranges would likely subsidise their feeding requirements from beyond the GSB.

22.10.8 Current ecosystem level modelling, including Ecopath models (e.g. Mackinson and Daskalov, 2007: (Ref. 22.517)) were not designed for the relatively minor species/population changes envisaged for the proposed development, or for small non-delineated geographic areas. Such ecosystem level modelling is therefore not appropriate. Instead, a qualitative approach using feeding pathway information derived from the North Sea ecosystem diet matrix (Ref. 22.517) has been applied. The underlying diet matrix allows a binary network approach to help depict ecosystem structure (taxa and interactions) and function (strength of those interactions). This approach allows the potential for system-level perturbations to be identified and described and represents an advancement in describing potential effects at the food web level.

22.10.9 The strength of feeding interactions was defined at the functional group-level and based on the resources available to a consumer within the GSB.

22.10.10 Key energy pathways and feeding link diversity which might affect food web resistance and/or resilience are considered.

22.10.11 This approach can be systematically reproduced for any North Sea site based on a species list and the North Sea ecosystem diet matrix and further afield providing there is sufficient feeding information for taxa within the community of interest. The full methodology is described in (Ref. 22.518).

c) Baseline food web

22.10.12 The key taxa represent 58 nodes within GSB connected by 889 predominantly weak interactions (**Plate 22.8**).

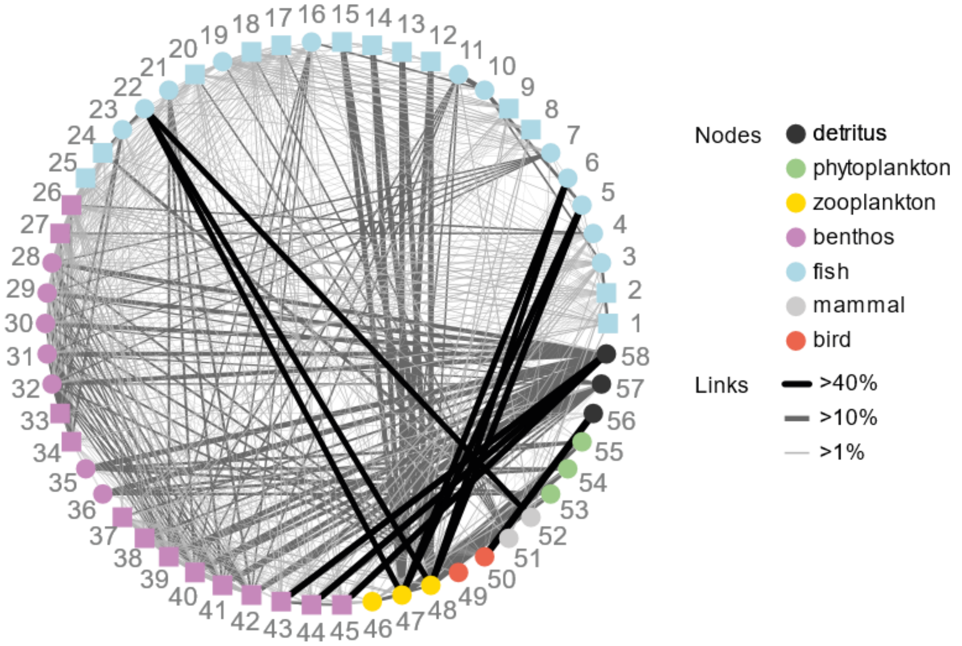
22.10.13 The skewed distribution of interaction strengths (many predominantly weak interactions) could act to stabilise the food web by dampening strong oscillatory consumer–resource interactions (Ref. 22.519; 520). A system with few strong interactions and lower alternative interaction pathways may be more vulnerable to perturbations leading to changes in any given population.

22.10.14 The populations and diversity of the key resources and their consumers could confer a degree of resistance and resilience to the GSB food web via alternative feeding pathways and ecological redundancy (Ref. 22.521; 522).

22.10.15 The key resources and consumers within the GSB food web are illustrated in **Plate 22.9**.

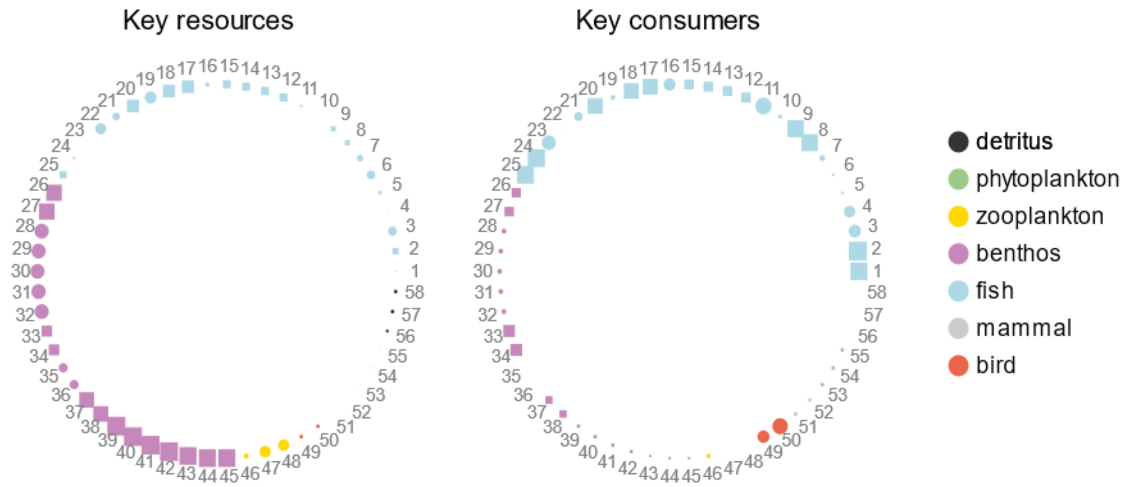
22.10.16 Key feeding pathways for fish, seabirds and marine mammals are depicted in greater detail in **Plate 22.10**. It is acknowledged that spatial and temporal plasticity in feeding behaviours occur, which is not encapsulated within the simple food-web model. Feeding interactions are based on the diet matrix from North Sea ecosystem models defined by Mackinson and Daskalov (2007) (Ref. 22.517). For highly mobile species, with large foraging areas the strength of feeding interactions at a North Sea level do not necessarily match the local abundance of available prey within the GSB.

Plate 22.8: A simplified depiction of the Greater Sizewell Bay food web showing feeding interactions (weighted lines) between key taxa (nodes; squares = cannibalistic) with adult (A) and juvenile (J) life-stages separated for specific taxa based on the North Sea ecosystem diet matrix (Mackinson and Daskalov, 2007). The weight of lines is based on the mean annual proportion of a resource to a consumer's diet defined for functional groups. Only links representing >1% of a consumer's diet are shown.



1 Gadus morhua (A)	16 Pleuronectes platessa	31 Nucula nitidosa	46 Gelatinous zooplankton
2 Gadus morhua (J)	17 Anguilla anguilla	32 Nucula nucleus	47 Copepoda
3 Limanda limanda	18 Chelon ramada	33 Cancer pagurus	48 Mysida
4 Platichthys flesus	19 Lampetra fluviatilis	34 Homarus gammarus	49 Diving seabirds
5 Clupea harengus (A)	20 Pomatoschistus	35 Mytilus edulis	50 Surface feeding seabirds
6 Clupea harengus (J)	21 Solea solea	36 Sabellaria spinulosa	51 Seals
7 Trachurus trachurus	22 Sprattus sprattus	37 Crangon crangon	52 Phocoena phocoena
8 Dicentrarchus labrax	23 Raja clavata	38 Pandalus montagui	53 Diatom
9 Salmo trutta	24 Merlangius merlangus (A)	39 Nephtys hombergii	54 Dinoflagellate
10 Galeorhinus galeus	25 Merlangius merlangus (J)	40 Notomastus	55 Microflagellate
11 Scomber scombrus	26 Buccinum undatum	41 Scalibregma inflatum	56 Discards
12 Alosa alosa	27 Ophiura ophiura	42 Spiophanes bombyx	57 DOM
13 Alosa fallax	28 Abra alba	43 Bathyporeia elegans	58 POM
14 Engraulis encrasicolus	29 Ensis	44 Corophium volutator	
15 Osmerus eperlanus	30 Limecola balthica	45 Gammarus insensibilis	

Plate 22.9: Key resources and key consumers in Greater Sizewell Bay food web with adult (A) and juvenile (J) life-stages separated for specific taxa (square nodes = cannibalistic). For key resources, node size increases in relation to the numbers of consumers per node, so large nodes are exploited by a relatively high number of consumers. For key consumers, node size increases with the number of key resources exploited, so large nodes reveal a consumer of many key resources. Note that species of seals, seabirds, phytoplankton and zooplankton have been aggregated into a subset of nodes which affects node size for these plots.



1 Gadus morhua (A)
2 Gadus morhua (J)
3 Limanda limanda
4 Platichthys flesus
5 Clupea harengus (A)
6 Clupea harengus (J)
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9 Salmo trutta
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15 Osmerus eperlanus
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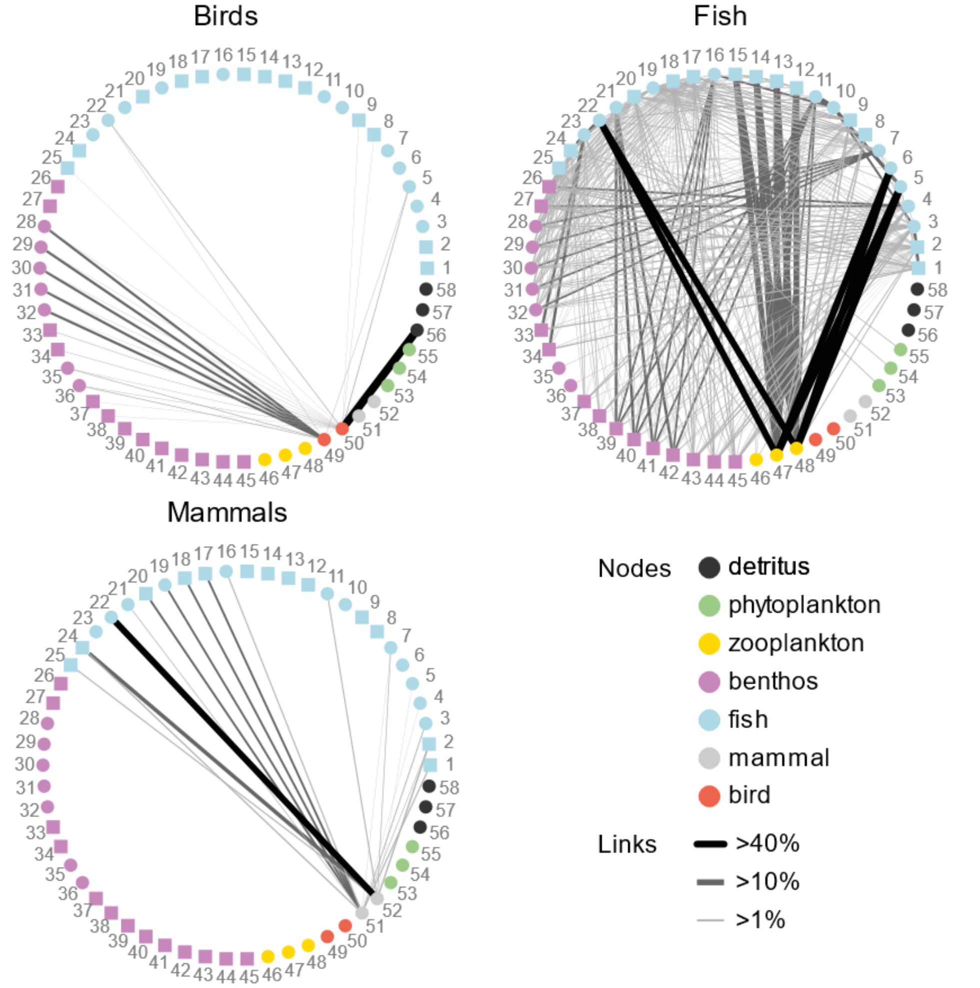
29 Ensis
30 Limecola balthica
31 Nucula nitidosa
32 Nucula nucleus
33 Cancer pagurus
34 Homarus gammarus
35 Mytilus edulis
36 Sabellaria spinulosa
37 Crangon crangon
38 Pandalus montagui
39 Nephtys hombergii
40 Notomastus
41 Scalibregma inflatum
42 Spiophanes bombyx
43 Bathyporeia elegans
44 Corophium volutator
45 Gammarus insensibilis
46 Gelatinous zooplankton
47 Copepoda
48 Mysida
49 Diving seabirds
50 Surface feeding seabirds
51 Seals
52 Phocoena phocoena
53 Diatom
54 Dinoflagellate
55 Microflagellate
56 Discards
57 DOM
58 POM

Plate 22.10: Prey (weighted lines) specific to seabirds, fish and marine mammals feeding in the Greater Sizewell Bay (square nodes = cannibalistic) with adult (A) and juvenile (J) life-stages separated for specific taxa. The weight of lines was based on the mean annual proportion of a resource to a consumer's diet defined for functional groups in the North Sea ecosystem diet matrix (Mackinson and Daskalov, 2007). Only links representing >1% of a consumer's diet are shown.



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d) Assessment of effects

22.10.17 This section provides a summary of the potential food web effects from the proposed development based on the conclusions of the individual receptor assessments during the construction and operational phase.

22.10.18 Pressures with the potential to affect food webs are summarised in (**Table 22.144**).

Table 22.144: Pressures associated with construction and operational activities with the potential for food web levels effect.

Pressure	Primary activities resulting in pressure.	Assessed for food webs.	Justification
Increases in SSC.	Construction dredging and dredge disposal associated with offshore infrastructure (FRRs, CDO and cooling water intake and outfall headworks). Construction and operation phase plough dredging for the BLF access channel.	No	The suspended sediment environment of the GSB is highly variable and dredging represents a short-term impact with the potential to cause minor changes in productivity at the base of the food web and the potential for localised avoidance behaviours for fish receptors. Effects are predicted to be minor and would not significantly peturb the food web.
Underwater noise.	Impact piling for the construction of the BLF and to a lesser degree dredging activities during the construction and operation phase.	No	Mortal and permanent injury ranges are predicted over very small spatial areas therefore, the primary impact of underwater noise on food webs relates to changes in the distribution and/or behaviour of fish and marine mammals. Piling represents a short-term impact, and displacement due to behavioural avoidance is predicted to be temporary. Effects are predicted to be minor and would not significantly peturb the food web.
Nutrient additions.	Construction and operational dicharges of N+P.	No	Nutrient aditions can cause food web pertubations by stimulating primary production. However, nutrient aditions are predicted to represent a very low level impact with negligible effects on primary productivey relative to large leves of natural variation. Effects are predicted to be negligible and would not significantly peturb the food web.

Pressure	Primary activities resulting in pressure.	Assessed for food webs.	Justification
Chemical contaminants from construction discharges.	Discharges of TBM chemicals during tunnelling for the cooling water tunnels, un-ionised ammonia from treated sewage, and heavy metals during the dewatering phase would be discharged from the CDO.	No	Discharges from the CDO during the construction phase are predicted to cause highly localised effects. Minor effects are predicted which would not significantly peturb the food web.
Chemical contaminants from construction discharges.	During cold-flush testing hydrazine would be discharged from the CDO.	No	Discharges at ecologically relevant concentrations are predicted to be highly localised. Hydrazine has a low bioconcentration factor meaning the bioaccumulation potential is low. Any toxicological effects are predicted to be minor and would not significantly peturb the food web.
Chemical contaminants from operational discharges.	Chlorinated discharges of TROs and associated chlorination by-products (bromoform) would occur seasonally whilst daily discharges of hydrazine would occur throughout the operational phase from the cooling water outfalls.	No	The offshore setting of the outfalls in deep tidal waters ensures a high degree of mixing and limits the spatial extent that contaminans are predicted to occur at ecologically relevant concnetrations. Direct effects are predicted to be minor and would not significantly effect the GSB food web.
Thermal discharges.	Cooling water discharges would result in the release of a thermally buoyant plume into the recieving waters of the GSB throughout the operational phase of the proposed development.	No	Acute effects of thermal discharges are predicted to occur over a very limited spatial area due to rapis mixinf in the offshore environment. Thermal uplifts may result in chronic effects which favour some species and have adverse implications for others. However, effects at the population level are predicted to be minor and no significant food web effects are predicted.
Impingement	Impingement has the potential to remove fish from the system. Should localised changes in fish		In the case of an open system where water exchange far exceeds abstraction, and where species are mobile, localised

Pressure	Primary activities resulting in pressure.	Assessed for food webs.	Justification
	abundnace occur, food web pertubations may ensue.		losses would not be expected to be distinguishable from natural variability in abundance.
Organic loading from FRR.	The FRR system is designed to minimise impacts on impinged fish and invertebrate populations. However, some species such are highly sensitive to mechanical damage caused during passage through the FRR systems and incur high mortality rates. The return of dead and moribund biota represents a seasonally variable source of organic carbon with the system, which would occur throughout the operational phase.	Yes	The FRR would act in a similar fashion to fisheries discards, which have been shown to result in localised increases in secondary production and attraction of mobile species due to the availability of prey. The potential for dead and moribund biota to effect the GSB food web is investigated further.

i. Organic loading: FRR discharges of dead and moribund biota

22.10.19 Biota that suffer mortality as a result of the impingement process would be discharged into the receiving waters via the FRR. This activity has the potential to affect food webs by increasing the availability of discards and detrital resources (FRR discards, particulate organic matter and dissolved organic matter, which confers an additional energy source across the food web.

22.10.20 The total biomass of dead and moribund biota to be discharged from the FRR has been estimated based on abstraction rates and information on the seasonal abundance of species, along with length-to-weight distributions of the species impinged at the existing Sizewell B station. The data show large seasonal variation in discharges. The highest discharge biomass would occur in December to April, when clupeids are most abundant, with peaks in abundance in March. During March, mean daily discharges of biomass of 1,318kg/d are predicted from the FRR systems. Between April to September, a lower mean daily discharge biomass of 155kg (wet weight) is predicted with an annual average of 408kg/d, provided in **Section 22.7.d)** of this chapter; **Table 22.57**. However, discharges would likely be sporadic.

22.10.21 Modelling the fate on impinged fish calculated that approximately 88% of dead fish (sprat) sink immediately. However, tidal resuspension would cause wider distribution in a predominantly north-south orientation from the two FRR headworks located approximately 300m apart. The remaining 12% would sink over the subsequent 24 hours and would be distributed more widely within the tidal environment on the GSB (Ref. 22.295).

22.10.22 Dead and moribund fish discharged from the FRR represents a seasonally high level of organic loading (not accounting for material exported by mobile predators or beyond the GSB by tidal processes) and would primarily settle over a spatially limited area near the FRR headworks. The pressure would last throughout the operational phase of the development.

22.10.23 The magnitude of impact is considered to be medium.

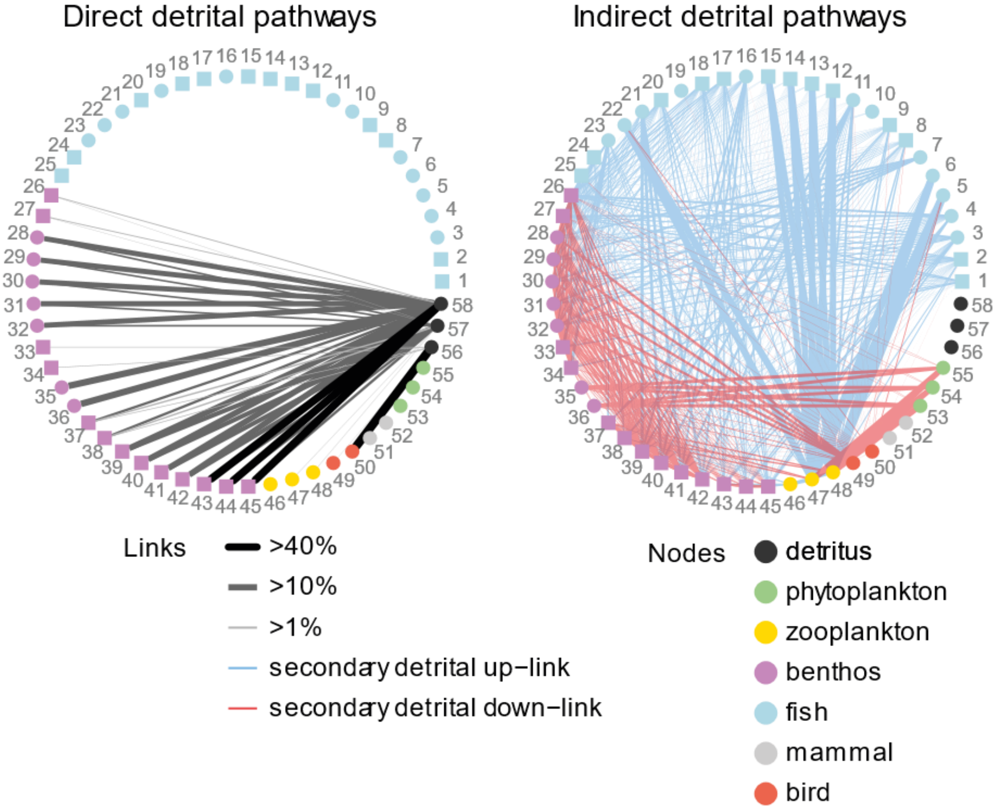
Sensitivity of the food web to organic loading

22.10.24 In the North Sea 30-40% of trawled fish catches were discarded prior to the discards ban and provided food sources for a range of seabirds, marine mammals and benthic fauna (Ref. 22.523). In the southern North Sea, discards were estimated to contribute 1-10% of the diet of benthic carnivores and demersal fish (Ref. 22.524). The FRR discharges are anticipated to have similar effects to fisheries discards. However, FRR discards would represent a food source to the same given area over a long period of time.

22.10.25 Based on relevant literature (Ref. 22.115; 116; 523; 524), the North Sea ecosystem diet matrix (**Plate 22.11**), and the traits of the key benthic taxa within the GSB, the following groups could be positively affected by the release of dead and moribund biota and associated elevated dissolved and particulate organic matter (i.e. detritus via scavenging and detritivory) due to local increases in population size or attraction of highly mobile species:

- *Bathyporeia elegans*
- *Buccinum undatum*
- *Cancer pagurus*
- *Corophium volutator*
- *Cragon crangon*
- *Gammarus insensibilis*
- *Homarus gammarus*
- Mysids
- *Ophiura ophiura*
- *Pandalus montagui*
- Demersal fish
- Seals
- Surface feeding, and to a lesser extent diving, seabirds

Plate 22.11: Detrital pathways in the Greater Sizewell Bay food web (square nodes = cannibalistic) with adult (A) and juvenile (J) life-stages separated for specific taxa. Direct links are shown between various forms of detritus and detrital consumers. Indirect links are highlighted from consumers of detritus to their other resources (in red) and predators (in blue) (i.e. down- and up-links where there is potential for changes to top-down and bottom-up effects, respectively).



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22.10.26 No clear evidence exists of increases in the local abundance of specific benthic taxa to the pre-existing discharges of dead and moribund biota from Sizewell B, see **Appendix 22C** of this volume. However, experimental evidence from UK waters has shown responses of whelks, crabs, amphipods, shrimps and echinoderms to discards (Ref. 22.115; 116).

Therefore, the potential for localised increased in abundance exists. There is some evidence of elevated populations of mysids close to the outfall of the existing Sizewell B station (Ref. 22.25), however, it is not clear if this is a result of the outfall itself or more specifically the elevated detritus from discharged dead and moribund biota.

22.10.27 Demersal fish, including juvenile seabass that are known to be more abundant within the warm waters within the Sizewell-Dunwich Bank during winter (Ref. 22.402), may utilise FRR discards resulting in localised attraction. For example, gadoids including cod (*G. morhua*) and whiting (*M. merlangus*) have all been shown to be attracted to fisheries discards (Ref. 22.116).

22.10.28 There are no reports of harbour porpoises consuming dead prey in the wild and it is widely acknowledged that they actively engage in foraging activities targeting live prey. There are reports of seals consuming fishery discards or dying fish entangled in fishing nets (Ref. 22.516), thus dead or moribund fish near the FRR could constitute a feeding opportunity for seals. Grey seals exhibit dietary flexible and opportunistic feeding habits. However, there is no evidence of seal aggregations around the existing Sizewell B outfall suggesting exploitation of such, albeit lesser, feeding opportunities have not been documented to date.

22.10.29 The marine waters adjacent to Sizewell support breeding and overwintering populations of designated seabirds. Whilst the majority of FRR discards sink and will therefore not be accessible to surface feeding seabirds, floating discards would represent a potential foraging opportunity to scavenging seabirds. Common terns (*Sterna hirundo*) and sandwich terns (*Sterna sandvicensis*) are known to extensively exploit fisheries discards in the Mediterranean (Ref. 22.525), whilst little tern (*Sterna albifrons*) do not follow trawlers to exploit discards (Ref. 22.526). Opportunistic gull species such as black-headed gull (*Chroicocephalus ridibundus*), common gull (*Larus canus*), great black backed gull (*Larus marinus*), herring gull (*Larus argentatus*), and lesser black backed gull (*Larus fuscus)* are present in the area during the period of highest FRR discards (Ref. 22.295). Of these species the lesser and greater black backed gulls and herring gull are known to extensively exploit fisheries discards in the North East Atlantic, whilst black-headed gull and common gull exploit fisheries discards less frequently (Ref. 22.525). Experiments have shown seabirds can take up to 71%, 8%, 12% and 4% of discarded roundfish, flatfish, elasmobranchs and invertebrates respectively in the southern North Sea (Ref. 22.527). As such, the FRR is likely to provide a foraging opportunity for scavenging seabirds.

22.10.30 The interactions discussed consider direct consequences on specific taxa. In reality, the impact of elevated detritus caused by the release of dead and moribund biota could be complex. Increases in detrital resources could coincide with localised reductions in intermediate predator populations due to impingement, e.g. sprat, which then re-enter the food web via both intermediate consumers and top predators with the potential for simultaneous changes to bottom-up and top-down effects (see indirect detrital pathways, **Plate 22.11**). For example, an increase in opportunistic seabirds attracted by fish discards could have a top-down effect on their other prey when discards are low (e.g. see (Ref. 22.528)). However, in the case of an open system where water exchange far exceeds abstraction and where species such as sprat are mobile, localised losses would not be expected to be distinguishable from natural variability.

22.10.31 Dead and moribund biota entering the GSB may result in localised increases in the population size of some secondary consumers due to increases in detritus and associated particulate organic matter and dissolved organic matter. Furthermore, discards may result in localised attraction of highly mobile scavengers attracted to opportunistic prey availability. However, the highly connected nature of GSB to the wider North Sea are likely to dampen the effects of discards, and the sensitivity to organic loading from the FRR is predicted to result in minor beneficial[71] effects. Effects are predicted to be **not significant** relative to large changes in seasonal and interannual variability in population size/local abundance observed in many taxa.

22.10.32 Sizewell Bay is not delineated from the North Sea as a discrete ecosystem, and it contains many taxa that are widely distributed in the region, and/or these taxa have ranges beyond the site in question. As such, only a proportion of the dietary requirements of highly mobile species of fish, seabirds and marine mammals would come from the GSB. Such features likely confer resistance to the GSB food web by acting to dampen any localised disturbance resulting from the proposed development.

22.11 Commercial and recreational fisheries

a) Introduction

22.11.1 This section presents the findings of the commercial and recreational fisheries assessment for the construction and operational phases of the proposed development.

22.11.2 This section identifies and describes potential significant effects arising from development activities and highlights any secondary mitigation and

[71] The effect is defined as beneficial due to the stimulatory effects of organic loading to a system. It could equally be argued that perturbation from a natural baseline is an adverse effect.

monitoring measures that are proposed to minimise any adverse significant effects.

b) Fisheries baseline

22.11.3 This section presents a description of the commercial and recreational fisheries baseline within the footprint of the proposed development and in the surrounding area. A detailed assessment of the commercial and recreational fisheries baseline is provided in **Appendix 22F** of this volume.

i. Commercial fisheries - current baseline

22.11.4 The commercial fisheries baseline is based on official landings statistics for 2017, obtained from the Marine Management Organisation (MMO) and updated through correspondence with the MMO in 2019 (Ref. 22.529).

22.11.5 Fishing vessels are required to submit daily information on their catches, including the fishing location, which is recorded by ICES rectangles. All sea areas are assigned a rectangle designation, and each rectangle is 1x0.5 degrees, which equates to approximately 30x30nm at this latitude. The GSB is located within ICES rectangle 33F1. Catches from this area were used as the baseline for the fisheries assessment.

22.11.6 Within the GSB area, landings are made into several local ports - Lowestoft, Pakefield/Kessingland, Southwold, Dunwich, Sizewell, Aldeburgh/River Alde, Orford, and Felixstowe Ferry/Orwell Estuary.

22.11.7 To place the fishery into wider context, landings were compared with catches in a) the five most adjacent rectangles (representing the east Anglian coast), b) the southern North Sea, and c) nationally. The full commercial fisheries baseline is described in **Appendix 22F** of this volume.

22.11.8 It should be noted that for reporting official landings data to the MMO there is no requirement to declare individual transactions of less than 30kg of fish. This is the case no matter how many transactions there are, so a fisher selling 20kg of seabass to each of ten buyers would not be recorded. Furthermore, the MMO dataset depends on fishers and purchasers completing accurate returns (Ref. 22.530).

22.11.9 Landings data are also compiled by local Eastern Inshore Fisheries and Conservation Authority Fishery Officers. The quality of Eastern Inshore Fisheries and Conservation Authority data depends on the Area Officer being able to sample the landings – either by personally checking, telephone conversations, or being in general contact with fishers. If the officer is unable to verify landings data, then data quality suffers. As much of the finfish activity is on small boats operating from small harbours or the open beach, it can be extremely difficult to monitor these activities.

22.11.10 Comparisons between MMO data and Eastern Inshore Fisheries and Conservation Authority estimates have been conducted for selected species. For seabass landed at Southwold in 2010-2012, comparisons showed that the Eastern Inshore Fisheries and Conservation Authority estimates were twice those of the official landings data. However, for sole landed at Aldeburgh and Orford during the same period, during two of the compared years there were no Eastern Inshore Fisheries and Conservation Authority estimates, and for the third year the landings estimates of the two methods were almost the same (~20t) (Ref. 22.530).

22.11.11 While it is noted that the MMO data may underestimate catches, these have been used as the baseline as they represent the official catch statistics.

22.11.12 In 2017, a live weight total of 375t of finfish and shellfish was landed from ICES rectangle 33F1, with a first sale value of £579,583 (Ref. 22.529). Compared with 2008, landings had increased notably, but the first sale value of those landings had decreased (267t; £911,866). Between 2008 and 2014 the most valuable species landed from 33F1 were sole (*Solea solea*), cod (*Gadus morhua*), seabass, thornback ray (*Raja clavata*) and herring (*Clupea harengus*), with lobster (*Homarus gammarus*) also frequently in the top 10 most valuable species. Since 2015, whelks (*Buccinum undatum*) have dominated the first sale value of catches from 33F1.

22.11.13 In 2017, six species accounted for almost 95% of the first sale value of landings from this ICES rectangle and included:

- whelks (£279,001; 48.1 %);
- seabass (£82,261; 14.2%);
- sole (£69,218; 11.9%);
- lobsters (£56,913; 9.8%);
- thornback ray (£30,872; 5.3%),
- herring (£16,263; 2.8%); and
- Brown shrimp (£15,432; 2.7%).

22.11.14 By live weight, smooth-hound replaces lobster in the top six species, which combined contributed almost 94% of the landings from 33F1 in 2017:

- whelks (279.5t; 74.5%);

- herring (31.3t; 8.3%);
- thornback ray (18.8t; 5.0%);
- sole (9.6t; 2.6%);
- seabass (7.3t; 2.0%); and
- and smooth-hound[72] (*Mustelus sp.*; 4.5t; 1.2%)

22.11.15 A comparison of values and landed quantities between ICES rectangle 33F1, the wider Sizewell area (ICES rectangles 32F1, 32F2, 33F1, 33F2, 34F1, 34F2) and ICES Division IVc is displayed in **Table 22.145**. Key-species are highlighted accounting for ca. 95% of the first sale value in ICES rectangle 33F1 and identified. Those species consist of whelks, seabass, sole, lobster, thornback ray and brown shrimp. Other species that contribute to the wider fisheries areas are included for information.

22.11.16 For vessels equal to or less than 10m in length (≤10m), shellfish were the most valuable landed component, at £329,523 first sale value (275.7t), followed by the demersal fish (£188,141; 45.5t) and pelagic fish (£11,560; 22.7t) catches (Ref. 22.529). For vessels larger than 10m length (>10m length), the total value of landings were lower than the ≤10m fleet, with the shellfish component at £35,946 (18.4t), and demersal and pelagic components at £9,134 (3.8t) and £5,279 (9.1t), respectively. In this ICES rectangle, the inshore (≤10m) component of landings is consistently higher than that of the >10m fleet.

22.11.17 Whelks tend to be caught year-round, with the highest landings in February followed by a slow decline through the year. Landings of thornback rays also tend to be consistent throughout the year. However, many other species show distinct seasonality in catches. Catches of soles start to increase in April, peaking in August before declining to December. Similarly, lobsters are a Summer species, with catches increasing from April and peaking in July and August before decreasing again. Seabass landings are highest in March-May with a smaller peak later in the year (September through to December). Cod are mainly landed in February to May. Herring are caught in the winter. Fish start to appear in October and catches peak in November before declining in December and remaining low until April, after which the species is not generally landed.

[72] Starry smooth-hound (*Mustelus asterias*) has been recorded in low numbers in impingement sampling at Sizewell B and in low numbers in otter trawls within the GSB (**Appendix 22D)**.

Table 22.145: First sale value (£) and live weight (t) of species landed from ICES rectangle 33F1; the wider Sizewell area (32F1, 32F2, 33F1, 33F2, 34F1, 34F2); and the southern North Sea in 2017. Species are ordered by their first sale value in ICES rectangle 33F1 and those species that contribute 95% of the total are in bold. Not all species landed are included.

Species	ICES Rectangle 33F1.			Wider Sizewell area.		ICES Division IVc.	
	First sale value (£).	% of first sale value.	Landed weight (t).	First sale value (£).	Landed weight (t).	**First sale value (£).**	Landed weight (t).
Whelks	279,001	48.1	279.5	1,232,784	1,156	3,367,726	3,175.9
Seabass	82,261	14.2	7.3	234,607	32.6	372,462	47.7
Sole	69,218	11.9	9.6	387,514	176.7	790,826	176.3
Lobster	56,913	9.8	4.4	605,471	50.3	1,397,043	114.8
Thornback ray.	30,872	5.3	18.8	157,047	106.5	278,076	263.5
Herring	16,263	2.8	31.3	32,176	59.3	66,472	164
Brown shrimp.	15,432	2.7	3.6	49,937	8.9	2,151,374	507.3
Scallops	8,676	1.5	3.2	8,686	3.2	92,026	31.6
Brown crab.	5,375	0.9	3.5	224,988	187.7	901,359	674.9
Smooth-hound.	3,833	0.7	4.5	8,619	8.3	27,881	31
Cod	3,383	0.6	1.1	21,231	10	49,883	19.9
Plaice	179	0.0	<1	5,014	116.9	61,396	61.7
Total	597,583		375	4,373,135	2,475	14,053,472	11,392

22.11.18 Catches in ICES rectangle 33F1 are almost all made with one of five gear types. Vessels ≤10m use pots (79.3% of landings in 2017), long-lines (6.7%), driftnets (6.4%), gillnets (3.4%), and otter trawls (2.7%). Vessels >10m also use pots (47.1 % of landings), driftnets (31.0%), otter trawls (12.1%), and long-lines (8.5%), but gillnets are not an important gear for this fleet. Landings by beam trawlers in this rectangle are negligible.

22.11.19 Some gears are highly selective in their target species. For example, pots are mainly used to catch whelks, brown crab (*Cancer pagurus*) or lobsters, and driftnets are used for herring. Other gears are less selective, catching a variety of species, e.g. the catches of long-liners include thornback ray, seabass, smooth-hound, lesser-spotted dogfish (*Scyliorhinus canicula*), blonde ray (*Raja brachyura*) and cod. For otter trawlers, the catch composition was markedly different depending on vessel size - vessels ≤10m catch a diverse range of species, while the >10m vessel(s) operating in this area target(s) brown shrimps (*C. crangon*).

22.11.20 Estimates of the number of vessels active in the GSB area vary from year to year and with the estimation method used. In 2017, 58 commercial vessels were registered at the local ports from Lowestoft to Felixstowe Ferry. One small beach-launched vessel operates almost exclusively within approximately 1nm of the Sizewell beach, provided in **Appendix 22F** of this volume. This vessel uses drift nets during the Winter for cod, herring and sprat (*S. sprattus*), fixed and drift nets in the Spring and Summer for seabass, Dover sole and thornback ray, and pots for brown crab and European lobster, provided in **Appendix 22F** of this volume. Another small vessel operates from Aldeburgh using pots to fish for lobsters and crabs over an area of Coralline Crag off Thorpeness.

22.11.21 To determine vessel activity, shore-based surveys have been completed at Sizewell. The results of two 14 day surveys in Summer and Winter 2014 to assess the types of vessels utilising the water adjacent to the proposed Sizewell C development (out to 12nm) are presented here (Ref. 22.487; 488).

22.11.22 In Summer an average of 72 vessels were observed per day and 14.7% of these vessels were commercial fishing vessels (**Table 22.146**). The local Sizewell-launched vessel was identified as the most active in the area, but two other potters (from Southwold and Aldeburgh) were recorded operating close to the shore. Other potting activity was recorded approximately 5nm south east of the proposed development. One trawler was recorded operating approximately 7nm to the northeast and 2.9nm southeast of the proposed development.

22.11.23 In Winter 2014, an average of 37 unique vessel sightings were recorded per day, and of these 10.3% of vessels were commercial fishing vessels (Ref. 22.487; 488). The local Sizewell vessel was the most frequently recorded, along with the Southwold potter. Fishing activity during the Winter was less than that recorded during the Summer.

22.11.24 Other surveys confirm that vessel densities adjacent to Sizewell are low (Ref. 22.531), as the shipping lanes are approximately ~10km offshore, with the nearest ports of heavy fishing traffic being Felixstowe to the south and Great Yarmouth to the north (both are approximately 40km away).

Table 22.146: Vessel types observed during shore-based observation in the Sizewell C area in Summer and Winter 2014 (Anatec, 2014 & 2015).

Vessel Type.	Summer 2014 (%)	Winter 2014 (%)
Cargo	23.5	47.9
Fishing	14.7	10.3
Recreational	22.1	0.8
Wind farm support.	18.5	12.7
Military	0.8	0.4
Dredger/Subsea.	5.6	9.3
Tug	3.0	1.6
Tanker	3.9	8.7
Passenger	4.5	5.9
Other	3.4	2.4

Gear types

22.11.25 Commercial fisheries assessments consider gear types due to the fishing method targeting different species and the differential sensitivities of fishing methods and target species to potential development impacts. Five gear types were defined:

- potters;
- netters (drift net and gill net combined);
- long-liners;
- otter trawlers; and
- beam trawlers.

22.11.26 Given their extremely low first sale value, the impacts on the beam trawl group was scoped out of further assessment.

22.11.27 Species exceeding £1,000 first sale value from 33F1 for 2017 were scoped in for assessment (**Table 22.147**).

Table 22.147: Key finfish and shellfish taxa commercially exploited in the GSB and their associated fishing gear types.

Species	Netters	Potters	Long-liners	Otter trawlers.	Recreational
Dover sole	✓			✓	
European plaice					✓
Whiting			✓	✓	
Atlantic cod	✓		✓		✓
Seabass			✓		✓
Atlantic herring	✓				
Thornback ray	✓		✓	✓	✓
Common whelk		✓			
European lobster		✓			
Brown crab		✓			

ii. Recreational fisheries - current baseline

22.11.28 Baseline information for recreational fisheries was available from charter boat surveys and shore and boat angler surveys conducted by the Eastern Sea Fisheries Joint Committee from 2009-2010, Cefas sea angling surveys carried out off the southeast coast in 2009 (Ref. 22.532), charter boat records from the Eastern IFCA in 2014 and sea angling surveys off the Suffolk coast in 2016 and 2017 through diarised catch records, provided in **Appendix 22F** of this volume.

22.11.29 Additional data on shore angling participation were available from images of the Sizewell beach adjacent to the proposed development. These images were obtained from four digital cameras mounted on the turbine hall of the decommissioned Sizewell A station (**Plate 22.12**). A total of 61,114 images were available between 2015 and 2017. Images were reviewed and following rejection of many based on poor quality, obstructions and corrupted files, a final set of 15,778 daylight images were selected, covering the period from April 2015 to December 2017, provided in **Appendix 22F** of this volume.

Plate 22.12: Orientation and field of view covered by the four fixed digital cameras at Sizewell A.

22.11.30 The digital camera provided images of 1,570 anglers fishing on Sizewell beach in 2015-2017. As some camera images were taken at half hour intervals, it was not possible to tell if these were individual anglers or the same anglers counted twice. Activity peaked in Winter and Summer. As the images were captured between 4am and 8pm only (daylight), no information was available on the utilisation of the site by anglers at night.

22.11.31 Charter boat anglers targeted cod, seabass, smooth-hound, skate/rays and whiting (*Merlangius merlangus*) in the Eastern IFCA district (Eastern Sea Fisheries Joint Committee , pers. comm). Cod were targeted throughout the year, whereas seabass were targeted from June to December. Smooth-hound were targeted from May to October and skate/rays (species unknown) were targeted from May to December, except for June. Whiting were only targeted from September to December. It should be noted that estimates for shore, boat and charter anglers operating in the area and made by Eastern Inshore Fisheries and Conservation Authority fishery officers represent records kept by individual officers and based on best judgement. There is, therefore, uncertainty around these estimates.

22.11.32 Most shore anglers operated from Dunwich to Orford Island (n=10,900 observations annually), compared to Lowestoft to Walberswick (n=7,400) and Hollesley Bay to Felixstowe (n=5,200) (Eastern Sea Fisheries Joint Committee, pers. comm). The busiest period for shore fishing was between October and December, in Dunwich to Orford Island (n=5,200) in comparison to Lowestoft to Walberswick (n=3,000) and Hollesley Bay to Felixstowe (n=5,200).

22.11.33 The busiest area for boat angling was Hollesley Bay to Felixstowe (n=12,400 visits), compared with Lowestoft to Walberswick (n=5,600) (Eastern Sea Fisheries Joint Committee, pers. comm). No angling vessels were observed in the Dunwich to Orford area, which is believed to be due to the lack of vessel-launch areas along this area of coastline.

22.11.34 Sea angling surveys conducted by Cefas (Ref. 22.532) found seabass, cod, flounder (*Platichthys flesus*), smooth-hound, whiting, dab (*Limanda limanda*), mackerel (*Scomber scombrus*) and rays to be the targeted species off the southeast coast. This species composition was similar to species targeted off the Suffolk coast (ascertained through diarised catches in 2016 and 2017), except for whiting, dab and mackerel. It can therefore be assumed that those species caught adjacent to the proposed development are also abundant further away.

22.11.35 For the recreational fisheries assessments, receptors have been placed into two groups:

- boat anglers (those fishing at sea), and;
- beach anglers (those fishing from the shore).

iii. Fisheries - future baseline

22.11.36 An overview of the predicted future baseline for fish ecology is provided in the Fish Ecology section, provided in **Section 22.8** of this chapter. The Marine Climate Change Impacts Partnership reviews provide insight into potential scenarios of stock displacement. There has been a trend in recent decades for warm-affinity species to increase in abundance, and cold-affinity species to decrease in abundance, with many cold-water species moving northwards (Ref. 22.336). The impacts expected in the southern North Sea specifically are summarised in **Table 22.148** (Ref. 22.337).

Table 22.148: Cold and warm water associated commercial finfish species and their predicted change as a result of climate change.

Group	Expected change.	Species
Warm water species.	Increase in abundance.	Sole, plaice, seabass, thornback ray.
Cold water species.	Decline or shift northwards or into deeper, cooler waters.	Whiting, cod, herring.

22.11.37 However, the effects on the associated fisheries are unpredictable due to uncertainties in future fisheries participation, management, legislation and bylaws.

c) Construction

22.11.38 Development activities and associated pressures with the potential to affect commercial and recreational fisheries during the construction phase of the proposed development are presented in **Table 22.149**. Activities are informed by the results of direct effects on commercially targeted fish and shellfish species described in **Section 22.7** and **Section 22.8,** both of this chapter, and based on knowledge of the baseline fishery within the study site.

Table 22.149: Pressures associated with construction activities with the potential to affect commercial and recreational fisheries during the construction phase.

Pressure	Activities resulting in pressure.	Groupings	Justification
Loss of access to fishing areas.	Physical presence of infrastructure.	Netters. Potters. Long-liners. Otter trawlers. Boat anglers.	Construction works and safety buffer zones around offshore infrastructure have the potential to restrict access to fishing grounds. Effects on commercial and recreational vessels will be assessed further.
Restricted access to beach frontage.	Whilst the BLF is constructed and operational, access to the beach may be restricted for fishers.	Netters. Potters. Long-liners Otter trawlers. Boat anglers Beach anglers.	Vessels which launch to and from the beach at Sizewell may have restricted access for a small area of beach frontage during construction of the BLF. Beach anglers may be restricted in where they can fish.
Vessel displacement and increased steaming times.	Construction works operating in fished areas.	Netters. Potters. Long-liners. Otter trawlers. Boat anglers. Beach anglers.	Construction works and exclusion zones have the potential to cause vessels to increase steaming times to access fishing grounds. However, the scale of the construction works means increases steaming times would be negligible and is not assessed further.
Changes in availability of target species.	Activities with the potential to alter the distribution and/or availability of target species.	Netters. Potters. Long-liners Otter trawlers. Boat anglers Beach anglers.	Activities that generate underwater noise, change the turbidity of the water, alter sedimentation rates or discharge contaminants into the water have the potential to cause displacement to fin-fish and shellfish. Direct effects on target species have the potential to effect fisheries.

i. Loss of access to fishing areas

22.11.39 Cooling water intakes and outfall tunnels would be subterranean resulting in no conflict with fisheries in the area. However, infrastructure would be installed within the marine environment and could require the implementation of safety buffer zones surrounding the construction vessels. Marine infrastructure is summarised in **Figure 22.16** and shows the position of the following components with potential safety buffer zones illustrated:

- The beach landing facility.
- Two cooling water outfall headworks, beyond the Sizewell-Dunwich Bank.
- Four cooling water intake headworks, beyond the Sizewell-Dunwich Bank.

22.11.40 In addition to the cooling water headworks and BLF, three small headworks would be installed ca. 400m offshore at the terminus of the fish return and recovery (FRR) systems (two) and the combined drainage outfall (CDO; one). A description of the development components is provided in **Section 22.5** in this chapter.

22.11.41 During the installation of offshore infrastructure hierarchical safety buffer zones of 250m to 500m depending on the activity and stage of construction would likely be applied surrounding construction vessels. These safety buffer zones would be implemented through Notice to Mariners (NtM). EDF Energy has a history of offshore operations within the area and has developed and maintained communications with fishers prior to offshore surveys. Where survey requirements and fishing activity coincide, necessary arrangements have been agreed to mitigate against any conflict. Such communications would be expected to continue throughout the construction phase.

22.11.42 It should be noted that the construction period is scheduled to last between nine to 12 years and the installation of various components would be staggered. The BLF and CDO are anticipated to be built within the first two years of the construction phase. The reactors units and associated cooling water infrastructure including intake headworks and FRR headworks are anticipated to be at least 12 months apart (**Plate 22.1**).

Netters

22.11.43 Onshore monitoring of vessel activity indicated that during the Summer and Winter, respectively, only 14.7% and 10.3% of vessels observed were fishing vessels (Ref. 22.487; 488). MMO data suggests that one vessel, a beach-launched ≤10m netter and potter, operates from Sizewell beach (Ref.

22.529), out to approximately 1nm (inside the Sizewell-Dunwich Bank). Fishing activity near the proposed infrastructure is therefore considered to be light.

22.11.44 The area offshore of the Sizewell-Dunwich Bank that will be restricted at any given period of time represents a minor proportion of the available fishing area. Whilst the construction phase is scheduled to last nine to 12 years the duration of safety buffer zones would be temporally staggered and not last the duration of the construction phase. The impact magnitude is assessed as *Low*.

22.11.45 Netters operating offshore of the Sizewell-Dunwich Bank are likely to have a large operational range and be able to operate in alternative areas and are likely to have low sensitivity to restricted access associated with the installation of offshore infrastructure.

22.11.46 Loss of access is predicted to have minor adverse effects on netters. Effects are **not significant**.

Potters

22.11.47 MMO data suggests that one vessel, a beach-launched ≤10m netter and potter, operates from Sizewell beach (Ref. 22.529), out to approximately 1nm (inside the Sizewell-Dunwich Bank). Potter activity, from crab and lobster occurs further south, off Thorpeness within areas of outcropping Coralline Crag. Other potters have been recorded operating close to shore (Ref. 22.487; 488).

22.11.48 The proposed location of the infrastructure is in soft sediments located 3km offshore. The location of the southern intakes is in an area of a sub-cropping and outcropping extension of the Coralline Crag feature, 3km offshore. Whilst there is currently no known potting activity in this area, there is the potential that other vessels may use the area to pot for crabs or lobsters.

22.11.49 In ICES rectangle 33F1, whelks dominated the landings and first sale value of catches. Whelks are fished over muddy sand and gravelly substrates. It is likely that the area affected by the construction of the intake and outfall structures would represent only a minor proportion of the available whelk fishing area, which is focused further offshore.

22.11.50 The area around the infrastructure represents a minor proportion of the potential area available for potting activities, particularly for whelk and it is beyond the typical fishing range of the ≤10m Sizewell netter and potter. There is the potential for temporary limited access for potting activity in the vicinity of the southern intakes. The magnitude of the impact is assessed as *Low*.

22.11.51 Potters operating offshore of the Sizewell-Dunwich Bank are likely to have a larger operational range than the inshore vessels and be able to operate in alternative areas. Potters are predicted to have low sensitivity to restricted access.

22.11.52 Loss of access is predicted to have minor adverse effects on potters. Effects are **not significant**.

Long-liners

22.11.53 Catches by long-liners in rectangle 33F1 in 2017 were only 14% of the total landings. Shore based observations of the area off Sizewell C suggest that most fishing near the proposed infrastructure is carried out by potting and trawling vessels (Ref. 22.487; 488). As the area offshore represents a minor proportion of the fishing area, and safety buffer zones would be temporary the impact magnitude is assessed as low.

22.11.54 Long-liners are likely to be able to operate in alternative areas and are likely to have low sensitivity to restricted access.

22.11.55 Loss of access is predicted to have minor adverse effects on long-liners. Effects are **not significant**.

Otter trawlers

22.11.56 Catches by otter trawlers ≤10m in rectangle 33F1 in 2017 were 2.7% of total landings while those of vessels >10m were 12.1% of landings. Shore based observations of the area off Sizewell C suggest that some trawling takes place to the northeast and southeast of the proposed development but that this is over 2nm offshore (Ref. 22.487; 488). As the area offshore represents a minor proportion of the fishing area, and safety buffer zones would be temporary the impact magnitude is assessed as low.

22.11.57 Trawlers are likely to be able to operate in alternative areas and are likely to have low sensitivity to restricted access.

22.11.58 Loss of access is predicted to have minor adverse effects on otter trawlers. Effects are **not significant**.

Recreational fisheries: Boat anglers

22.11.59 Estimates of recreational boat-angler visits to the Sizewell study area based on expert judgement of local officers (Ref. 22.533) and suggest that no vessels operate from Dunwich to Orford Island, due to the lack of slipways/beach-vessel access along this strip of coast. However, these estimates are highly uncertain and data on boat angling activity is limited.

22.11.60 Currently boat angling near the infrastructure of the proposed development is considered to be minimal, as anglers tend to target wrecks and other seabed features for fishing. There are no known underwater features that would be the focus for fishing in the development area. Boat anglers are more likely to fish around the Sizewell B outfall infrastructure, which is located ~2km away from the proposed Sizewell C offshore infrastructure.

22.11.61 As the area represents a minor proportion of the fishing area available to boat anglers, and there is minimal known boat angling in the vicinity, the impact magnitude is assessed as very low.

22.11.62 Anglers can operate in alternative areas and are likely to have low sensitivity to restricted access.

22.11.63 Loss of access is predicted to have negligible effects on boat anglers. Effects are **not significant**.

Recreational fisheries: Beach anglers

22.11.64 Beach anglers would not be affected by the loss of access of the proposed infrastructure and have been scoped out.

ii. Restricted access to beach landing frontage

22.11.65 During the construction phase, the proposed beach landing facility (BLF) would be used to import rock armour, abnormal indivisible loads (AILs) and receive marine freight. During the construction of the BLF a 500m safety buffer zone would be anticipated. During the operation of the BLF to receive deliveries during campaign periods (primarily 31 March to 31 October), a temporary 250m radius safety buffer zone may be implemented, thereby resulting in localised, restricted access for beach-launched commercial vessels and beach anglers.

Netters and Potters

22.11.66 One vessel was identified as beach-launched (using pots and nets) from Sizewell beach. Whilst the exact location of the vessel's launch/landing site on the beach is unknown, given the size of the beach compared to the size of the proposed BLF and the homogenous subtidal beach profile, it is likely that there would be sufficient alternative areas for the vessel to be launched/landed. In the worst-case of a 500m safety buffer zone, there is the potential for restricted access of the fisher to deploy nets or pots. It is predicted that the area restricted by the BLF construction is a minor proportion of the available fishing area. The magnitude of the impact is considered the be low.

22.11.67 Given the known limited fishing range of inshore potters and netters, sensitivity is predicted to be medium.

22.11.68 The impact of loss of access to the beach landing frontage is predicted to have a minor adverse effect on netting and potting activities in the inshore waters. Effects are **not significant**.

Long-liners and Otter trawlers

22.11.69 There are no known long-liners or otter trawlers either launching from or operating around the BLF and these receptors have been scoped out.

Recreational fisheries: Boat anglers

22.11.70 There are no records of boat anglers launching from this site, but data in the area is limited. If boat angling were to take place inside the Sizewell-Dunwich Bank, with anglers targeting fish around the Sizewell A and Sizewell B seabed infrastructure, it is possible that launching of boats may occur. In such a case it is likely anglers would launch from as close to the car park (located to the south of the Sizewell A site) as possible, rather than travel the ~2km north that would be required to be affected by the BLF safety buffer zone before launching. It is predicted that the area restricted by the BLF construction is a minor proportion of the available fishing area and the magnitude of the impact is considered the be very low. Boat anglers are also able to launch from other sites further afield and the loss of access to the beach frontage due to the BLF construction and sensitivity to this pressure is predicted to be low.

22.11.71 The impact of loss of access to the beach landing frontage is predicted to have a negligible effect on boat anglers. Effects are **not significant**.

Recreational fisheries: Beach anglers

22.11.72 Digital images captured from the Sizewell A turbine hall building recorded 1,570 anglers fishing during daylight hours from Sizewell beach between 2015 and 2017, with activity peaking in Summer and Winter. This is consistent with data from the Eastern Sea Fisheries Joint Committee which also showed peak fishing activity in Summer and Winter in 2009 and 2010. In that study 10,900 beach anglers were recorded during one year in the area between Dunwich to Orford Island. During construction of the BLF, a worst case 1km stretch of the beach (500m radius safety buffer) may be unavailable for fishing for a short period of time. The area that will be affected by the construction of the BLF is approximately 2km from the car park located to the southeast of the Sizewell A site. It is considered that only a proportion of anglers would walk this distance. Construction activities may also impact on the enjoyment of the fishing activity. The magnitude is considered low.

Access to the beach itself will not be impacted, therefore beach anglers will be able to move to other areas and the sensitivity is considered as low.

22.11.73 The impact of loss of access to the beach to beach anglers is predicted to have a minor adverse effect. Effects are **not significant**.

iii. Vessel displacement and increased steaming times

22.11.74 Safety buffer zones surrounding installation vessels are spatially restricted and are predicted to have minimal impact on the passage of vessels to fishing grounds (i.e. the increases in steaming times and fuel costs associated with avoiding safety buffer zones). Should fishers become displaced due to restricted access issues and need to access more distant fishing grounds there is the potential for increased steaming times. However, restricted access has been assessed as a minor effect. Furthermore, fishers would be notified in advance of construction plans through NtM and communications from SZC Co.

22.11.75 Vessel displacement and increases in steaming times are predicted to have negligible effects on fisheries.

iv. Changes in availability of target species

22.11.76 During the construction phase of the proposed development various activities have the potential to cause localised displacement of target fin fish species. Changes in the distribution of target commercial or recreational fish could have implications for fisheries.

22.11.77 Construction activities with the potential to displace fish include:

- Underwater noise generating activities (piling for the BLF, dredging prior to the installation of infrastructure, and vessel traffic).
- Increases in suspended sediment concentration associated with dredging activities.
- Discharges from the CDO.

22.11.78 The direct effects on fish is assessed in **Section 22.8** of this chapter, whilst effects on benthic taxa including commercially important crab and lobster is assessed in **Section 22.7** of this chapter. The potential for indirect effects on commercial fisheries is considered in **Table 22.150**.

Table 22.150: Review of the direct effects on commercial fish and shellfish species with the potential to effects fisheries during the construction phase.

Pressure	Activities resulting in pressure.	Potential for effects on fisheries.
Underwater noise.	Dredging, drilling, impact piling.	Impact piling represents the largest impact magnitude with the potential to affect the distribution and catchability of sensitive finfish receptors. Piling is a short lived activity and mortality and recoverable injury is restricted to small spatial areas within the safety buffer zone. Acoustically sensitive fish species including herring, seabass, and cod may display behavioural responses due to impact piling of up to 5.6km as a worst case, provided in **Appendix 22L** of this volume. Behavioural effects are likely to be short-lived and do not necessitate displacement from the ensonified area. Assessments of fish ecology concluded that the potential for behavioural responses due to impact piling would have a minor adverse effect on the availability of fisheries resources. However, the short term nature of the impacts and the precautionary nature of the activity indicates effects would not be significant, provided in **Section 22.8** of this chapter. No further assessment is undertaken.
Increases in suspended sediment (turbidity).	Dredging and dredge disposal.	Finfish, primarily pelagic species may avoid sediment plumes at the highest concentrations close to the dredge activity. Dredge activities are short-term and suspended sediment plumes are predicted to be transient, returning to baseline levels within days of dredging being completed, provided in **Appendix 22J** of this volume. **Section 22.8** of this chapter, concluded that no significant changes in the availability of fisheries resources are predicted as a result of dredging activities.
Increases in sedimentation rates.	Dredging and dredge disposal.	Commercially valuable species such as crab and lobster are targeted at the area of the Coralline Crag. Sedimentation as a result of dredging activities is anticipated to be very light and naturally high resuspension rates mean sediment deposits would not persist. Effects on commercial species are predicted to be minimal with no subsequent implications for the fishery, provided in **Section 22.7** of this chapter.

Pressure	Activities resulting in pressure.	Potential for effects on fisheries.
Chemical contaminants.	Construction and commissioning discharges from the CDO.	Construction and comissioning phase discharges including tunnel boring machine chemicals, hydrazine, un-ionised ammonia from treated sewage and trace metals from dewater groundwater discharges were assessed in relation to direct effects on fish. The low level discharges and high degree of mixing resulted in localised areas of chemical excedance of relevant standards. Whilst highly localised avoidance behaviours were not ruled out, no significant effects on the availability of fisheries resources was concluded, provided in **Section 22.8** of this chapter.

d) Operation

22.11.79 Development activities and associated pressure with the potential to effect commercial and recreational fisheries during the operational phase of the proposed development are presented in **Table 22.151**. Activities are informed by the results of direct effects on commercially targeted fish and shellfish species described in **Section 22.9** and **Section 22.8**, both of this chapter, and based on knowledge of the baseline fishery within the study site relative to the construction activities.

Table 22.151: Pressures associated with operation activities with the potential to affect commercial and recreational fisheries during the operational phase.

Pressure	Activities resulting in pressure.	Groupings	Justification
Restricted access to beach frontage.	Occasional deliveries to the BLF may require a safety buffer zone. Recharge works as part of the mitigation of the SCDF could temporarily restrict access.	Netters. Potters. Long-liners. Otter trawlers. Boat anglers Beach anglers	Vessels which land and launch to and from the beach at Sizewell, and fishers angling from the shore, may have restricted access to a small area of beach frontage during operation of the BLF.
Changes in availability of target species: Maintenance of the BLF.	Dredging activities have the potential to alter the distribution and/or	Based on direct effects of targeted species assessments	Dredging activities generate underwater noise, change the turbidity of the water and alter sedimentation

Pressure	Activities resulting in pressure.	Groupings	Justification
	availability of target species.		rates with the potential to cause displacement of finfish and shellfish. Direct effects on target species have the potential to indirectly effect fisheries.
Restricted access to fishing areas.	Physical presence of infrastructure and maintenance activities.	Netters. Potters. Long-liners. Otter trawlers. Boat anglers.	Maintenance works and safety buffer zones around offshore infrastructure have the potential to restrict access to fishing grounds. Effects on commercial and recreational vessels will be assessed further.
Changes in availability of target species: Impingement.	Fish/ shellfish being impinged by the proposed development.	Netters. Potters. Long-liners. Otter trawlers. Boat anglers Beach anglers	Impingement assessments consider the effects of cooling water abstraction on the stocks of fish and shellfish. Significant effects on stocks have the potential to affect fisheries and is assessed.
Changes in availability of target species: Attraction to FRR and inshore thermal discharges	Thermal discharges and discharges of dead and moribund biota from the FRR.	Netters. Potters. Long-liners. Otter trawlers. Boat anglers Beach anglers	Warm water species such as seabass may be attracted to thermal discharges and discharges of dead and moribund biota from the FRR. Fishers might choose to operate close to the outfall site to target seabass.
Changes in availability of target	Thermal discharges may deter cold-	Based on direct effects of targeted	Species may be attracted to or deterred from warm

Pressure	Activities resulting in pressure.	Groupings	Justification
species: Thermal plume	water finfish / shellfish.	species assessments	waters associated with the thermal plume potentially causing shifts in their distributions which could affect their catchability.
Changes in availability of target species: Chemical plume.	Chemical discharges may deter cold-water finfish / shellfish.	Based on direct effects of targeted species assessments	The thermally buoyant nature of the plumes mean there is minimal interaction of chemical discharges with the seabed with negligible effects for the fishery of shellfish. Chemical discharges 3km offshore may cause localised avoidance near the outfalls however significant changes in species distribution and therefore availability of target species to the fishery are not predicted. No further assessment is made.

i. Restricted access to beach frontage

22.11.80 Occasional AIL deliveries during the operational phases (every 5-10 years) may result in a temporary safety buffer zone being implemented, resulting in localised, restricted access for beach-launched commercial vessels and beach anglers. Furthermore, there is the potential requirement for recharge works associated with the SCDF to result in temporary restricted access to the beach across the Sizewell C frontage. Monitoring and mitigation activity of the SCDF is detailed in **Chapter 20** of this volume.

Netters and Potters

22.11.81 One vessel was identified as beach-launched (using pots and nets) from Sizewell beach. Whilst the exact location of the vessel's launch/landing site on the beach is unknown, given the size of the beach compared to the Sizewell C frontage and the homogenous subtidal beach profile, it is likely that there would be sufficient alternative area for the vessel to be launched/landed. A safety buffer zone (notionally 250m), may impact on the ability of a fisher to deploy nets or pots, but the area restricted by the BLF usage and/or SCDF maintenance is a minor proportion of the available fishing area and the magnitude of the impact is considered the be low. Given the known limited fishing range of the fisher, the predicted sensitivity is predicted to be medium.

22.11.82 The impact of loss of access to the beach frontage is predicted to have a minor adverse effect on netters and potters. Effects are **not significant**.

Long-liners and Otter trawlers

22.11.83 There are no known long-liners or otter trawlers either launching from or operating around the BLF construction and these receptors have been scoped out.

Recreational fisheries: Boat anglers

22.11.84 There are no records of boat anglers launching from this site, but data in the area is limited. If boat angling were to take place inside the Sizewell-Dunwich Bank, with anglers targeting fish around the Sizewell A and Sizewell B seabed infrastructure, it is possible that launching of boats may occur. In such a case, it is likely that anglers would launch from as close to the car park (located to the south of the Sizewell A site) as possible, rather than travel the ~2km north that would be affected by BLF usage and/or SCDF maintenance safety buffer zone before launching. It is predicted that the area restricted by the BLF operation is a minor proportion of the available fishing area and the magnitude of the impact is considered to be very low. Boat anglers can launch from other sites further afield and the loss of access to the beach frontage, sensitivity to this pressure is predicted to be low.

22.11.85 The impact of loss of access to the beach landing frontage is predicted to have a negligible effect on boat anglers. Effects are **not significant**.

Recreational fisheries: Beach anglers

22.11.86 Digital images captured from the Sizewell A turbine hall building recorded 1,570 anglers fishing during daylight hours from Sizewell beach over one year, with activity peaking in Summer and Winter. This is consistent with data from the Eastern Sea Fisheries Joint Committee which also showed peak fishing activity in Summer and Winter (Eastern Sea Fisheries Joint Committee 2009, 2010). In that study 10,900 beach anglers were recorded during one year in the area between Dunwich to Orford Island. During BLF activity or SCDF maintenance restricted access to the Sizewell C beach frontage would occur for a short period of time. The area that will be affected when the BLF is in use is approximately 2km from the car park located to the southeast of the Sizewell A site. It is considered that only a proportion of anglers would walk this distance. BLF operations (e.g. additional vessels, noise) may also impact on the enjoyment of the fishing activity. The magnitude is considered low. Access to the beach itself will not be impacted, and beach anglers will be able to fish from other areas of the beach. Sensitivity is considered as low.

22.11.87 The impact of loss of access to the beach to beach anglers is predicted to have a minor adverse effect. Effects are **not significant**.

ii. Changes in availability of target species: Maintenance of the BLF

22.11.88 During the operational phase of the proposed development occasional deliveries to the BLF (approximately every 5-10 years) would require dredging activities to take place resulting in increases in turbidity (suspended sediments) and localised sedimentation.

22.11.89 The direct effects on fish resulting from BLF dredging activities is assessed in **Section 22.8** of this chapter, whilst effects on benthic taxa including commercially important crab and lobster is assessed in **Section 22.7** of this chapter. The potential for indirect effects on commercial fisheries is considered in **Table 22.152**.

Table 22.152: Review of the direct effects of dredging of the BLF on commercial fish and shellfish species with the potential to effects fisheries during the operational phase.

Pressure	Activities resulting in pressure.	Potential for effects on fisheries.
Underwater noise.	Dredging.	Dredging for the BLF would be required to create a navigable channel. Dredging is anticipated to be via plough dredger and smaller scale maintenance dredge events may be required to maintain the access channel at approximately monthly intervals during use. Dredging represents a continous noise source with no instantaneous effects on finfish. Dredging is a short lived activity and mortality and recoverable injury following 24-hour exposure to dredging noise is restricted to very small spatial areas. Precautionary behavioural assessments indicate that acoustically sensitive fish species including herring, seabass, and cod may display behavioural responses due to dredging of up to 2.4km from the BLF, provided in **Appendix 22L** of this volume. Behavioural effects

Pressure	Activities resulting in pressure.	Potential for effects on fisheries.
		are likely to be short-lived and do not necessitate displacement from the ensonified area. Assessments of fish ecology concluded that the potential for behavioural responses due to dredging would have a minor adverse effect on the availability of fisheries resources. However, the short term nature of the impacts and the precautionary nature of the activity indicates effects would not be significant, provided in **Section 22.8** of this chapter. No further assessment is undertaken.
Increases in suspended sediment (turbidity).	Dredging and dredge disposal.	Finfish, primarily pelagic species may avoid sediment plumes at the highest concentrations close to the dredge activity. Dredge activities are short-term and suspended sediment plumes are predicted to be transient, returning to baseline levels within days of dredging being completed, provided in **Appendix 22J** of this volume. **Section 22.8** of this chapter, concluded that no significant changes in the availability of fisheries resources are predicted as a result of dredging activities.
Increases in sedimentation rates.	Dredging and dredge disposal.	Commercially valuable species such as crab and lobster are targeted at the area of the Coralline Crag. Sedimentation as a result of dredging activities is anticipated to be very light and naturally high resuspension rates mean sediment deposits would not persist. Effects on commercial species are predicted to be minimal with no effects on the fishery, provided in **Section 22.7** of this chapter.

iii. Restricted access to fishing areas

22.11.90 During the 60-year operational life, each reactor unit would undergo refuelling and maintenance shutdowns (otherwise known as 'outages') at approximately 18-month intervals. The duration of these outages would vary according to the maintenance and inspections required but would typically be up to two months. Maintenance of the offshore cooling water infrastructure may result in temporary loss of access to fishing areas. Cooling water infrastructure is shown in **Figure 22.16**.

22.11.91 During maintenance of offshore infrastructure hierarchical safety buffer zones of 250m to 500m depending on the activity would likely be applied surrounding construction vessels. These safety buffer zones would be implemented through Notice to Mariners (NtM). EDF Energy has a history of offshore operations within the area and has developed and maintained communications with fishers prior to offshore works. Such communications would be expected to continue throughout the operational phase for maintenance activities.

Netters

22.11.92 The area offshore of the Sizewell-Dunwich Bank that will be restricted at any given period of time represents a minor proportion of the available fishing area. Whilst maintenance activities would occur for a short duration approximately every 18 months. The impact magnitude is assessed as low

22.11.93 Netters operating offshore of the Sizewell-Dunwich Bank are likely to have a large operational range and be able to operate in alternative areas and are likely to have low sensitivity to restricted access associated with the installation of offshore infrastructure

22.11.94 Loss of access is predicted to have minor adverse effects on netters. Effects are **not significant**.

Potters

22.11.95 The proposed location of the infrastructure is in soft sediments located 3km offshore. The southern intakes may be located in an area of a sub-cropping and outcropping extension of the Coralline Crag feature, 3km offshore. Whilst there is currently no known potting activity in this area, there is the potential that other vessels may use the area to pot for crabs or lobsters.

22.11.96 In ICES rectangle 33F1, whelks dominated the landings and first sale value of catches. Whelks are fished over muddy sand and gravelly substrates. It is likely that the area affected by the construction of the intake and outfall structures would represent only a minor proportion of the available whelk fishing area, which is focused further offshore.

22.11.97 The area around the infrastructure represents a minor proportion of the potential area available for potting activities, particularly for whelk, which are of highest commercial values in 33F1 and are fished over muddy sand and gravelly substrates. Temporary limited access for potting activity in the vicinity of the southern intakes may occur. The magnitude of the impact is assessed as low.

22.11.98 Potters operating offshore of the Sizewell-Dunwich Bank are likely to have a larger operational range than the inshore vessels and be able to operate in alternative areas. Potters are predicted to have low sensitivity to restricted access.

22.11.99 Loss of access is predicted to have minor adverse effects on potters. Effects are **not significant**.

Long-liners

22.11.100 As the area offshore represents a minor proportion of the fishing area, and safety buffer zones would be temporary the impact magnitude is assessed as low.

22.11.101 Long-liners are likely to be able to operate in alternative areas and are likely to have low sensitivity to restricted access.

22.11.102 Loss of access is predicted to have minor adverse effects on long-liners. Effects are **not significant**.

Otter trawlers

22.11.103 As the area offshore represents a minor proportion of the fishing area, and safety buffer zones would be temporary the impact magnitude is assessed as low.

22.11.104 Trawlers are likely to be able to operate in alternative areas and are likely to have low sensitivity to restricted access.

22.11.105 Loss of access is predicted to have minor adverse effects on otter trawlers. Effects are **not significant**.

Recreational fisheries: Boat anglers

22.11.106 Currently boat angling near the infrastructure of the proposed development is considered to be minimal, as anglers tend to target wrecks and other seabed features for fishing.

22.11.107 As the area represents a minor proportion of the fishing area available to boat anglers, and they there is minimal known boat angling in the vicinity, the impact magnitude is assessed as very low.

22.11.108 Anglers can operate in alternative areas and are likely to have low sensitivity to restricted access.

22.11.109 Loss of access is predicted to have negligible effects on boat anglers. Effects are **not significant**.

Recreational fisheries: Beach anglers

22.11.110 Beach anglers would not be affected by the loss of access during maintenance of the offshore infrastructure and have been scoped out.

iv. Changes in availability of target species: Impingement

22.11.111 During the abstraction process, finfish and shellfish will be drawn into the cooling water systems. The fitting of the low velocity side entry intake head is designed to reduce the numbers of fish and shellfish drawn into the cooling water systems. Any individuals that are abstracted will be removed by drum or band screens and returned to the GSB via a fish recovery and return (FRR) system. Not all will survive and there is the potential for reduction in adult stock abundance, because of the impingement losses.

22.11.112 Most of the fish impinged are juveniles and at these young ages will suffer higher natural mortality than adults of the same species. Therefore, the loss of one juvenile does not equate to the loss of one adult. To evaluate their potential loss to the spawning stock, they must first be converted to adult equivalents. Impingement predictions were made in which the numbers of abstracted fish and shellfish were converted to adult equivalent numbers and adult equivalent weights.

22.11.113 The equivalent weights of adults lost were compared with the spawning stock biomass (SSB), and a loss of <1% of SSB was considered negligible when compared with the size of the stock and natural population variability.

22.11.114 Comparisons were made with the relevant stock unit rather than ICES rectangle 33F1, as these are the spatial scales at which ICES undertakes the assessments based on knowledge of the life history of individual species and their fisheries.

22.11.115 If no estimate of SSB was available for a species, impingement losses were compared with the international landings for that stock. The landings would not represent the entire spawning population of the stock and the use of this indicator would therefore overestimate the potential impingement effect.

22.11.116 Impingement losses were predicted for Sizewell C in the absence of embedded mitigation and with embedded fish recovery and return systems (FRR) and the fitting of the LVSE.

Netters, Long-liners and Otter trawlers

22.11.117 For the commercially-exploited finfish species that are targeted by nets and long-lines in 33F1 (e.g. seabass, sole, cod), the predicted adult equivalent losses were <1% of the SSB where it was available for that stock, or losses were <1% of international landings for species where SSB was not available (thornback ray) (**Table 22.153**). Further details of impingement predictions are provided in **Section 22.8.d)** of this chapter and **Appendix 22I** of this volume.

Table 22.153: Predicted effects of impingement on commercially or recreationally targeted finfish species with embedded FRR and LVSE headwork mitigation. Species underlined contribute to the top 95% of landings values in 33F1.

Species	Equivalent number of adults.	Weight (t)	Mean SSB (t).	% of SSB	Mean landings (t).	% of landings from stock unit.
Sole	4,200	0.90	43,770	0.00	12,800	0.01
Plaice	689	0.17	690,912	0.00	80,367	0.00
Whiting	140,044	40.03	151,881	0.03	17,570	0.2
Cod	1,395	3.63	103,025	0.00	34,701	0.01
Seabass	27,172	41.60	14,897	0.28 [73]	3,051	1.36
Herring	700,103	132.08	2,198,449	0.01	400,244	0.03
Thornback ray.	164	0.52	NA	NA	1,573	0.03
Thin-lipped grey mullet	1,190	0.62	NA	NA	120	0.52

22.11.118 The GSB is an open system and commercially exploited species are highly mobile with large stock units. Any effects of the proposed development on the population would therefore be diluted by species movements and not be limited to the local ICES rectangle. It is expected that individuals would move in and out of the rectangle to replace those fish that are lost. As the stock units of the commercially exploited species have wide spatial ranges and impingement losses are predicted to be negligible at the stock level, the magnitude of the impact on netters and long-liners is assessed as low.

22.11.119 Most finfish impinged are of a smaller size than caught commercially, so the reduction in availability of those size classes to the fishery would be small. The sensitivity of the fishery to impingement losses is assessed as low.

22.11.120 The impact of impingement losses to netters and long-liners is predicted to have minor adverse effects. Effects are **not significant**.

[73] Seabass are not uniformly distributed across the site with evidence demonstrating that juvenile seabass are attracted to the warm water effluents of Sizewell B in Winter. Accounting for the significantly greater distribution of seabass in the inshore waters away from the Sizewell C intakes (Ref. 22.402), impingement predictions reduce to **12,886** individuals (EAV number) or **0.13% of SSB**, provided in **Appendix 22I** of this volume.

Potters

22.11.121 For shellfish that are commercially exploited in 33F1 (brown shrimp, brown crab and lobster), the predicted adult equivalent impingement losses were <1% of the stock unit landings in the presence of embedded full mitigation (**Table 22.154**).

Table 22.154: Predicted effects of impingement on key shellfish species with embedded mitigation (FRR + LVSE).

Species	Number impinged Sizewell C.	Equivalent number of adults.	Weight (t)	Mean landings (t).	% of landings from stock unit.
Brown shrimp.	16,072,093	3,310,851	4.30	693	0.62
Brown crab.	104,284	4,940	2.47	450	0.55
Lobster	43	26	0.01	114	0.01

22.11.122 Brown crabs appear only to be fished (off Sizewell) by a single ≤10m vessel, although other potters were also recorded in the adjacent area. The current minimum landing size 11.5cm carapace width, is larger than most of the specimens impinged. Therefore, the loss in availability of those size classes to the fishery would have minimal impact.

22.11.123 Whelks were absent in impingement sampling, and no effect on this species is expected.

22.11.124 Given the negligible effects predicted for impingement losses of commercially exploited shellfish, the magnitude of the impact on potters is assessed as low. As the stock units of the commercially exploited species have wide spatial ranges, and impinged individuals are typically smaller than legal landing sizes the sensitivity of the fishery to impingement losses is assessed as low.

22.11.125 The impact of impingement losses to potters is predicted to have a minor adverse effect. Effects are **not significant**.

Recreational fisheries: Boat and beach anglers

22.11.126 Recreational fishers target a variety of finfish species, including those targeted by commercial fishermen (e.g. seabass, cod, thornback rays) and several that are not but which are regarded as key within the GSB area (e.g. thin-lipped grey mullet (*Liza ramada*)). The effect of impingement losses on commercially exploited species to recreational fishers is the same as that assessed for netters and long-liners. Impingement predictions for other recreationally important key finfish species suggest that with full mitigation, losses would not exceed the 1% negligible threshold limit (**Table 22.153**).

However, for this species, the impingement losses were compared against landings, and losses against the SSB will be below the 1% threshold, provided in **Appendix 22I** of this volume.

22.11.127 Given the negligible effects predicted for impingement losses, the magnitude of the impact on recreational fisheries is assessed as low. As the stock units of the targeted species have wide spatial ranges, the sensitivity to impingement losses is assessed as low.

22.11.128 The impact of impingement losses to recreational fishers is predicted to have a minor adverse effect. Effects are **not significant**.

v. Changes in availability of target species: Thermal Plume

22.11.129 Thermal discharges have the ability to alter the distribution of commercially important species. The direct effects of the thermal plume on finfish and shellfish are assessed in detail in **Section 22.8** and **Section 22.7**, respectively of this chapter.

Netters, Long-lines and Otter trawlers

22.11.130 Conclusions of finfish assessments predicted that minor localised displacement of fish receptors may occur due to the thermal discharges from the proposed development. Depending on the thermal preference of fish species attraction (e.g. warm water seabass[74]) or avoidance (e.g. cold water such as cod and herring) could occur. Ecologically relevant impacts are species specific and occur over relatively small areas. Consequently, the thermal plume is predicted to result in minor changes in the availability of finfish resources, provided in **Section 22.8** of this chapter. This section considers the potential for localised changes in distribution of finfish on the fishery.

22.11.131 Finfish fisheries target a range of species that includes both warm and cold-water species. Coldwater species may avoid areas of high thermal uplifts, however, areas of behavioural avoidance are predicted to be small, provided in **Section 22.8** of this chapter. Seabass are known to be attracted to the warm water effluents of power stations, particularly juveniles in Winter (Ref. 22.424). Seabass surveys at Sizewell have shown statistically significant increases in seabass abundance in the inshore waters with 95% higher abundance caught in trawls close to the inshore Sizewell B outfalls relative to the offshore surveys in proximity to the proposed Sizewell C cooling water infrastructure, provided in **Appendix 22I** of this volume. Any

[74] The potential for seabass attraction to the inshore waters due to the thermal plume and FRR discards has been assessed 'Changes in availability of target species: Attraction to FRR and thermal discharges'

increased local abundance may lead to an increase in catches, but landings would depend on the size distribution of the attracted seabass, and landing limits. The majority of seabass caught in fish surveys of Sizewell were juveniles smaller than legal catch limits. It is considered unlikely therefore that other fishers will travel from further afield to target seabass. With high fuel costs, it may not be cost effective to travel further to target these species and, given the current restrictions on fishing for seabass, the opportunity to increasingly target this species would be limited.

22.11.132 The plume represents a minor proportion of the available fishing area and changes in the distribution of fish within landing limits is likely to be minor. The magnitude of impacts is low. Minor, localised decreases in abundance of cold water and minor increases in warm water species may occur. Changes in abundance may not be of commercially targetable size classes, therefore the sensitivity of the fisheries to increases in abundance is likely to be low.

22.11.133 The thermal plume is predicted to have a minor beneficial to minor adverse effect on the availability of commercially exploited finfish species. Effects are **not significant**.

22.11.134 However, it should be noted that climate change and future sea temperature warming may result in long-term changes in the distribution of species with warm-water species becoming increasingly more abundant in the southern North Sea at the expense of cold-water species. This could lead to a reduction in the availability of species such as cod and whiting, but an increase in the availability of seabass, thornback ray and sole (Ref. 22.337).

22.11.135 This would lead to changes at a scale much greater than that currently fished by local fishers. The ability for fishers to target different species will confer resilience to changes resulting from climate change and potentially localised effects of thermal discharges.

Potters

22.11.136 Commercially exploited shellfish are predicted to have low sensitivity to thermal discharges and effects are predicted to be minor and **not significant**, provided in Benthic Ecology, provided in **Section 22.7** of this chapter. Therefore, minimal effects on the potting fishery is predicted from thermal discharges.

22.11.137 The plume represents a minor proportion of the available fishing area and stock area of commercially exploited shellfish and direct effects on targeted species is predicted to be minor. The magnitude of impacts is low.

22.11.138 The thermal plume is predicted to have a minor adverse effect on the availability of commercially exploited shellfish species. Effects are **not significant**.

Recreational fisheries: Boat and Beach anglers

22.11.139 Recreational anglers target a range of species that includes both warm (e.g. seabass, thornback ray) and cold water (e.g. cod) species. Given the high value placed on seabass as a premier recreational species, increases in abundance as a result of the thermal plume are likely to be welcomed by anglers. It is likely that minor decreases in the availability of cold-water species in the area of the thermal plume would be offset by an increase of warm water species.

22.11.140 The plume represents a minor proportion of the available fishing area and stock area of species targeted by recreational anglers and direct effects on targeted species is predicted to be minor. The magnitude of impacts is low.

22.11.141 The thermal plume is predicted to have a minor beneficial to minor adverse effect on the availability of recreational species. Effects are **not significant**.

vi. Changes in availability of target species: Attraction to FRR discharges

22.11.142 The availability of prey from the FRR has the potential to alter the distribution of demersal species of high commercial value species. Dead and moribund biota discharged from the FRR has been proposed as a potential food source for predatory species such as seabass, provided in **Section 22.10** of this chapter.

Netters

22.11.143 One vessel is known to use nets inshore of the Sizewell-Dunwich Bank to target species such as seabass. Any increased local abundance may lead to an increase in catches, but landings would depend on the size distribution of the attracted seabass, and landing limits. The majority of seabass caught in fish surveys of Sizewell were juveniles smaller than legal catch limits. It is considered unlikely therefore that other fishers will travel from further afield to target seabass.

22.11.144 Based on the potential for small increases in seabass abundance the impact magnitude is expected to be very low. Increases in abundance may not be of commercially targetable size classes, therefore the sensitivity of the fisheries to increases in abundance is likely to be low.

22.11.145 The impact of availability of target species as a result of attraction to the FRR on netters is predicted to have a negligible effect. Effects are **not significant**.

Potters

22.11.146 Potters are unable to target finfish. However, it is possible that the presence of prey at the FRR outfall may lead to a localised increase in crab abundance close to the outfall. The majority of crabs caught at Sizewell B were smaller than the current minimum landings size, and it is expected that if there is an increase in abundance the increased proportion that could be landed would be minimal. As known potting activity in the area primarily focuses on areas hard substrate away from the current Sizewell B outfalls, changes to the areas in which pots are deployed are likely to be minimal. The magnitude of the impact is expected to be low. The area affected would be only a proportion of the area available for potting and the sensitivity is expected to be low.

22.11.147 The impact of availability of target species as a result of attraction to the FRR or thermal discharges on potters is predicted to have a negligible effect. Effects are **not significant**.

Long-liners and Otter trawlers

22.11.148 Long-liners and otter trawlers were scoped out as there are no known vessels using these gears operating in the area.

Recreational fisheries: Boat anglers

22.11.149 Small localised increases in seabass abundance in response to the available prey from the FRR may lead to an increase in boat angling activity. However, given the limited recreational boat activity in the vicinity, this increase would likely be limited. The magnitude of the impact is expected to be low. The area affected would be only a proportion of the area available for recreational fishing and the sensitivity is expected to be low.

22.11.150 The impact of availability of target species as a result of attraction to the FRR or thermal discharges on boat anglers is predicted to have a negligible to minor beneficial effect. Effects are **not significant**.

Recreational fisheries: Beach anglers

22.11.151 Due to the distance offshore of the Sizewell C FRR headworks, any increase in predator abundance would likely have no effect on recreational beach anglers.

22.11.152 The magnitude of this impact is expected to be very low. The area affected would be only a proportion of the area available for recreational fishing and the sensitivity is expected to be low.

22.11.153 The impact of availability of target species as a result of attraction to the FRR or and thermal discharges on beach anglers is predicted to have a negligible effect. Effects are **not significant**.

22.12 Mitigation and monitoring

a) Introduction

22.12.1 Throughout the iterative planning process, the preliminary design for the marine structures was developed and primary (embedded) mitigation measures integrated into the proposed development to minimise the potential for significant effects.

22.12.2 Primary and tertiary (legislative) mitigation measures incorporated within the design of the proposed development are detailed in **Chapters 2, 3** and **4** of this volume and are summarised in **Section 22.5** of this chapter.

22.12.3 This section describes the proposed secondary (additional) mitigation measures for all marine ecology and fisheries receptors.

22.12.4 This section also describes recommended monitoring programmes, including monitoring of specific receptors/resources, or monitoring the effectiveness of a mitigation measure. The requirements, scope, frequency and duration of a given monitoring programme are described.

b) Mitigation

22.12.5 The proposed secondary mitigation measures for each of the receptors are described below based on the assessment of construction and operational effects from the proposed development. In addition to secondary mitigation, a site **CoCP** (Doc Ref. 8.11) has been developed, setting out the management measures which SZC Co. will require its contractors to adopt and implement during construction to maintain satisfactory levels of environmental protection and limit disturbance from construction activities as far as reasonably practicable.

i. Plankton mitigation

22.12.6 Assessment of construction and operational impacts on plankton receptors predicted no significant effects as a result of the proposed development. Therefore, no additional secondary mitigation measures are proposed.

ii. Benthic Ecology mitigation

22.12.7 The assessment has concluded no significant effects on benthic ecology receptors during construction or operation of the proposed development. No additional secondary mitigation measures are proposed.

22.12.8 The **CoCP** (Doc Ref. 8.11) notes that "*anchoring and positioning of jack-up barges should be carried out with attention to sensitive features such as the longshore bars or exposed Coralline Crag deposits, to minimise as far as possible the placement of legs or anchors into these features*" (Doc Ref. 8.11). These measures are equally relevant during maintenance activities during the operational phase. Monitoring the broad level extent of *S. spinulosa* reefs in areas of construction and operational impacts is recommended in **Section 22.12.c)** of this chapter.

iii. Fish Ecology mitigation

Construction

22.12.9 Primary construction impacts for fish receptors relate to underwater noise arising from impact piling. Tertiary mitigation, will include implementation of '*JNCC Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise'* (Ref. 22.23) and includes soft start procedures where hammer energy (or hammer frequency) is ramped up. Where technically feasible, impact piling may avoid periods of high water[75], thereby minimising the potential for underwater noise propagation and reducing predicted auditory effect ranges.

22.12.10 In the case UXOs were identified on site, appropriate management actions and mitigation measures would be required to minimise effects including the potential for seasonal effects, consideration of alternative disposal methods or relocation. Such measures would be highly dependent on the location of the UXO, HSE considerations and logistical constraints and would therefore require review on a case-by-case basis. If deemed necessary to detonate, tertiary mitigation measures would be applied, where appropriate, in accordance with '*JNCC guidelines for minimising the risk of injury to marine mammals from using explosives'* (Ref. 22.18). See **Section 22.3.i)**, of this chapter, for further details.

22.12.11 No further mitigation measures are proposed.

Operation

22.12.12 Mitigation measures have been embedded into the design of the proposed development to minimise effects on fish. Maintenance of the drum screens and FRR systems would occur during the operational phase to retain efficient functionality. No further mitigation measures are proposed.

[75] Underwater noise assessment are highly precautionary and assume all piling is completed at high water when maximum sound propagation would occur (**Appendix 22L**). This secondary mitigation, where technically feasible, may help minimise acoustic impacts.

iv. Marine Mammal mitigation

Construction

22.12.13 Primary construction impacts for harbour porpoise and seals relate to underwater noise arising from impact piling. Tertiary mitigation, will include implementation of '*JNCC Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise'* (Ref. 22.23) and includes soft start procedures where hammer energy (or hammer frequency) is ramped up. Where technically feasible, impact piling may avoid periods of high water[76], thereby minimising the potential for underwater noise propagation and reducing predicted auditory effect ranges.

22.12.14 A detailed and Sizewell C Project specific marine mammal mitigation plan (MMMP) will be compiled and implemented during all piling events during the construction phase. A draft MMMP has been submitted as part of the Sizewell C DCO application, provided in **Appendix 22N** of this volume. A marine licence condition is proposed within **the Draft Development Consent Order** (Doc Ref. 3.1) to secure this.

22.12.15 In the case UXOs were identified on site, appropriate management actions and mitigation measures would be required to minimise effects including the potential for seasonal effects, consideration of alternative disposal methods or relocation. Such measures would be highly dependent on the location of the UXO, HSE considerations and logistical constraints. The available mitigation measures would therefore require review on a case-by-case basis in consultation with statutory consultees. A Marine Licence condition is proposed within the Draft Order (Doc Ref. 3.1) to secure this.

22.12.16 If deemed necessary to detonate, a MMMP for UXO detonation would be completed accounting for site-specific factors and following the tertiary mitigation measures, where appropriate, in accordance with '*JNCC guidelines for minimising the risk of injury to marine mammals from using explosives'* (Ref. 22.18). This would be secured by a Marine Licence condition. See **Section 22.3.i)**, of this chapter, for further details.

22.12.17 No further mitigation measures are proposed.

[76] Underwater noise assessment are highly precautionary and assume all piling is completed at high water when maximum sound propagation would occur (**Appendix 22L**). This secondary mitigation, where technically feasible, may help minimise acoustic impacts.

Operation

22.12.18 Operational effects on marine mammals are predicted to be minor and limited additional mitigation measures are available beyond those already part of the embedded mitigation of the proposed development.

v. Commercial and Recreational Fisheries mitigation

22.12.19 The assessment has concluded minor to negligible effects on commercial and recreational fisheries during the construction and operation of the proposed development. Effects are **not significant** and no additional secondary fisheries mitigation measures are proposed.

22.12.20 In specific cases, construction activities and operational maintenance activities may restrict access and limit the ability for local fishers with limited fishing ranges and little access to alternative areas to operate. Under such circumstances, additional mitigation may be arranged on a case-by-case basis in accordance with current evidence-based practices. This would be secured by a marine licence condition.

c) Monitoring

i. Dredge Monitoring

22.12.21 A Marine Licence condition for dredging activities includes the requirement to monitor sediment contamination levels to ensure material is deemed acceptable for the proposed disposal route. Samples must have been collected within three years of dredging activities and analysed in an MMO accredited laboratory. Prior to capital dredging for the installation of infrastructure additional sediment samples would be collected to ensure contaminant levels remain within accepted levels.

ii. *Sabellaria* Monitoring

Construction

22.12.22 During the construction phase, installation of the Unit 1 cooling water intake headworks has the potential to effect *Sabellaria spinulosa* reef like formations associated with the exposed Coralline Crag habitat. Effects are predicted to be minor adverse based on the spatial scale of impacts and potential for recovery throughout much of the impacted area. However, monitoring would be implemented to assess changes in the extent of the *S. spinulosa* feature as part of a Marine Licence Condition.

22.12.23 *Sabellaria spinulosa* reef structures are ephemeral and subjected to natural changes, therefore change through time is expected as part of natural processes. Construction monitoring would include a minimum of two pre-construction surveys at yearly intervals to predict the extent of the reef features and establish a basis for variability. The surveys would involve acquisition of geophysical data (for example, side-scan sonar and multibeam echosounder) coupled with ground truthing from acoustic imaging video footage (for example, ARIS camera) at the offshore Coralline Crag.

22.12.24 A post-construction survey would be completed at the same time of year as pre-construction surveys to provide an indication of changes in reef extent.

22.12.25 It should be noted that acoustic methods are required as traditional light-based imaging systems are not available for habitat classification in the high turbidity waters at the offshore Crag (Ref. 22.122). Whilst, habitat mapping incorporates best available techniques for detection of *S. spinulosa*, mapping confidence is limited to interpretation of acoustic signatures and application of expert judgement. The ability to determine localised effects at the intakes would be limited but the application of safety buffers around the infrastructure preventing ground-truthing the area of highest likelihood of adverse change. As such, predicted extents should be regarded as indicative and monitoring would be able to approximate broad scale changes in extent/distribution rather than identify small scale changes in reef parameters such as reef elevation or patchiness.

Operation

22.12.26 During the operational phase minor adverse effects are predicted on *S. spinulosa* reefs formations in the immediate vicinity of the intakes headworks due to entrainment reducing the potential for larvae to settle from the plankton. However, across the wider offshore Coralline Crag habitat, small thermal uplifts (2^{o}C as a 98th percentile) may have a minor beneficial effect on growth of the warm water species, provided in **Section 22.7d)** of this chapter.

22.12.27 Monitoring the general reef extent, as part of a Water Discharge Activity permit condition is recommended at intervals of 3-5 years during the operational phase until satisfactory evidence has been gathered of no adverse effects, at which point monitoring would cease. As previously stated, acoustic measures would be limited to general changes in extent and distribution of the reef on the Coralline Crag. The ability to determine localised effects at the intakes would be limited but the application of safety buffers around the infrastructure preventing ground-truthing the area of highest likelihood of adverse change.

iii. Operational impingement monitoring

22.12.28 Effects of impingement are predicted to be negligible/minor, however, monitoring would be a requirement of the Marine Licence.

22.12.29 A Comprehensive Impingement Monitoring Programme (CIMP), such as that currently used at the Sizewell B station and described in **Appendix 22I** of this volume, would be implemented for the proposed development as a Condition on the Marine Licence. The CIMP would be used to establish seasonal and interannual variability in impingement numbers by species and confirm the impingement predictions for the proposed development. The proposed monitoring would be run in parallel with a CIMP programme at Sizewell B for a period of 3 years after which the results would be reviewed to determine whether the monitoring had satisfactorily demonstrated that the impingement predictions were sufficiently robust.

iv. Fish recovery and return outfall monitoring

22.12.30 Discharges of dead and moribund biota from the FRR have the potential to locally effect water quality parameters whilst some taxa, are expected to exploit the increased food supply. These effects are likely to be minor and localised within the vicinity of the outfall, where organic loading would be concentrated. Operational safety constraints, preventing development of benthic sampling equipment close to the FRR outfall, would likely limit the ability to detect localised changes in abundance/populations size. Monitoring should therefore consider the potential for water quality issues and would be defined in a Condition o the Water Discharge Activity permit.

22.12.31 It should be noted that the FRR would not be a route for chemical discharges at any stage of the development. However, decay of dead and moribund biota discharged during the operational phase has the potential to influence water quality. Water quality parameters including dissolved oxygen, pH, temperature, ammonium (NH_4), total oxidizable nitrogen, nitrite, silicate and phosphate should be sampled. Water quality samples would be collected throughout the water column at sites as close to the FRR headworks as operationally feasible and at control sites. Samples would be collected quarterly for one year to capture seasonal variation in FRR discharges and ambient water quality. Sampling should focus on periods of full operational power once both systems are commissioned to determine the potential worst-case seasonal scenarios. Should reductions in water quality be identified monitoring may be extended, however, monitoring near the existing Sizewell B outfalls has not detected significant changes in the parameters described, provided in **Appendix 21E** of this volume.

22.13 Residual effects

a) Introduction

22.13.1 This section provides a summary of the construction, commissioning and operational effects for each receptor group. Effects are presented with and without secondary mitigation (where required). These, residual effects, are described as either beneficial or adverse and the scale and significance of effects are detailed.

b) Construction

i. Plankton

22.13.2 This section presents a summary of the construction impact assessments for plankton receptors. Residual effects, both beneficial and adverse, on plankton receptors following mitigation measures are provided in **Table 22.155**.

Table 22.155: Summary of effects of construction phase impacts on plankton receptors.

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
Phytoplankton / Zooplankton	Increases in suspended sediment concentrations (SSC) resulting from individual dredging and dredge disposal activities for installation of the: • CDO; • FRR (x2); • cooling water headworks (x6), and; • plough dredging for the BLF navigational channel (including maintenance – no disposal).	None	Minor adverse effects.	None	Minor adverse effects **Not significant.**
Zooplankton	Increases in sedimentation rates following dredging activities (as described).	None	Minor adverse effects.	None	Minor adverse effects **Not significant.**
Plankton	In-combination effect of concurrent dredge activities increasing SSC and sedimentation rates.	None	Minor adverse effects.	None	Minor adverse effects **Not significant.**
Plankton	Heavy metal (zinc and chromium) contamination from CDO discharges of groundwater during main development site dewatering phase.	None	Negligible effects.	None	Negligible effects **Not significant.**

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
Phytoplankton	Nutrient (N+P) discharges from the CDO during the construction and commissioning phase.	None	Negligible effects.	None	Negligible effects **Not significant.**
Plankton	Un-ionised ammonia discharges from the CDO from treated sewage and commissioning discharges.	None	Negligible effects.	None	Negligible effects **Not significant.**
Plankton	Tunnelling wastewater on the floor of the cooling water tunnels containing tunnel boring machine (TBM) chemicals would be discharged via the CDO.	Most TBM surfactants would adhere to the tunnelling spoil which would be transported landward to the muck bay for disposal. CDO discharges would be treated with a silt-buster to reduce sediment (and associated contaminants) being discharged.	Minor adverse effects.	None	Minor adverse effects **Not significant.**
Plankton	Commissioning discharges of hydrazine during cold flush testing via the CDO.	Discharges would be directed to a storage tank prior to controlled release.	Minor adverse effects.	None	Minor adverse effects **Not significant.**

ii. Benthic ecology

22.13.3 This section presents a summary of the construction impact assessments for benthic ecology receptors. Residual effects, both beneficial and adverse, on benthic ecology receptors following mitigation measures are provided in **Table 22.156**.

Table 22.156: Summary of effects on benthic ecology receptors during the construction phase.

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
Benthic invertebrates	Compaction of substratum due to heavy plant operations for the installation of the BLF.	Heavy plant movements on the active beach face would be restricted to minimise disturbance of beach sediments.	Minor adverse effects.	None	Minor adverse effects **Not significant.**
Benthic invertebrates	Substratum extraction/reprofiling due to dredging activities for installation of the: • CDO; • FRR (x2); • cooling water headworks (x6), and; • plough dredging for the BLF navigational channel (including maintenance)	None	Minor adverse effects.	None	Minor adverse effects **Not significant**
Sabellaria spinulosa reef	Substratum extraction / ground preperation for the installation of the Unit 1 cooling water intake headworks.		Minor adverse effects.	Monitoring a	Minor adverse effects **Not significant**
Benthic invertebrates	Increases in suspended sediment concentration (SSC) following dredging and dredge disposal activities for installation of the: • CDO; • FRR (x2); • cooling water headworks (x6), and;	None	Minor adverse to minor beneficial effects.	None	Minor adverse effects **Not significant**
Sabellaria spinulosa reef			Minor beneficial effects.		Minor beneficial effects **Not significant**

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
	• plough dredging for the BLF navigational channel (including maintenance)				
Benthic invertebrates.	Increases in sedimentation rates following dredging and dredge disposal activities (as described).	None	Minor adverse effects.	None	Minor adverse effects **Not significant**
Sabellaria spinulosa reef			Negligible effects.		Negligible effects **Not significant**
Benthic invertebrates	Underwater noise and vibration due to dredging activities and impact piling for CWS installation.	None	Minor adverse effects.	None	Minor adverse effects **Not significant**
Benthic invertebrates	Changes in wave exposure due to plough dredging for the BLF navigational channel and presence of the BLF structure.	None	Negligible effects.	None	Negligible effects **Not significant**
Benthic invertebrates	Physical change (loss) to another seabed type due to presence of structures (BLF, CDO head, CWS intake and outfall heads, FRR outfall heads).	None	Negligible to minor adverse effects.	None	Minor adverse effects **Not significant**
Sabellaria spinulosa reef	Physical change (loss) to another seabed type due to presence of of the Unit 1 cooling water intake headworks.		Minor adverse effects.	None	Minor adverse effects **Not significant**
Benthic invertebrates	Spread of non-indigenous species due to presence of structures (as described).	None	Minor adverse effects.	None	Minor adverse effects

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
					Not significant
Benthic invertebrates	Un-ionised ammonia discharges from the CDO from treated sewage discharges.	None	Negligible effects.	None	Minor adverse effects **Not significant**
Benthic invertebrates	Heavy metal (zinc and chromium) contamination from CDO discharges of groundwater during dewatering phase.	None	Negligible effects.	None	Minor adverse effects **Not significant**
Benthic invertebrates	Tunnelling wastewater containing tunnel boring machine (TBM) chemicals would be discharged via the CDO.	Most TBM surfactants would adhere to the tunnelling spoil which would be transported landward to the muck bay for disposal. CDO discharges would be treated with a silt-buster to reduce sediment (and associated contaminants) being discharged.	Negligible effects.	None	Negligible effects **Not significant.**
Benthic invertebrates	Commissioning discharges of hydrazine during cold flush testing via the CDO.	Discharges would be directed to a storage tank prior to controlled release.	Minor adverse effects.	None	Minor adverse effects **Not significant**
Sabellaria spinulosa reef			Minor adverse effects.		Minor adverse effects **Not significant**

iii. Fish ecology

22.13.4 This section presents a summary of the construction impact assessments for fish ecology receptors. Residual effects, both beneficial and adverse, on fish ecology receptors following mitigation measures are provided in **Table 22.157**.

Table 22.157: Summary of effects for the construction phase of fish receptors.

Receptor	Component, Activity and Impact.	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
All fish receptors	Physical change (to another seabed type) from the installation of infrastructure and scour protection for the: • BLF structure; • FRR (x2); • CDO, and; • cooling water headworks (x6).	None	**Negligible effects.**	None	Negligible effects **Not significant.**
All fish receptors	Extraction of substratum by dredging for the: • BLF structure; • CDO; • FRR (x2); and • cooling water headworks (x6).	None	**Negligible effects.**	None	Negligible effects **Not significant.**
All fish receptors	Increases in suspended sediment concentrations (SSC) resulting from individual	None	**Minor adverse effect.**	None	Minor adverse effects **Not significant**

Receptor	Component, Activity and Impact.	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
	dredging and dredge disposal activities for installation of the: • CDO; • FRR (x2); • cooling water headworks (x6), and; • plough dredging for the BLF navigational channel (including maintenance – no disposal)				
All fish receptors	Changes in sedimentation from: • plough dredging for the BLF navigational channel; • CDO; • FRR (x2), and; • cooling water headworks (x6).	None.	**Negligible effects.**	None.	Negligible effects **Not significant.**
Fish hearing groups: • fish with a swim bladder or other air cavities to aid hearing. • fish with a swim bladder that does not aid hearing.	Changes in underwater noise from dredging associated with: • plough dredging for the BLF navigational channel • CDO; • FRR (x2); and • cooling water headworks (x6).	None.	**Minor adverse effects.**	None.	Minor adverse effects **Not significant**

Receptor	Component, Activity and Impact.	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
• eggs and larvae.					
Other hearing groups: • fish without a swim bladder.	Changes in underwater noise from dredging associated with: • plough dredging for the BLF navigational channel • CDO; • FRR (x2); and • cooling water headworks (x6).	None.	**Negligible effects.**	None.	Negligible effects **Not significant.**
Fish hearing groups: • fish with a swim bladder or other air cavities to aid hearing. • fish with a swim bladder that does not aid hearing. Other hearing groups: • Fish without a swim bladder. • Eggs and larvae.	BLF construction – impact piling to install eight piles (1m dimater) and four fenders/dolphins (1.5m diamter) below MHWS.	Soft-start procedures for ramping up piling hammer energy, where technically feasible.	**Minor adverse effects.**	None.	Minor adverse effects. **Not Significant.**
All fish receptors	Hypothetical unexploded ordnance (UXO) clearance - underwater noise.	Unmitigated worst-case assessment.	**Minor adverse effects.**	As required depending on the UXO location and size and	Minor adverse effects. **Not Significant.**

Receptor	Component, Activity and Impact.	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
				available mitigation options. A detailed MMMP would be implemented in consultation with the statutory stakeholders.	
All fish receptors	Cooling water infrastructure – drilling for vertical connecting tunels and seismic qualification (installation of pin piles to secure heawork to the seabed): underwater noise.	None.	**Negligible effects.**	None.	Negligible effects **Not significant.**
All fish receptors	Construction discharges of trace metals from the CDO.	None.	**Negligible effects.**	None.	Negligible effects **Not significant.**
All fish receptors	Discharges of tunnel boring machine chemical discharges from the CDO.	Most of the tunneling spoil and TBM chemicals would be returned landward to the muckbay. Only TBM chemicals in leachate would be discharged via the CDO, discharged	**Negligible effects.**	None.	Negligible effects **Not significant.**

Receptor	Component, Activity and Impact.	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
		would be treated with a silt busted.			
All fish receptors.	Commissioning discharges of hydrazine from the CDO. Precautunary assessment assuming concurrent commissioming of both reactor units.	Discharges would be directed to a storage tank prior to controlled release.	**Minor adverse effects.**	None	Minor adverse effects **Not significant**
All fish receptors	Un-ionised ammonia discharges from the CDO from treated sewage and commissioning discharges.	None	**Negligible effects.**	None	Negligible effects **Not significant.**
Assessment of Inter-relationships					
All fish receptors	All development components – Physical change (to another seabed type).	None.	Inter-relationship would not increase the significance of the effects alone. **Negligible effects.**	None.	Negligible effects **Not significant.**
All fish receptors	All development components dredging and disposal – Increases in suspended sediment concentration.	None.	Inter-relationship would not increase the significance of the effects alone. **Minor adverse effects.**	None.	Minor adverse effects **Not significant**

Receptor	Component, Activity and Impact.	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
All fish receptors	All development components dredging and disposal – Changes in sedimentation rate.	None.	Inter-relationship would not increase the significance of the effects alone. **Minor adverse effects.**	None.	Minor adverse effects **Not significant**
All fish receptors	BLF Navigational dredging an construction dredging for CW intakes - underwater noise (based on zone of Temporary Threshold Shift).	None.	Inter-relationship would not increase the significance of the effects alone. **Minor adverse effects.**	None.	Minor adverse effects **Not significant**
All fish receptors	Dredging and disposal - underwater noise (based on zone of Temporary Threshold Shift), combined with increases in suspended sediment concentration.	None.	**Minor adverse effects.**	None.	Minor adverse effects **Not significant**
All fish receptors	BLF navigational dreding - underwater noise (based on zone of Temporary Threshold Shift), combined with changes in sedimentation rate.	None.	Inter-relationship would not increase the significance of the effects alone. **Minor adverse effects.**	None.	Minor adverse effects **Not significant**

iv. Marine Mammals

22.13.5 This section presents a summary of the construction impact assessments for marine mammal receptors. Residual effects, both beneficial and adverse, on marine mammal receptors following mitigation measures are provided in **Table 22.158**.

Table 22.158: Summary of effects for the construction phase on marine mammal receptors.

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
Marine mammals	Increases in suspended sediment concentrations (SSC) resulting from individual dredging and dredge dissopsal activities for installation of the: • CDO; • FRR (x2); • cooling water headworks (x6), and; • plough dredging for the BLF navigational channel (including maintenance).	None	**Negligible effects.**	None	Negligible effects. **Not significant.**
Marine mammals	Underwater noise resulting from: • Piling driving for construction of BLF; • Dredging during construction of BLF, CDO, FRR, and CWS; • Drilling during construction of CWS; • Vessel traffic.	Statutory nature conservation agency protocol for minimasing the risk of injury to marine mammals from piling noise (JNCC, 2010). Where feasible piling should be avoided during periods of high water to reduce the potential for	**Minor adverse effects.**	None	Minor adverse effects **Not significant.**

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
		underwater noise propagation.			
Marine mammals	Hypothetical unexploded ordnance (UXO) clearance - underwater noise.	Unmitigated worst-case (1,500lb TNT equivalent) assessment.	Harbour porpoise: Major adverse effects. Grey/harbour seal: **Moderate adverse effects.**	A detailed MMMP with appropriate mitigation measures would be implemented in consultation with the statutory stakeholders.	Minor adverse.**Not significant**.
Marine mammals	Visual disturbance from artificial lighting during navigation and construction of BLF, CDO, FRR and CWS.	A lighting strategy with the aim to minimise light spill into the marine environment.	**Negligible effects.**	None	Negligible effects **Not significant.**
Marine mammals	Physical disturbance from vessel activity during construction of BLF, CDO, FRR and CWS.	Site-wide speed restrictions for all working vessels as instructed by the Harbour Master.	**Minor adverse effects.**	None	Minor adverse effects **Not significant..**
Marine mammals	Heavy metal (zinc and chromium) contamination from CDO discharges of groundwater during main development site dewatering phase.	None	**Negligible effects.**	None	Negligible effects **Not significant.**
Marine mammals	Commissioning discharges of hydrazine during cold flush testing via the CDO.	Discharges would be directed to a storage tank	**Minor adverse effects.**	None	Minor adverse effects

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
		prior to controlled release.			**Not significant..**
Marine mammals	Nutrient enrichment - un-ionised ammonia discharges from the CDO treated sewage.	None	**Negligible effects.**	None	Negligible effects **Not significant.**
Marine mammals	Tunnelling wastewater on the floor of the cooling water tunnels containing tunnel boring machine (TBM) chemicals would be discharged via the CDO.	Most TBM surfactants would adhere to the tunneling spoil which would be transported landward to the muck bay for disposal. CDO discharges would be treated with a silt-buster to reduce sediment (and associated contaminants) being discharged.	**Minor adverse effects.**	None	Minor adverse effects **Not significant..**
Marine mammals.	In-combination effects of noise generating activities (dredging at two locations simultatneosly).	None	**Minor adverse effects.**	None	Minor adverse effects **Not significant..**
Marine mammals.	In-combination effects of changes in SSC and underwater noise.	None	**Minor adverse effects.**	None	Minor adverse effects **Not significant..**
Marine mammals.	In-combination effects of changes in SSC from combined dredging and disposal activties.	None	**Negligible effects.**	None	Negigible effects **Not significant..**

v. Fisheries

22.13.6 This section presents a summary of the construction impact assessments for fisheries receptors, both commercial and recreational. Residual effects, both beneficial and adverse, on fisheries following mitigation measures are provided in **Table 22.159**.

Table 22.159: Summary of effects for the construction phase on fisheries receptors.

Receptor	Component, Activity and Impact.	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
Netters Potters Long-line Otter trawlers	Loss of access to fishing grounds. Temporary buffer zones of up to 500m around the construction vessels during installation of offshore infrastructure could restrict access to fishing grounds.	Notice to Mariners (NtM).	**Minor adverse effects.**	In specific cases restricted access may reduce acces of local fishers with limited operational ranges to fish areas. Under such circumstances additional mitigation may be arranged in accordance with current practices.	Minor adverse effects **Not significant.**
Boat anglers	Loss of access to fishing grounds. Temporary buffer zones of up to 500m around the construction vessels during installation of offshore infrastructure could restrict access to fishing grounds.	None	**Negligible effects**	None	Negligible effects **Not significant.**
Netters Potters	Restricted access to beach frontage. A temporoary buffer zone of up to 500m could restrict access to beach frontage during the construction of the BLF.	None	**Minor adverse effect.**	None	Minor adverse effects **Not significant.**

Receptor	Component, Activity and Impact.	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
Boat anglers.	Restricted access to beach frontage. A temporoary buffer zone of up to 500m could restrict access to beach frontage during the construction of the BLF.	None	**Negligible effect.**	None	Negligible effects **Not significant.**
Beach anglers.	Restricted access to beach frontage. A temporoary buffer zone of up to 500m could restrict access to beach frontage during the construction of the BLF.	None	**Minor adverse effect.**	None	Minor adverse effects **Not significant**

c) Operation

i. Plankton

22.13.7 This section presents a summary of the operation impact assessments for plankton receptors. Residual effects, both beneficial and adverse, on plankton receptors following mitigation measures are provided in **Table 22.160**.

Table 22.160: Summary of effects for the operational phase on plankton receptors.

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
Phytoplankton	Increases in SSC resulting from plough dredging for the BLF navigational channel (including lower magnitude maintenance dredging).	None	Minor adverse effects.	None	Minor adverse effects **Not significant**
Zooplankton	Increases in SSC resulting from plough dredging for the BLF navigational channel (including lower magnitude maintenance dredging).	None	Minor adverse effects.	None	Minor adverse effects **Not significant**
Phytoplankton	Entrainment of abstracted phytoplankton in the cooling water system. Discharged via the cooling water outfall.	None	Minor adverse effects.	None	Minor adverse effects **Not significant**
Zooplankton	Entrainment of abstracted zooplankton in the cooling water system. Discharged via the cooling waterr ourfall.	None	Minor adverse effects.	None	Minor adverse effects **Not significant**
Zooplankton	Impingement within the cooling water system (discharged via the FRR). Few zooplankton apart from gelatinous zooplankton are subject to impingement.	Chlorination would be applied after the drum screens, hence no exposure to chlorination.	Minor adverse effects.	None	Minor adverse effects **Not significant**

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
Plankton	**In-combination effects** of entrainment and impingement.	As above.	Minor adverse effects.	None	Minor adverse effects **Not significant**
Phytoplankton	Temperature changes due to cooling water discharges.	Intake headworks located 3km offshore in deep water to allow initial mixing and minimise intersection with the coastline.	Minor adverse tominor beneficial effects.	None	Minor adverse effects **Not significant**
Zooplankton	Temperature changes due to cooling water discharges.	Intake headworks located 3km offshore in deep water to allow initial mixing and minimise intersection with the coastline.	Minor beneficial effects.	None	Minor beneficial effects **Not significant**
Phytoplankton	Seasonal chlorinated discharges to control biofouling.	Seasonal discharges limited the duration of exposure.	Minor adverse effects.	None	Minor adverse effects **Not significant**
Zooplankton	Seasonal chlorinated discharges to control biofouling.	Seasonal chlorination limits the period of exposure.	Minor adverse effects.	None	Minor adverse effects **Not significant**
Plankton	Operational discharges of hydrazine.	None	Minor adverse effects.	None	Minor adverse effects **Not significant**
Phytoplankton	Nutrient (N+P) discharges during operations.	None	Negligible effect.	None	Negligible effects **Not significant**
Plankton	**In-combination effects** of the thermo-chemical plume.	Intake headworks located 3km offshore in deep water to allow initial mixing and	Minor adverse effects.	None	Minor adverse effects

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
		minimise intersection with the coastline. Seasonal chlorination limits the period of exposure.			**Not significant**
Plankton	**In-combination effects** of entrainment and the thermo-chemical discharge plume.	As above.	Minor adverse effect.	None	Minor adverse effects **Not significant**

ii. Benthic ecology

22.13.8 This section presents a summary of the operation impact assessments for benthic ecology receptors. Residual effects, both beneficial and adverse, on benthic ecology receptors following mitigation measures are provided in **Table 22.161**.

Table 22.161: Summary of effects for the operational phase on benthic ecology receptors.

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
Benthic invertebrates.	Emergence regime changes in the future due to the presence of the CDF (coastal squeeze).	None	Minor adverse effects.	None	Minor adverse effects **Not significant**
Benthic invertebrates	Reprofiling of substratum due to plough dredging for the BLF navigational channel (including maintenance).	None	Minor adverse effects.	None	Minor adverse effects **Not significant**
Benthic invertebrates	Increases in suspended sediment concentration (SSC) following plough dredging for the BLF navigational channel (including maintenance).	None	Minor adverse to minor beneficial effects.	None	Minor adverse to minor beneficial effects **Not significant**
Sabellaria spinulosa reef			Minor beneficial effects.		Minor beneficial effects **Not significant**
Benthic invertebrates.	Increases in sedimentation rates following plough dredging for the BLF navigational channel (including maintenance).	None	Minor adverse effects.	None	Minor adverse effects **Not significant**
Sabellaria spinulosa reef.			Negligible effects.		Negligible effects **Not significant**

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
Benthic invertebrates	Underwater noise and vibration due to plough dredging for the BLF navigational channel.	None	Minor adverse effects.	None	Minor adverse effects **Not significant**
Benthic invertebrates	Changes in wave exposure due to plough dredging for the BLF navigational channel and presence of the BLF structure.	None	Negligible effects.	None	Negligible effects **Not significant**
Benthic invertebrates	Physical change to another seabed type due to presence of structures (BLF, CDO head, CWS intake and outfall heads, FRR outfall heads).	None	Negligible to minor adverse effects.	None	Minor adverse effects **Not significant**
Benthic invertebrates	Spread of non-indigenous species due to presence of structures (as described).	None	Minor adverse effects.	None	Minor adverse effects **Not significant**
Benthic invertebrates	Cooling water abstraction: entrainment.	None	Minor adverse effects.	None	Minor adverse effects **Not significant**
Sabellaria spinulosa reef			Minor adverse effects.		Minor adverse effects **Not significant**
Benthic invertebrates	Cooling water abstraction: entrainment.	Chlorination would be applied after the drum screens, hence no exposure to chlorination.	Minor adverse effects.	None	Minor adverse effects **Not significant**
Benthic invertebrates	Temperature changes due to thermal discharges from CWS outfalls.	Outfall headworks located 3km offshore in deep water to allow initial	Minor adverse to minor positive effects.	None	Minor adverse effects

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
		mixing and minimise intersection with the coastline.			**Not significant**
Sabellaria spinulosa reef			Minor beneficial effects.		Minor beneficial effects **Not significant**
Benthic invertebrates	Chlorinated discharges from CWS outfalls, including TROs and chlorination by-products .	Seasonal discharges to limit the duration of exposure.	Minor adverse effects.	None	Minor adverse effects **Not significant**
Sabellaria spinulosa reef		Outfall headworks located 3km offshore in deep water to allow initial mixing and minimise intersection with the coastline.	Minor adverse effects.		Minor adverse effects **Not significant**
Benthic invertebrates	Operational discharges of hydrazine from CWS outfalls.	None	Minor adverse effects.	None	Minor adverse effects **Not significant**
Sabellaria spinulosa reef			Minor adverse effects.		Minor adverse effects **Not significant**
Benthic invertebrates	Organic loading due to discharges of dead and moribund biota from FRR outfalls.	None	Minor beneficial effects.	None	Minor beneficial effects **Not significant**
Benthic invertebrates	Increases in un-ionised ammonia due to discharges of dead and moribund biota from FRR outfalls.	None	Minor adverse effects.	None	Minor adverse effects **Not significant**
Sabellaria spinulosa reef			Minor adverse effects.		Minor adverse effects

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
					Not significant
Benthic invertebrates.	Combined effects of thermal and chemical discharges.	Outfall headworks located 3km offshore in deep water to allow initial mixing and minimise intersection with the coastline. Seasonal chlorination limits the period of exposure.	Minor adverse effects.	None	Minor adverse effects **Not significant**
Sabellaria spinulosa reef			Minor adverse to minor beneficial effects.		Minor adverse effects **Not significant**
Benthic invertebrates	Combined effects of entrainment and exposure to thermochemical discharges.	Outfall headworks located 3km offshore in deep water to allow initial mixing and minimise intersection with the coastline. Seasonal chlorination limits the period of exposure.	Minor adverse effects.	None	Minor adverse effects **Not significant**
Sabellaria spinulosa reef			Minor adverse to minor beneficial effects.		Minor adverse effects **Not significant**
Benthic invertebrates	Combined effects of impingement and exposure to thermochemical discharges.		Minor adverse effects.	None	Minor adverse effects **Not significant**
Benthic invertebrates	Combined effects of the presence of structures and thermal discharges on the spread of non-indigenous species.	None	Minor adverse effects.	None	Minor adverse effects **Not significant**

iii. Fish ecology

22.13.9 This section presents a summary of the operation impact assessments for fish ecology receptors. Residual effects, both positive and adverse, identify the fish receptor/s likely to be impacted at the local and stock level. Where the effect is deemed to be significant, the tables include the mitigation proposed and the resulting residual effect.

Table 22.162: Summary of effects for the operational phase on fish receptors.

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
All fish receptors.	**Physical change (to another seabed type) from the installation of infrastructure and scour protection for the:** • BLF structure; • FRR (x2); • CDO, and; • cooling water headworks (x6).	None	Negligible effects.	None	Negligible effects **Not significant**
All fish receptors	BLF dredging –removal of substratum (extraction)	None	Negligible effects.	None	Negligible effects **Not significant**
All fish receptors	BLF dredging – Increases in suspended sediment concentration.	None	Minor adverse effect.	None	Minor adverse effects **Not significant**
All fish receptors	BLF dredging – Changes in sedimentation rate.	None	Negligible effects.	None	Negligible effects **Not significant**
All fish receptors (early life stages).	Cooling water abstraction: entrainment.	None	Negligible effects.	None	Negligible effects **Not significant**

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
All fish receptors	Cooling water abstraction: impingement.	Low cross section intake head and unchlorinated FRR systems fitted.	Negligible to minor adverse effects.	None.	Negligible effects **Not significant**
Cold-water icthyoplankton	Cooling water discharges: thermal changes. (absolute water temperature and thermal uplift).	Outfall headworks located 3km offshore in deep water to allow initial mixing and minimise intersection with the coastline.	Negligible effects.	None.	Negligible effects **Not significant**
Cold-water juveniles and adults			**Minor adverse effects.**	None.	Minor adverse effects **Not significant**
Warm-water icthyoplankton and egg cases			Negligible effects.	None	Negligible effects **Not significant**
Warm-water juveniles and adults			Minor adverse to minor beneficial effects.	None	Minor adverse effects **Not significant**
Migratory fish			Minor adverse effects.	None	Minor adverse effects **Not significant**
Demersal fish and elasmobranch eggs/cases and larvae	Cooling water discharges: total residual oxidants (TROs).	Seasonal chlorination limits the period of exposure. Outfall headworks located 3km offshore in deep water to allow initial	Negligible effect.	None	Negligible effects **Not significant**
Demersal fish and elasmobranch juveniles and adults			Minor adverse effects.	None	Minor adverse effects **Not significant**

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
Pelagic fish eggs and larvae		mixing and minimise intersection with the coastline.	Negligible effects.	None	Negligible effects **Not significant**
Pelagic fish juveniles and adults			Minor adverse effects.	None	Minor adverse effects **Not significant**
Migratory fish			Minor adverse effects.	None	Minor adverse effects **Not significant**
Demersal fish and elasmobranchs	Cooling water discharges: formation of chlorination by-product (bromoform) from chlorination.	Seasonal chlorination limits the period of exposure. Outfall headworks located 3km offshore in deep water to allow initial mixing and minimise intersection with the coastline.	**Minor adverse effects.**	None	Minor adverse effects **Not significant**
All fish receptors	Cooling water discharges: daily hydrazine discharges (Waste stream).	Outfall headworks located 3km offshore in deep water to allow initial mixing and minimise intersection with the coastline.	**Negligible effects.**	None	Negligible effects **Not significant**
Demersal fish and elasmobranchs	FRR systems- Organic enrichment from discharge of dead and moribund biota.	None	**Minor positive effects.**	None	Minor adverse effects

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
					Not significant
All fish receptors	FRR systems - Un-ionised ammonia release from dead and moribund biota.	None.	**Negligible effects.**	None.	Negligible effects **Not significant**
Assessment of Inter-relationships					
All fish receptors	All development components – Physical change (to another seabed type).	None.	**Negligible effects.**	None.	Negligible effects **Not significant**
All fish receptors.	Cooling water discharges: total residual oxidants and temperature changes.	Seasonal chlorination limits the period of exposure. Outfall headworks located 3km offshore in deep water to allow initial mixing and minimise intersection with the coastline.	**Minor adverse effects.**	None.	Minor adverse effects **Not significant**
All fish receptors	Cooling water discharges: Bromoform and temperature changes.		**Negligible effects.**	None.	Negligible effects **Not significant**
All fish receptors	Cooling water discharges: Hydrazine and temperature changes.		**Negligible effects.**	None.	Negligible effects **Not significant**
All fish receptors	Chlorinated discharges and treated sewage in the cooling water system	None.	**Negligible effects.**	None.	Negligible effects **Not significant**
All fish receptors	Primary and secondary entrainment (within the discharge plume).	None.	**Negligible effects.**	None.	Negligible effects **Not significant**
All fish receptors	Entrapment (entrainment and impingement).	Low cross section intake head and FRR systems fitted.	**Minor adverse effects.**		Minor adverse effects **Not significant**

iv. Marine Mammals

22.13.10 This section presents a summary of the operation impact assessments for marine mammal receptors. Residual effects, both positive and adverse, on marine mammal receptors following mitigation measures are provided in **Table 22.163**.

Table 22.163: Summary of effects for the operational phase on marine mammal receptors.

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
Marine mammals	Visual disturbance from artificial lighting during navigation and maintenance of BLF.	A lighting strategy with the aim to minimise light spill into the marine environment.	Negligible effects.	None	Negligible effects **Not significant**
Marine mammals	Physical disturbance from vessel activity during maintenance of BLF.	Site-wide speed restrictions for all working vessels as instructed by Harbour Master.	Minor adverse.	None	Minor adverse effects **Not significant**
Marine mammals	Increases in SSC resulting from plough dredging for the BLF navigational channel (including lower magnitude maintenance dredging).	None	Negligible effects.	None	Negligible effects **Not significant**
Marine mammals	Underwater noise from dredging activities for maintance of BLF.	None	Minor adverse effects.	None	Minor adverse effects **Not significant**
Marine mammals	Impigement of small marine mammals or fish in the cooling water system.	Coarse bar screens at the intake are in place to prevent large marine mammals entering the cooling water system.	Minor adverse effects.	None	Minor adverse effects **Not significant**
Marine mammals	Temperature changes due to cooling water discharges.	None	Minor adverse effects.	None	Minor adverse effects **Not significant**

Receptor	Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
Marine mammals	Seasonal chlorinated discharges to control biofouling.	Seasonal discharges limited the duration of exposure.	Minor adverse effects.	None	Minor adverse effects **Not significant**
Marine mammals.	Operational discharges of hydrazine.	None	Minor adverse effects.	None	Minor adverse effects **Not significant**
Marine mammals	Organic enrichement due to discharge of dead or moribund biota from the FRR.	The FRR system designed to minimise impacts on impinged fish and invertebrates.	Harbour porpoise: Negligible effects. Seals: Minor beneficial effects.	None	Minor adverse effects **Not significant** Minor beneficial effects **Not significant**
Marine mammals	In-combination effects of temperature changes and syntetic compaund contamination.	None	Minor adverse effects.	None	Minor adverse effects **Not significant**
Marine mammals	In-combination effects of nutrient enrichement and syntetic compaund contamination.	None	Minor adverse effects.	None	Minor adverse effects **Not significant**

v. Fisheries

22.13.11 This section presents a summary of the operation impact assessments for fisheries receptors, both commercial and recreational. Residual effects, both positive and adverse, on fisheries following mitigation measures are provided in **Table 22.164**.

Table 22.164: Summary of effects for the operational phase on fisheries receptors.

Receptor	Component, Activity and Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
Netters. Potters	Restricted access to beach frontage. (Occassional BLF delivery and SCDF mitigation).	None.	Minor adverse effects.	None.	Minor adverse effects **Not significant**
Boat anglers	Restricted access to beach frontage. (Occassional BLF delivery and SCDF mitigation).	None.	Negligible effect.	None.	Negligible effects **Not significant**
Beach anglers	Restricted access to beach frontage. (Occassional BLF delivery and SCDF mitigation).	None.	Minor adverse effect.	None.	Minor adverse effects **Not significant**
Potters, Netters, Long-lines and Otter trawlers	Restricted access to (offshore) fishing areas. Physical presence and maintenance.	Notice to Mariners (NtM).	Minor adverse effects.	In specific cases restricted access may reduce acces of local fishers with limited operational ranges to fish areas. Under such circumstances proportional compensation may be arranged in accordance with current practices.	Minor adverse effects **Not significant**
Boat anglers	Restricted access to (offshore) fishing areas. Physical presence and maintenance.	Notice to Mariners (NtM).	Negligible effects.	None	Negligible effects **Not significant**

Receptor	Component, Activity and Impact	Primary or Tertiary Mitigation.	Assessment of effects.	Additional Mitigation.	Residual Effects.
Potters, Netters, Long-lines and Otter trawlers	Changes in availability of target species: Impingement.	FRR and LVSE headwork.	Minor adverse effects.	None.	Minor adverse effects **Not significant**
Boat and beach anglers	Changes in availability of target species: Impingement.	FRR and LVSE headwork.	Minor adverse effects.	FRR.	Minor adverse effects **Not significant**
Potters	Changes in availability of target species: Thermal plume.	None.	Negligible effects.	None.	Negligible effects **Not significant**
Netters, Long-lines and Otter trawlers.	Changes in availability of target species: Thermal plume.	None.	Minor adverse to minor beneficial effect	None.	Minor adverse effects **Not significant**
Beach and boat anglers.	Changes in availability of target species: Thermal plume.	None.	Minor adverse to minor beneficial effect.	None.	Minor adverse effects **Not significant**

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