TotalEnergies EP DANMARK A/S

ENVIRONMENTAL SIGNIFICANCE ASSESSMENT REPORT

DAGNY CCS GEOPHYSICAL SURVEY

07 MARCH 2024

CONFIDENTIAL

ENVIRONMENTAL SIGNIFICANCE ASSESSMENT REPORT

DAGNY CCS
GEOPHYSICAL SURVEY

TotalEnergies EP DANMARK A/S

TYPE OF DOCUMENT (VERSION 1.0)
CONFIDENTIAL

PROJECT NO.: 22004041
DATE: MARCH 2024

WSP
LINES ALLÉ
2630 TAASTRUP

PHONE: +45 91-17-43-02

WSP.COM

QUALITY MANAGEMENT

ISSUE/REVISION	VERSION 1.0	VERSION 2.0	VERSION 3.0	VERSION 4.0	VERSION 5.0	VERSION 6.0	VERSON 7.0	VERSON 8.0
Date	20-12-2023	24-01-2024	30-01-2024	31-01-2024	31-01-2024	09-02-2024	01-03-2024	03-03-2024
Prepared by	SAKJ, MAVO	SAKJ, MAVO, KARI	SAKJ, MAVO, KARI	SAKJ, MAVO, KARI	SAKJ, MAVO, KARI	SAKJ, MAVO, KARI	SAKJ, MAVO, KARI	SAKJ, MAVO, KARI
Checked by	KARI	KARI	KARI	KARI	KARI	KARI	KARI	KARI
Authorised by	Charlotte Larsen, TEPDK	Ilaria Valentini, TEPDK	Ilaria Valentini, TEPDK	Ilaria Valentini, TEPDK	Ilaria Valentini, TEPDK	Ilaria Valentini, TEPDK	Ilaria Valentini, TEPDK	Ilaria Valentini, TEPDK

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

1. Noise model for Dagny CCS site survey by Genesis (2024, under preparation)
2. Changes to Dagny seismic survey location

LIST OF ABBREVIATIONS

AA	Appropriate Assessment according to the Habitat Directive
BfN	Bundesamt für Naturschutz
dB	Decibels
dB re 1 µPa	Decibels relative to one micro Pascal
dB re 1 $\mu Pa^2 s$	Decibels relative to one micro Pascal square second
DE	Germany
DEA	Danish Energy Agency
DEPA	Danish Environmental Agency
DK	Denmark
DUC	Danish Underground Consortium
EC	European Commission
EEZ	Exclusive Economic Zone
EU	European Union
GES	Good Environmental Status
HF	High Frequency
Hz	Hertz
ICES	International Council for the Exploration of the Sea
IUCN	International Union for Conservation of Nature
JNCC	Joint Nature Conservation Committee
kHz	Kilohertz
km	Kilometres
km^2	Square kilometres
LC	Least Concern (IUCN categories)
LF	Low Frequency
m	Metres
MSFD	Marine Strategy Framework Directive
MERP	Marine Ecosystems Research Program
MMO	Marine Mammal Observer
NE	Netherlands
NMFS	National Marine Fisheries Service
NO	Norway
NT	Near Threatened (IUCN categories)
OSPAR	Oslo and Paris Convention
Pa	Pascal
PAM	Passive Acoustic Monitoring
PDV	Phocine Distemper Virus
PTS	Permanent Threshold Shift
SAC	Special Area of Conservation
SCANS	Small Cetacean Abundance in the North Sea
SCI	Sites of Community Importance
SEL	Sound Exposure Level
SVO	Particularly Vulnerable Areas (marine protected areas in Norway)
SPA	Special Protection Area
SPL	Sound Pressure Level
TEPDK	TotalEnergies Exploration and Production Danmark A/S
TTS	Temporary Threshold Shift
UK	United Kingdom

UWNM	Underwater Noise Model
VU	Vulnerable (IUCN categories)

1 SUMMARY

TotalEnergies EP Danmark A/S is planning to conduct a geophysical (seismic) survey in the Dagny CCS license (Oligocene aquifer) that is part of the Bifrost (DK) CCS project in Danish waters. This environmental significance assessment report (ESAR) is prepared based on the Danish Offshore Habitat Order and evaluates if the proposed activities can affect designated international nature protection areas within or outside the Danish territory and/or the protection of certain animal species. The Offshore Habitat Order applies to surveys requiring approval under section 28(1) of the Danish Subsoil Act, cf section 1(2) no. 7 of the Offshore Habitat Order.

The ESAR also considers the Marine Strategy Framework Directive (MSFD) which is implemented in Danish law through the Marine Strategy Act (Consolidation Act no. 123 of 01 February 2024 and the associated national monitoring program (NOVANA).

Geophysical (seismic) survey is carried out as part of the pre-survey of a future CCS (Carbon Capture and Storage) area in the North Sea. The survey area is centered around the well P11 and covers an area of 3.8 km x 3.8 km (14.4 km^2). The survey area is located within a larger working area of 6.5 km x 6.5 km (42.3 km^2) used for line turns. The survey area is located approximately 195 km away from the Danish coast and approximately 23 km away from the Norwegian Exclusive Economic Zone (EEZ). The planned geophysical survey is expected to be completed in 45 working days (including downtime of 21 days when the equipment is not in use). The survey is planned to be carried out between March and October depending on weather conditions and vessel availability.

The equipment with the greatest impact on marine mammals, fish, fish eggs and fish larvae has been assessed by undertaking an underwater noise model. The loudest sound sources for the Dagny CCS site survey are the sound emitted during airgun array.

The survey will be conducted according to the Danish standard terms as recommended by the DEA and by using TEPDK best-practice measures. A prolonged soft-start period of 45-minutes has been defined to reduce the potential impacts on harbour porpoise due to mother calf separation.

Including the prolonged soft-start mentioned above, the Dagny CCS site survey is assessed to have no significant impact on harbour porpoise, minke whale and white-beaked dolphin (Annex IV species potentially present in the survey area) and there will be no significant impact on the conservation objectives of habitats and species in national and international Natura 2000 sites.

The Dagny CCS site survey is unlikely to hinder or delay the achievements of good environmental status for the Danish targets of the descriptors according to the Marine Strategy Act. It is hereby also assessed that there is no significant impact on fish populations including fish eggs or fish larvae. There is also no significant impact on Marine Strategy Areas and the national monitoring program (NOVANA).

Overall, the Dagny CCS site geophysical survey will have *no significant* impacts on the marine environment.

2 SAMMENFATNING

TotalEnergies EP Danmark A/S planlægger at gennemføre en geofysisk (seismisk) undersøgelse indenfor Dagny CCS licensen (Oligocene aquifer), som er en del af Bifrost (DK) CCS projektet i dansk farvand. Denne miljø- og væsentlighedsvurderingsrapport er baseret på offhorehabitatbekendtgørelsen og vurderer om der om de planlagte aktiviteter vil kunne medføre skade på internationale beskyttede områder indenfor eller udenfor dansk territorium og/eller på beskyttelsen af visse arter af dyr. Offshorehabitatbekendtgørelsen finder anvendelse på undersøgelser, der kræver godkendelse efter undergrundslovens § 28, stk. 1, jf. § 1, stk. 2, 7 i offshorehabitatbekendtgørelsen.

Miljø- og væsentlighedsvurderingsrapporten forholder sig også til Havstrategidirektivet (MSFD), der er implementeret i dansk lovgivning gennem havstrategiloven og det dertilhørende nationale overvågningsprogram (NOVANA).

Undersøgelserne gennemføres som led i forundersøgelserne af et kommende CCS-område (Carbon Capture and Storage) i Nordsøen. Undersøgelsesområdet er centreret omkring brønden P11 og dækker et område på 3,8 km x 3,8 km (14,4 km^2). Undersøgelsesområdet ligger inden for et større arbejdsområde på 6,5 km x 6,5 km (42,3 km^2), der bruges til venderinger mellem linjerne. Begge områder ligger ca. 195 km fra den danske kyst og ca. 23 km fra Norges eksklusive økonomiske zone (EEZ). De planlagte geofysiske undersøgelser forventes afsluttet på maksimalt 45 arbejdsdage (inklusive nedetid på 21 dage hvor udstyret ikke benyttes). Undersøgelsen er planlagt til at blive gennemført mellem marts og oktober afhængigt af vejrforholdene og fartøjstilgængelighed.

Udstyret med størst indvirkning på havpattedyr, fisk, fiskeæg og fiskelarver er blevet vurderet på baggrund af en undervandsstøjmodel . De højeste støjkilder som anvendes i forbindelse med Dagny CCS undersøgelserne er lyden fra luftkanoner til de seismiske undersøgelser.

Undersøgelsen vil blive udført i henhold til de danske standardvilkår, som anbefalet af Energistyrelsen samt TEPDK's justerede 'bedste praksis'-foranstaltninger en forlænget soft-startperiode på 45 minutter er blevet defineret for at reducere de potentielle påvirkninger på marsvin som følge af mor-kalv separation.Med den foreslåede afværgeforanstaltning vurderes Dagny CCS-lokalitetsundersøgelsen ikke have nogen væsentlig indvirkning på marsvin, vågehval og hvidnæset delfin (bilag IV-arter), og der vil ikke være nogen væsentlig påvirkning af bevaringsmålsætningerne for levesteder og arter i nationale og internationale Natura 2000-områder.

Det er usandsynligt, at undersøgelsen af Dagny CCS-lokaliteten vil hindre eller forsinke opnåelsen af en god miljøtilstand i henhold til havstrategiens deskriptorer. Det vurderes således også, at der ikke er nogen væsentlig indvirkning på fiskebestande, herunder fiskeæg eller fiskelarver. Der er heller ingen væsentlig indvirkning på havstrategiområder og det nationale overvågningsprogram (NOVANA).

Samlet set vil de geofysiske undersøgelser af Dagny CCS-lokaliteten *ikke* medføre en væsentlig påvirkning på det marine miljø.

3 INTRODUCTION

TotalEnergies EP Danmark A/S (TEPDK) intends to conduct a geophysical site survey at Dagny Carbon Capture and Storage (CCS) in the Danish sector of the North Sea (Figure 3-1). The survey area is centred around the TEPDK well P11 and lies approximately 195 km from the nearest coastline (the Danish coast) and 23 km from the Norwegian EEZ. The proposed site survey area is 3.8 km x 3.8 km (14.4 km^2) and is located within a greater working area of 6.5 km x 6.5 km (42.3 km^2) used for line turns.

The site survey is expected to be completed in a maximum of 45 working days (including downtime) with a total of 24 days airgun use. The survey is planned to be conducted between March and October depending on weather conditions and vessel availability.

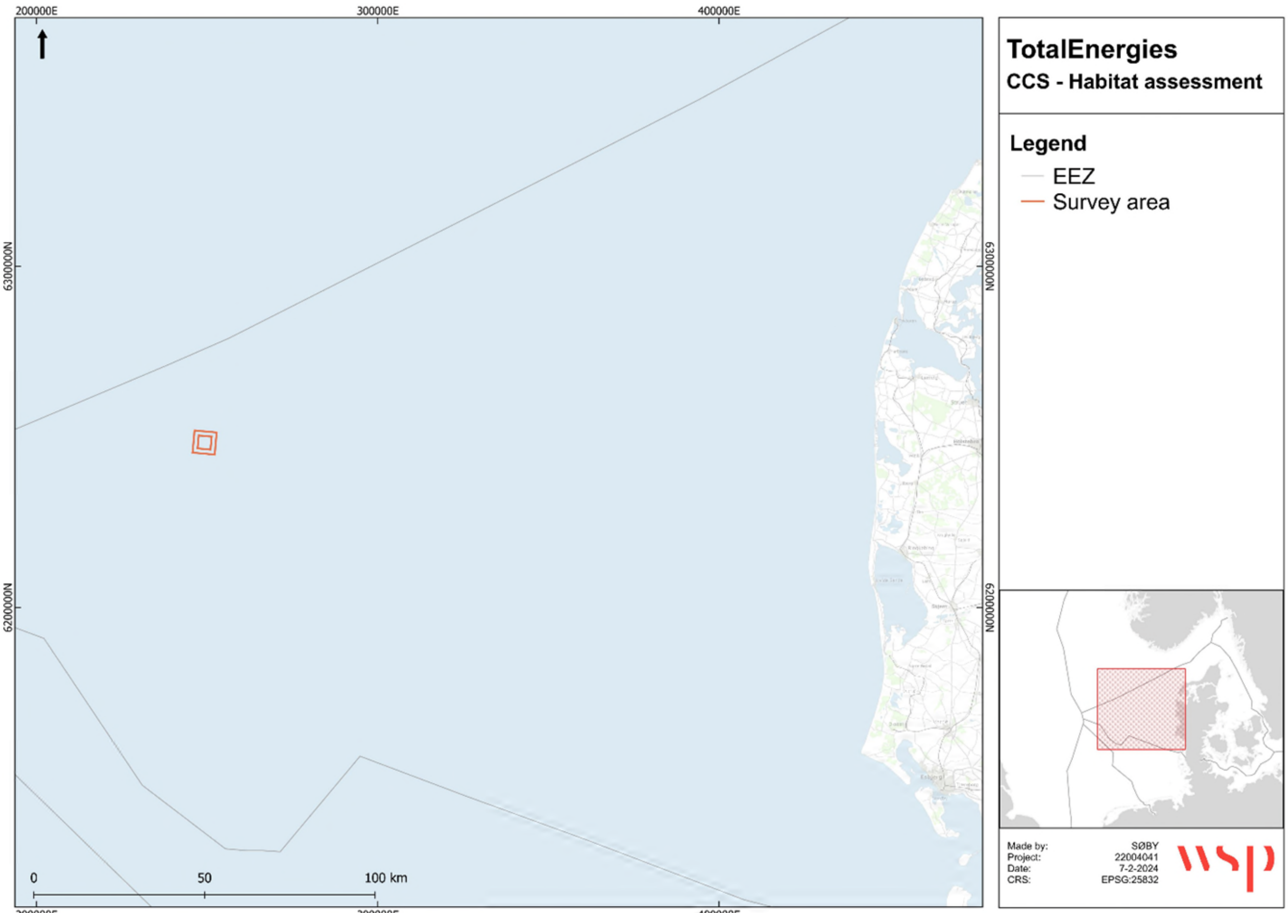

Figure 3-1 Location of the proposed Dagny CCS survey. The figure includes the proposed survey area and the greater working area.

Two-dimensional high-resolution (2DHR) and ultra-high-resolution (2DUHR) seismic data will be acquired over the site survey area using a 160 cubic inch (cu.in.) airgun array and 24 cu.in. airgun array, respectively. Data will also be acquired using a sub-bottom profiler (SBP), multi-beam echosounder (MBES), single-beam echosounder (SBES) and side scan sonar (SSS).

Before marine surveys can be conducted in Danish waters, permission needs to be granted by the DEA according to the Subsoil Act (Consolidation Act. No. 1461 of 29 November2023) and the Offshore Habitat Order (Executive Order 786 of 14 June 2023).

This document is an Environmental Significance Assessment Report (ESAR) that is prepared to support a formal permit application by TEPDK for the seismic activities. The report includes an Appropriate Assessment of the impact on Natura 2000 and an assessment of Annex IV species (cetaceans). The ESAR also include assessments according to the descriptors in the Marine Strategy Act and an assessment of the potential impact on the national monitoring programme NOVANA.

The assessed impacts are based on an underwater noise model undertaken by Genisis (2024) for two locations (Appendix 1). Since the underwater noise modelling was completed, the proposed location for the Dagny seismic survey has been changed. The new survey location is partly overlapping with the greater working area of the two locations for which the modelling has been undertaken. The survey area has the same dimensions, same depth, and same seabed substrate as the survey areas for which the modelling has been completed for. The recent Dagny noise modelling is therefore considered representative results for the Dagny survey location (Appendix 2).Scope of the report

The scope of the report is to prepare an ESAR to evaluate if the proposed activities will affect designated international nature protection areas within or outside the Danish territory (Natura 2000 sites) and/or Annex IV species in the area affected by the seismic survey according to the Offshore Habitat Order. In addition, the report includes necessary assessments according to the Marine Strategy Act.

The report will include assessment of:

- Impacts on Natura 2000 sites (Appropriate Assessment) including:
    - Impacts on marine mammals (cetaceans and pinnipeds)
- Impacts on Annex IV species including:
    - Impacts on cetaceans
- Impacts on 11 descriptors in the Marine Strategy Act and impact on Marine Strategy Areas and monitoring stations. This includes assessment of:
    - Impacts on marine mammals, seabirds, fish, fish eggs and fish larvae
- Cumulative impacts
- Transboundary impacts.

3.1 READING GUIDE

The structure and content of the report is built upon the requirements in the law and intends to provide the necessary information to obtain permit for marine seismic survey. The content of each chapter is outlined below:

- Chapter 1: Presents a summary of the key conclusions in English.
- Chapter 2: Offers a Danish summary of the most important conclusions.
- Chapter 3: Introduces the project and present the scope of the report.
- Chapter 4: Provides background information on the potential impact of seismic survey and describes the physical environment.
- Chapter 5: Describes the legal framework, including information to be covered in a seismic survey permit. It also outlines the obligations related to internationally protected areas (Natura 2000 sites), protection of marine mammals under international conventions, and relevant obligations under the Offshore Habitat Order and the Marine Strategy Act.
- Chapter 6: Includes a detailed project description, outlining planned activities.
- Chapter 7: Provides an overview of the assessment methodology used.
- Chapter 8: Conducts an environmental assessment of the impacts of underwater noise on marine mammals (Seals and harbour porpoises) and fish, fish egg and fish larvae.
- Chapter 9: Conducts a screening of the impacts on Natura 2000 sites (screening for Appropriate Assessment).
- Chapter 10: Makes up an Appropriate Assessment (AA) of the impact on Natura 2000 sites.
- Chapter 11: Assesses the impact on species listed on the Habitat Directives Annex IV (cetaceans).

- Chapter 12: Summarizes the findings in relation to the goals set in the Marine Strategy Framework Directive.
- Chapter 13: Describes the cumulative impacts of the other planned projects and plans.
- Chapter 14: Describes the potential transboundary effects.
- Chapter 15: Provides a summary of the major conclusions.

4 BACKGROUND

4.1 UNDERWATER NOISE FROM SEISMIC SURVEY

Underwater noise from seismic surveys can have a variety of potential impacts on marine life. For example, it can interfere with the ability of animals to communicate with each other, which can disrupt behaviors such as breeding, foraging, and socializing. Noise can also affect the ability of animals to navigate and orient themselves in their environment, as many species rely on sound to locate food, avoid predators, and navigate.

There is evidence that underwater noise can cause physical harm to animals. For example, the intense sounds used in some types of human activities, such as seismic survey, can cause hearing damage and other injuries to animals. In some cases, this noise can be intense enough to cause temporary or permanent hearing loss, and it may also cause physical damage to internal organs.

The potential impacts of underwater noise on marine organisms depend on a variety of factors, including the intensity and frequency of the noise, the duration of the noise, and the distance of the animals from the sound source. In general, the closer an animal is to the source of the noise, the greater the potential impact on the animal.

Marine mammals such as whales, seals and dolphins are particularly sensitive to underwater noise. However, there is also evidence that underwater noise may affect fish, although the impacts are less clear. The selection of species to include in this study is based on the current knowledge of their abundance and sensitivity to underwater noise.

To mitigate the potential impacts of seismic survey on marine life, the Danish Energy Agency and JNCC, have imposed guidelines for emission of underwater noise (Danish Energy Agency, 2018). These include thresholds for noise emissions, and requirements of using soft-start, Passive Acoustic Monitoring (PAM) and the use of Marine Mammal Observers (MMO). The standard terms and conditions from the DEA are integrated in the project.

4.2 PHYSICAL ENVIRONMENT

Water depth, physical properties of water (temperature, salinity), stratification and sediment type strongly influence sound propagation. The water depth in the site survey area is approximately 60 m (Appendix 2). Sediments in the region are expected to predominantly comprise mixed sediments, sand and mud (Appendix 2).

4.3 TEMPERATURE

The site survey is expected to be completed in a maximum of 45 working days (including downtime) with a total of 24 days airgun use from March to October 2024. Within this period the water temperature varies greatly with the coldest month being March and the warmest month being August (Figure 4-1). The modeled threshold distances are greatly impacted by the different temperature profiles used where lower temperatures results in much higher modeled threshold distances than higher temperatures. The temperature profiles used for the sound propagation model are March and August as these months yield the biggest difference in the results of the model (Appendix 1).

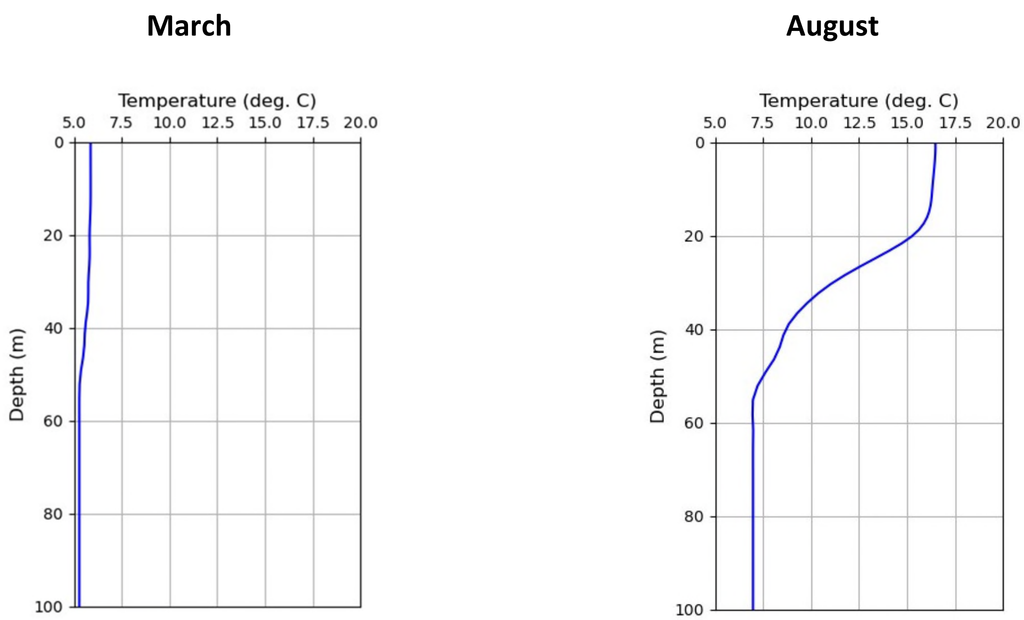

Figure 4-1 Temperature profiles used in the sound propagation models from March and August (see Appendix 1)

5 LEGAL FRAMEWORK

5.1 PERMIT FOR SEISMIC SURVEY

Before a permit can be granted for seismic survey, the DEA needs to grant environmental approval according to the Subsoil Act (Consolidation Act. no. 1461 of 29 November 2023), the Offshore Habitat Order (Executive Order no. 786 of 14 June 2023) and the Marine Strategy Act (Consolidation Act no. 123 of 01 February 2024).

The legal framework for the permit for seismic survey and the standard terms for conducting seismic survey in Denmark is presented in following sections.

5.1.1 PERMIT APPLICATION

The DEA describes the permit application process in the document "*standard terms for investigations at sea*" (Danish Energy Agency, 2019). The document is a guideline and is not binding.

Applications for seismic survey should as a minimum include:

- A model of the potential noise distribution based on (Tougaard, 2016) including soft-start procedures and best-practice.
- A description of planned mitigating efforts and expected effects.
- An elaborated description of the planned seismic equipment to be deployed related to the expected necessary outcome and any potential alternatives.
- Assessment of the potential impacts the activity may have on international nature protected areas (Natura 2000) (see section 5.2)
- Assessment of the potential impacts the activity may have on species listed on the EU Habitats Directive Annex IV (see section 5.4).
- Potential cumulative effects from other known projects should be included in modelling.
- Potential transboundary effects the activity may have on international nature protected areas (Natura 2000).

After submission, the DEA may circulate the application to relevant authorities for comments and input. This includes among others, the Danish Environmental Protection Agency (DEPA), the Danish Defence Command, the Danish Maritime Authority (DMA) and Espoo.

5.1.2 TERMS AND CONDITIONS

The seismic survey follows the standard terms and conditions for marine surveys at sea as described in the guidelines by the DEA (Danish Energy Agency, 2018). To minimise the risk of potential impacts of sound from the seismic survey, TEPDK have also integrated the guidelines of the Joint Nature Conservation Committee (JNCC) into the project (JNCC, 2017). The DEA may also add additional conditions to the permit.

The main differences between JNCC guidelines and Danish standards are listed in Table 5-1.

Table 5-1 Main differences between Danish standards and JNCC guidelines (Danish Energy Agency, 2018; JNCC, 2017).

	DANISH STANDARDS	JNCC GUIDELINES
General terms	No equipment must be left at sea unless specific permits have been granted.	No requirements, but they follow the EU's Habitat Directive which define "Areas of Importance"
MMO and PAM	No requirements of educated MMP and PAM operators	Require specific education or certification of all MMO and PAM operators.
Mitigation airgun during data acquisition	If an animal is detected within the Danish EEZ within 500 m, mitigating airguns should be used until the animal is outside a 200 m safety zone.	No requirements about use of mitigation airguns while the seismic acquisition is ongoing
Soft start	Monitoring at start-up: 30 min (MMO) at < 200 m depth 20 minute start-up. If no animals within 500 m collection with energy source at full strength can start.	•From the start of the soft-start until full operational power: minimum of 20 minutes; •From the start of the soft-start until the start of the survey line: maximum of 40 minutes. for surveys where the maximum airgun volume is <180 cubic inches • From the start of the soft-start until full operational power: minimum of 15 minutes; • From the start of the soft-start until the start of the survey line: maximum of 25 minutes
Line shifts	If line shifts are less than 20 minutes, the source is reduced to mitigating level and MMO and PAM are operating. If no mammals are observed within 500 m, full survey level can be initiated. If line shifts are longer than 20 minutes, the source is to be turned off and observation period and soft-start to be re-initiated. If mammals are observed, initiation must be stopped.	If the line shifts are <40 min, airgun can continue, if the energy is reduced to 180 m^3. SPI is increased. If the line shifts are >40 min the firing is terminated and 20 minute soft-start procedure is initiated. If mammals are observed, initiation must be stopped.
Interruptions	Unplanned interruptions for less than 5 minutes are allowed. If interruptions are 5-10 minutes, mammal observation should be employed, and full survey can continue if no marine mammals are within 500 m. If so, mitigation airguns should be used until 20 minutes after animals have left the 500 m zone, whereafter observation period and soft-start can begin. Interruptions of >10 minutes require observation period, and soft-start must be re-initiated.	Unplanned interruptions for <10 min are allowed. No requirements about soft-start if there are no mammals observed in the area. If the interruption is planned for <10 min, MMO/PAM operator should observe 20 minutes before the pause and continue in the pause period. Interruption of source for more than 10 minutes (intended or unintended): Observation of mammals and use of soft-start.
Information of Danish fishers	Danish Fishers Producent organization (https://fiskeriforening.dk/english-version) to be informed and cooperated with to minimise potential disturbance for fishermen. The organisation may be allowed to be represented aboard the survey vessel and information on planned surveys should be published.	No requirements

	DANISH STANDARDS	JNCC GUIDELINES
Reporting	Danish standards require that submission of data shall follow terms stipulated in Executive Order no. 56 of 4. January 2002. Furthermore, weekly progress reports must be delivered by email. Post survey information on start and end dates and total number of lines/km^2 are to be submitted to the DEA. Furthermore, a noise register must be completed and submitted to the DEA.	No requirements of data submission. Risk assessment before survey and submission of MMO report after survey.

5.2 NATURA 2000

Natura 2000 is a network of nature protection sites established under the EU Habitats Directive (92/43/EEC) and the Birds Directive (2009/147/EC). The Habitats Directive sets requirements for protection against damage caused by marine surveys and against degradation and significant disturbance of species in Natura 2000 sites. The directive is implemented in Danish legislation through the Subsoil Act (Consolidated Act no. 1461 of 29 November 2023) and the Offshore Habitat Order (Executive Order no. 786 of 14 June 2023).

5.2.1 APPROPRIATE ASSESSMENT

The Appropriate Assessment process (AA) is an assessment of the potential for adverse or negative effects of a plan or project, in combination with other plans or projects, on the conservation objectives of a Natura 2000 site and their conservation objectives. According to Article 6(3) and 6(4) of Directive (92/43/EEC), projects or plans that are likely to have significant effects on Natura 2000 sites must be subjected to an AA before a permit can be granted.

The precautionary principle plays a central role in administrating Natura 2000 sites. The principle implies, among other things, that if there is scientific doubt about harmful effects, i.e., that damage cannot be ruled out, this doubt must benefit the Natura 2000 site. Consideration for the protected sites must therefore be given the highest weight.

5.2.2 STAGE 1: SCREENING FOR APPROPRIATE ASSESSMENT

The first step in the AA process is that a screening for an AA is carried out for the designation basis for Natura 2000 sites near the survey area to determine whether the project individually, or in combination with other plans and projects is likely to have a significant effect on Natura 2000 sites.

The screening should demonstrate that the project activities, in view of the conservation objectives, will not lead to significant effect on the site (Danish Environmental Protection Agency, 2020).

The screening should be sufficient to support the competent authority in determining whether a project will adversely affect the integrity of the Natura 2000 site. The screening should use best scientific knowledge.

5.2.3 STAGE 2: APPROPRIATE ASSESSMENT

If potential significant impacts are considered likely, a complete AA should be undertaken where the conservation objectives for the Natura 2000 sites should be considered. The AA may involve additional calculations or collection of new data. Where it cannot be excluded that adverse effects may occur, mitigating measures should be considered.

If significant effects cannot be mitigated, permission to the project cannot be granted unless proceeding to alternative solutions or imperative reasons of overriding public interest (IROPI).

5.2.4 CONSERVATION OBJECTIVES

The overall conservation objective for the Natura 2000 sites is to maintain a "favourable conservation status" for habitat types and species that the site has been designated to protect (the designation basis).

According to the Habitats Directive, the following criteria must be met to achieve favourable conservation status:

- Habitat types cannot decline in spatial extend – the natural range of areas and the spaces the habitat type covers within the area must be stable or increasing in spatial extent.
- The structures and functions necessary to obtain the nature types must be continuously present.

5.3 PROTECTION OF MARINE MAMMALS

Whale (cetacean) species are listed on Annexes II and IV of the EU Habitats Directive (92/43/EEC) and are covered by the EU's Marine Strategy Framework Directive, where reports must be made and evaluated under the directive's Descriptor 1 regarding distribution, number, and bycatch. Furthermore, they appear on Annex II of the Bern Convention, Annex II of the Bonn Convention and Annex II of the Convention on the International Trade in Endangered Species (CITES) and small cetaceans are covered by the 'Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas' (ASCOBANS under the Bonn Convention). All large whales are under the remit of the International Whaling Commission (IWC), which protects and manages whales and whaling. All species relevant to the present project are assessed as having a favourable conservation status according to the habitat directive and all species are on the IUCN red list as not threatened[1], i.e., Least Concern (LC).

Seals (pinnipeds) species are on Annexes II and V of the EU Habitats Directive (92/43/EEC) and are also covered under the EU's Marine Strategy Directive, where distribution, numbers and bycatch must be reported and evaluated under the directive's Descriptor 1. They are listed on Annex II of the Bern Convention (19th September 1979), Annex II of the Bonn Convention and Annex II for the Convention on the International Trade in Endangered Species (CITES). Furthermore, Denmark has acceded to a trilateral agreement under the Conservation of Migratory Species of Wild Animals, which was introduced to protect seals in the Wadden Sea.

The grey seal is assessed as vulnerable (VU) on the IUCN red list in Denmark, and this is a non-favourable status according to the Habitats Directive. The harbour seal is assessed as not threatened (LC) and as having a favourable conservation status according to the Habitats Directive.

The recommendations regarding which species to include in assessments follows Tougaard et al. (2021).

5.4 HABITAT DIRECTIVE ANNEX IV SPECIES

All cetacean species are listed on Annex IV of the EU Habitats Directive (see also section 5.3). The Habitats Directive requires that the member states must introduce strict protection for certain animal species covered by the Habitats Directive's Article 12 and Annex IV, regardless of whether these occur within or outside a Natura 2000 site. The Habitat Directive is implemented for offshore activities through the Offshore Habitat Order (Executive Order no. 786 of 14 June 2023).

Harbour porpoise is the only resident Annex IV species relevant to the present project. White-beaked dolphin and minke whales are also included in the assessment, as they occur regularly in the open part of the North Sea.

According to the Offshore Habitat Order, it should be assessed if the activity will:

1. Intentionally disturb Annex IV species in their natural range, during periods when the animals breed, overwinter or migrate, with damaging impact on the species or the population.
2. Damage or destroy breeding or resting areas in the natural range of Annex IV species.

5.5 MARINE STRATEGY FRAMEWORK DIRECTIVE (MSFD)

The EU has a marine strategy that aims to maintain or establish a 'Good Environmental Status' (GES) in all European marine areas by 2020. This strategy is set forth in the Directive of the European Parliament and by the Council of 17 June 2008 on establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). The directive is implemented in Danish legislation through the Marine Strategy Act (Consolidation Act no. 123 of 01/02/2024. The Marine Strategy Act sets environmental goals and action plans to achieve or maintain good environmental status in the marine ecosystems. It follows of the Marine Strategy Act §18

[1] A threatened species is any species which is vulnerable, endangered, or critically endangered.

that public authorities are bound to the environmental goals of the marine strategy and the action plan. The application for marine surveys should include a description and an assessment of the potential impact on the environmental goals and the potential impact on monitoring stations under the national monitoring program (NOVANA).

The Danish Ministry of Environment defines what is regarded as 'Good Environmental Status' of the marine environment using 11 descriptors. A set of qualitative environmental targets and preliminary indicators are set for each descriptor. The 11 descriptors are listed below:

› D1 Biodiversity
› D2 Non-indigenous species
› D3 Commercially exploited fish stocks
› D4 Marine food webs
› D5 Eutrophication
› D6 Sea floor integrity
› D7 Alteration of hydrographical conditions
› D8 Contaminants
› D9 Contaminants in fish and other seafood for human consumption
› D10 Marine litter
› D11 Underwater noise

Thresholds are only defined for the descriptors D8 Contaminants and D11 Underwater noise. The remaining targets are defined as trends that describe a positive development or descriptive target. Several indicators regarding descriptor D1 Biodiversity are linked to the goals and objectives of Natura 2000 sites.

OSPAR (Oslo and Paris Convention) is currently working on a common framework of indicators and assessment values to be used in the Northeast Atlantic. In this environmental assessment, a draft version of the list of indicators has been used to assess the impact of the seismic survey on the objectives of the Marine Strategy Act.

6 PROJECT DESCRIPTION

The proposed Dagny CCS site survey will be conducted around the TEPDK well P11 over an area of 3.8 km x 3.8 km (14.4 km^2) located within a greater working area of 6.5 km x 6.5 km (42.3 km^2). The survey area lies approximately 195 km from the nearest coastline (the Danish coast) and 23 km from the nearest median line (the Norwegian EEZ). Two-dimensional high-resolution (2DHR) and ultra-high-resolution (UHR) seismic data will be acquired over the site survey area using a 160 cubic inch (cu.in.) airgun array and 24 cu.in. airgun array, respectively. Data will also be acquired using a sub-bottom profiler (SBP), multi-beam echosounder (MBES), and side-scan sonar (SSS). Figure 6-1 gives an overview of the survey area location (see Genesis 2024 for more details on equipment).

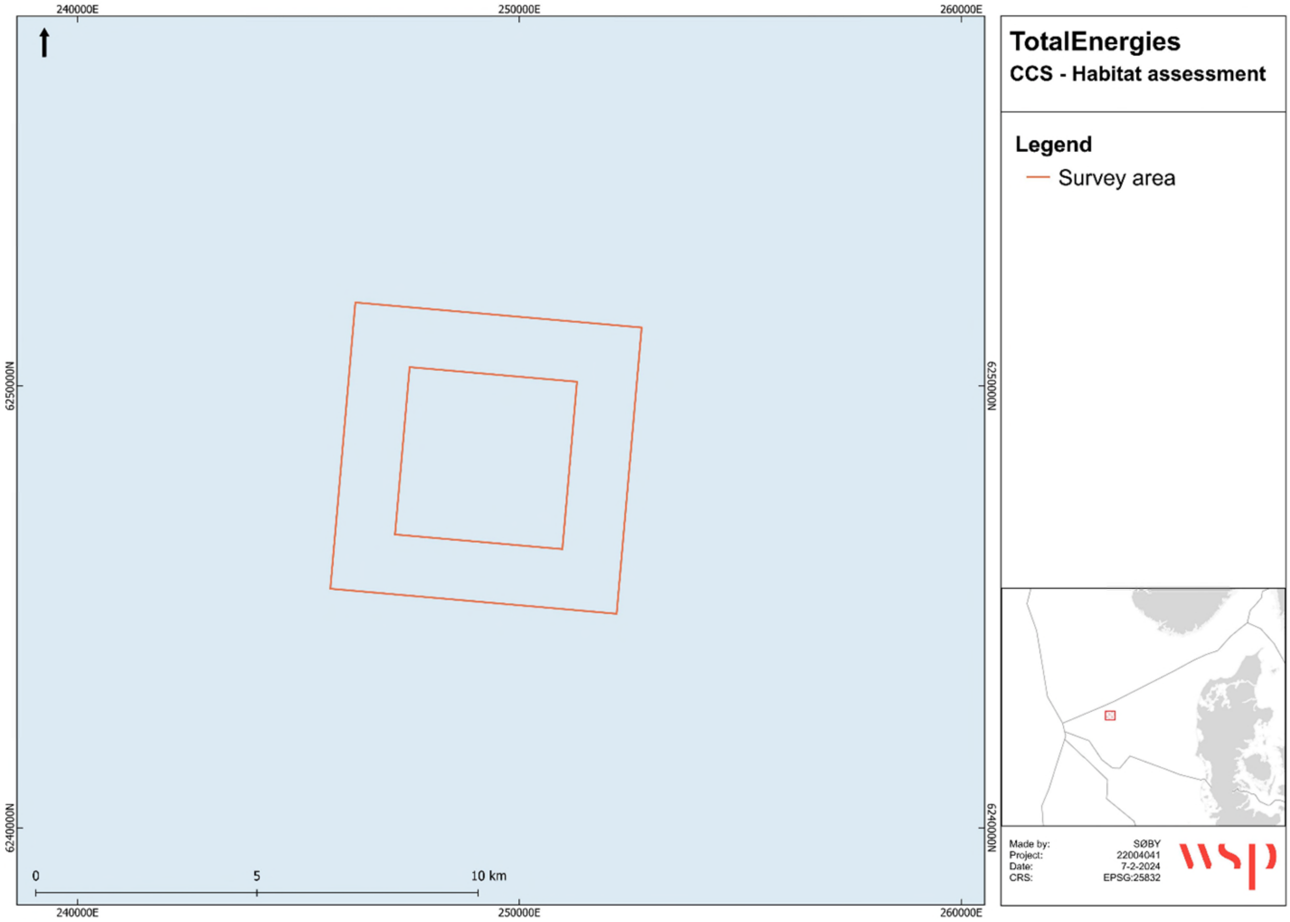

Figure 6-1 Overview of the proposed options for the Dagny CCS survey. The figure includes proposed survey area and the greater working area.

6.1 SURVEY PERIOD AND LENGTH

The Dagny CCS site survey is expected to be completed within a maximum of 45 working days (including downtime) with a total of 24 days airgun use. The survey will be conducted between March and October 2024 depending on vessel availability and weather conditions.

6.2 SURVEY EQUIPMENT

6.2.1 AIRGUN ARRAYS

The site survey will acquire 2DHR seismic data using a 160 cu.in. airgun array comprising four TI Sleeve airguns and UHR seismic data using a 24 cu.in. airgun array comprising two Mini-G-Gun airguns. Parameters for the airgun arrays used during the survey are summarised in Table 6-1. Further details of the airgun arrays are provided in the underwater noise modelling report by Genesis (2024) (Appendix 1).

Table 6-1 Properties of the airgun arrays that will be used during the Dagny CCS site survey.

<table>
<tr><th colspan="2">Parameters</th><th>160 cu.in. airgun Array (2DHR survey)</th><th>24 cu.in. airgun array (UHR survey)</th></tr>
<tr><td colspan="2">Source</td><td>Airgun array comprising four TI Sleeve airguns</td><td>Airgun array comprising two Mini-G-Gun airguns</td></tr>
<tr><td colspan="2">Dimensions</td><td>160</td><td>24</td></tr>
<tr><td rowspan="3">Source levels (single pulse)[1]</td><td>Zero-to-peak SPL (dB re 1 µPa-m)</td><td>245.5</td><td>239.6</td></tr>
<tr><td>Rms SPL 2
(dB re 1 µPa m)</td><td>222.3</td><td>216.3</td></tr>
<tr><td>SEL (dB re 1 µPa²s-m)</td><td>213.2</td><td>207.3</td></tr>
<tr><td colspan="2">Peak frequency (Hz)</td><td>c. 10</td><td>c. 12</td></tr>
<tr><td colspan="2">Tow depth (m)</td><td>3</td><td>1</td></tr>
<tr><td colspan="2">Tow speed (knots)</td><td>4</td><td>4</td></tr>
<tr><td colspan="2">Shoot point interval (m)</td><td>6.25</td><td>3.125</td></tr>
<tr><td colspan="4">[1] Source levels for single pulses have been computed using Gundalf airgun array modelling software (Oakwood Computing, 2023) over a frequency range of 0 Hz to 50 kHz. The source levels quoted here are unweighted i.e., do not include any frequency weighting.
[2] The rms SPL source level has been calculated over a 125 ms time window.</td></tr>
</table>

6.2.2 SUB-BOTTOM PROFILER (SBP)

SBP data will be acquired during the Dagny CCS site survey. The SBP source that will be used is the EdgeTech 3300 hull-mounted CHIRP (Compressed High-Intensity Radar Pulse) system (EdgeTech, 2017). This SBP comes in different configurations and many of the properties (such as signal type, frequency range, pulse length, duty cycle) are variable or user selected (EdgeTech, 2017). During the Dagny survey, the SBP will generate frequency modulated CHIRP signals sweeping from 3 kHz to 7 kHz. Source levels and other properties of the SBP are summarised in Table 6-2. Further details of the SBP are provided in the underwater noise modelling report by Genesis (2024) (Appendix 1).

Table 6-2 Properties of the SBP that will be used during the Dagny CCS site survey.

Parameters		Value
Source		EdgeTech 3300 7 transducer hull-mounted CHIRP SBP
Source levels	Zero-to-peak SPL (dB re 1 µPa-m)	212.0
	Rms SPL (dB re 1 µPa-m)	209.0
	SEL (dB re 1 µPa^{2}s-m)	199.0
Frequency range (kHz) [1]		3-7
Tow depth		Hull-mounted
Tow speed (knots)		4
Pulse length (ms)		20
Duty cycle		0.1
Pulse rate		5 Hz
Beam width		3 dB beamwidth: 16º 16 dB beamwidth: 29º

[1] **The majority of sound energy will be contained between 3 kHz and 7 kHz. However, sound energy will also be produced outside of this range.**

6.2.3 MULTI-BEAM ECHOSOUNDER (MBES) AND SIDE-SCAN SONAR (SSS)

MBES and SSS data will be acquired during the Dagny CCS site survey. MBES and SSS operate at very high frequencies (Above 200 kHz). The sound generated by MBESs and SSSs is typically outside the main hearing ranges of marine mammals and well outside the hearing ranges of fish species. Furthermore, these devices are highly directional and therefore have a small acoustic footprint (Tougaard, 2016; Pace, Robinson, Lumsden, & Martin, 2021; Crocker & Fratantonio, 2016; Crocker S. , et al., 2018).

SSS can be operated in conjunction with an ultra-short baseline (USBL) high-precision positioning system. The USBL is an omnidirectional source. The addition of a USBL positioning system can cause the impact range of SSS to be greater than the impact range of SBP (Pace *et al.*, 2021). However, even with the use of USBL, the SSS will generate lower sound levels than the airgun arrays (Genesis (2024)).

For further details see Genesis (2024) (Appendix 1).

6.3 BEST PRACTICE MEASURES

To minimise the risk of potential impacts of sound from the seismic survey, the following standard terms recommended by the Danish Environmental Agency Strategic Environmental Assessment (Danish Energy Agency, 2018) and the JNCC (2017) 'Guidelines for minimising the risk of injury to marine mammals from geophysical survey' are used:

1. The airguns used will be no more powerful than necessary to conduct the survey.
2. The airguns will not be used outside the lines, except in the soft-start procedure immediately prior to arrival of the vessel in the survey area and in connection with short transit lines and for the strictly necessary testing of equipment. The soft-start procedure will be followed during the testing of any equipment.
3. Two properly qualified, trained and equipped marine mammal observers (MMOs) will be deployed onboard the seismic survey vessel.
4. The MMOs will carry out a 30-minute pre-data acquisition survey of the 500 safety zone and, if a marine mammal is detected, the soft-start of the seismic sources will be delayed for at least 20 minutes following the last sighting.
5. A soft-start activation of the airgun array will be employed over a period of 40 minutes (NB: TEPDK will employ a 45-minute soft-start for this project after specific calculations based on modelling results). This will allow any marine mammal to move away from the sound source and reduce the likelihood of exposure to sounds that could potentially cause injury. A soft start will be employed whenever the airgun array is used.
6. The equipment will be shut down when the transit time between lines exceeds 20 minutes. Before the next line is commenced, the equipment will be started up again slowly, following the soft start procedure. If the transit time is less than 20 minutes, the equipment will remain on, although only at reduced power.
7. If the airgun array has been inactive for a period of 10 minutes, the MMO will perform a visual inspection of the 500 m safety zone. If a mammal is detected within the 500 m safety zone, the start of the seismic sources will be delayed for at least 20 minutes following last sighting; and
8. Passive Acoustic Monitoring (PAM) will be operated during the pre-data acquisition survey, during the soft-start procedure and during seismic acquisition in association with the MMOs to detect marine mammal presence.

TEPDK integrates these measures into project planning as Best Environmental Practice (BEP) and implements them as standard best-practice in accordance with DEA guidelines.

A soft-start period of 45 minutes will allow harbour porpoises, white beaked dolphin and minke whales to swim approximately 4 km assuming a flee speed of 1.5 m/s. Adding the 500 m safety zone and the speed of the vessel which is 2.2 m/s will allow the harbour porpoises, white beaked dolphin and minke whales to swim 7.4-10.5 km from the vessel in 40 minutes, assuming a starting position of the animal at 500 meters distance and variable angles to the survey vessel (see more in section 8.1.4).

It is expected that marine mammals would swim away from the airgun array quickly if the sound generated is causing them distress. The chosen speed of 1.5 m/s is based on Tougaard (2021).

7 IMPACT ASSESMENT METHOD

This chapter describes the sources of data and the methodological approach to the impact assessment.

7.1 DATA SOURCES FOR THE IMPACT ASSESMENT

The assessment of potential impacts is based on the following sources:

- Description of the Dagny CCS site survey (see chapter 6 -Project description)
- Identification of species present (see section 8.1.2, 8.1.3 and 8.2.2)
- Results of underwater noise modelling (Appendix 1)
- Official guidelines (cited in the text)
- Scientific literature (cited in the text)

7.1.1 CRITERIA FOR THE IMPACT ASSESSMENT

The assessment criteria for assessment of the environmental significance used in the present report is based on the character, the magnitude, the extent, the level of complexity and the reversibility of the environmental impact. The criteria for the assessment are listed in Table 7-1.

Table 7-1 **Criteria for assessment of nature, magnitude, extend, level of complexity, duration, and reversibility.**

CRITERION	
Character	*The character of the environmental change*
Positive	Beneficial environmental change
Negative	Adverse environmental change
Magnitude	*The magnitude of the impact*
None/negligible	Very little change in structure/ function of the receptor from baseline conditions. Change barely distinguishable, approximating to a "no change" situation.
Small (low)	Minor shift away from baseline conditions in the structure/function of the receptor.
Medium	Loss or alteration to one or more key structure/functions of the receptor from the baseline conditions.
Large (high)	Major alteration in structure/function of the receptor from baseline conditions.
Extent	*The geographical area that is affected*
Local	Local impacts are limited to the area close to the seismic survey vessel, the airgun arrays, and the immediate vicinity.
Regional	Regional extent further away from the project area. Regional extent also includes local, short and fully reversible impacts in international waters if the extent is also defined as local to regional in Danish waters.
National	Impacts within the Danish EEZ
Cross border	Transboundary impacts
Level of complexity	*The intensity and complexity of the impact*
None/negligible Small (low) Medium Large (high)	A major impact implies that an important environmental function is lost. The complexity is included by assessing impacts of entire systems, e.g., a food web, which is weighted higher than the impacts of a single species. There are both direct and indirect impacts, which can increase complexity. In the case of direct impact, the source can affect the recipient directly, while indirect influence occurs when an intermediary is affected, after which the influence passes on to the recipient.
Duration	*The time that an impact will occur but will depend on the specific receptor assessed.*
Short	Short-term impacts stop when the activity in question ceases within 3 months
Medium	Impacts last from 3 months-1 year
Long	Long-term impacts are >1 years
Reversibility	*The reversibility of the impact*
Short Medium Long	Reversibility is closely linked to the duration of the impact. Classification of an impact as *short* or *medium-term* requires that the environmental state returns to the starting point after the end of the impact (full reversibility), while fully or partially irreversible impacts will always be classified as *long-term*. Longer-lasting impacts should thus be further characterized according to their reversibility. However, the existing knowledge of the ecological system or physical conditions is not always sufficient for this to be possible.

The probability that an impact will occur will be assessed using the criteria shown in Table 7-2.

Table 7-2 Criteria for assessment of the probability of that an impact will occur.

PROBABILITY OF IMPACT ON THE RECEPTOR	*DEGREE OF POSSIBILITY OF IMPACT OCCURRENCE*
None	Not likely that an impact will occur
Very low	The possibility of occurrence is very low, either due to the project design or due to the project nature, or due to the characteristics of the project area
Low	The possibility of occurrence is low, either due to the project design or due to the project nature, or due to the characteristics of the project area
Medium	There is possibility of impact occurrence
High	Possibility of impact occurrence is almost certain
Definite	There is a certainty that the impact will occur

The overall significance is determined from the character, magnitude, extent, level of complexity, duration, the reversibility, and the probability. The criteria for the assessment of the overall significance are defined in Table 7-3.

Mitigating measures are suggested if the overall significance is assessed as moderate or major, despite that moderate is an insignificant impact on the environmental receptor.

Table 7-3 **Criteria for assessment of overall significance. The table shows the principle of the classification, but not all possible combinations of the magnitude, extent, level and complexity, duration, and probability is included. Negligible, minor and moderate impact are considered non-significant impacts.**

Overall significance	Impacts on the environmental receptors
Positive	Positive impact on the structure or function of the receptor.
No impact	The assessed ecological or socioeconomic feature or issue is not affected.
Negligible (non-significant)	1) No measurable impact on the structure or function of the receptor; or 2) Low impact on the structure and function of the receptor, with local extent, short-term duration.
Minor (non-significant)	1) Low impact on the structure or function of the receptor, with any combination of other criteria (except for local extent and short-term duration (*Negligible*), and long-term duration and national or international extent (*Moderate*)); or 2) Medium impact on the structure or function of the receptor, with local extent and short-term duration. The function of the impacted receptor restores to pre-impact status through natural recovery, or 3) High impact on the structure or function of the receptor, with local extent, short-term duration and medium/low/very low probability. The function of the impacted receptor restores to pre-impact status through natural recovery or some degree of intervention.
Moderate (non-significant)	1) There is low impact on the structure or function of the receptor, with national or international extent and long-term duration, or 2) There is medium impact on the structure or function of the receptor, with any combination of other criteria (except for local extent and short-term duration; and national extent and long-term duration), or 3) When the activity ceases, the impacted area naturally restores to pre-impact status, or 4) There is a high impact on the structure or function of the receptor, with local extent and short-term duration and high/very high probability. The function of the impacted receptor restores to pre-impact status through natural recovery or some degree of intervention, or 5) There is a medium or high impact on the structure or function of the receptor, with any combination of other criteria (except for local extent, short-term, definite/high/medium probability). The receptor cannot restore to pre-impacted status without intervention if the probability is low or very low.
Major (significant)	1) There is a medium impact on the structure or function of the receptor, with national or international extent and long-term duration. The receptor cannot restore to pre-impacted status without intervention. The probability that the impact will occur is medium, high or definite, or 2) There is a high impact on the structure or function of the receptor, with any combination of other criteria (except for local extent, short-term duration and medium, low or very low probability). The receptor cannot restore to pre-impacted status without intervention. The probability that the impact will occur is medium, high or definite.

7.1.2 APPROPRIATE ASSESSMENT

The screening and the complete Appropriate Assessment (AA) use the same assessment methodology as for other environmental receptors as described in Section 7.1.1. The AA screening (chapter 9) and the full AA (chapter 10) involves the following:

- Identification of relevant Natura 2000 sites (SAC/SCI) and compilation of the designation basis
- Assessment of likely effects (direct, indirect, and cumulative)
- Summary statement with conclusions.

The assessment of the overall significance of an impact is closely linked to the assessment of the need for mitigation measures. In the case of significant impacts, it may be necessary to implement measures to avoid, reduce or neutralize the harmful impacts on the environment. These measures will typically be attached to the later permit as conditions.

DEFINITION OF SIGNIFICANT IMPACT

The EU Court of Judgement has ruled that a small, but permanent and irreversible reduction of a prioritised habitat type can constitute a significant impact, and thus be considered as damage to the integrity of a Natura 2000 site.

On the other hand, it must be assumed that an impact is not significant, if:

- the impact is estimated to involve negative fluctuations in population sizes that are smaller than the natural fluctuations considered to be normal for the species or habitat type,
- it is assessed that the protected habitat type or species is deemed to quickly recover without human intervention. The probability that the impact will occur is medium, high or definite.

7.2 POTENTIAL IMPACTS

Table 7-1 provides an overview of the equipment that will be used during the seismic survey. The table also indicates whether the equipment is relevant for the impact assessments. The reasoning for excluding or including the equipment is provided in section 7.2.2 potential impacts from seismic survey.

Table 7-1 Overview of the equipment being deployed for the site survey and potential impact on the environment. Relevance of the equipment used is based on (Genesis, 2024).

Equipment	Potential impact	Relevance
Airgun arrays (2DHR/2DUHR))	2DHR and 2DUHR transmit underwater noise	Yes
SBP	SBP transmit underwater noise	No
MBES	MBES transmit underwater noise	No
SSS	SSS transmit underwater noise	No

7.2.1 POTENTIAL IMPACTS FROM SURVEY VESSELS

Survey vessels may also produce underwater noise from propellers and thrusters causing cavitation around the blades whilst moving or operating thrusters under load to maintain a vessel’s position. The noise produced is typically broadband noise, with some low tonal peaks. Additionally, vessel noise is not impulsive noise, as produced by the seismic airgun arrays. Vessel noise from the survey vessels is typical for the shipping that traverses the Danish EEZ including the survey area and is unlikely to have a significant impact on marine animals. Therefore, underwater noise from survey vessels is not assessed further.

7.2.2 POTENTIAL IMPACTS FROM SEISMIC SURVEY

The SBP will generate lower sound levels than the airgun arrays (Genesis, 2024) and the MBES, SBES and SSS operate at very high frequencies and the sound generated by this equipment is typically outside the main hearing ranges of marine mammals and well outside the hearing ranges of fish species. Furthermore, these devices are highly directional and therefore have a small acoustic footprint (Crocker & Fratantonio, 2016; Crocker S. , et al., 2018). Two airguns which will be used are a 160 cu.in airgun array comprising four TI Sleeve airguns and a 24 cu.in. airgun array comprising two Mini-G-Gun airguns. It is observed from the Gundalf modelling results that the 160 cu.in. airgun array generates higher sound levels than the 24 cu.in. array, which is due to it comprising more individual airguns and having a larger overall volume (Genesis, 2024). Thus, the 160 cu.in. airgun array that will be used during the Dagny CCS site survey will have the largest impact on marine mammals. The noise modelling for the site survey therefore focuses on predicting impacts from this source.

Potential impacts are divided into three categories:

- Increased underwater noise (direct impact due to underwater noise from seismic survey airgun arrays)
- Temporary habitat loss (indirect impact caused by displacement of receptor from habitat)
- Temporary reduced food supply (indirect impact due to displacement of receptors prey).

The impact assessment is conducted in section 8.1 for marine mammals and in section 8.2 for fish, fish egg and fish larvae.

8 IMPACT ASSESSMENT

8.1 MARINE MAMMALS

This chapter includes the following sections: method, existing conditions for relevant marine mammal species, summary of seasonal sensitivity, impact assessment of underwater noise for the relevant marine mammal species.

8.1.1 METHOD

Relevant marine mammal species and their occurrence is described based on existing data and scientific literature. The assessments are furthermore based on existing knowledge about the animals' injury and behavioural thresholds for underwater noise.

The assessment of impact distances for relevant marine mammal species is based on a targeted noise modeling for the seismic survey for March and August, including 40 min soft-start period (Genesis, 2024). The impact has been modelled for two locations (3.8 km x 3.8 km) centered around the wells P2 and P3 (Figure 8-1). Since the model was undertaken, the survey area has been changed to be centered around the well P11 which is located slightly more Northerly than the P2 and P3 wells. The performed modelling is considered to provide representative results for the new survey location (Appendix 2). In cases where the model results are different for the two areas, the largest effect distances (worst case) have been used for the assessments. The method and results for the performed noise model (Genesis, 2024) are specified in Appendix 1.

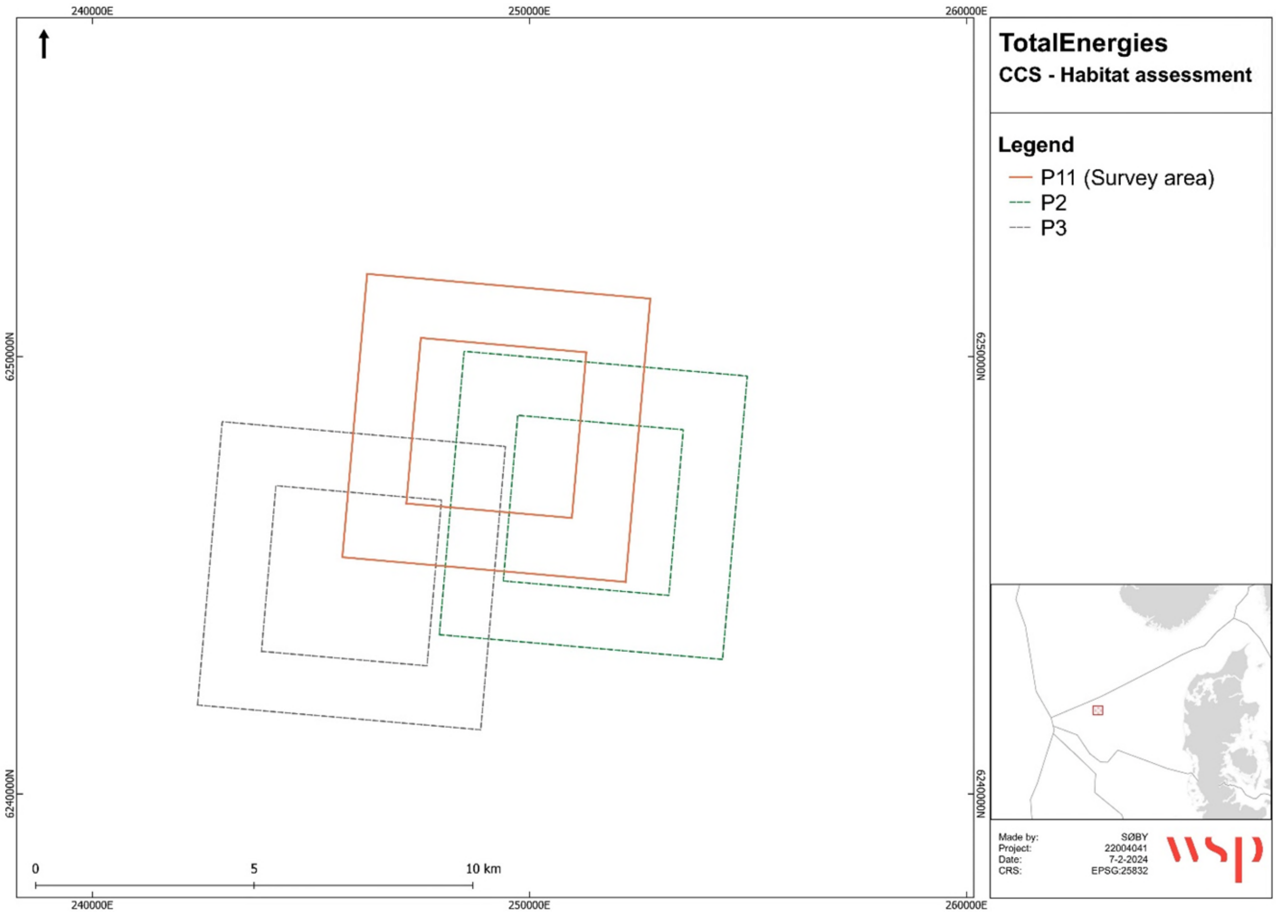

Figure 8-1 Location of the survey area and greater working area for P11 and the two areas for which the underwater noise model was undertaken (P2 and P3).

The assessment of the possible impacts on marine mammals follows Danish Energy Agency's guidelines for underwater noise (DEA, 2022) as well as other relevant guidelines (Tougaard, 2016; Thompson, et al., 2013; Lucke, Siebert, Lepper, & Blanchet, 2009; NMFS , 2018; BUM, 2014), adapted to the most recent knowledge and a recent assessment report from DCE (Aarhus University) of a larger geophysical survey in the North Sea (Kyhn, et al., 2021).

The site survey is expected to be completed within a maximum of 45 working days, including any downtime (21 days), between March and October 2024 depending on vessel availability (section 6.2).

The assessments are based on an impact period of 45 days between March and October 2024. The assessment considers the actual data acquisition duration and potential downtime as it can not be certain that the marine mammal manages to return to the area in the potential downtime periods. Based on available literature, it is likely that harbour porpoises will return to the area after the activities stop (Sarnocińska, et al., 2020). Thompson et al. (2013) observed that harbour porpoises, displaced by a seismic survey in the Moray Firth (airgun), returned to the survey area within one day after the survey finished where as monitoring around Danish oil and gas platforms, where harbour porpoises are sighted around the platform installations, observed that the animals returned to the area a few hours after a 3D seismic survey ended (SPE International, 2020). Thus, a short break in the seismic acquisition and airgun firing might not be sufficient for the animal to return to the area.

The expected time for the marine mammals to return to the area is based on available knowledge, which only includes harbour porpoises. Further, it is also expected that the harbour porpoise is the most sensitive of the marine mammal species in the area and is the species with the highest abundance in the area.

8.1.2 SCOPING OF SPECIES

CETACEANS

Many species of marine mammals have been registered in Danish waters. However, only a few occur regularly and thus are relevant to this project.

The Marine Ecosystems Research Program (MERP) has produced monthly distribution maps for cetaceans in the North-East Atlantic (Waggitt, et al., 2019). These distribution maps were generated from species distribution models using survey data taken between 1980 and 2018. The distribution maps produced by Waggitt et al. (2019) suggest that harbour porpoise (*Phocoena phoceana*) is the most abundant species in the region of the proposed seismic survey area. White-beaked dolphin (*Lagenorhynchus albirostris),* Atlantic white-sided dolphin *(Lagenorhynchus acutus),* common dolphin *(Delphinus delphis*), minke whale (*Balaenoptera acutorostrata*) and killer whale (*Orcinus orca*) may also be present in the region but will occur in lower numbers. Figure 8-1 shows the maximum yearly distribution of these species across the North Sea (Waggitt, et al., 2019).

The JNCC has compiled an Atlas of Cetacean Distribution in Northwest European Waters (Reid, Evans, & Northridge, 2003). Similar to Waggitt et al. (2019), the Reid et al. (2003) data show that harbour porpoise, white-beaked dolphin, common dolphin and minke whale have been sighted in the region of the proposed survey area in low to moderate numbers at different times throughout the year with harbour porpoise being the most sighted species.

Sightings around oil and gas installations in Danish waters reported by Delefosse et al*.* (2018) also indicate that harbour porpoise are the most sighted cetacean species in the region. Delefosse et al. (2018) also reported sightings of white-beaked dolphin, minke whale, killer whale and pilot whale (*Globicephala* spp.) near Danish oil and gas activities. However, only harbour porpoise, white-beaked dolphin and minke whale are encountered regularly in the western part of the Danish sector of the North Sea (Sveegaard, Nabe-Nielsen, & Teilmann, 2018; Reid, Evans, & Northridge, 2003; Hammond, et al., 2021).

The cetacean species included in this assessment are based on the recommendations by Tougaard et al. (2021) and include harbour porpoise, minke whale and white-beaked dolphin.

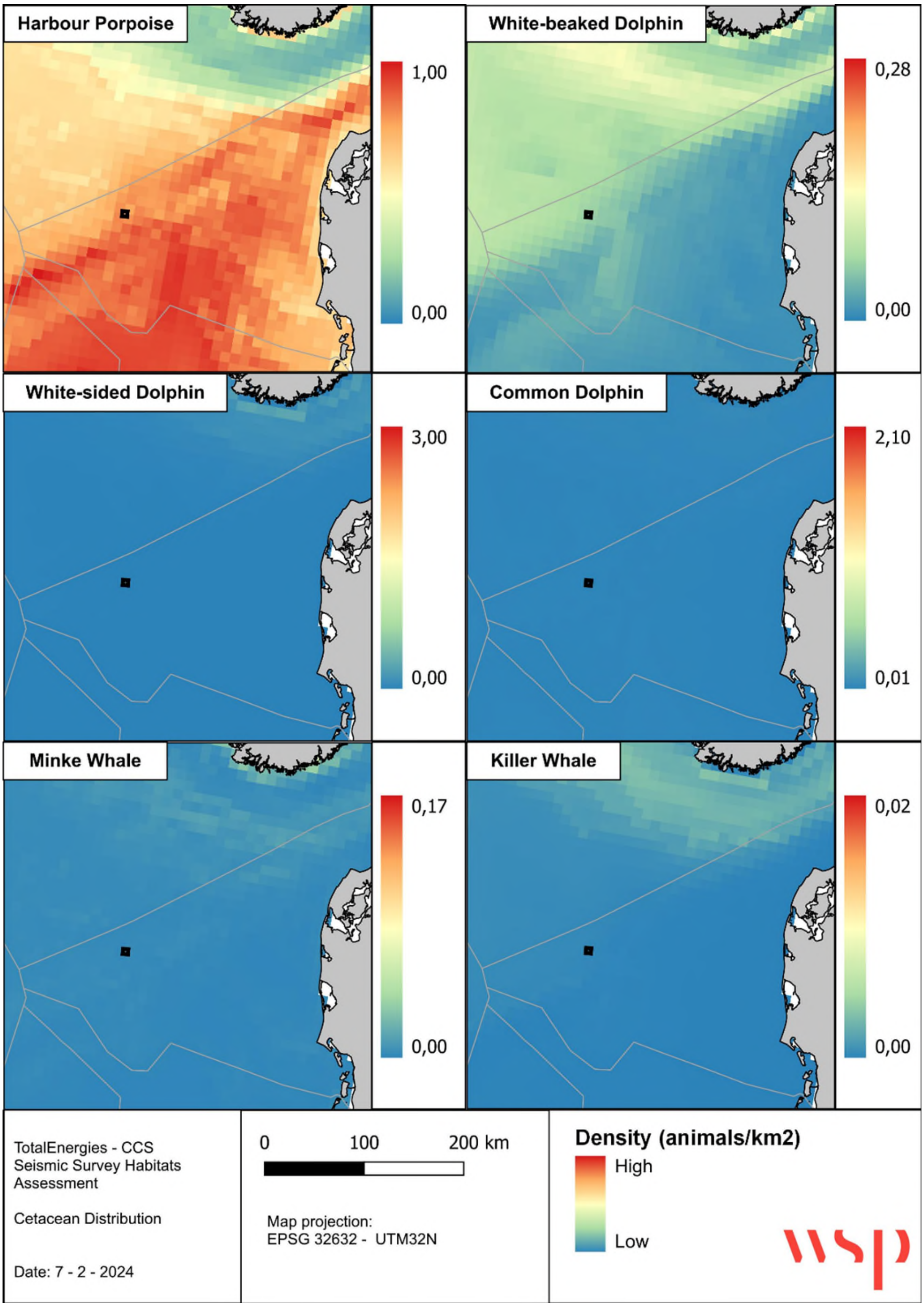

Figure 8-2 **Maximum yearly distribution of selected cetacean species in the North Sea. Densities are derived from a species distribution model based on collated data (Waggitt, et al., 2019). Survey area is marked with black. The maximum density month was chosen as the one with the highest density within the survey area and not in the entire North Sea. The month with the highest density within the survey area is not necessarily the same month as the month with the highest density in other parts of the north area or for other species. Note different density scales between species.**

PINNIPEDS

Harbour seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) are the only pinnipeds that occur in the North Sea. Seals are generally coastal, depending on isolated and undisturbed land areas for resting, breeding, and molting (such as undisturbed islands, islets sandy beaches, reefs, skerries and sandbanks). They may however undertake long foraging migrations and may occasionally occur in the survey area. The two seal species are included in the impact assessment.

8.1.3 EXISTING CONDITIONS

HARBOUR PORPOISE (PHOCOENA PHOCOENA)

Harbour porpoises are listed on the Habitat Directives Annex IV and are thus a strictly protected species regardless of whether it occurs inside or outside an international protected area (e.g., a Natura 2000 site). Porpoises are the most common and the only breeding whale in Danish waters. Based on studies of morphology, genetics and satellite tagging, porpoises in Danish waters are divided into three populations: 1) The Baltic Sea population – the waters around the island Bornholm and eastward into the Baltic Sea, 2) The Belt Sea population – the inner Danish waters (incl. the Baltic Sea, the Sound, southern Kattegat and western Baltic Sea) and 3) the North Sea population – northern Kattegat, Skagerrak and the North Sea (Hansen & Høgslund, 2023; Sveegaard, et al., 2015; Galatius, Kinze, & Teilmann, 2012; Wiemann, et al., 2010).

Porpoises occurring in and around the survey area are expected to be individuals from the North Sea population. The estimated size of the North Sea population (including the North Sea, Skagerrak, and northern Kattegat) is approximately 350,000 individuals from 1994-2016 (Hammond, et al., 2021). The latest knowledge on the movements of harbour porpoises in this area is provided by satellite-tracking of animals that were tagged after being accidently captured alive in fishermen's nets. The data provides position and dive data for individual porpoises via satellite for up to 1.5 years. Based on the aggregated movement patterns of the tagged animals, it does not appear that the survey area is an important area for the tagged porpoises. However, the marking sites are far from the seismic survey area, and data suggests, that tagged porpoises primarily move around near to the marking site. Since no animals were tagged close to study area, the extent to which the data is representative of the real use of the area by harbour porpoises is unclear (Kyhn, et al., 2021).

A series of Small Cetacean Abundance In the North Sea (SCANS) surveys have been conducted to obtain an estimate of cetacean densities in the North Sea and adjacent waters; the most recent which is SCANS-IV from 2022 (Gilles, et al., 2023). However, obtained estimates of cetacean densities from the SCANS -III in the North Sea in 2016 will also be included in the assessment, as the counting of harbour porpoises in the SCANS block covering the survey area in 2022 was lower than in 2016 (Hammond, et al., 2021). The lower estimates of harbour porpoise densities in 2022 compared to the estimates of harbour porpoise densities in 2016 is not at expression of a general decline in the North Sea population (Gilles, et al., 2023).

Naming of the SCANS block has changed from 2021 to 2023. However, the boundaries of the blocks are the same. In the following we only refer to the latest names of the SCANS blocks (Gilles, et al., 2023) even though we also present the result for the counting's in the North Sea from 2016 (Hammond, et al., 2021).

The survey area is located in the SCANS Block NS-J (see Figure 8-2).

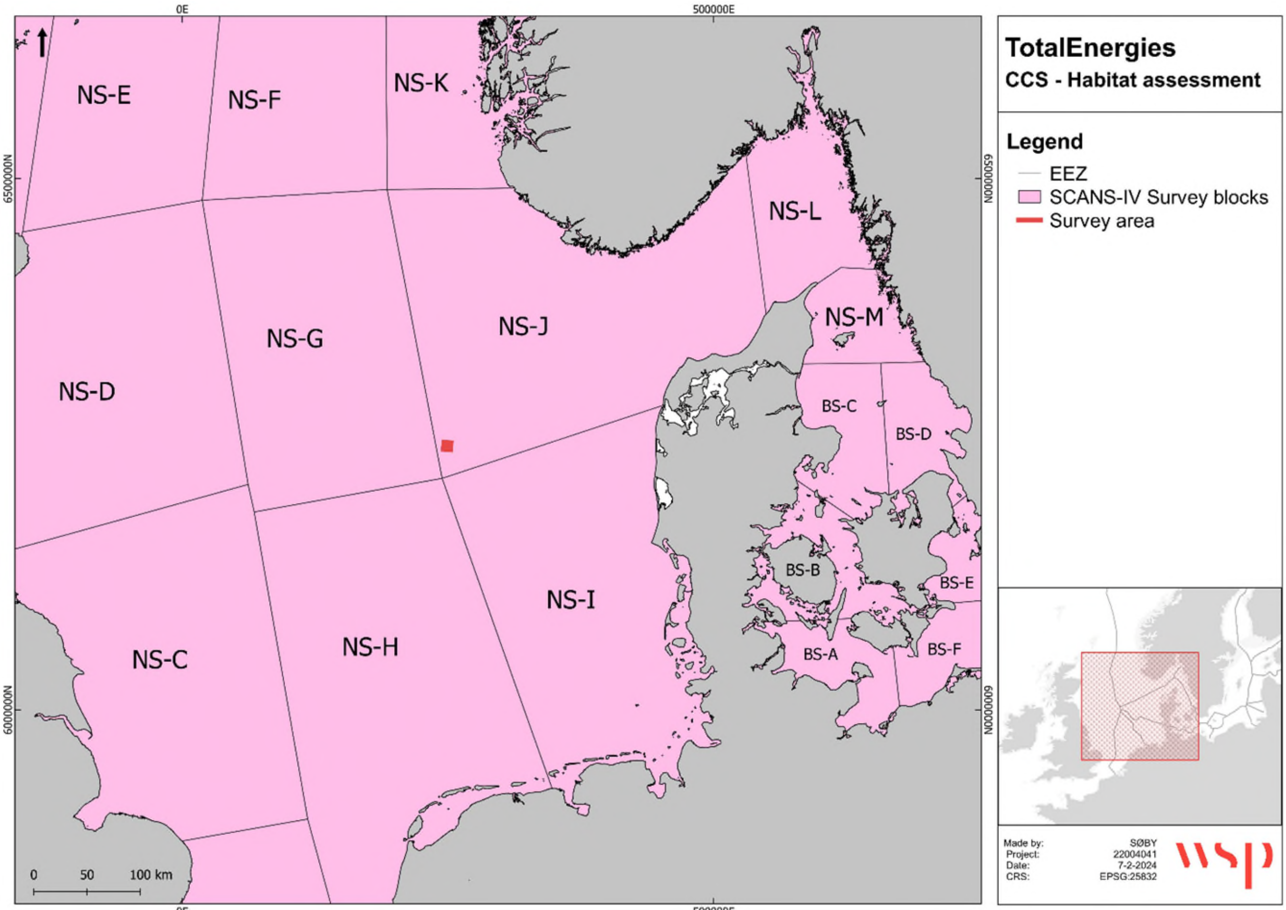

Figure 8-3 Location of the SCANS Survey Blocks and the combined site survey area (modified by (Gilles, et al., 2023)).

During both the SCANS-III and SCANS-IV surveys all three relevant species of cetacean (Tougaard, Sveegaard, & Galatius, 2021) were sighted in SCANS Blocks NS-J N. Table 8-1 shows the estimated densities of these species from the SCANS-III survey in 2016 (Hammond, et al., 2021) and the SCANS IV in 2022 (Gilles, et al., 2023). Even through there have been an almost halving in the estimates of harbour porpoise from 2016 to 2022 this decrease is not significant and the overall North Sea population seems to be stable (Figure 8-3)

.

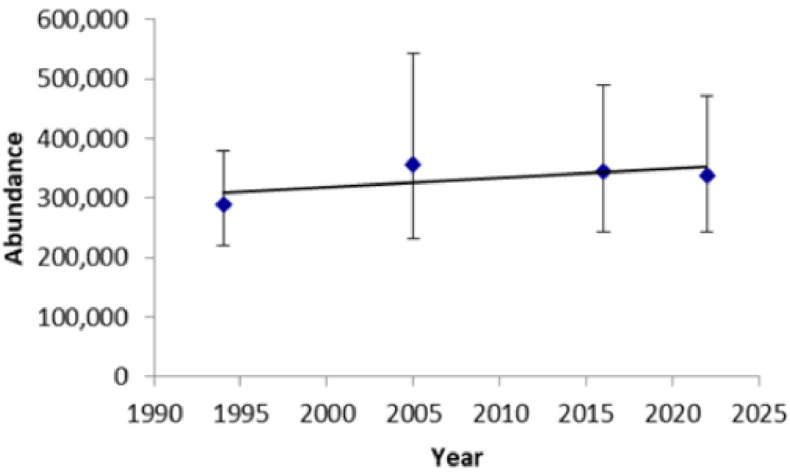

Figure 8-4 Trend lines fitted to time series of four abundance estimates for Harbour porpoise in the North Sea (Gilles, et al., 2023)).

Data on cetaceans have been collected for many years in the North Sea than the results presented in Table 8-1. Table 8-2 presents the maximum yearly distribution of selected cetacean species, modelled specifically for the survey area based on a species distribution model that is based on available standardised data collected between 1980 and 2018 (Waggitt, et al., 2019) – same data as illustrated on Figure 8-1 (Data from August was chosen as it generally was the month with the highest density of animals).

The data from Hammond et al (2021) is also included in the species distribution model by Waggitt et al. (2019). The estimated density for the specific survey area is based on the model data from Waggitt et al. (2019) applying the layout for the survey area (see table Table 8-1 and Table 8-2).

Table 8-1 Cetacean densities in SCANS-III and SCANS-IV Survey Blocks (NS-J) (Gilles, et al., 2023; Hammond, et al., 2021).

Year (data collection)	**Species**	**Density [animals/km^2], (coefficient of variation)**
2016 (SCANS-III)	Harbour porpoise	0.823 (0.315)
	White Beaked Dolphin	0.030 (0.385)
	Minke whale	0.0096 (0.657)
2022 (SCANS IV)	Harbour porpoise	0.473 (0.263)
	White Beaked Dolphin	0.0622 (0.572)
	Minke whale	0.0100 (0.632)

Table 8-2 Cetacean maximum densities (August) given as average and upper and lower densities based on the results of a species distribution model (Waggitt, et al., 2019). The Dagny site survey area is included in the area where data has been drawn form.

Area	**Species**	**Estimated densities (animals/km^2) (based on collated and standardised data from 1980-2018)** **Average [animals/km^2] (lower-upper estimates)**
Survey Block NS-J	Harbour porpoise	0.5002 (0.0607 – 0.9236)
	White-beaked dolphin	0.0695 (0.0088 – 0.1555)
	Minke whale	0.0083 (0.0020 – 0.0655)
Dagny CCS site survey area	Harbour porpoise	0.7884 (0.7562 – 0.8127)
	White-beaked dolphin	0.0622 (0.0589 – 0.0643)
	Minke whale	0.0043 (0.0037 – 0.0049)

Harbour porpoise calves are entirely reliant on their mother for the first 10 months of life, while nursed and learning to fend for themselves (Teilmann, Larsen, & Desportes, 2007; Lockyer, 2003). Harbour porpoises are therefore sensitive to disturbances which can lead to mother-calf separation. In the North Sea, the calving season is from April to September, with most new-borns occurring in June and July (Sonntag, Benke, Hiby, Lick, & Adelung, 1999). The vulnerable period therefore covers the whole year for North Sea porpoises.

Sarnocińska et al. (2020) studied the harbour porpoise reaction to a 3D seismic airgun survey in the North Sea. The study found that decreased counts of echolocation signals were detected 8-12 km from the active airgun. This may indicate temporary displacement of porpoises or a change in porpoise echolocation behaviour. The study furthermore indicates that underwater noise has the potential to temporarily affect foraging efficiency and social communication in porpoises. By comparing the porpoise activity within the survey area with the activity at reference stations placed 15 km from the survey area, Sarnocińska et al. (2020) found that porpoises used the general seismic survey area to a similar degree at any time as the reference stations. This suggests that there were no long-term and large-scale displacements of porpoises during the 103 days of seismic shooting. However, it is not known whether it was the same animals that remained in the area during the survey or displaced animals were continuously replaced by new animals moving into the area during the seismic survey.

Thompson et al. (2013) observed that harbour porpoise, displaced by a seismic survey (airgun) in the Moray Firth, returned to the survey area within one day after the survey finished. Another study, monitoring around Danish oil and gas platforms, sighted harbour porpoises around the platform installations few hours after a 3D seismic survey had ended (SPE International, 2020).

Disturbed animals will in general have less time available for foraging, communicating, resting or any other behaviour they were engaged in when they were disturbed. A few disturbance events are likely insignificant to the energetic status of a porpoise, but these disturbances may have fitness consequences if repeated frequently. The magnitude of these effects on the population level are unknown at present. This is due to the lack of data available which makes it impossible to track the energy expenditure and intake of individuals with sufficient precision that could be translated directly into impact by the disturbance on the fitness of individuals (Sarnocińska, et al., 2020).

The approximate swimming speed for harbour porpoises has been measured to approximately 5.3 km/h (1.5 m/s) for wild harbour porpoises (Tougaard, Sveegaard, & Galatius, 2021)), however flee speed is much faster <25 km/h and approximately 7 km/h >30 minutes (Kastelein, Van de Voode, & Jennings, 2018; Oceanwide, 2023a).

The main threats to the harbour porpoise population are according to the IUCN Red List categories 1) Fishing: bycatch in nets, reduced food availability and habitat destruction, 2) Pollution from industry and agriculture, 3) Noise pollution, 4) Climate and habitat changes, 5) Recreational activities: physical disturbances and noise.

Harbour porpoise has most recently been assessed for the IUCN Red List of Threatened Species in 2020. Harbour porpoise is listed as Least Concern (LC) (see more in section 5.3). Further, the status for harbour porpoises in the Atlantic region was based on counting's in the North Sea in 1994, 2005 and 2016 assessed as favourable in the Habitats Directive Article 17 report (Fredshavn, et al., 2019).

WHITE-BEAKED DOLPHIN (LANENORHYNCHUS ALBIROSTRIS)

White-beaked dolphins are found in open waters in the North Sea, the Skagerrak, and north and west of the British Isles (Galatius & Kinze, 2016). They are rarely seen by the coast (Hammond, et al., 2021).

The white-beaked dolphin population have been counted four times in Danish waters and adjacent waters under SCANS surveys in 1994, 2005, 2016 and 2022 (Hammond, et al., 2021; Gilles, et al., 2023) and show that there is a stable population of approximately 20,000 individuals (Hammond, et al., 2021). The carrying capacity of the area is unknown as the first counts were undertaken in 1994. The white-beaked dolphins in Danish waters belong to the North Sea population, which cannot be divided into separate populations. There is limited knowledge on the behaviour and distribution of white-beaked dolphins in Danish waters.

The biology of white-beaked dolphins is not well known, but both mating and parturition are thought to occur during the summer month (Galatius, Jansen, & Kinze, 2013; Galatius & Kinze, 2016). During this period, and the following months, mothers and calves are particularly vulnerable to disturbances that can lead to separation. In other more well-studied dolphin species, calves are dependent on their mothers for several years (Kyhn, et al., 2021)

Figure 8-1 shows a maximum distribution model for white-beaked dolphin based on collated and standardised data from 1980-2018 (Waggitt, et al., 2019). The modelled distribution on white-beaked dolphin indicates that the survey area is of low importance to white-beaked dolphin with 0.0622 (0.0589 – 0.0643) ind./km^2 (Waggitt, et al., 2019). The density based on Table 8-1 is 0.03 (CV=0.39) ind./km^2 based on counts from 2016 and 0.06 (CV=0.57) ind./km^2 based on counts in 2022 in the SCANS block where in the seismic survey area in planned (Hammond, et al., 2021; Gilles, et al., 2023). Even though there has been a doubling in the estimates of white-beaked dolphins from 2016 to 2022 this increase is still not significant (Figure 8-4).

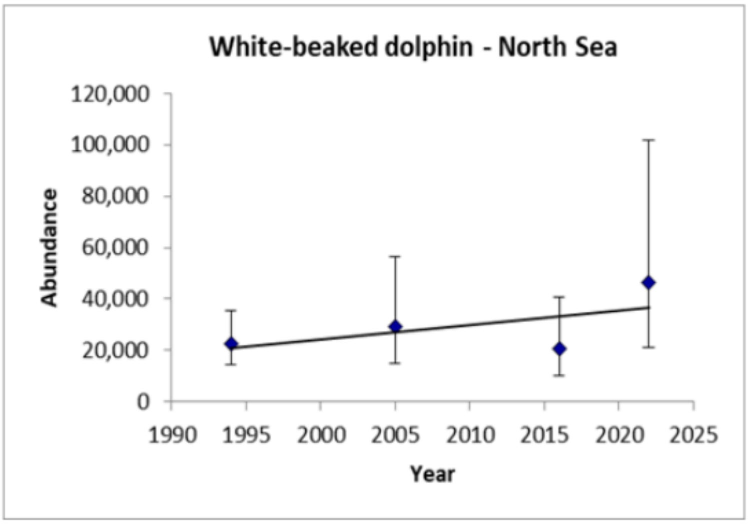

Figure 8-5 Trend lines fitted to time series of four abundance estimates for white-beaked dolphin in the North Sea (From (Gilles, et al., 2023)).

The main threats to the population of white-beaked dolphins are according to the IUCN Red List categories; 1) Fishing: bycatch in nets, reduced food availability and habitat destruction, 2) Pollution from industry and agriculture, 3) Noise pollution, 4) Climate and habitat changes, 5) Recreational activities: physical disturbances and noise.

White-beaked dolphin has most recently been assessed for the IUCN Red List of Threatened Species in 2018 and is listed as Least Concern (see more in section 5.3).

MINKE WHALE (BALAENOPTERA ACUTOROSTRATA)

Minke whales are widely distributed in all oceans except 0–30° latitude, around the equator. They are mainly associated with the temperate and arctic zones of the oceans (Perrin, Mallette, & Brownell Jr., 2018). The minke whale lives in the open water in the North Sea and Skagerrak and occurs irregularly in inner Danish waters (Hammond, et al., 2021). Minke whales in the North Sea are probably part of a larger population in the Northeast Atlantic.

Minke whale populations have been monitored four times in July-August in the Danish and adjacent waters during SCANS surveys in 1994, 2005, 2016 and 2022 (Hammond, et al., 2013; Hammond, et al., 2002; Hammond, et al., 2021; Gilles, et al., 2023). The counts indicate a stable population of approximately 10,000 individuals. The minke whales that occur in Danish waters belong to the population in the North Sea, which probably also uses a larger part of the North Atlantic. There is limited knowledge on the behaviour and distribution of minke whales in Danish waters. Individuals have been tagged with satellite transmitters at Skagen and both times they swam north of the British Isles and then south around the Canary Islands during the autumn and winter (Fraija-Fernandez, et al., 2015). Thus, there is no evidence of an independent stock in Danish waters.

Knowledge about minke whale population size, variation in numbers over the year and behaviour in Danish waters is limited. The modelled distribution on minke whales indicates that the survey area is of low importance to minke whales with 0.0043 (0.0037 – 0.0049 ind./km^2 (Waggitt, et al., 2019) (see Figure 8-1 and Table 8-2).

However, minke whales have been sighted in the region of the proposed survey area in low numbers at different times throughout the year in block NS-N with 0.0096 animal/km^2 in 2016 and 0.0100 animal/km^2 in 2022 (Table 8-1) (Gilles, et al., 2023; Hammond, et al., 2021). The counts of minke whales are thus almost identical from 2016 to 2022. All counts of minke whales in the North Sea can be seen in Figure 8-5.

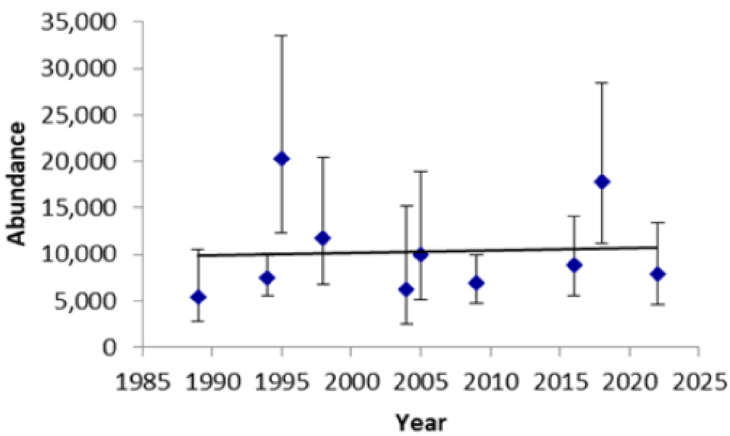

Figure 8-6 Trend lines fitted to time series of four abundance estimates for minke whales in the North Sea (Gilles, et al., 2023).

There is no data to determine when minke whales are most vulnerable to disturbances in the survey area. However, mating is expected, according to the limited knowledge in this topic, to occur from October to March in the Northern hemisphere, gestation is about ten months, thus calving occurring primarily between December and January (The Sea Watch foundation, 2012). Minke whales can swim up to 40 km/h Their normal cruising speed can be anywhere from 5 km/h to 25 km/h (Oceanwide, 2023b).

The main threats to the population of common minke whale are according to the IUCN Red List categories; 1) Fisheries: reduced food availability and habitat destruction, 2) Pollution from industry and agriculture, 3) Noise pollution, 4) Climate and habitat changes.

Minke whale has most recently been assessed for the IUCN Red List of Threatened Species in 2018 and is listed as Least Concern (see more in section 5.3).

HARBOUR SEAL (PHOCA VITULINA)

Harbour seals are widespread in Danish waters, except around Bornholm (Søgaard, et al., 2018). It is the only seal species that has been observed regularly in the Danish sector of the central part of the North Sea.

Based on genetics and migration data, four geographically separated stocks have been identified in Denmark: The Wadden Sea (shared with Germany and the Netherlands), the Limfjord, the Kattegat (shared with Sweden) and the Western Baltic Sea (shared with Sweden) (Olsen, et al., 2014).

Harbour seals do not generally venture more than 20 km offshore. However, radio-tagging experiments using satellite tracing have indicated that harbour seals may undertake foraging migrations far out into the North Sea from their core areas along the coast (Tougaard S., 2007; Tougaard, Ebbesen, Tougaard, Jensen, & Teilmann, 2003). The nearest resting places for harbour seals in relation to the survey area are in the Limfjord at 201 km and 207 km from the survey area 1 and survey area 2, respectively and the Wadden Sea at 223 km and 227 km from the survey area 1 and survey area 2, respectively (see Figure 8-6).

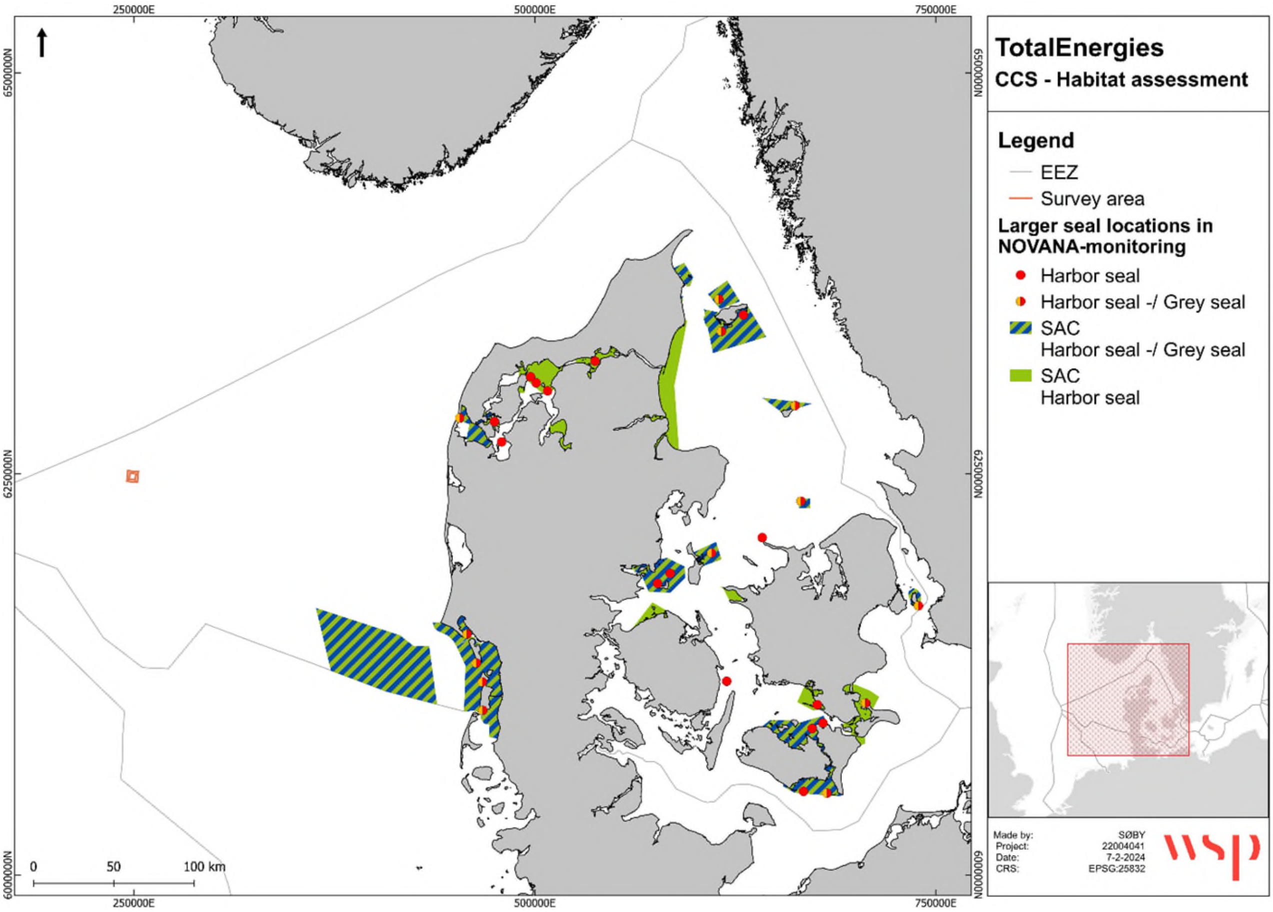

Figure 8-7 Map of SAC for harbor seals and grey seals in Danish waters. Larger harbour seal colonies and localities where grey seals are regularly observed, are shown with red and yellow circles, respectively, or a red/yellow combination if both species are found in the same locality. The shades of grey indicate the four management areas (Limfjord, Wadden Sea, Kattegat and western Baltic Sea) for harbor seals in Denmark. (Adjusted according to Hansen & Høgslund (2023)).

q

Twenty-two marine SACs are designated for harbour seals in Denmark (Figure 8-6). There are permanent colonies of harbour seals in 17 of these areas. The rest of the areas are important for their foraging and movements (Hansen & Høgslund, 2023).

The population has increased after Denmark initiated a national protection of harbour seals and established seal reserves in 1977. The population has been highly affected by epidemics including the Phocine Distemper Virus (PDV) epidemics in 1988 and 2002, when up to half of the individuals in the populations died (Härkönen, et al., 2006). The populations were further impacted in 2007 by an unknown disease (Härkönen, et al., 2008), and in 2014 by a bird flu epidemic (Søgaard, et al., 2018). In recent years, the population has stabilised suggesting the carrying capacity of the environment has been reached (Kyhn, et al., 2021).

Harbour seals give birth to their young on land in May-June. When the young are born, they can follow their mother in the water. They use resting places for lactation during the first month. In July-August, the seals molt and require a calm resting place. Mating takes place in the water. Male seals maintain territories and attract females with underwater sounds (Boness, Bowen, Buhleier, & Marshall, 2006). Harbour seals are most vulnerable around the resting areas in May-August.

Harbour seals may pass through the region of the proposed seismic survey area, but they are unlikely to occur in significant numbers.

Threats according to the IUCN Red List categories are 1) Fishing: bycatch in nets, reduced food availability and habitat destruction, 2) Pollution from industry and agriculture, 3) Noise pollution, 4) Climate and habitat changes, 5) Recreational activities: physical disturbances and noise. Harbour seals are listed as Least concern on IUCN's Red List.

GREY SEAL (HALICHOERUS GRYPHUS)

Grey seals have been sighted around oil and gas fields in the Danish sector of the North Sea (Delefosse, Rahbek, Roesen, & Clausen, 2018). The grey seal breeds in several colonies on islands on the east coasts of Great Britain and in the German Bight where colonies exist on the islands of Sylt, Amrum and Helgoland. In 2020, the population in the Wadden Sea was estimated to be approximately 300 individuals (Kyhn, et al., 2021). Grey seals occurring in the Danish sector of the North Sea are non-breeding seals from the large populations in the UK and German/Dutch sectors of the Wadden Sea and are primarily searching for food.

Thirteen marine SACs are designated for grey seal (Figure 8-6) in Denmark. Grey seals are regularly occurring on land in nine of these areas. The rest of the areas are important for their foraging and movements (Hansen & Høgslund, 2023).

The grey seal became locally extinct in Denmark after extended culling (Galatius, et al., 2020). The re-population of Danish waters started around the year 2000. The numbers are increasing in the Wadden Sea, the Kattegat and the Baltic Sea (Søgaard, et al., 2018).

Grey seals are most vulnerable when they are about to give birth to their young, and during mating. The female seal gives birth to one pup in an undisturbed place and nurses the young for three weeks. If mother and pup are disturbed during this period, there is a risk that the mother leaves the pup (Kyhn, et al., 2021). The North Sea population gives birth in December-January. The mating period starts approximately three weeks after the nursing (lactation) period of the pup. Grey seals from the North Sea molt in March-April. Grey seals are most vulnerable around their resting places during December-January and March-April (Kyhn, et al., 2021).

Seals may pass through the proposed seismic survey area, but they are unlikely to occur in significant numbers.

Threats according to the IUCN Red List categories are 1) Fishing: bycatch in nets, reduced food availability and habitat destruction, 2) Pollution from industry and agriculture, 3) Noise pollution, 4) Climate and habitat changes, 5) Recreational activities: physical disturbances and noise. Grey seals are listed as Endangered on IUCN's Red List.

SEASONAL SENSITIVITY

Table 8-3 gives a summary of the most vulnerable/highly sensitive periods for the five relevant marine mammal species in the seismic survey area. Light green periods indicate most vulnerable/highly sensitive periods and dark green periods indicate periods when most new-borns occurring (based on available knowledge). Even in periods not marked in green, all species will be sensitive to disturbances, which can lead to mother-calf/mother-pup separation.

The red box indicates the survey period. The seismic survey will be completed in 45 working days (including downtime of 21 days) within a eight-month period from March to October.

Table 8-3 Summary of the most sensitive periods of marine mammals in the survey area (The Sea Watch foundation 2012, Kyhn, et al. 2021, Galatius, Jansen & Kinze 2013, Galatius & Kinze 2016, Sonntag, et al. 1999).

Species	J	F	M	A	M	J	J	A	S	O	N	D	Spawning location
Grey seal (*Halichoerus gyous*)													On land
Harbour seal (*Phoca vitulina*)													On land
Harbour porpoise (*Phoceana phoceana*)													Water column
Minke whale (*Balaenoptera acutorostrata*)													Water column
White-beaked dolphin (*Lagenorphychus albirostris*)													Water column

Most calves/pups

Highly sensitive periods

Indicates the period where the seismic survey may be conducted

The summary shows that the survey period overlaps with the highly sensitive periods for harbour porpoise, harbour seals and an overlap in two out of four sensitive months for grey seals. However, both harbour seals and grey seals are most sensitive at their onshore resting areas, which is irrelevant for the seismic survey. The survey period overlaps with the highly sensitive periods for white-beaked dolphin and only March and October overlaps with the sensitive period for minke whales.

The survey period has been selected to accommodate the feasible weather window to undertake seismic survey and seismic survey vessel availability and logistic considerations (March- October). The site survey is expected to be completed in 24 days within a 45-day period (including down time).

8.1.4 IMPACTS

The potential impacts of the Dagny CCS site survey are listed in Table 8-4. All the potential impacts are related to the 160 cu.in. airgun array as it generates higher sound levels than the 24 cu.in. array.

Table 8-4 Potential impacts on marine mammals: species considered the main sound source, and potential impacts.

Species	Sound source	Potential impacts
All marine mammals	Airgun arrays	- Increased underwater noise (injury and/or behavioural reactions) - Temporary habitat loss - Temporarily reduced food supply

Based on the distance from the survey area to resting, moulting, or breeding sites for seals (>200 km) and given there are no defined breeding areas for harbour porpoises, white-beaked dolphin and minke whales, no further assessment of possible impacts on these locations is required.

The following sections assess the potential impact the seismic survey may have on individuals/populations and feeding grounds of seals, harbour porpoises, white-beaked dolphin and minke whales.

The best-practice measures listed in section 6.3 is a prerequisite for the performed assessments including 40-minute soft start period which is standard practice for all TEPDK projects (TEPDK will employ a 45-minute soft-start for this project after specific calculations based on modelling results).

UNDERWATER NOISE

There are many natural sources of noise in the marine environment (background, noise, rain, waves and turbulence, lightning strike, mating call, echolocation click, etc.). Natural background noise (the source level at 1 m) is approximately 100 dB re. 1 µPa on a calm day in shallow waters. The level of underwater background noise worldwide has increased in the last century due to anthropogenic sound. Noise may cause stress in animals, increase the risk of mortality by unbalancing predator-prey interaction, and interfere with sound-based orientation and communication, especially in reproductive contexts.

It is generally accepted that the marine mammal auditory system is the most sensitive organ to acoustic injury, meaning that injury to the auditory system can occur at lower sound levels than injuries to other tissues (Tougaard, 2016; Southall, et al., 2019; NMFS , 2018). Sound is important for marine mammals for navigation, communication, and prey detection. Therefore, introduction of anthropogenic sound which could impact/disturb marine mammals needs to be addressed.

Possible effects of underwater noise on marine mammals include hearing damage, behavioral reactions, and masking of communication cues (Figure 8-5).

Table 8-5 Potential impacts on marine mammals from underwater noise.

Impact	Description
Hearing damage	Intense underwater noise may damage hearing of cetaceans and seals. Noise-induced hearing impairment includes permanent threshold shift (PTS) and temporary threshold shift (TTS). PTS is a permanent change in hearing threshold from which marine mammals do not recover, whilst TTS is a temporary change in hearing threshold that mammals recover from over time, depending on the severity (the larger the initial TTS the longer the recovery period). Marine mammals will recover from small amounts of TTS within minutes, whereas it could take hours to days to recover from severe TTS (Tougaard, 2016). PTS is an irreversible hearing loss. Generally, PTS will occur only after repeated TTS episodes or exposure to higher levels of sound than causes TTS (Southall, et al., 2019).
Behavioural reactions	Underwater noise may cause avoidance reactions and other behavioural effects in cetaceans and seals, such as changes in surfacing, breathing and diving behaviour, cessation of feeding, aggression, aversion and panic (Sarnocińska, et al., 2020; Thompson, et al., 2013; Bejder, Samuels, & Whitehead, 2006; Pirotta, Brookes, Graham, & Thompson, 2014). Behavioural impacts of acoustic exposure are generally more variable, context-dependent, and less predictable than the effects of noise exposure on hearing.
Masking	Because cetaceans depend on the underwater acoustic environment for orientation (echo location) and communication, an emitted cetacean sound can be obscured or interfered with (masked) by anthropogenic underwater noise (Tougaard, 2014). There are examples of whales changing their vocalisation because of underwater noise (Weilgart, 2007).

PTS AND TTS

Finneran (2015), Tougaard (2016), Kastelein , Gransier, & Hoek (2013), Southhall, et al., (2019), Luke, et al., (2019) and NMFS (2018) have conducted studies to estimate the sound levels required to cause auditory injury to various marine mammals (Finneran, 2015; Tougaard, 2016; Kastelein, Gransier, & Hoek, 2013; Southall, et al., 2019; Lucke, Siebert, Lepper, & Blanchet, 2009; NMFS , 2018). Various PTS and TTS thresholds have been proposed using different sound metrics (e.g., zero-to-peak SPL, peak-to-peak SPL, unweighted/weighted single-pulse SEL and unweighted/weighted cumulative SEL).

The thresholds adopted in this assessment are those included in the guideline from the Danish Energy Agency (DEA, 2022), which are based on Southall, et al., (2019) and summarised in Table 8-6.

The cumulative SEL thresholds proposed by Southall, et al., (2019) have been established for impulsive and non-impulsive noise. In this assessment the impulsive thresholds are used to assess potential impacts from the airgun array that will be used during the Dagny CCS survey.

Southall, et al., (2019) established thresholds for different marine mammal hearing groups. The hearing groups that are relevant for this assessment are low frequency (LF) cetaceans, high frequency (HF) cetaceans, very high frequency (VHF) cetaceans, and phocid pinnipeds. Table 8-6 shows the marine mammal species that are most likely to be present in Danish waters and relevant for the assessment (Tougaard, Sveegaard, & Galatius, 2021), categorised according to these hearing groups.

Table 8-6 Marine mammal PTS and TTS thresholds applied in this assessment.

Hearing Group	Relevant Species	Cumulative SEL Thresholds (dB re 1 µPa^{2}s)[1]	
		PTS	**TTS**
Impulsive thresholds			
LF cetaceans	Minke whale	183	168
HF cetaceans	White-beaked dolphin	185	170
VHF cetaceans	Harbour porpoise	155	140
Phocid pinnipeds	Harbour seals, grey seals	185	170
[1] In this assessment the impulsive thresholds are used to assess potential impacts to marine mammals from the airgun arrays that will be used for the survey.			

The thresholds shown in Table 8-6 are based on the cumulative SEL metric, which accounts for the hearing capabilities of different marine mammal hearing groups and exposure time (Southall, et al., 2019; Tougaard, 2021; DEA, 2022). Received sound levels are frequency-weighted according to the generalised auditory weighting functions shown in Figure 8-7 (Southall et al., 2019), and the resulting weighted sound levels are integrated over the duration of exposure to calculate the cumulative SEL. The effect of the auditory-weighting functions shown in Figure 8-8 is to reduce received sound levels at frequencies for which a hearing group is less sensitive.

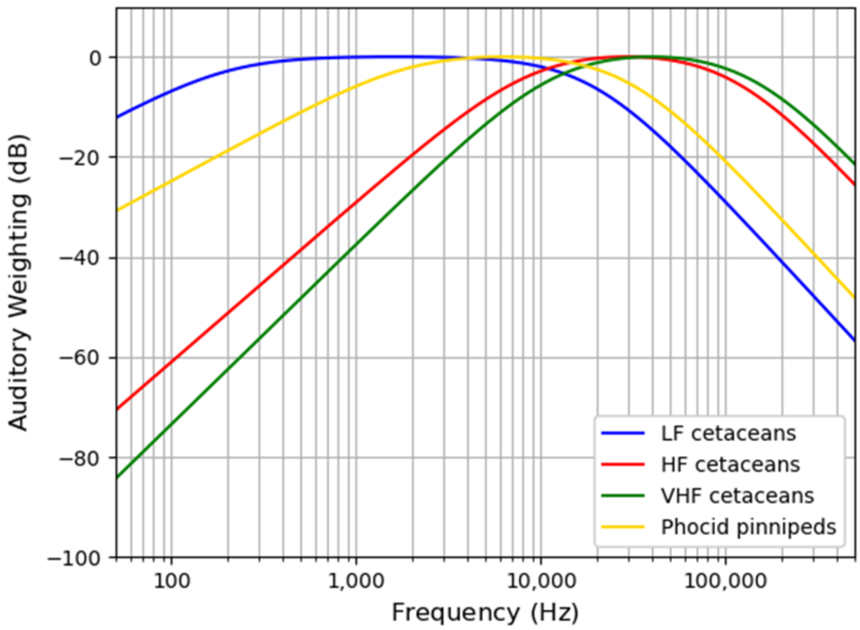

Figure 8-8 Auditory weighting functions for different marine mammal hearing groups (Southall, et al., 2019).

Figure 8-8 illustrates the summarised source levels 1 m vertically below the airgun array (for the 160 cu.in.) both unweighted and weighted by the marine mammal auditory weighting functions. Only in the frequency ranges, where the weighted levels for different marine mammal hearing groups are the same as the unweighted levels, animals "hear" the full sound levels of the airgun. For further details on the specific equipment, see section 1.2.1 in the noise modelling report by Genesis (2024).

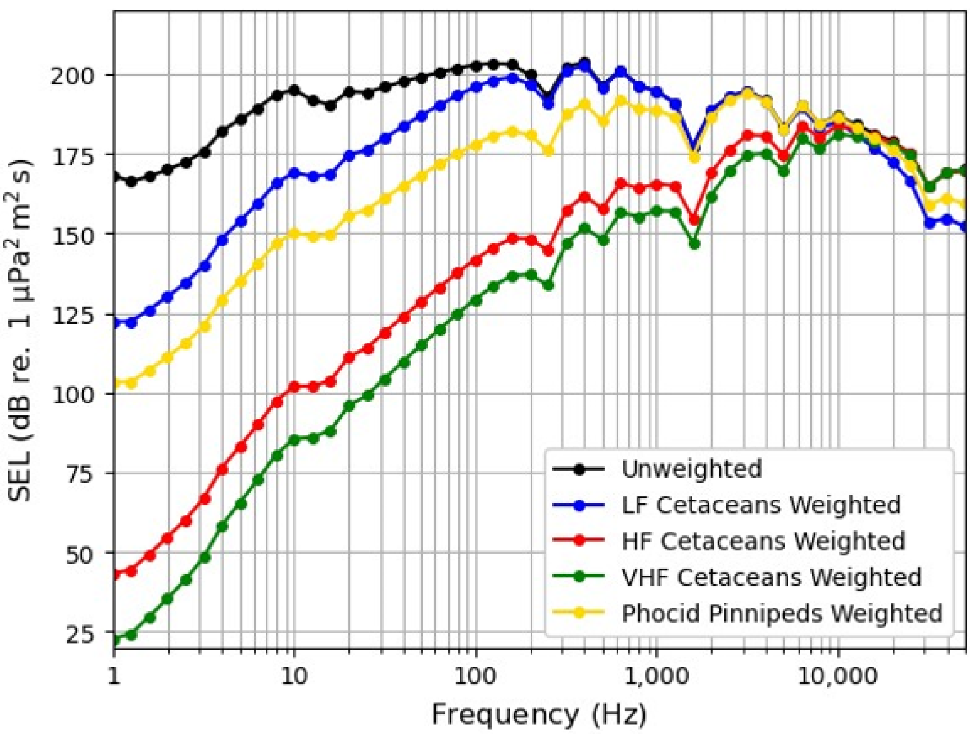

Figure 8-9 Deci-decadal band SEL source levels 1 m vertically below the 160 cu.in. airgun array. (Genesis, 2024).

BEHAVIOURAL DISTURBANCE THRESHOLDS

Sound at lower levels than those potentially inducing PTS or TTS to marine mammals can still have an adverse impact since it may alter their normal behaviour i.e., cause behavioural disturbance. Marine mammals can exhibit varying behavioural responses to underwater sound depending on the level and duration of the sound. The most immediate effects are flight reactions, which potentially can lead to mortality, e.g., marine mammals beaching in coastal waters (D'Amico et al., 2009; Balcomb and Claridge, 2001) or calves being separated from their mothers. However, the more probable behaviour effects caused by the proposed seismic survey activities will be displacement (Sarnocińska, et al., 2020; Thompson, et al., 2013; Bejder, Samuels, & Whitehead, 2006; Pirotta, Brookes, Graham, & Thompson, 2014), or disturbance to feeding behaviours (Stimpert, et al., 2014; Isojunno, et al., 2016; Wisniewska, Johnson, Teilmann, Galatius, & Madsen, 2018). At lower sound levels, less severe behavioural effects may include changes in swimming behaviour and vocalisation (Beest, et al., 2018; Robertson, Koski, Thomas, Richardson, & A., 2013). Any long-term changes in normal behaviour can have implications for the long-term survival and reproductive success of individuals and in extreme cases may have consequences at a population level (Tougaard, 2016).

Southall et al., (2019) concluded that thresholds for behavioural disturbance were difficult to define conclusively since behavioural responses to sound are highly variable and context specific. Southall et al., (2019) therefore recommend assessing whether sound from a specific activity could cause disturbance by comparing the circumstances of the situation with empirical studies reporting similar circumstances.

To calculate the extent of disturbance to marine mammals from an activity, it is necessary to know reaction thresholds for noise impact for the various species. The empirical basis is not extensive in the area and the Danish guidelines (DEA, 2022) only includes a generalized threshold of 103 dB re. 1 µPa calculated as rms average over 125 ms and frequency weighted with the VHF weighting function for harbour porpoises. This threshold has been derived from observations of displacement of harbour porpoises (VHF cetaceans) from noise from piling (DEA, 2022). For other species of marine mammals there are no generalised thresholds for behavioural disturbance, i.e., thresholds expressed as a frequency-weighted received sound level. Instead, observations of displacement of other marine mammal species during similar activities should be considered if possible.

Tougaard (2016) suggests that behavioural disturbance to harbour porpoise from seismic survey should be assessed using an unweighted single-pulse SEL threshold of 145 dB re 1 $\mu Pa^2 s$. This threshold was derived based on measurements of harbour porpoise disturbance from airgun arrays (Lucke, Siebert, Lepper, & Blanchet, 2009; Thompson, et al., 2013). In lieu of specific data for other marine mammals, Tougaard (2016) also suggested that this threshold should be used for assessing impacts to other marine mammals. This will likely be conservative since it is suspected that harbour porpoises are more sensitive to noise than most other species (Tougaard, 2016). The threshold from Tougaard (2016) is used in this report to estimate potential behavioural disturbance to all marine mammals from the proposed site survey using the airgun array.

Behavioural disturbance of marine mammals from high-resolution geophysical survey equipment such as SBPs, MBESs, and SSSs is not as well understood as behavioral disturbance from seismic surveys using airgun arrays and piling. The National Marine Fisheries Service (NMFS) currently adopts an rms SPL threshold of 120 dB re 1 µPa for assessing behavioural disturbance to all marine mammals from non-impulsive sound sources, whereas the Danish guidelines (DEA, 2022) instruct to use the threshold of 103 dB re 1 µPa weighted, using the Southall et al. (2019) VHF cetaceans auditory weighting function for harbour porpoises.

The behavioural disturbance threshold adopted in this assessment for marine mammals is summarised in Table 8-7.

Table 8-7 Behavioural disturbance threshold.

Behaviour Disturbance Threshold	Species	Source	Application
145 dB re 1 µPa²s (single-pulse un-weighted SEL)	All marine mammals	Tougaard (2016) Thompson et al., (2013) Lucke et al., (2009)	This threshold has been derived from observations of displacement of harbour porpoises during seismic survey. In this assessment it is used to estimate displacement of all marine mammals from sound generated from the **airgun arrays** during the proposed site survey.
103 dB re 1 µPa (rms SPL over a time window of 125 ms weighted for VHF cetaceans)	Harbour porpoise	(DEA, 2022)	This threshold has been derived from observations of behavioural disturbance to harbour porpoises from piling during wind farm site construction. In this assessment it is used to estimate the displacement of **harbour porpoise** from the sound generated by the **airgun arrays** during the proposed site survey

UNDERWATER NOISE – MODEL RESULTS

This section presents the noise modelling results and impact assessment for the Dagny CCS site survey for March and August (Genesis, 2024).

The 160 cu.in. airgun array that will be used to acquire 2DHR seismic data will be the loudest sound source associated with the Dagny CCS site survey. The airgun array that will be used to acquire UHR data will be smaller (24 cu.in.) and will generate lower sound levels than the 160 cu.in. airgun array. The SBP will also generate lower sound levels than the 160 cu.in. airgun array, whilst the MBES and SSS equipment will operate at higher frequencies that will be outside the main hearing range of marine mammals. Thus, the 160 cu.in. airgun array that will be used during the Dagny CCS site survey will have the largest impact on marine mammals. The noise modelling for the site survey therefore focuses on predicting impacts from this source.

PTS AND TTS

The model results both include the predicted distances from any seismic line where the cumulative SEL thresholds for potential PTS and TTS onset are exceeded for stationary marine mammals and for swimming marine mammals. It is very unlikely that any marine mammals that are caused discomfort by noise will not move away from the source. The presented results in the assessment below are based on swimming animals assuming an average speed for wild harbour porpoise of approximately 1.5 m/s (Tougaard, Sveegaard, & Galatius, 2021). The fleeing speed can be much faster if they feel discomfort. Additional to a swimming speed of 1.5 m/s of the animals, a survey speed of 2.2 m/s for the survey vessel will be considered. Discomfort in the form of PTS and TTS which cannot be avoided will be mitigated if needed.

The modelling results predict that the threshold for marine mammal PTS will not be exceeded, given that the airgun array is activated with a 40 minute soft-start (i.e. use of best-practice) and marine mammals swim away from the airgun array (1.5 m/s (Table 8-8)). During the survey, a MMO will observe a 500 m exclusion zone before the start of the airgun array. Further, PAM will be operated to detect marine mammal present in the immediate vicinity of the vessel. If any marine mammals are observed within 500 m from the survey vessel, the airgun activation will be postponed until all mammals have vacated the exclusion zone. Given these measures, which are standard best-practices employed by TEPDK and in accordance with DEA guidelines, it is not expected that any marine mammals will be exposed to sound levels that will cause PTS, even when not considering the speed of the survey vessel.

Further, the modelling predicts that the TTS threshold for LF cetaceans (e.g., minke whales) and VHF cetaceans (harbour porpoises) may be exceeded at larger distances over several kilometres (Table 8-8). However, TTS is a temporary change in hearing and any marine mammal that could potentially suffer TTS will recover over time. The thresholds for the hearing group of HF and phocid pinnipeds (e.g., white-beaked dolphin and harbour seal/grey seal) are not exceeded for either PTS or TTS based on the swimming speed of the animals. Additionally, the model carried out by Genesis (Genesis, 2024) only presents the highest TTS threshold distances for March and August representing the worst and best case respectively. The TTS threshold distances are significantly influenced by temperature with the highest impact distances in early spring (March- April) and lowest impact distances in summer (August). Thus, the modeled TTS threshold distances would be significantly lower in the months when the harbour porpoise calves and thus the highest sensitivity of this species is expected.

To calculate the time it takes for an animal to reach the TTS-threshold, when swimming away from the survey vessel, one needs to consider both the swimming speed of the animal (1.5 m/s) and the speed of the survey vessel (2.2 m/s). A simple iteration has been performed where the iteration considers the position of the animal relative to the boat sailing at a constant speed. The direction of the swimming animal is given as the direct line between the boat and the animal itself at every iteration.

An illustration of the iteration is given in Figure 8-9 for nine potential iterations starting position for the animal, either in front of, to the side or straight behind the vessel (180-0.01° from the tip of the vessel). The starting distance of the animal to the vessel is set to 500 m, as MMO and PAM will be performed before any data acquisition.

As illustrated in Figure 8-9 it will take longer time for a harbour porpoise in front of the vessel to reach the TTS threshold distance than for a harbour porpoise at any other starting position. The same iteration is performed for the TTS threshold distance for minke whales. Table 8-8 indicates the time to reach TTS Threshold Exceedance (in an 180-0.01° angle from the survey direction) for harbour porpoises and minke whales.

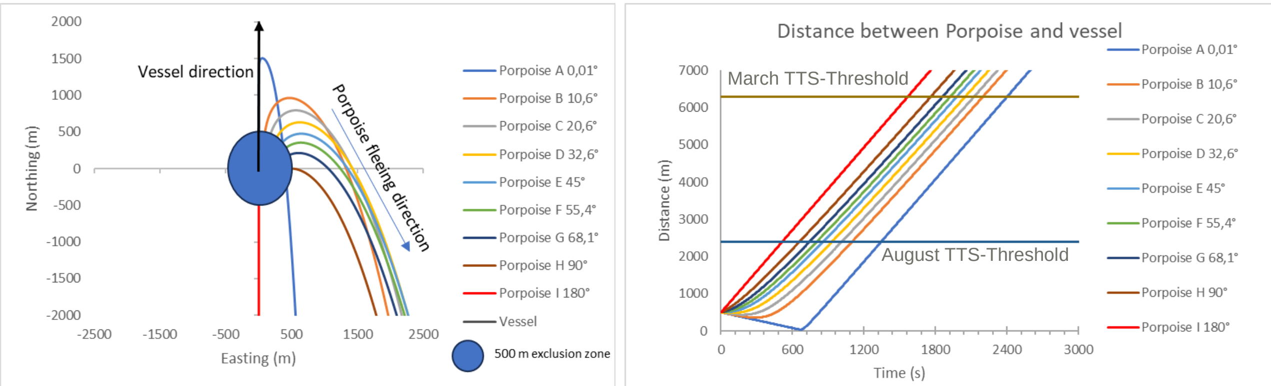

Figure 8-10 Left: Illustration of the iteration which considers the position of the animal moving (1.5 m/s) away relative to the boat sailing at a constant speed (2.2 m/s). Right: Distance between survey vessel and porpoise relative to the time. Horizontal lines represent the TTS-threshold distance in March and August.

Table 8-8 Adopted weighted cumulative SEL thresholds for PTS and TTS for the distance to Threshold Exceedance (Genesis, 2024) and the time it takes for an animal situated 500 m away from the vessel to reach a distance greater than the Threshold Exceedance distance. All values are represented as March / August. Time is given for the best-off (August) and worst-off (March) case. Animal swimming speed of 1.5 m/s and survey vessel speed of 2.2 m/s.

Hearing Group	Relevant Species	Month	Cumulative SEL Threshold (dB re 1 µPa2s)		Distance to PTS & TTS-Threshold Exceedance (km)		Time to reach TTS-Threshold Exceedance (180-0.01o angle from the survey direction)
			PTS	TTS	PTS	TTS	(min)
LF cetaceans	Minke whale	March	183	168	Not exceeded	5.8	23.8-37.8
		August			Not exceeded	2.0	6.7-20.6
HF cetaceans	White-beaked dolphin	March	185	170	Not exceeded	Not exceeded	-
		August			Not exceeded	Not exceeded	-
VHF cetaceans	Harbour porpoise	March	155	140	Not exceeded	6.3	26.1-40.1
		August			Not exceeded	2.4	8.6-22.4
Phocid pinnipeds	Harbour seals, grey seals	March	185	170	Not exceeded	Not exceeded	-
		August			Not exceeded	Not exceeded	-

BEHAVIOURAL DISTURBANCE THRESHOLDS

To estimate potential behavioural disturbance on marine mammals caused by the survey activities, two thresholds are considered: 1) the thresholds based on unweighted single-pulse SEL (Tougaard, 2016) and 2) VHF cetaceans weighted rms SPL calculated over a time window of 125 ms (DEA, 2022).

The threshold distances for behavioural disturbance are, as the distance to threshold for PTS and TTS, significantly influenced by temperature with the highest impact distances in early spring (March) and lowest in summer (August). For behavioural disturbance of marine mammals, separate threshold distances were modeled based on average temperatures for both March and August (Table 8-9). This is done to reflect that the threshold distances drop significantly during the summer when the harbour porpoise calves and thus the highest sensitivity of this species is expected.

The predicted distances and areas where the Tougaard (2016) and DEA (2022) behavioural disturbance thresholds are exceeded are summarised in Table 8-9. The Tougaard (2016) threshold predicts that disturbance to marine mammals may occur up to 6.5 km from the airgun array in March and 4.8 km from the airgun array in August. The DEA (2022) threshold predicts that disturbance may occur to harbour porpoise within 55.6 km from the airgun array for the Dagny site survey in March and 24.7 km from the airgun array in August. Measurements made during a seismic survey conducted in the Moray Firth with a 470 cu.in. array showed that harbour porpoises were displaced at distances of 5 to 10 km (Thompson, et al., 2013). These observations are in line with the predicted disturbance distance of ≈6.5 km by using the Tougaard (2016) threshold. The predicted distance using the DEA (2022) threshold (≈55.6 km) appears to be highly conservative given the observations of displacement of harbour porpoises during the seismic survey made by Thompson et al., (2013). However, it has not been considered if the airguns used in the present study and the one used in the Thompson et al., (2013) study are operating in the same frequency range. The assessment for harbour porpoises is based on DEA guidelines (2022), whereas the assessment for other marine mammal species will be based on Tougaard (2016) since it is based on an unweighted threshold criteria.

Table 8-9 Predicted distance and area where the applied marine mammal behavioural disturbance threshold is exceeded during the Dagny CCS site survey. Worst case results from Genesis (2024) are used for the assessment.

Species	Behavioural Disturbance Threshold	Source	Month	Distance to Threshold[1] (km)	Area of Threshold Exceedance[2] (km^2)
All marine mammals	145 dB re 1 μ Pa^2s (single-pulse unweighted SEL)	Tougaard (2016) Thompson et al., (2013) Lucke et al., (2009)	March	6.5	206
			August	4.8	130
Harbour porpoise	103 dB re 1 μ Pa (rms SPL over a time window of 125 ms weighted for VHF cetaceans)	(DEA, 2022)	March	55.6	5,998
			August	24.7	1,628
	[1] Predicted distance has been rounded up to the nearest 0.1 km. [2] Predicted area has been rounded up to the nearest 1 km^2.				

Any marine mammals disturbed from the area by the proposed seismic survey will likely return after the activities stop (Sarnocińska, et al., 2020; Thompson, et al., 2013). Thompson et al., (2013) observed that harbour porpoises, displaced by a seismic survey in the Moray Firth, returned to the survey area within one day after the survey finished. This is supported by monitoring around oil and gas fields that indicate regular presence of harbour porpoises (SPE International, 2020).

ASSESSMENT –UNDERWATER NOISE

The assessment of the underwater noise impact of the Dagny CCS site survey is combined in the following. The Basis for the assessment is given in Table 8-10.Table 8-11 and Table 8-12 sums the **extent** and **duration** of the impact, the level of **reversibility** of the impact (considering PTS, TTS, and behavioural impact), the **magnitude**, **level and complexity** of the impact and the **probability** of the impact on the receptor. The different criteria are used to assess the overall significance of the impact according to section 7.

Table 8-10 Basis for the assessment. Distance to threshold values and durations of the impact indicated in bold are applied in the assessment. NE = Threshold Not Exceeded. [1]Assumed swim speed of 1.5 m/s. [2] The vessel surveying at 2.2 m/s is considered when calculation the Time to reach TTS Threshold exceedance. Exceedance PTS and TTS values for the relevant hearing groups can be seen in Table 8-8. Worst case results (option 2 in Genesis 2024) are used for the assessment.

Site survey								
Hearing Group	**Relevant Species**	**Month**	**PTS[1]**	**TTS[1]**	**Time to reach TTS Threshold Exceedance[2]**	**Behavioural disturbance**		**Working days**
			Distance (km) to threshold[2]		The maximal calculated value (Minutes)	Distance (km) to threshold (103 dB)	Distance (km) to threshold (145 dB)	Without/with downtime
LF cetaceans	Minke whale	March	NE	**5.8**	**37.8**	**-**	**6.5**	24/**45**
		August	NE	**2.0**	**20.6**	-	**4.8**	24/**45**
HF cetaceans	White-beaked dolphin	March	NE	NE	**-**	-	**6.5**	24/**45**
		August	NE	NE	-	-	**4.8**	24/**45**
VHF cetaceans	Harbour porpoise	March	NE	**6.3**	**40.1**	**55.6**	6.5	24/**45**
		August	NE	**2.4**	**22.4**	**24.7**	4.8	24/**45**
Phocid pinnipeds	Harbour seals Grey seals	March	NE	NE	-	**55.6**	6.5	24/**45**
		August	NE	NE	-	**24.7**	4.8	24/**45**

The modelling predicts that the marine mammal PTS thresholds will not be exceeded for any of the marine mammal species, given that the airgun array is activated with a soft start (40 min.) and marine mammals swim away from the airgun array (1.5 m/s). During the survey, MMOs will observe within a 500 m exclusion zone before the start of the airgun array. Further, a PAM system will be operated to detect marine mammal presence in the immediate area of the survey.

For the site survey, no TTS thresholds will be exceeded for HF cetaceans (e.g., white-beaked dolphin) or phocid pinnipeds (seals). However, the TTS thresholds will be exceeded for LF cetaceans (e.g., minke whales) and VHF cetaceans (e.g., harbour porpoise) within the range of 5.8 km and 6.3 km in March and within a distance of 2.0 km and 2.4 km in August, respectively (Table 8-10) considering a swimming speed of 1.5 m/s (Genesis, 2024). Marine mammals are likely to swim away from the airgun array quickly if the sound generated is causing them distress, depending on the degree of discomfort.

A soft start period of 40 minutes will allow potential marine mammals to swim approximately 3.6 km from the survey vessel assuming a conservative flee speed of 1.5 m/s. If also considering the movement of the vessel of 2.2 m/s, the animal will be at a minimum of 6,292 m from the survey vessel before the equipment is used at full power. This distance is only valid for animals straight in front of the vessel at a starting distance of 500 m to the survey vessel. Animals in any other angle to the surveying direction will be at a greater distance to the survey vessel. Further, it is highly important that the MMO has increased focus on the survey area ahead of the vessel as the vessel will catch up with potential animals +/- 45° of the surveying direction assuming the animals flees directly away from the vessel (See Figure 8-9).

Thus, LF cetaceans (e.g., minke whales) will be outside the distance for threshold exceedance for TTS. However, few harbour porpoise can potentially be within the distance for threshold exceedance for TTS. Further, TTS is a temporary change in hearing and any mammal that could potentially suffer TTS will recover over time.

Marine mammals may exhibit behavioural disturbance effects (such as displacement from an area) within approximately 5.6 to 55.6 km in March and 4.8 to 24.6 km in August, distance to the survey vessel and airgun array as it operates over the site survey depending on the threshold used (Table 8-7). The **extent** of the impact (behavioural disturbance) potentially covers an area of 130-206 km^2 based on Tougaard (2016), Thompson et al., (2013) and Lucke et al., (2009) and 1628-5998 km^2 based on the DEA guidelines (2022) where the range reflects the dependence of the temperature/season in the model results from March and August (Table 8-9). The disturbed area at any given time during the active survey period of ~24 days within a 45 period is thus 130-5998 km^2 depending on the chosen disturbance threshold and season of the survey.

The impacted area where the impact is either permanent (PTS) or temporary (TTS) is considered *local* compared to the North Sea and *local* compared to similar foraging areas available within the Danish EEZ, whereas the extent where the animals may exhibit behavioural disturbance effects are considers local to regional (depending on the threshold and season considered).

The **magnitude** is *medium,* but **level and complexity** of the impact is *high* as harbour porpoise may have calves during the survey period. However, in the months where the harbour porpoise calves, and thus have the highest sensitivity, significantly lower TTS threshold distances are expected (than those of March) based on the modelled results from August. Further, normal behaviors such as breeding, foraging, and socializing are locally disrupted which, combined with a direct impact of e.g., fish near the survey vessel leads to a *medium* impact regarding **level and complexity** for other species of marine mammals near the survey area. However, the area is not a hotspot for any of the relevant mammal species. The duration of the impact is assessed as **short** since the duration of the impact is limited to ~24 days within a 45-working period within an eight-month period (March-October), which is assessed not to impact the energy balance of the animals significantly. The **probability** of impact on marine mammals is low to high (depending on the species); however, all impacts are fully **reversible** for all other species except harbour porpoises. For harbour porpoises, there is a risk for mother-calf separation which is assessed as a permanent loss of the function of this receptor. However, this is only a risk for animals in front of the vessel at a starting position of 500 m for the survey vessel.

Based on scientific literature and the performed model (Genesis, 2024), any marine mammal disturbed from the area by the proposed seismic survey is likely to return after the survey has been completed regardless of which threshold being used to model the extent of the disturbed area. The predicted distances and areas based on the threshold by Tougaard (2016) predicts that disturbance to marine mammals may occur within 6.4-6.5 km in March and 4.7-4.8 in August from the airgun array, whereas DEA (2022) threshold predicts that disturbance may occur to harbour porpoise within 55.2-55.6 km in March and 23.5-24.7 in August from the airgun array. The predicted disturbance distance based on DEA (2022) is far greater than the observations from Thompson et al. (2013), with displacement of harbour porpoise during the seismic survey within distances of 5 to 10 km, which indicates that the impact distances calculated based on the DEA (2022) are very conservative (see more in (Genesis, 2024)).

It is assessed that potential mother-calf separation for animals in front of the surveying vessel can be mitigated by increasing the soft-start period from 40 minutes (JNCC practise and TEPDK standard) to 45 minutes and this will reduce the overall impact from **moderate** to **minor** for harbour porpoise. For all other relevant marine mammal species, the overall assessment impact is already assessed as **minor** with the application of the standard soft start period (40 min). . A soft-start period of 45 minutes would allow harbour porpoise to reach 7.4 km from the survey vessel before the airgun is shooting at full effect (see Table 8-10). This distance exceeds the distance to threshold exceedance for TTS for harbour porpoise swimming at 1.5 m/s and a survey vessel moving at 2.2 m/s. Thus, the potentially impacted area naturally restores to pre-impacted status (fully reversible). Further, all species are assessed as having a favourable conservation status according to the habitat directive and all species are on the IUCN red list assessed as not threatened (LC). With at prolonged soft-start period the **reversibility** is reduced from long term (in case of mother calve separation) to *medium/short*. *Medium* for the season with most calves (season with the highest sensitivity) and *short* for the rest of the year. This assessment is based on the expected lower threshold distances in the months where harbour porpoise calves, compared to the results of the model in March (see model result from March and August in Appendix 1). It has to be noted that, the modeled threshold distances will be lower (closer to August results) in the months where the harbour porpoise calves (warmer summer months) and the highest sensitivity of this species is expected (see section 8.1).

Regardless, it must be considered that a potential longer soft-start period, will reduce the potential impact for animals in front of the vessel at a starting distance of 500 m from the survey vessel. However, it should also be considered that a prolonged soft-start period, will lead to a disturbance by itself and prolongs the overall disturbance period of the survey.

The potential impacts related to underwater noise for marine mammals are summarised in Table 8-11 using TEPDK standard best practice measures, whereas Table 8-12 considers the same impacts with a longer soft-start period to avoid the potential risk of TTS for potential harbour porpoises in front of the survey vessel.

Table 8-11 Potential impacts (PTS, TTS and behavioural disturbance). [1]For behavioural disturbance in March to May and October >2500 km^2. [2]In case of mother-calf separation for individuals located in front of the vessel.

Receptor	Extent	Duration	Magnitude	Level of complexity	Reversibility	Probability	Overall significance
Harbour porpoise	Local/Regional[1]	Short	Medium	High	Long term[2]	High	Moderate
White beaked dolphin	Local	Short	Low	Medium	Short	Medium	Minor
Minke whale	Local	Short	Low	Medium	Short	Low	Minor
Harbour seal and grey seal	Local	Short	Low	Medium	Short	Medium	Minor

Table 8-12 Potential impacts (PTS, TTS and behavioural disturbance) with a longer soft-start period (45 min). [1]For behavioural disturbance in March to May and October >2500 km^2. [2] The reversibility is medium in the season with most calves (highest sensitivity).

Receptor	Extent	Duration	Magnitude	Level of complexity	Reversibility	Probability	Overall significance
Harbour porpoise	Local/Regional[1]	Short	Low	Medium	Medium[2]/Short	High	Minor
White beaked dolphin	Local	Short	Low	Medium	Short	Medium	Minor
Minke whale	Local	Short	Low	Medium	Short	Low	Minor
Harbour seal and grey seal	Local	Short	Low	Medium	Short	Medium	Minor

HABITAT LOSS

Noise distribution from seismic survey may lead to temporary loss of habitat as marine mammals have been shown to move away from noise sources to avoid negative impacts. Once surveys are completed, individuals re-enter the areas. Studies on harbour porpoises in the North Sea has previously been linking local density displacement effects to airgun seismic survey activity, but without obvious long-term avoidance (i.e., greater than 1 day) (Sarnocińska, et al., 2020).

Habitat conditions will not be impacted directly unless mobile ecosystem components such as pelagic fishes do not return after the noise emission stops. However, such permanent ecological impact has not been observed for seismic survey.

ASSESSMENT - TEMPORARY HABITAT LOSS

Assuming that the soft-start period will be prolonged from 40 to 45 minutes, no marine mammals will experience either TTS or PTS when considering a swimming speed of 1.5 m/s or faster (same as the average swimming speed for wild harbour porpoises (Tougaard, 2021)).

Based on the results of the noise modelling, the seismic survey will affect marine mammals within a radius 4.8 to 6.5 km from the airgun array based on Tougaard (2016) and 24.7-55.6 km based on DEA (2022) where the range depends of the seasonality of the survey (March-October). The threshold distances for behavioral disturbance are significantly lower in the months where the harbour porpoise calves and thus the highest sensitivity of this species is expected (see Table 8-7). Additionally, the predicted disturbance distance based on DEA (2022) is far greater than the observations from Thompson et al., (2013), with displacement of harbour porpoise during the seismic survey within 5 to 10 km, which indicates that the impact distances calculated based on the DEA (2022) are very conservative (see more in (Genesis, 2023)).

The disturbed area at any given time during the active survey period of ~24 days within a 45-day working period (including down time) is thus 130-5,912 km^2.

The **extent** of the impacted area is *local* compared to the North Sea and *local-regional* (depending on the threshold used and the final season for the survey) compared to similar foraging areas available within the Danish EEZ. The **magnitude** is *low* since there is no injury of individuals. The **level and complexity** of the impact is *medium* as normal behaviors such as breeding, foraging, and socializing could be disrupted, and the marine mammals are potentially displacement from an area. However, any marine mammal displaced from the area by the proposed seismic survey will likely return after the activities from the site survey (Sarnocinska, et al. 2020, Thompson, et al. 2013). Further, several elements in the food web might be affected at the same time (mainly fish near the survey vessel, see section 8.2).

The survey area is not a hotspot for any of the relevant mammal species and the duration of the impact is assessed as short and is limited to ~24 days within a 45-day working period within March to October 2024. The **extent** of the impact (behavioural disturbance) potentially covers an area of 130-5,912 km^2, depending on the threshold used and the seasonally of the survey. A short impact as for this survey is not considered to impact the energy balance of the animals significantly as they can search for food locally around the survey area in the short period when the survey is ongoing. The **probability** of the impact is **low** to **high** (depending on the species); however, all impacts are fully reversible for all marine mammal species. Based on scientific literature and the performed model, any marine mammals disturbed from the area by the proposed seismic survey are likely to return after the survey has been completed. Thus, the potentially impacted area naturally restores to pre-impacted status. However, the **reversibility** is set to *medium* for the season with most calves (season with the highest sensitivity) and *short* for the rest of the year.

Furthermore, all species are assessed as having a favourable conservation status according to the habitat directive and all species are on the IUCN red list assessed as not threatened (LC).

Regardless, it must be considered that a potential longer soft-start period, to reduce the number of animals being potential disturbed by the airgun, will lead to a disturbance by itself and prolongs the overall disturbance period of the survey.

The summarised potential impact on marine mammals related to habitat loss is given in Table 8-13. The potential impact on habitat loss is the same for the standard (40 min) or longer soft-start period (45 min).

Table 8-13 Potential impacts (habitat loss). [1]For behavioural disturbance in March to May and October >2500 km^2. [2] The reversibility is medium in the season with most calves (highest sensitivity).

Receptor	Extent	Duration	Magnitude	Level of complexity	Reversibility	Probability	Overall significance
Harbour porpoise	Local/Regional[1]	Short	Low	Medium	Medium[2]/Short	High	Minor
White beaked dolphin	Local	Short	Low	Medium	Short	Medium	Minor
Minke whale	Local	Short	Low	Medium	Short	Low	Minor
Harbour seal and grey seal	Local	Short	Low	Medium	Short	Medium	Minor

REDUCED FOOD SUPPLY

Harbour porpoises and white-beaked dolphins primarily feed on fish such as cod, whiting, mackerel, herring, and sprat (Santos & Pierce, 2003). Minke whale feed on pelagic fish such as sprat and herring, and small crustaceans (NOAA fisheries, 2022).

Mortal injury of fish caused by underwater noise can indirectly affect marine mammals by reducing their food supply. The vertical displacement of fish due to underwater noise may also reduce the general abundance of fish in the survey area. However, the potential increased mortality of fish during the survey period is unlikely to affect the fish stocks significantly (see section 8.2). Furthermore, small cetaceans follow the seasonal migration of pelagic fish over large distances. Therefore, a potential temporal and local displacement of fish is unlikely to affect the natural fluctuations in food availability for marine mammals significantly. Shortly after the survey stops, the fishes and their predators will return to the area.

ASSESSMENT – REDUCED FOOD SUPPLY

The extent of the impact covers 130-5,912 km^2 for the site survey (~24 days within a 45-day working period (including down time)), within which marine mammals might be disturbed during the entire survey period. Within this area, animal behaviours such as foraging and socializing might be disturbed.

The modelling predicts that zero-to-peak SPL sound levels will be below threshold values associated with injury to the most sensitive fish beyond 80 m from the airgun array. Predicted distances are lower for less sensitive fish species. The soft-start of the airgun array is likely to disperse any mobile fish away from the sound source to further distances where injury impacts are unlikely to occur.

There will not be any marine mammals within 500 m of the survey when the airgun and SBP is operating (MMO and PAM systems will be used according to JNCC (2017), DEA (2018) and TEPDK best practise measures – see section 6.3) and thus, no marine mammals will occur within the radius where fish potentially might be injured.

The **magnitude** of the impact is low since the change in food supply is negligible. The **level and complexity** of the impact is assessed as *small* although several elements in the food web might be affected at the same time (mainly fish near the survey vessel, see sections 8.2). The area is not a hotspot for any of the relevant mammal species. The **duration** of the impact is *short* and is limited up to (~24 days within a 45-day working period from March to October, which is assessed not to impact the energy balance of the animals significantly. Further, fish are expected to return to the area shortly again after the survey period. The **probability** of the impact on marine mammals is low to high (depending on the species), as some fish are expected to be injured by the seismic survey. However, all impacts on marine mammals caused by reduction in food supply are fully **reversible** and fish from the surrounding areas are expected to return to the area *shortly* after the survey period.

Reduced food supply is assessed to have a minor impact on all marine mammal species in the area (Table 8-14).

Table 8-14 Potential impacts on marine mammals due to reduced food supply.

Receptor	Extent	Duration	Magnitude	Level of complexity	Reversibility	Probability	Overall significance
Harbour porpoise	Local	Short	Low	Small	Short	High	Minor
White beaked dolphin	Local	Short	Low	Small	Short	Medium	Minor
Minke whale	Local	Short	Low	Small	Short	Low	Minor
Harbour seal and grey seal	Local	Short	Low	Small	Short	Medium	Minor

8.2 FISH

This chapter includes the following sections: method, existing conditions for relevant fish species in the survey area and summary of seasonal sensitivity, impact assessment of underwater noise on fish, fish eggs and fish larvae.

8.2.1 METHOD

The assessments of the impact on fish, fish larvae and fish eggs are based on existing knowledge about injury and behavioural thresholds for fish, fish eggs and fish larvae caused by underwater noise. The assessment of impact distances for relevant fish groups is based on a targeted noise modeling (Genesis, 2024). The impact has been modelled for two locations (3.8 km x 3.8 km) centered around the wells P2 and P3 (Figure 8-1). Since the model was undertaken, the survey area has been changed to be centered around the well P11 which is located slightly more Northerly than the P2 and P3 wells. The performed modelling is considered to provide representative results for the new survey location (Appendix 2). In cases where the model results are different for the two areas, the largest effect distances (worst case) have been used for the assessments.

The method and results for the performed noise model (Genesis, 2024) is specified in Appendix 1.

The site survey is expected to be completed within a maximum of 45 working days, including any downtime (21 days), between March and October 2024 depending on vessel availability (section 6.2).

The underwater noise criteria for impacts on fish, fish eggs and fish larvae used in the assessment include: 1) injury (e.g., damage to internal organs and swim bladder, Temporal Threshold Shift (TTS) and Permanent Threshold Shift (PTS)), and 2) behavioral reactions (e.g. vertical migration or flight). The thresholds are defined in the following sub-sections.

INJURY THRESHOLDS

Popper et al. (2014) have defined criteria for injury to fish, fish eggs and fish larvae based on a review of relevant publications and propose three categories for analysing the effects of sound in fishes based on the presence or absence of gas-filled structures (e.g. swim bladder) and the potential of using this structure to improve hearing. The three categories of fishes are the following:

1) Fishes that only detect particle motion. This group lack a swim bladder or gas filled chamber.
2) Fishes with a swim bladder or gas filled chamber that is not involved in hearing. This group is susceptible to physical injury such as barotrauma, although hearing only involves particle motion.
3) Fishes with a swim bladder or gas filled chamber involved in hearing. This group is sensitive to both particle motion and to sound pressure.

Furthermore, Popper et al. (2014) has defined an injury threshold for fish eggs and larvae. The thresholds proposed by Popper et al. (2014) for mortality and potential mortal injury to fish species, fish eggs and fish larvae from seismic survey are shown in Table 8-15.

Table 8-15 Injury thresholds for potential injury to fish. After Popper et al. (2014).

FISH GROUP	INJURY THRESHOLDS[1]	
	Zero-to-peak SPL (dB re 1 Mpa)	**Cumulative SEL (dB re 1 µPa^{2}s)**
Fishes with no swim bladder	213	219
Fishes with swim bladder involved in hearing	207	207
Fishes with swim bladder not involved in hearing	207	210
Eggs and larvae	207	210

[1] In this assessment the seismic survey thresholds are used to assess potential impacts to fish from the airgun arrays that will be used during the survey.

BEHAVIOURAL DISTURBANCE THRESHOLDS

Documented behavioural effects of sound on fish behaviour are variable, ranging from no discernible effect (Wardle et al., 2001) to startle reactions followed by immediate resumption of normal behaviour (Hassel, et al., 2004; Wardle, et al., 2001). Avoidance of airgun array sound has also been observed (Hassel et al., 2004). However, there are no well-established thresholds for assessing behavioural disturbance of fish. Popper et al. (2014) argue that sufficient evidence is lacking to recommend specific thresholds that correspond to behavioural disturbance in fish. Behavioural disturbance in fish is therefore not assessed in this report.

8.2.2 EXISTING CONDITIONS

The area of the Dagny CCS site survey is located within the International Council for the Exploration of the Sea (ICES) rectangles 41F4 and 41F45. Fisheries sensitivity maps have been used to identify potential spawning and nursery grounds for commercial fish species in these ICES rectangles (Coull, Johnstone, & Rogers, 1998; Ellis, Milligan, Readdy, Taylor, & Brown, 2012). The typical commercial fish species in the area include anglerfish, blue whiting, cod, European hake, herring, lemon sole, ling, mackerel, plaice, sand eel, sprat, whiting and blue whiting. Spottet ray, spurdog and tope shark also occur in the area.

Most of the commercially exploited North Sea stocks of the typical fish species encountered in the survey area are in good condition and are fished at a sustainable level. However, the cod stock in the North Sea is in a poor condition and categorised on the IUCN list as vulnerable (VU). Although the spawning stock biomass of cod has increased from the historic low in 2006, it is still below sustainable level and the fishing mortality is still too high (ICES, 2022).

8.2.3 SUMMARY OF SEASONAL SENSITIVITY

Nursery grounds have been found for all the above-mentioned species within the survey area except lemon sole (Ellis, Milligan, Readdy, Taylor, & Brown, 2012).

The survey period will overlap with the spawning period of cod, lemon sole, mackerel, plaice, sprat and whiting and peak spawning period for cod, mackerel and sprat (Table 8-16). A summary of spawning activity in the survey area is provided in Table 8-16. Further details of spawning and nursery activity in the relevant ICES rectangle is provided in Appendix 1 (Genesis, 2024).

Table 8-16 Summary of spawning activity for species that are likely to spawn in the region of the Dagny CCS site survey (ICES Rectangle 41F4 and 41F5) (Ellis, et al. 2012, Coull, Johnstone and Rogers 1998).

Species	J	F	M	A	M	J	J	A	S	O	N	D	Spawning location
Cod													Water column
Lemon sole													Water column
Mackerel													Water column
Plaice													Water column
Sand eel													Sediment
Sprat													Inshore waters
Whiting													Water column

Peak spawning period

Spawning period

Indicates the period where the seismic survey may be conducted

8.2.4 IMPACTS

The Dagny CCS site survey can potentially cause injury, disturbance, and habitat deterioration for the fishes in the area.

In relation to the survey activity, it is assessed that the following elements potentially have a negative impact on fish in the area:

- Increased underwater noise (injury and/or behavioural reactions)
- Temporary habitat loss
- Temporarily reduced food supply.

The potential impact the site survey may have on fish, fish eggs and fish larvae is assessed in the following sections.

UNDERWATER NOISE

There are many natural sources of noise in the marine environment (background, noise, rain, waves and turbulence, lightning strike, mating call, echolocation click, etc.). Natural background noise (the source level at 1 m) is approximately 100 dB re. 1 µPa on a calm day in shallow waters. The level of underwater background noise worldwide has increased in the last century due to anthropogenic sound. Noise may cause stress in animals, increase the risk of mortality by unbalancing predator-prey interaction, and interfere with sound-based orientation and communication, especially in reproductive contexts.

Sound levels at a given distance (unweighted zero-to-peak SPL and unweighted cumulative SEL) have been predicted by Genesis (2024) and compared to the Popper et al. (2014) thresholds for injury to quantitatively assess any potential injury to fish, fish eggs and fish larvae from the proposed site survey.

The maximum predicted distances where the zero-to-peak SPL sound levels from airgun activity during the site survey exceed the Popper et al. (2014) thresholds for injury of fish, fish egg and fish larvae are shown in Table 8-17. The modelling predicts that zero-to-peak SPL sound levels will be below threshold values associated with injury to the most sensitive fish species beyond a maximum of 80 m from the airgun array. Predicted distances are lower for fishes with no swim bladder involved in hearing. It is expected that the soft-start of the airgun array will disperse any mobile fish away from the sound source to further distances where injury impacts are unlikely to occur.

Table 8-17 Predicted distances from the airgun array where the Popper et al. (2014) zero-to-peak SPL thresholds for injury to fish are exceeded.

Fish Group	Injury Threshold [1] (dB re 1 µPa)	Maximum distance to threshold exceedance [2] (m)
Fishes with no swim bladder	213	30
Fishes with swim bladder involved in hearing	207	80
Fishes with swim bladder not involved in hearing	207	80
Eggs and larvae	207	80

[1] Injury thresholds are in terms of unweighted zero-to-peak SPL.

[2] Predicted distances have been rounded up to the nearest 10 m.

ASSESSMENT – UNDERWATER NOISE

The Dagny CCS site survey may take place during the spawning season for cod, lemon sole, mackerel, plaice, sprat and whiting; thus eggs and larvae of these fish may be affected by the airgun depending on the starting time of the survey. However, the modelling predicts that zero-to-peak SPL sound levels will be below threshold values associated with injury to the most sensitive fish beyond a maximum **extent** of 80 m from the airgun array (*local*). Predicted distances are lower (30 m) for less sensitive fish species (i.e., fish species without gas filled organs – this includes lemon sole, mackerel, and plaice). It is expected that the soft-start of the airgun will likely disperse any mobile fish away from the sound source to further distances where injury impacts are unlikely to occur. The **magnitude** and the **level and complexity** of the impact is *small* since only fish near the airgun are affected which will have negligible impact on the population size. This is assumed since the **duration** of the impact is *short* (~24 days within a 45-day period and not across the entire area at the same time) and that fish are expected to return to the area shortly after the survey period. The **probability** of the impact is *medium* since most fish species are expected to flee from the area to avoid injury and since they are expected to return to the area shortly after the survey period. Most impacts on fish are thus fully **reversible.**

It is assessed that the impact from underwater noise on fish, fish eggs and fish larvae may have a minor impact on fish stocks.

HABITAT LOSS

The noise distribution from seismic survey may lead to temporary habitat loss since some fish species move away from the area to avoid negative impacts from underwater noise. However, it has been shown that most fish undertake vertical migration in response to seismic survey rather than horizontal displacement. Shortly after the surveys are completed, fish re-enter the habitat (Carroll, Przeslawski, Duncan, Gunning, & Bruce, 2017).

The habitat conditions will not be impacted directly unless mobile ecosystem components such as their food supply (e.g. small crustaceans affected by underwater noise) do not return after the noise stops. However, such permanent ecological impact has not been observed for seismic surveys (Carroll, Przeslawski, Duncan, Gunning, & Bruce, 2017).

ASSESSMENT – HABITAT LOSS

Some fish species are likely to be displaced from a small part of their habitat (e.g. spawning grounds) if the sound generated is causing them distress. Based on the noise modelling results, the **extent** of the temporary habitat loss is maximum 80 m from the air gun (*local*). The maximum distance where fish might be affected is insignificant compared to foraging and spawning grounds available to the typical fish species in the North Sea, incl. spawning grounds for cod. Based on scientific literature and the performed model, fish in general are likely to return to the area after the survey has been completed.

The **magnitude** is *low* since no fish will be directly affected. The **level and complexity** of the impact of habitat loss is assessed to be *small* although several elements in the food web might be affected at the same time. The **duration** of the impact is *short* (~24 days within a 45-day period). The **probability** of the impact is *medium*, however all impacts are fully **reversible**. Based on this, the overall impact of temporary habitat loss on fish is assessed to be minor for all fish species. However, it should be noted that the cod stock in the North Sea is in a poor condition and categorised on the IUCN list as vulnerable (VU). Therefore, the impact would be highest in the spawning season (January -April).

REDUCED FOOD SUPPLY

The typical fish species in the area feed on small crustaceans. Pelagic fish species such as herring, sprat, mackerel, and fish larvae and juvenile fish primarily feed on copepods. Demersal (bottom dwelling) fish species in the survey area such as plaice, whiting and cod feed on benthic invertebrates. The zooplankton in the North Sea is dominated by larger copepod species that have been shown to be robust to underwater noise (Fields, et al., 2019). The impact of underwater noise on invertebrates is understudied, but the few existing studies on molluscs and crustacean larvae have not identified any significant effects (Carroll, Przeslawski, Duncan, Gunning, & Bruce, 2017).

ASSESSMENT – REDUCED FOOD SUPPLY

Measurable impacts on invertebrates such as zooplankton, molluscs and crustaceans that comprise the major food supply for fish in the survey area are unlikely to occur. The area has a relatively high abundance of copepods in the spring (Sundby, Kristiansen, Nash, & Johannesen, 2017; ICES, 2021), but the mortality of copepods is not expected to increase significantly due to the seismic survey. The **extent** of the impact is *local* as plankton is only affected from a few meters from the sound source to 4.5 km^2. Furthermore, the **duration** of the impact is *short* (~24 days within a 45-day period). The **magnitude** is *low* and the **level and complexity** of the impact is *small* since fish are only affected near the airguns. The **probability** of the impact is *low*, and even if there is an impact, the impact is fully **reversible**.

The impact of underwater noise on the food supply for fish is assessed to be negligible.

8.2.5 SUMMARY

The over all impact of the site survey on fish, fish eggs and fish larvae is summarised in Table 8-18.

Table 8-18 Potential impacts from Dagny CCS site survey on fish, fish eggs and fish larvae.

FISH SPECIES	UNDERWATER NOISE	HABITAT LOSS	REDUCTION IN THE FOOD SUPPLY
Anglerfish	Minor	Minor	Negligible
Blue whiting	Minor	Minor	Negligible
Cod	Minor	Minor	Negligible
European hake	Minor	Minor	Negligible
Herring	Minor	Minor	Negligible
Lemon sole	Minor	Minor	Negligible
Ling	Minor	Minor	Negligible
Mackerel	Minor	Minor	Negligible
Plaice	Minor	Minor	Negligible
Sandeel	Minor	Minor	Negligible
Spotted ray	Minor	Minor	Negligible
Sprat	Minor	Minor	Negligible
Spurdog	Minor	Minor	Negligible
Tope shark	Minor	Minor	Negligible
Whiting	Minor	Minor	Negligible
Eggs and Larvae	Minor	Minor	Negligible

9 SCREENING FOR APPROPRIATE ASSESSMENT

9.1 METHOD

Relevant marine mammal species and their occurrence is described based on existing data and scientific literature. The assessments are furthermore based on existing knowledge about the animals' injury and behavioural thresholds for underwater noise.

9.2 IDENTIFICATION OF NATURA 2000 SITES

Natura 2000 sites within a 100 km radius from the project area includes the German SAC DE1003301 Doggerbank and the Dutch SAC NL2008001 Doggerbank. The Danish Natura 2000 site no. 245 Jyske Rev is more than 108 km from the survey areas. It is assessed to be highly unlikely that Natura 2000 sites located further away than 100 km will be affected by the seismic activities and site no. 245 Jyske Rev is therefore not considered further in this report.

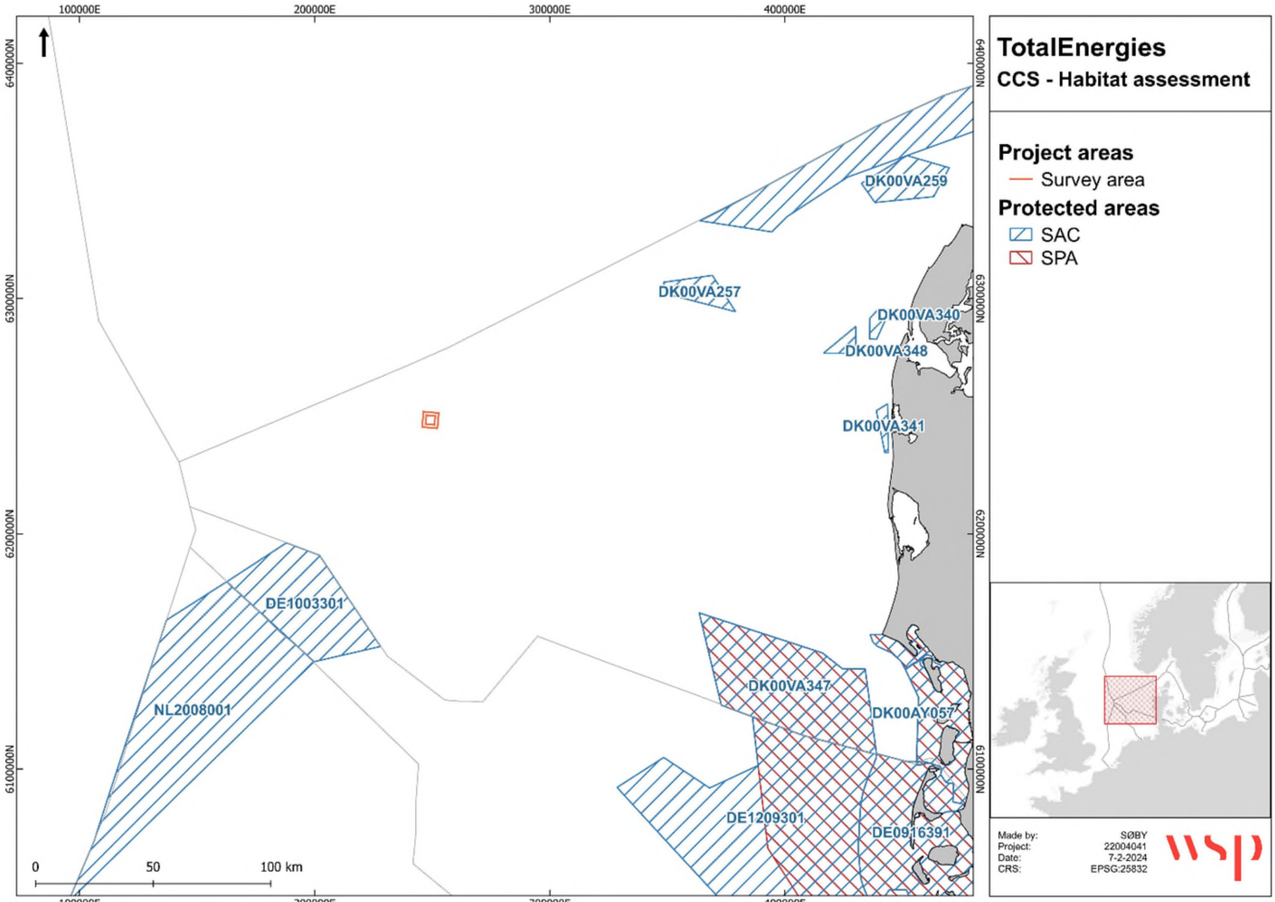

Figure 9-1 Natura 2000 sites (Special Area of Conservation, SAC; Sites of Community Importance, SCI; Special Protection Area, SPA).

9.3 DESIGNATION BASIS

The nearest SAC site is the German SAC DE1003301 Doggerbank 69.8 km from the Dagny CCS site survey. Figure 9-1 gives the shortest distance from the survey area. The Dogger Bank SAC is designated for the Annex I habitat '*Sandbanks which are slightly covered by sea water all the time*'. The SAC also lists the Habitats Directive Annex II species harbour porpoise, grey seal, and harbour seal as qualifying features. The Dutch SAC NL2008001 Doggerbank is 99.9 km from the survey area and is also designated to protect '*Sandbanks which are slightly covered by sea water all the time*', harbour porpoise, harbour seal and grey seal. Table 9-1 provides an overview of the designation basis for Natura 2000 sites within a radius of 100 km from the survey area.

Seabirds and all marine mammals are based on their high mobility and sensitivity to underwater noise, the only designation basis for the relevant Natura 2000 sites, assessed to be relevant for the screening (Table 9-1). In contrast, animals attached to the habitat types far from the survey area will not be affected by underwater noise from the project activities. The impact on habitat types will therefore not be assessed any further. The potential impact on seabirds, harbour porpoise and seals are assessed in section 9.3.1, 9.3.2 and 9.3.3.

Table 9-1 Marine Natura 2000 sites within 100 km of the survey area.

Natura 2000 site	Distance	Designation basis	Relevance (X)
DE1003301 Doggerbank (SAC)	70km	Annex I habitat type 1110 Sandbanks	Due to the long distance to the habitat, animals attached to the biotope are unlikely to be affected by underwater noise.
		Species listed under Annex II 1351 Harbour porpoise 1365 Harbour seal	 X X
		Birds listed under Annex II A009 *Fulmarus glacialis* A641 *Larus fucus* A188 *Rissa tridactyla* A016 *Morus bassanus* A678 *Uria aalge*	 X X X X X
NL2008001 Doggerbank (SAC)	105 km	Annex I habitat type 1110 Sandbanks	Due to the long distance to the habitat, animals attached to the biotope are unlikely to be affected by underwater noise.
		Species listed under Annex II 1351 Harbour porpoise 1365 Harbour seal 1364 Grey seal	 X X X

9.3.1 SEABIRDS

There are limited studies on the potential effects of seismic surveys on seabirds. Loud underwater noise from shooting of airguns may be uncomfortable for birds, and it has been shown that diving seabirds like auks and penguins avoid areas where artificial underwater noise, including seismic surveys, are taking place (Melvin, Parrish, & Conquest, 1999; Pichegru, Nyengera, McInnes, & Pistorius, 2017).

Northern fulmar (*Fulmarus glacialis), lesser* black-backed seagull *(Larus fucus)* and black legged kittiwake (*Rissa tridactyla*) may be encountered in the survey area (Waggitt, et al., 2019). Additionally, northern gannet (*Morus bassanus*) and common guillemot (*Uria aalge*) are likely to occur within the survey area in low densities during winter (Waggitt, et al., 2019).

Since gulls like northern fulmar, lesser black backed seagull and black legged kittiwake find their food in the surface, they are less likely to be affected by underwater noise. In contrast, gannets and common guillemots forage in deeper waters and are likely to be more sensitive to underwater noise. These species may be temporarily displaced from their feeding grounds due to increased underwater noise.

Since the displacement is temporary (45 working days, including any downtime (21 days)) and is locally centered around the source, and since there are more suitable feeding elsewhere (Doggerbank), it is assessed that the impact on seabirds will not be significant. The impact of seabirds will not be further assessed.

9.3.2 HARBOUR PORPOISE

Harbour porpoise have been sighted in the region of the proposed survey area in low to moderate numbers at different times throughout the year (Waggitt, et al., 2019). Harbour porpoises are known to undertake long migrations and may thus migrate between the SAC Doggerbank and other SACs in the North Sea. Since harbour porpoises are highly sensitive to underwater noise (e.g. (Tougaard, 2016; Southall, et al., 2019; DEA, 2022)), there is a risk of significant impact on harbour porpoises migrating or foraging in the survey area. Since a significant risk cannot be excluded based on objective information, an appropriate assessment (AA) will be undertaken for harbour porpoise. Chapter 10 includes a full AA for harbour porpoise.

9.3.3 SEALS

Harbour seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) are the only pinnipeds that occur in the North Sea. Seals are generally coastal, depending on isolated and undisturbed land areas for resting, breeding, and molting (such as undisturbed islands, islets sandy beaches, reefs, skerries and sandbanks). They may however undertake long foraging migrations and may occasionally occur in the survey area. Seals are sensitive to underwater noise and may potentially be affected by underwater noise during their migration. Since a risk of significant impact cannot be excluded based on objective information, an appropriate assessment (AA) will be undertaken for harbour seal and grey seal. Chapter 10 includes a full AA for grey seals and harbour seals.

9.4 SUMMARY STATEMENT

A screening for Appropriate Assessment has been conducted for the seismic survey in relation to the Dagny CCS site survey. Potential significant impacts are restricted to underwater noise. A risk of significant impact from seismic survey on grey seal, harbour seal and harbour porpoise cannot be excluded based on objective information.

Following Article 6 in the Habitat Directive, an Appropriate Assessment should be undertaken to assess whether harbour porpoise and seals designated to protect SAC DE Doggerbank and SAC NL Doggerbank could be significantly affected by the seismic survey.

Due to the long distance to other Natura 2000 sites (>100 km), it is assessed that the site survey will not negatively affect the conservation status of habitats and species in these Natura 2000 sites. Nor will the survey activities affect the integrity of these sites.

A complete AA for harbour porpoise, harbour seal and grey seal is conducted in chapter 10.

10 APPROPRIATE ASSESSMENT (AA)

A screening for Appropriate Assessment (AA) has been conducted for the seismic survey in relation to the Dagny CCS site survey (chapter 9). Based on objective information, the screening concludes that there is no risk of significant impact on habitats and seabirds on the designation basis of the Doggerbank SACs NL2008001 and DE1003301 (Figure 10-1). However, risk of significant impact from seismic survey on grey seal, harbour seal and harbour porpoise could not be excluded based on objective information for these sites.

Potential impacts are restricted to the impact on harbour seal, grey seal, and harbour porpoise from underwater noise. This chapter makes up the AA for grey seal, harbour seal and harbour porpoise.

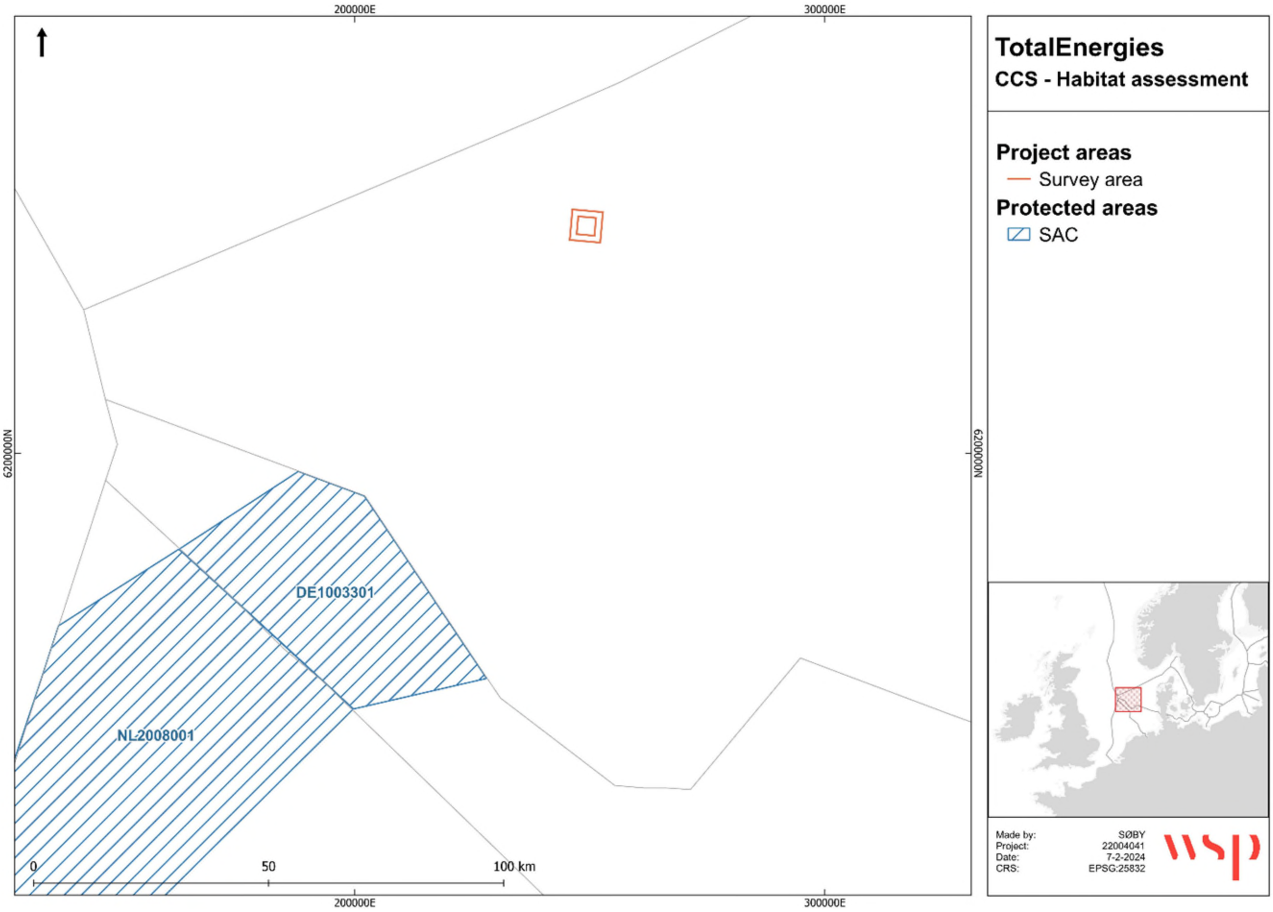

Figure 10-1 Overview of the Dagny CCS site survey and the Doggerbank SAC (nearest SAC sites).

10.1 METHOD

The method for the assessment of impact on harbour porpoise, grey seal and harbour seal is based on the noise modelling in Appendix 1 (Genesis, 2024) and follows the methodology for assessment of marine mammals as described in section 8.1.

The potential impact on the conservation objectives for species is assessed along with the environmental targets for the Doggerbank SACs. The environmental targets are defined in the Natura 2000 plan for the specific areas.

The assessment of the significance of the impact has been carried out in accordance with the guidelines in the existing Danish guidance for the Habitat Directive (Danish Environmental Protection Agency, 2020).

10.2 DESIGANTION BASIS

The Dogger Bank SACs are designated for the Habitats Directive Annex II species harbour porpoise, grey seal, and harbour seal as qualifying features. The SACs are also designated to protect Annex I habitat '*Sandbanks which are slightly covered by sea water all the time*'. In addition, DE1003301 Doggerbank list five seabirds. The AA will only address the impact on marine mammals. The reasoning for not assessing seabirds and habitat types is provided in the screening for AA (chapter 9).

10.3 CONSERVATION OBJECTIVES

The conservation objectives for harbour porpoise and harbour seal for the German and Dutch SACs are for maintenance and recovery of a favourable conservation status of the harbour porpoise and harbour seal, and its habitats.

BfN (BfN, 2008) lists conservation objectives for harbour porpoise and harbour seal but they are formulated in general terms, not specifically for the Dogger Bank. For the harbour porpoise and harbour seal, conservation objectives include:

- At least maintenance of numbers at date of nomination considering natural population dynamics
- Maintenance of ecological quality of areas for foraging, migration, and reproduction in the southern and central North Sea
- Maintenance of population structure, reproductive fitness, ecological connectivity, genetic exchange, and others.

For the Dutch Doggerbank SAC, the conservation objectives are based on the national conservation status. For the harbour porpoise, it is recommended to follow a North Sea-wide approach for protection (Jak, Witbaard, & Lindeboom, 2009).

10.4 POTENTIAL IMPACTS

The Dagny CCS site survey can potentially cause disturbance and habitat deterioration for the marine species, which forage or migrate within the affected area.

The following elements due to survey activities may potentially have a negative impact on marine mammals in the Dogger Bank SACs:

- Increased underwater noise (injury and/or behavioural reactions)
- Temporary habitat loss (displacement from feeding grounds/migration routes).

The potential impacts from the Dagny CCS site survey include underwater noise from firing of airguns. Other operations and incidences taking place during the survey such as disturbance from survey vessels and other types of equipment are not assessed further, since potential impacts are much smaller and insignificant compared to the airguns.

In the following, an assessment is conducted on the potential impact the seismic survey may have on grey seal, harbour seal and harbour porpoise that are all on the designation basis of the Doggerbank SACs (NL2008001 and DE1003301).

10.5 ASSESMENT

The German authorities suggest that sound levels exceeding an SEL of 140 dB re 1 μPa^{2}s should not cover more than 10% of the Dogger Bank SAC during September to April and should not cover more than 1% of the Dogger Bank SAC during May to August. The noise modelling results show that the 140 dB re 1 μPa^{2}s threshold will not be exceeded anywhere in DE1003301 Doggerbank. Thus, it is only mobile designated species that migrate into the affected areas outside the SAC that may be exposed to an impact (see section 8.1).

10.5.1 HARBOUR PORPOISE

Harbour porpoise is included in the designation basis for DE1003301 Doggerbank and the NL2008001 Doggerbank since they have relatively high abundance in the Dogger Bank area where they feed on fish. However, they may also feed or undertake migration outside the Dogger Bank area and the impact on individuals outside the SACs is therefore also considered. A detailed assessment of the direct (injury) and indirect (habitat loss/reduced food supply) impacts of underwater noise on harbour porpoise is conducted in section 8.1. The main points are highlighted below.

The Dagny CCS site survey will emit intense sound impulses (SEL 213.2 dB re 1 μPa^{2}s-m). The Dagny CCS site survey area where the highest sound levels emitted (airguns) is located approximately 66.8-71.3 km from the German Dogger Bank SAC and 99.9 km from the Dutch Doggerbank SAC. Since the German SAC is nearest, the assessment focuses on the German Doggerbank SAC.

It is expected that marine mammals would swim away from the airgun array quickly if the sound generated is causing them distress. The PTS thresholds will not be exceeded for any of the marine mammal species assuming a swimming speed of 1.5 m/s. The maximum distance to injury threshold (TTS) exceedance for harbour porpoise is 2.4-6.3 km depending on the timing of the survey. Harbour porpoises within the SAC are therefore not exposed to underwater noise that may cause injury (TTS or PTS).

During the commencement of the survey and between survey lines, a soft-start period of 45 minutes will be performed. It is argued that TTS for harbour porpoises occurring outside the SAC is unlikely by applying a 45 minute soft-start period (see section 8.1.4). Thus, it unlikely that any marine animals will suffer from TTS.

The effect distance for behavioral impacts for harbour porpoise using the 103 dB re 1 μ Pa (rms SPL over a time window of 125 ms weighted for VHF cetaceans) based on the threshold by the DEA (2022) is 55.2-55.6 km for harbour porpoise in the coldest months (March) and 23.5-24.7 km in the warmer months (August) (See section 8.1.4) and 4.7-6.5 km for all marine mammals using the 145 dB re 1 μ Pa^{2}s (single-pulse unweighted SEL) threshold recommended by Tougaard (2016). The seismic survey underwater noise will not exceed the threshold for behavioral reactions within any SAC areas. Harbour porpoises displaced from their feeding grounds outside the SAC will likely return after the activities stop (Sarnocińska, et al., 2020; Thompson, et al., 2013). Furthermore, there are alternative feeding grounds in the area close to the survey area. Additionally, the predicted distances based on the threshold by DEA (2022) is far greater than observations from similar survey from Thompson et al. (2013) (within distances of 5 to 10 km) and predicted distances for the threshold by Tougaard (2016) (4 km) specifically developed for similar activities. This indicates that the impact distances calculated based on the DEA (2022) are very conservative (see more in Genesis, (2023)). Finally, the survey period is short (maximum of 45 working days, including any downtime (21 days)).

Direct impact (injury) and indirect impact (habitat loss/reduced food supply) from underwater noise is assessed to be minor and will not affect the conservation objectives for harbour porpoise in the North Sea.

10.5.2 SEALS

Harbour seal and grey seal are included in the designation basis for DE1003301 Doggerbank and the NL2008001 Doggerbank since they forage in the Dogger Bank area. The survey area is not considered a hotspot feeding area or migration route for seals, although they may be occasionally observed in the area. A detailed assessment of the direct (injury) and indirect (habitat loss/reduced food supply) impacts of underwater noise on harbour seal and grey seal is included in section 8.1. The main points are highlighted below.

The PTS and TTS thresholds for harbour seal and grey seal will not be exceeded assuming a swimming speed of 1.5 m/s away from the airgun array. Seals within the SAC are therefore not exposed to underwater noise that may cause injury (TTS or PTS).

The effect distance for behavioral impacts for marine mammals is 4.8-6.5 km and seals may therefore exhibit behavioural disturbance effects (such as displacement from an area) within approximately 4.8-6.5 km from the survey vessel and airgun array. However, seals displaced from their feeding grounds will likely return after the activities stop. Furthermore, there are alternative feeding grounds in the area close to the survey area.

Direct impact (injury) and indirect impact (habitat loss/reduced food supply) on seals from underwater noise is assessed to be minor and will not affect the conservation objectives for harbour seal or grey seal.

10.6 SUMMARY

Based on a targeted noise model, the impact distances for relevant marine mammal species have been conducted for the Dagny CCS site survey (Genesis, 2024) (see section 8.1).

The result of the modelling predicts that the PTS and TTS thresholds for harbour seal and grey seal will not be exceeded. The maximum distance to injury threshold (TTS) exceedance for harbour porpoise is 6.3 km (based on the most conservative model results from March, see section 8.1.4). Since the nearest SAC is located 65 km from the survey site, it is only mobile animals foraging outside the SAC or migrating between SACs that may be affected. The impact to individuals is unlikely with a 45 minute soft start, since this will allow the porpoises to flee from the area before the arrays start assuming a speed of 1.5 m/s and a surveying speed of 2.2 m/s. The PTS and TTS threshold will, with a 45-minute soft start (prolonged soft-start period), not be exceeded for harbour porpoise. The PTS and TTS thresholds for harbour seal and grey seal will not be exceeded assuming a swimming speed of ≥1.5 m/s away from the airgun array.

The modeled threshold distance for behavioural disturbance does not reach into any SACs.

It is assessed that the Dagny CCS site survey will not hinder or delay maintenance and recovery of a favourable conservation status of the harbour porpoise, harbour seal and grey seal in the North Sea including the Doggerbank SACs.

11 ASSESEMENT OF ANNEX IV SPECIES

All cetacean species are listed on Annexes II and IV of the EU Habitats Directive (see further in section 5.3).

The Habitats Directive and the Habitats Executive Order require that the member states must introduce strict protection for several animal and plant species covered by the Habitats Directive's Article 12 and Annex IV, regardless of whether these occur within or outside a Natura 2000 site.

Harbour porpoise is the only resident Annex IV species relevant to the present project. White-beaked dolphin and minke whales are also included, as they occur regularly in the open part of the North Sea.

Animal species covered by Annex IV must not be caught, killed, intentionally disturbed or have their breeding or resting areas damaged or destroyed. The directive provision implies, among other things, that where there is a regular occurrence of Annex IV species, permission cannot immediately be granted for activities that may damage or destroy the breeding and roosting areas of the species in question. Breeding areas are areas that are necessary for animals to mate or courtship, nest building, den building, birth, egg laying or rearing of brood and young (Miljøministeriet, 2020). Resting areas are defined as areas which are important to ensure the survival of individual animals or populations when they are at rest.

When assessing whether a project can affect the breeding or resting area of an Annex IV species, it is necessary to look at how the project affects the site's overall "ecological functionality" for the specie'' requirements. Ecological functionality is the overall conditions that a breeding and resting area can offer the population of the species (Miljøministeriet, 2020).

11.1 METHOD

The method for the assessment of impact on cetaceans is based on the noise modelling in Appendix 1 (Genesis, 2024) and follows the methodology for assessment of marine mammals as described in section 8.1. The cetacean species included in this assessment of Annex IV species are based on the recommendations by Tougaard et al. (2021) and includes harbour porpoise, minke whale and white-beaked dolphin.

The assessment of the significance of the impact has been carried out in accordance with the guidelines in the existing guidance for the Executive Order on habitats (Miljøministeriet, 2020).

The principle of ecological functionality has been applied in the assessment of possible impacts on the Annex IV species (harbour porpoise, minke whale and white beaked dolphin). It is based on a broader ecological understanding of the species and its way of life without disregarding protection considerations.

The Dagny CCS site survey can potentially cause temporary disturbance and habitat deterioration for the marine mammals, which stay in the area.

The following direct and indirect effects may potentially have a negative impact on marine mammals in the area:

- Increased underwater noise (injury and/or behavioural reactions)
- Temporary habitat loss
- Temporarily reduced food supply.

There are no defined breeding areas for harbour porpoises, white-beaked dolphin and minke whales, and consequently no further assessment of possible impacts on these locations is undertaken. However, the assessment has considered impacts which potentially could lead to mother-calf separation.

The following sections assess the potential impact that the Dagny CCS site survey may have on harbour porpoises, white-beaked dolphin and minke whales.

11.2 EXISTING CONDITIONS

The existing conditions and conservation status of the marine mammals are described in section 8.1.3.

The abundance and composition of fish fauna is important in assessing the ecological importance of a habitat for marine mammals as it is the main source of food for most mammal species. The typical fish species in the area include anglerfish, blue whiting, cod, European hake, herring, lemon sole, ling, mackerel, plaice, sandeel, sprat, whiting and blue whiting. Spottet ray, spurdog and tope shark also occur in the area. Herring and sprat are common in the autumn, while mackerel primarily is present in the summer. Benthic species are present year-round.

Overall, the marine habitat in the project area can be characterised as typical for the central North Sea with lower-than-average biological production and abundance, and with no special ecological importance.

11.3 ASSESEMENT

Annex IV species are, as mentioned above, strictly protected, regardless of whether these occur within or outside a SAC. Potential temporary habitat loss will occur when the animals show behavioural disturbance. Marine mammals are likely to swim away from the airgun array if the sound generated is causing them distress.

Based on a targeted noise model, effect distances have been calculated by Genesis (2024) and have been used to assess the impact on marine mammals in section 8.1.4. The main conclusions from the assessment are summarised below.

The PTS thresholds will not be exceeded for harbour porpoise, white beaked dolphin or minke whales. The maximum distance to injury threshold (TTS) exceedance is 6.3 km for harbour porpoise and 5.8 km for minke whale. The TTS threshold for white-beaked dolphin will not be exceeded. By applying TEPDK best practice measure (section 6.3), potential TTS can be avoided for minke whale, whereas a prolonged soft-start period of 45-minutes is likely to avoid potential TTS also for harbour porpoise. A prolonged soft-start period is considered to allow potential mother-calves in the area to reach a distance greater than the distance for potential TTS at a swimming speed of 1.5 m/s, which is relatively slow and should thus minimise the potential risk of mother-calf separation.

To estimate the impact of habitat loss, the effect distance for behavioral impacts has been modelled based on temperature dependencies reflecting the time of the survey (See section 4.3, Table 8-9). The behavioral effect distance is predicted to be 24.7 to 55.6 km for harbour porpoise considering the 103 dB re 1 µPa (rms SPL over a time window of 125 ms weighted for VHF cetaceans) threshold and 4.8 to 6.5 km for all cetaceans considering the 145 dB re 1 $\mu Pa^2 s$ (single-pulse unweighted SEL) threshold depending on the timing of the survey. Since the disturbance period is limited to 45 working days, including any downtime (21 days), and since alternative habitats of similar quality and value for food supply are available, the temporary habitat loss in the project area is assessed to be non-significant to Annex IV species. Further, the modeled threshold distances will be at the lower listed values using both threshold criteria (103 and 145 dB) in the months where the harbour porpoise calves and thus the highest sensitivity of this species is expected.

11.4 SUMMARY

There is no significant disturbance, injury, or death of Annex IV species due to the Dagny CCS site survey. Deterioration or destruction of their breeding sites will also not occur. The proposed survey does not threaten the strict protection of cetaceans under Article 12 of the Habitats Directive.

12 MARINE STRATEGY FRAMEWORK DIRECTIVE

An environmental assessment of seismic survey in Danish waters requires an assessment of potential impacts on goals and conditions of defined descriptors in the Marine Strategy Framework Directive (MSFD) in Denmark. In addition, an application should include a description and an assessment of the potential impact on marine strategy areas and on monitoring stations under the national monitoring program (NOVANA).

The following text briefly describes relevant descriptors and the potential impacts from the project on the descriptors on national monitoring stations.

12.1 ENVIRONMENTAL DESCRIPTORS

The Danish Marine Strategy II implements EU's Marine Strategy Framework Directive (MSFD) in Denmark. The MSFD has defined Good Environmental Status by 11 descriptors. The project activities may potentially affect the Danish environmental targets (Good Environmental Status (GES)) of these descriptors.

The potential effects from the survey include underwater noise from seismic survey. SBP and MBES are assessed to have negligible impact and are thus assessed not to have an impact on the environmental descriptors. Foreign vessels used for the Dagny CCS site survey may also introduce non-indigenous species from marine fouling. A summary of the potential impacts on relevant descriptors is provided in Table 12-1.

Table 12-1 Summary of potential impact on MSFD descriptors.

Descriptor	Targets	Assessment
D1 Biodiversity	1.2 Populations and habitats for birds are conserved and protected in accordance with objectives under the Birds Directive.	The Dagny CCS site survey is temporary and is not conducted within areas protected under the Birds or Habitats Directive. Seabirds may be temporarily affected by underwater noise in the survey area. A potential impact on seabirds listed under the habitat directive will not be significant (9.3.1). The survey will not prevent or delay the achievement of good environmental status for this descriptor.
	1.8 Harbour porpoise, harbour seal and grey seal achieve favourable conservation status in accordance with the timeline laid down in the Habitats Directive.	Harbour porpoise, harbour seal and grey seal may be affected by underwater noise from airgun arrays fired during the Dagny CCS site survey. The Dagny CCS site survey is assessed not to have a significant impact on populations of harbour porpoise, harbour seal and grey seal (assessed in section 8.1) The Dagny CCS site survey will not prevent or delay the achievement of good environmental status for this descriptor.
	1.13 The abundance of plankton follows the long-term natural average as defined from monitoring data.	The survey area is located outside major hydrographical fronts with high primary production (ICES, 2021). In addition, plankton generally have a short generation time (days to months) and since the duration of the impact is temporary and

Descriptor	Targets	Assessment
		restricted to 24 days within 45 working days (including downtime), the zooplankton population is likely to recover shortly after the survey ends. Based on the arguments above, the seismic survey is assessed to not to have a significant impact on plankton. The project will not hinder that plankton follows the long-term natural average.
D2 Non-indigenous species	The number of new non-indigenous species introduced through ballast water, ship fouling, and other relevant human activities is decreasing.	The vessels used for the survey will follow IMO guidelines that implements the Ballast Water Convention and the risk of introduction of new species with ballast water is not assessed to be higher than the risk from marine traffic in general. It is assessed that the seismic survey will not prevent or delay the achievement of good environmental status for this descriptor.
D3 Commercially exploited fish stocks	Within the framework of the Common Fisheries Policy, fish mortality (F) is at levels that can ensure a maximum sustainable yield (Fmsy). Within the framework of the Common Fisheries Policy, spawning biomass exceeds the level that can ensure a maximum sustainable yield.	Commercially exploited fish stocks can potentially be affected by underwater noise. The potential impacts on commercially exploited fish stocks are addressed under section 8.2. The potential impacts on the environmental targets for this descriptor are assessed not to prevent or delay the achievement of good environmental status for this descriptor.
D4 Marine food webs	The relevant environmental targets under descriptor 1 (biodiversity) and descriptor 3 (commercial exploited fish stocks).	Marine mammals, fish, fish eggs, fish larvae and plankton can potentially be affected by underwater noise from seismic survey. Potential impact on these taxa that are important components of the marine food web in the North Sea is addressed under section 8.1 (marine mammals) 8.2 (fish) and 8.2.4 (plankton). The potential impacts on the environmental targets for this descriptor are assessed not to prevent or delay the achievement of good environmental status for this descriptor.
D5 Eutrophication	The Danish part of discharges of total nitrate (TN) and phosphorus (P) follows the maximal acceptable discharges set in HELCOM.	There will be marginal discharge of sewage from the survey vessels. Vessels will follow international conventions on sewage discharges. Discharge of nitrate and phosphorus will not prevent or delay the achievement of good environmental status for this descriptor.
D6 Sea floor integrity	6.5 The marine habitat types under the Habitats Directive achieve favourable conservation status in accordance with the timeline laid down in the Habitats Directive.	The few existing studies on benthic invertebrates indicate that there is no significant impact on benthic invertebrates from seismic survey (Carroll, Przeslawski, Duncan, Gunning, & Bruce, 2017). There will be no significant impact on benthic fauna. The

Descriptor	Targets	Assessment
	6.7 The most important habitats contain the typical species and communities for Danish marine areas.	Dagny CCS site survey will not prevent or delay the achievement of good environmental status for this descriptor.
D7 Alteration of hydrographical conditions	Not relevant	The survey activities will not lead to changes in hydrographical conditions as no structures or equipment will be installed on or above the seabed. The Dagny CCS site survey will not prevent or delay the achievement of good environmental status for this descriptor.
D8 Contaminants (concentrations and species health)	Not relevant	The survey activities will not involve drilling or chemical discharges. The Dagny CCS site survey will not prevent or delay the achievement of good environmental status for this descriptor.
D9 Contamination of fish and seafood	Not relevant	The survey activities will not involve discharge of chemicals that may lead to contamination of fish and seafood. The Dagny CCS site survey will not prevent or delay the achievement of good environmental status for this descriptor.
D10 Marine litter	10.1 The amount of marine litter is reduced significantly to achieve the UN goal that marine litter is prevented and significantly reduced by 2025.	All solid waste items on vessels are collected, sorted, and sent to shore. The Dagny CCS site survey will not prevent or delay the achievement of good environmental status for this descriptor.
D11 Underwater noise	11.1 As far as possible, marine animals under the Habitats Directive are not exposed to impulse sound which leads to permanent hearing loss (PTS). The limit value for PTS is currently assessed as 200 and 190 dB re.1 uPa2s SEL for seals and harbour porpoise, respectively. The values are the sound-exposure level accumulated over two hours.	During the Dagny CCS site survey, thresholds for TTS will be exceeded. However, through prolonged soft start (45 min) potential TTS of harbour porpoise is excluded (assessed in section 8.1). The Dagny CCS site survey will not prevent or delay the achievement of good environmental status for this descriptor.

Descriptor	Targets	Assessment
	11.2 Anthropogenic activities causing impulse sound are planned such that direct adverse effects on vulnerable populations of marine animals from the spatial distribution, temporal extent, and levels of anthropogenic impulsive sound are avoided as far as possible and such that these effects are assessed not to have long-term adverse effects on population levels.	The survey is planned such that direct adverse effects on vulnerable populations are avoided as far as possible. For best-practice measures and DEA standard terms see section 6.3. The Dagny CCS site survey will not prevent or delay the achievement of good environmental status for this descriptor.
	1.3 Activities by the authorities under the Ministry of Defence that cause impulse noise in the marine environment are, as far as possible, being assessed and adapted to reduce possible adverse effects on marine animals under the Habitats Directive, provided this does not conflict with national security or defence objectives. Defence Command Denmark applies current NATO standards when carrying out environmental assessments.	Not applicable.
	11.4 When conducting preliminary seismic studies, adequate remedial action is taken in accordance with the Danish Energy Agency's guidelines on standard terms and conditions for preliminary studies at sea.	The Dagny CCS site survey is conducted according to the DEA guidelines and TEPDK best practice measures (see chapter 6).
	11.5 The Ministry of Environment contributes to work regionally and in the EU regarding establishment of threshold values and determination of good environmental status and is working to ensure that the level of underwater noise is in accordance hereto.	Not applicable.
	11.6 In connection with licensing offshore activities requiring an environmental impact assessment (EIA), the approval authority is encouraging reporting to the Danish Environmental Protection Agency (monitoring program) of registrations of impulse noise.	No monitoring program has been agreed yet, but the survey follows the DEA guidelines, which includes monitoring and reporting requirements.

Descriptor	Targets	Assessment
	11.7 Through increased monitoring, the Ministry of Environment is improving knowledge about the extent and levels of low-frequency noise in the Baltic Sea and the North Sea.	No monitoring program has been agreed yet, but the survey follows the DEA guidelines, which includes monitoring and reporting requirements.

12.2 MARINE STRATEGY AREAS

The third and final part of Denmark's marine strategy consists of a programme of measures that contains concrete measures to achieve the established environmental goals and thus ensure GES in the future. One of these measures is the designation of 13 marine protection areas called Marine Strategy Areas of which 5 are in the North Sea (Figure 12-1)

The Dagny CCS site survey area is situated approximately 80 km from Marine Strategy Area “H” designated as a protected area and strictly protected area. It is prohibited to conduct seismic survey in the area. It is assessed that the Dagny CCS site survey does not interfere with the scope of the protection, since no impacts (PTS, TTS or behavioral disturbances) overlap with Marine Strategy Area “H”.

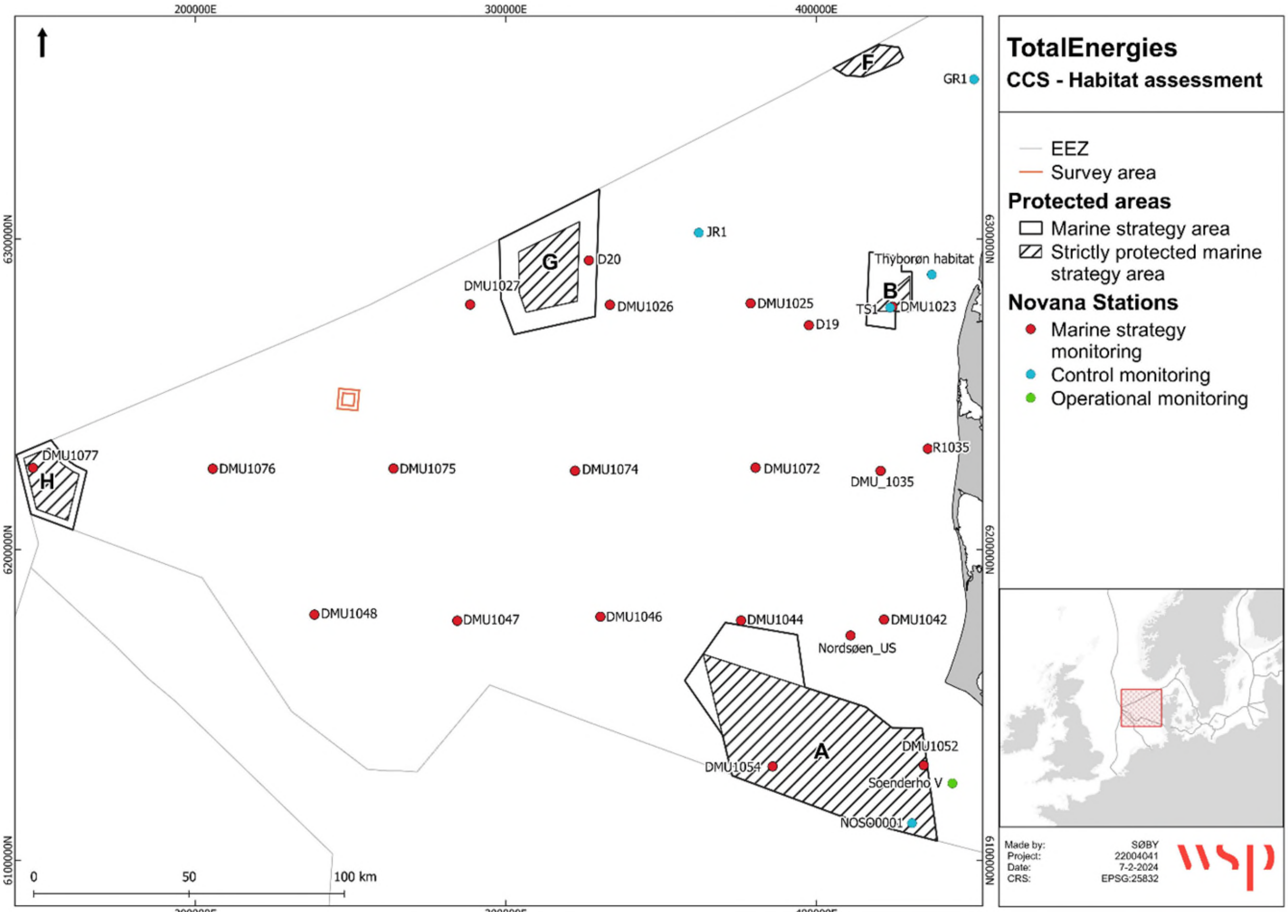

Figure 12-1 Marine Strategy Areas and national monitoring stations (NOVANA) (MiljøGIS 2023).

12.3 NATIONAL MONITORING STATIONS

The survey area does not overlap with any national monitoring stations (Figure 12-1). The closest monitoring station is NOVANA station DMUJ1075 25 km from the Dagny CCS site survey area. The monitoring stations in the central part of the North Sea are used for monitoring infauna, water chemistry, contaminants, etc. Since underwater noise will not affect these parameters, it is assessed that the national monitoring stations will not be affected.

The harbour porpoise population is monitored yearly by flight observations in Skagerrak and the Southern part of the North Sea within and near the two Danish Natura 2000 sites ‘Skagens Gren og Skagerrak’ and ‘Sydlige Nordsø’. The monitoring is undertaken in July/August and there might be an overlap with the survey period depending on the timing of the survey. As the areas for flight observations are >100 km from the Dagny CCS site survey area, they will not be affected by the seismic survey.

13 CUMULATIVE IMPACT ASSESSMENT

Cumulative effects are the combined effects of projects or ongoing activities within the region. Potential cumulative effects from the Dagny CCS site survey may interact with:

- Underwater noise from other seismic surveys
- Impacts from other activities such as installation of wind farms, cable and pipeline installation, fishery, and shipping in the region.

Vessels used as part of the Dagny CCS site survey may produce underwater noise from propellers and thrusters. The noise produced is typically broadband noise, with some low tonal peaks and is not impulsive noise, as produced by the seismic airgun arrays. Vessel noise from the small seismic and service vessels is typical of general large and small shipping vessels that traverses the Danish EEZ and the seismic survey area and is therefore unlikely to change the underwater noise levels and to have a significant impact on marine animals. Therefore, underwater noise from project vessels is not included in the cumulative effects assessment.

Potential cumulative impacts from the Dagny CCS site survey with other noisy activities may occur since there may be further development activity in the North Sea during Q2 and Q3 in 2024.

The relevant authorities (the Danish Energy Agency, DEA) are responsible for reporting all impulse noise activities to the Danish Environmental Protection Agency (DEPA). The reporting of activities causing impulse noise makes it possible for the responsible authorities to coordinate noisy activities in Danish waters.

Figure 13-1 lists the planned, approved, and currently known projects with potential cumulative impacts.

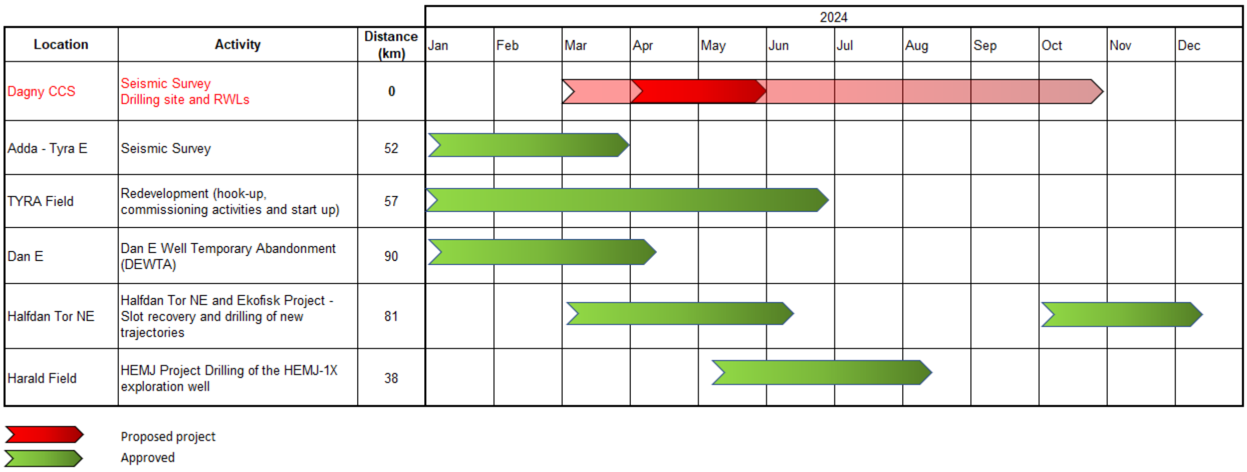

Figure 13-1 Planned and approved projects/activities with potential cumulative impacts with the current Dagny CCS site survey.

No wind farms or related activities are planned close to the survey area. Noise from fisheries and general ship traffic is assessed to be irrelevant as cumulative impacts as it is more sporadic, and noise distribution occurs on other frequencies than the noise emitted in a seismic survey. Underwater noise from vessels is low intensity, broadband noise that is confined to the areas around the vessels. The activities are assessed as irrelevant.

Project activities in the central part of the North Sea with the potential to overlap in time and space with the Dagny CCS site survey is described below:

- **Adda – Tyra E involves seismic survey** for a new platform in the Adda field and a pipeline that connects to the existing Tyra East platform complex. A geotechnical survey will also be undertaken along the pipeline route. For the geophysical activities, the proposed Adda site survey covers an area of 4 km x 4 km (16 km^2) and the Adda pipeline route survey is approximately 11 km x 1 km (11 km^2). The Adda site is located 52 km from Dagny CCS site survey. The activities at the Adda-Tyra field and the Dagny CCS survey will be planed in sequence and there will be no temporal overlap. The Adda-Tyra E project will be prioritised, and the Dagny seismic survey will be paused/postponed. It is assessed that no significant cumulative impacts will occur.

- **TYRA Field** involves hook-up and commissioning activities and include installation of a J-tube on an existing underwater structure, burial of an integrated cable in the seabed, installation of mechanical protection (rock dump) and installation of an underwater pipe section. Tyra East is located 57 km from the Dagny CCS site survey. The outstanding work will include vessel movements but does not include additional discharges, drilling or pile driving. Since the project does not involve noisy activities such as conductor driving, pile driving or seismic explosions, the project is assessed as irrelevant.
- **Dan E** involves installation of a rig, milling activities but no drilling. Dan E is located 90 km from the Dagny CCS site survey. The activities are not expected to involve underwater noise. If noisy activities will occur, they will not be within the same frequency range as for the Dagny CCS site survey and are thus assessed as irrelevant. The project activities are assessed as irrelevant.
- **Halfdan Tor NE** project will occur in the Halfdan field and includes drilling of two trajectories into the Tor NE reservoir from March to June. Two conductors will be driven for each well. The conductor driving might therefore be carried out simultaneously with the Dagny CCS site survey. The Halfdan Tor NE is located 81 km from the Dagny CCS site survey. Since the maximum behavioural effect distance of the Dagny CCS site survey is 6.5 km for all cetaceans considering the 145 dB re 1 μ Pa2 s (single-pulse unweighted SEL) and 55.6 km for harbour porpoises considering the 103 dB re 1 μ Pa, significant cumulative impacts are unlikely to occur.

  Harald Field project involves drilling of a new exploitation well in the period May to early August. The conductor driving might therefore be carried out simultaneously with the Dagny CCS site surveyy. Harald Field is located 38 km from the Dagny CCS site survey. The maximum behavioural effect distance of the Dagny CCS site survey is 6.5 km for all cetaceans considering the 145 dB re 1 μ Pa2 s (single-pulse unweighted SEL) and 55.6 km for harbour porpoises considering the 103 dB re 1 μ Pa. Behavioural effect distance for harbour porpoises is reduced up to 24.7 km from March to August. A behavioural effect distance between the two modelled ones is expected for harbour porpoises since the geophysical survey will take place not before end of April / May. Potential cumulative impacts on harbour porpoises' behaviour with Harald fields activities that are about 40 km away are unlikely to occur. Nevertheless, a SIMOPS[2] dossier will be consolidated during the preparation, it will describe the protocol (communication, priority etc.) in place between the drilling and seismic activities at the operational stage to avoid that activities will occur simultaneously. This will prevent any cumulative impact from both activities.

No significant cumulative impacts are expected from the Dagny CCS site survey based on the current knowledge of other projects in the North Sea. This is due to the survey being paused during conductor driving at the Halfdan Tor NE field and the Harald field, which are the main activities with potential for cumulative impacts. Other activities either do not overlap in time or are separated by large distances.

13.1 SUMMARY OF CUMULATIVE EFFECTS ASSESSMENT

Based on the current knowledge of simultaneous and sequential projects (Figure 13-1), *no significant cumulative impacts* are expected because of the Dagny CCS site survey being put on standby during conductor driving, the large distances between the various projects and given that most of the project activities do not overlap in time.

14 TRANSBOUNDERY IMPACTS

The survey area is centered around the well P11 (Dagny) and covers an area of 3.8 km x 3.8 km (14.4 km^2). The area is located 23 km from the Norwegian EEZ and 68 km away from the German EEZ. The site survey will emit intense sound impulses (SEL 213.2 dB re 1 µPa^{2}s-m). The loudest sound sources are emitted by airgun array. Impact on marine mammals, fish, fish eggs and fish larvae has been assessed by underwater noise model (Genesis, 2024).

In Norway, there are currently no specific guideline threshold criteria employed by authorities to assess the impact of underwater noise. Thus, the threshold from the Danish guidelines have been used to assess transboundary impacts in the Norwegian EEZ.

The behavioral effect distance is predicted to be 25 to 56 km for harbour porpoise considering the 103 dB re 1 µPa (rms SPL over a time window of 125 ms weighted for VHF cetaceans). Since the behavioral impact is temporary, the impact is assessed as negligible. The 145 dB re 1 µPa^{2}s (single-pulse unweighted SEL) threshold will not be exceeded in the Norwegian EEZ. Based on this, the survey is assessed to have no significant transboundary impact on harbour porpoise, minke whale and white-beaked dolphin.

In Norway there are marine protected areas known as SVOs (Particular Valuable Areas) (Figure 14-1). SVOs are areas of significant importance for biological diversity and biological production in the marine area. The closest SVO is the Tobisfelt Sør which is designated to protect sand eel spawning areas. The SVO is located 45.5 km from the Dagny survey area. Since the maximum predicted distance where the zero-to-peak SPL sound levels exceed the Popper et al. (2014) thresholds for fish injury is 80 m, there is no impact on sandeel or other fishes in the Norwegian EEZ or within the SVOs.

The German authorities are using a guideline threshold criteria of unweighted single-pulse SEL of 140 dB re 1 µPa^{2}s to assess the impact of underwater noise in the German EEZ. There is no exceedance of this threshold within the German EEZ including German Natura 2000 sites. Due to the long distance to the German EEZ the potential transboundary impact is not assessed further.

No other impacts are considered relevant as subject to transboundary impact for the Dagny site survey.

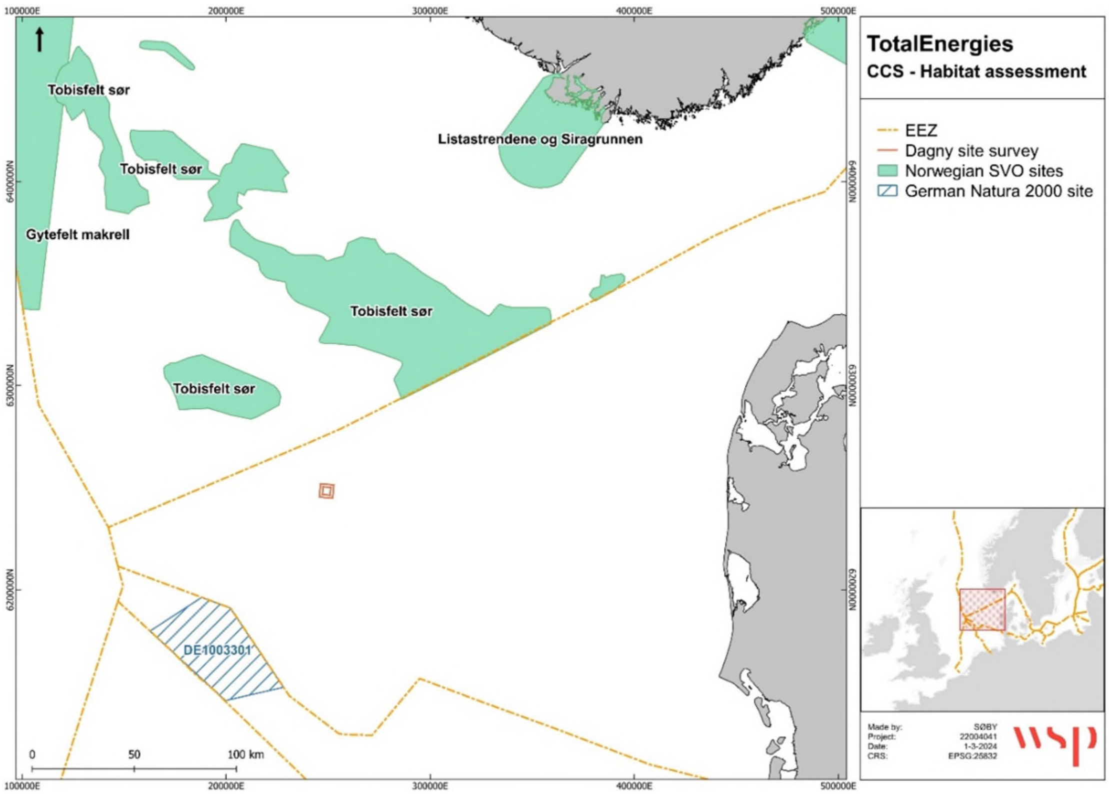

Figure 14-1 Marine protected areas in Germany (SAC DE 1003301 Doggerbank) and Norway (SOVs) .

15 CONCLUSION

The proposed Dagny CCS site survey will be conducted in the central North Sea around the well P11. The dimensions of the survey area is 3.8 km x 3.8 km (14.4 km^2) located within a greater working area of 6.5 km x 6.5 km (42.3 km^2). The survey will acquire two-dimensional high-resolution (2DHR) and ultra-high-resolution (UHR) seismic data using airgun array, SBP, MBES and SSS.

The entire survey will be completed within approximately 45 days, including 21 days of potential downtime for bad weather. The survey is planned to be conducted between March and October.The ESAR has been developed taking into consideration the standard best-practise measures already implemented in the project, and applying a conservative prolonged soft-start period of 45-minutes (defined after specific calculations based on modelling results) to further limit the potential harbour porpoise mother calf separation.

The main conclusions of the environmental significance assessment are summarised below:

- **Natura 2000**. The nearest internationally protected area (Natura 2000 site) is located more than 65 km from the site survey area. A targeted noise model shows that there will be no threshold exceedance within Natura 2000 sites. Further, injury of mobile species (marine mammals) migrating or foraging outside the Natura 2000 sites is unlikely with a 45-minute soft start. Thus, there is *no significant* impact on the conservation objectives of habitats and species on the designation basis of internationally protected areas (Natura 2000 sites).
- **Annex IV specie**s. Harbour porpoise, minke whale and white-beaked dolphin (Annex IV species) will not be intentionally disturbed within their natural range to an extent that may damage the species or the populations. Furthermore, there is no documentation in the existing literature that supports deterioration or destruction of breeding sites or loss of ecologically important habitat areas for Annex IV species. It is assessed that there will be *no significant* impact on Annex IV species.
- **Marine Strategy Framework Directive (MSFD).** The Dagny CCS site survey is unlikely to hinder or delay the achievements of good environmental status for the Danish targets of the MSFD descriptors. The risk of affecting fish, fish eggs and fish larvae is limited to the survey area where there may be a temporary impact locally around the noise source (80 m radius). It is assessed that there is no significant impact on fish, fish eggs or fish larvae. There is also *no significant* impact on Marine Strategy Areas and the national monitoring program (NOVANA).
- **Cumulative impacts.** Based on available knowledge of simultaneous and sequential activities in the North Sea, there are *no significant* cumulative impacts from the Dagny CCS site survey.
- **Transboundary impacts.** There are no significant transboundary impacts.

Overall, the Dagny CCS site geophysical survey will have *no significant* impacts on the marine environment.

16 REFERENCES

Danish Environmental Protection Agency. (2020). *Vejledning til bekendtgørelse nr. 1595 af 6. december 2018 om udpegning og administration af internationale naturbeskyttelsesområder samt beskyttelse af visse arter.*

Beest, v., F.M., T. J., Hermannsen, L., Galatius, A., Mikkelsen, L., Sveegaard, S., . . . Nabe-Nielsen, J. (2018). Fine-scale movement responses of free-ranging harbour porpoises to capture, tagging and short-term noise pulses from a single airgun. Royal Society Open Science. 5: 170110. http://dx.doi.org/10.1098/rsos.170110. .

Bejder, L., Samuels, A., & Whitehead, H. (2006). Decline in relative abundance of bottlenose dolphins exposed to longterm disturbance. *Conservation Biology*, pp. 20, pp. 1791-1798.

BfN. (2008). *Erhaltungsziele für das FFH-Gebiet „Doggerbank“ (DE 1003-301) in der deutschen AWZ der Nordsee. .* Bundesamt für Naturschutz, Stand Januar 2008.

Boness, D., Bowen, W. D., Buhleier, B. M., & Marshall, G. J. (2006). Mating tactics and mating system of an aquatic-mating pinniped: The harbour seal. *Behavioral Ecology and Sociobiology*, pp. 61(1), 119-130.

BUM. (2014). Concept for the protection of harbour porpoises from sound exposures during the construction of offshore wind farms in the German North Sea (Sound Protection Concept).

Carroll, A. G., Przeslawski, R., Duncan, A., Gunning, M., & Bruce, B. (2017). A critical review of the potential impacts of marine seismic surveys on fish & invertebrates. *Marine Pollution Bulletin*, pp. 114(1), 9-24.

Coull, K. A., Johnstone, R., & Rogers, S. I. (1998). Fisheries sensitivity maps in British waters. *UKOOA Ltd.*

Crocker, S., & Fratantonio, F. D. (2016). Characteristics of high-frequency sounds emitted during high-resolution marine geophysical surveys. Nav. Undersea Warfare Center, Newport, RI USA, NUWC-NPT Tech. Rep. 12,203, 2016. [Online]. Available: http://www.data.boem.gov/PI/PDFImages/ESPIS/5/5551.pd.

Crocker, S., Fratantonio, F., Hart, P. Foster, D., Brien, T., & Labak, S. (2018). Measurement of sounds emitted by certain high-resolution geophysical survey systems. *IEEE Journal of Oceanic Engineering. PP. 1-18. 10.1109/JOE.2018.2829958.*

Danish Energy Agency. (August 2018). *Standard terms and conditions for geophysical surveys at sea. Danish Energy Agency, Copenhagen, Denmark. (English version).* Hentet fra https://ens.dk/sites/ens.dk/files/OlieGas/standardvilkaar_for_forundersoegelser.pdf

Danish Energy Agency. (2019). *Ansøgningsvejledning for forundersøgelser til havs.* Center for Energiressourcer. Undergrundsenheden.

DEA. (2022). *Guidelines for underwater noise, Prognosis for EIA and SEA .*

Delefosse, M., Rahbek, L., Roesen, L., & Clausen, K. (2018). Marine mammals sightings around oil and gas installations in the central North Sea. *Journal of Marine Biology Association*, pp. 98(5): 993-1001.

Ellis, J. R., Milligan, S. P., Readdy, L., Taylor, N., & Brown, M. J. (2012). Spawning and nursery grounds of selected fish species in UK waters. . *Sci. Ser. Tech. Rep., Cefas Lowestoft, 147: 56 pp.*

Fields, D., Handegard, N., Dalen, J., Eichner, C., Malde, K., Karlsen, Ø., . . . Browman, H. (2019). Airgun blasts used in marine seismic surveys have limited effects on mortality, and no sublethal effects on behaviour or gene expression in the Calanus finmarchicus. *ICES Journal of Marine Science*(76, 2033–2044), pp. 76(7), 2033-2044.

Finneran, J. J. (2015). Noise-induced hearing loss in marine mammals: A review of temporary threshold shift studies from 1996 to 2015. *The Journal of the Acoustical Society of America*, pp. 138:1702-1726.

Fraija-Fernandez, N., Picazo, J. L., Domènech, F., Míguez-Lozano, R., Palacios-Abella, J. F., Rodríguez-González, A., . . . Gozalbes, P. (2015). *First Stranding Event of a Common Minke Whale Calf, Balaenoptera acutorostrata Lacépède, 1804, Reported in Spanish Mediterranean Waters.*

Fredshavn, J., Nygaard, B., Ejrnæs, R., Damgaard, C., Therkildsen, O., Elmeros, M., . . . Teilmann, J. (2019). Bevaringsstatus for naturtyper og arter – 2019. Habitatdirektivets Artikel 17-rapportering. Aarhus Universitet, DCE – Nationalt Center for Miljø og Energi, 52 s. Videnskabelig rapport nr. 340 .

Galatius, A., & Kinze, C. C. (2016). *Whitebeaked dolphin – Lagenorhynchus albirostris Species Account. Mammalian Species.*

Galatius, A., Jansen, O., & Kinze, C. (2013). Parameters of growth and reproduction of white-beaked dolphins (Lagenorhynchus albirostris) from the North Sea. *Marine Mammal Science*, pp. 29(2), 348-355.

Galatius, A., Kinze, C. C., & Teilmann, J. (2012). Population structure of harbour porpoises in the Baltic region: evidence of separation based on geometric morphometric comparisons. *Journal of the Marine Biological Association of the United Kingdom*, pp. 92(8), 1669-1676.

Galatius, A., Teilmann, J., Dahne, M., Ahola, M. P., Westphal, L., Kyhn, L., . . . Olsen, M. (2020). Grey seal Halichoerus grypus recolonisation of the southern Baltic Sea, Danish Straits and Kattegat. *Wildlife Biology*, pp. 2020(4), 1-10.

Genesis. (2023). *Noise Modelling for Bifrost CCS Survey.* Genesis: TotalEnergies EP Danmark A/S.

Genesis. (2024). *Noise Modelling for Bifrost CCS Survey.* Genesis: TotalEnergies EP Danmark A/S.

Gilles, A., Authier, M., Ramirez-Martinez, N., Araújo, H., Blanchard, A., Carlström, J., . . . p., H. (2023). Estimates of cetacean abundance in European Atlantic waters in summer 2022 from the SCANS-IV aerial and shipboard surveys. Final. *https://www.tiho-hannover.de/itaw/scans-iv-survey*.

Hammond, P., Berggren, P., Benke, H., Borchers, A., Collet, A., Heide-Jørgensen, M., . . . Øien, N. (2002). Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. *Journal of Applied Ecology.*, pp. 39:361-376.

Hammond, P., Lacey, C., Gilles, A., Viquerat, S., Börjesson, P., Herr, H., . . . Øien, N. (2021). *Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys.* Wageningen Marine Research.

Hammond, P., Macleod, K., Berggren, P., Borchers, D. L., Burt, L., Cañadas, A., & ... & Vázquez, J. A. (2013). Cetacean abundance and distribution in EuropeanAtlantic shelf waters to inform conservation and management. *Biological Conservation*, pp. 164, 107-122.

Hansen, J., & Høgslund, S. (2023). *Marine områder 2021. NOVANA.* Aarhus Universitet, DCE - Nationalt Center for Energi og Miljø. Retrieved from http://dce2.au.dk/pub/SR355.pdf

Hassel, A. K., Dalen, J., Skaar, K., Løkkeborg, S., Misund, O. A., & ... & Haugland, E. K. (2004). Influence of seismic shooting on the lesser sandeel (Ammodytes marinus). *ICES Journal of Marine Science, 61(7), 1165-1173.*

Härkönen, T., Backlin, B., Barrett, T., Bergman, A., Corteyn, M., Dietz, R., . . . Teilmann, J. (2008). Mass mortality in harbour seals and harbour porpoises caused by an unknown pathogen. *he Veterinary Record*, pp. 162(17), 555.

Härkönen, T., Dietz, R., Reijnders, P., Teilmann, J., Harding, K., Hall, A., . . . Thompson, P. (2006). The 1988 and 2002 phocine distemper virus epidemics in European harbour seals. *Diseases of aquatic organisms*, pp. 68(2), 115-130.

ICES. (2021). *Greater North Sea Ecoregion – Ecosystem overview. ICES Advice: Ecosystem Overviews. Report. https://doi.org/10.17895/ices.advice.9434* . Hentet fra https://doi.org/10.17895/ices.advice.9434

ICES. (2022). *Advice on fishing opportunities, catch and effort. Cod (Gadus morhua) in Subarea 4, Division 7d and Subdivision 20 (North Sea, eastern English Channel, Skagerrak).*

Isojunno, S. C., Kvadsheim, P., Lam, F.-P., Tyack, P., Wensveen, P., & Miller, P. (2016). Sperm whales reduce foraging effort during exposure to 1–2 kHz sonar and killer whale sounds. Ecolological Applications. 26: 77–93.

Jak, R. B., Witbaard, R., & Lindeboom, H. (2009). *Conservation objectives Natura 2000 sites (SACs and SPAs) in the Dutch sector of the North Sea. .* IMARES rapp. nr C065/09. .

JNCC. (2017). *JNCC Guidelines for minimising the risk of injury to marine mammals from geophysical surveys.* Aberdeen: Joint Nature Conservation committee.

Kastelein, R. A., Van de Voode, S., & Jennings, N. (2018). Swimming Speed og Harbour Porpoise (Phocoena Phocoena) During Palyback og Offshore Pile Driving Sounds.

Kastelein, R., Gransier, R., & Hoek, L. (2013). Comparative temporary threshold shifts in harbour porpoise and harbour seal, and a severe shift in a seal (L). *Journal of the Acoustic Society of America*, pp. 134:13-16.

Kvadsheim, P. H., Forland, T. N., de Jong, K., Nyqvist, D., Grimsbø, E., & & Sivle, L. D. (2020). *Impact of anthropogenic noise on the marine environment – status of knowledge and management.* Forsvarets forskningsinstitutt (FFI), Havforskningsinstitut.

Kyhn, L., Sveegaard, S., Galatius, A., Teilmann, J., Tougaard, J., & Mikaelsen, M. (2021). *Geofysiske og geotekniske forundersøgelser til energiø Nordsø. Vurdering af påvirkning på havpattedyr. Aarhus Universitet, DCE – Nationalt Center for Miljø og Energi, 44 s -VIdenskabelig rapport nr. 433 http://dce2.au.dk/pub/SR433.pdf.*

Lockyer, C. (2003). Harbour porpoises (Phocoena phocoena) in the North Atlantic: Biological parameters. . *NAMMCO Scientific Publications*, pp. 5, 71-89.

Lucke, K., Siebert, U., Lepper, P. A., & Blanchet, M. A. (2009). Temporary shift in masked hearing thresholds in a harbour porpoise (Phocoena phocoena) after exposure to seismic airgun stimuli,. *The Journal of the Acoustical Society of America*, pp. 125 (6), pp. 4060-4070.

Melvin, E. F., Parrish, J., & Conquest, L. D. (1999). Novel tools to reduce seabird bycatch in coastal gillnet fisheries. *Conservation Biology* , pp. 13, 11386–1397.

Miljødirektoratet. (2021). *Vurdering av behovet for ytterligere regulering av seismikk for å ivareta hensynet til marine pattedyr.* Miljødirektoratet.

Miljøministeriet. (2020). *Vejledning til bekendtgørelse nr. 1595 af 6. december 2018 om udpegning og administration af internationale naturbeskyttelsesområder samt beskyttelse af visse arter.*

NMFS . (2018). *Revision to: Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing: underwater acoustic thresholds for onset of permanent and temporary threshold shifts (Version 2.* NMFS, National Marine Fisheries Service, 2018.

NOAA fisheries. (2022). *www.fisheries.noaa.gov*. Hentet fra https://www.fisheries.noaa.gov/species/minke-whale

Oceanwide. (2023a). Hentet fra https://oceanwide-expeditions.com/to-do/wildlife/harbour-porpoise-1

Oceanwide. (2023b). Hentet fra https://oceanwide-expeditions.com/to-do/wildlife/minke-whale#:~:text=How%20fast%20can%20Minke%20Whales%20swim%3F%20The%20Minke%E2%80%99s,km%20per%20hour%20to%2025%20km%20per%20hour.

Pace, F., Robinson, C., Lumsden, C., & Martin, S. (2021). Underwater Sound Sources Characterisation Study: Energy Island, Denmark. Document 02539, Version 2.1. Technical report by JASCO Applied Sciences for Fugro Netherlands Marine B.V.

Perrin, W. F., Mallette, S. D., & Brownell Jr., R. L. (2018). *Minke Whales: Balaenoptera acutorostrata and B. bonaerensis.* In Encyclopedia of marine mammals (pp. 608-613). Academic Press.

Pichegru, L., Nyengera, R., McInnes, A. M., & Pistorius, P. (2017). Avoidance of seismic survey activities by penguins. *Scientific Reports*, pp. 7(1), 1-8.

Pirotta, E., Brookes, K. L., Graham, I. M., & Thompson, P. M. (2014). Variation in harbour porpoise activity in response to seismic survey noise. *Biology letters*, pp. 10(5), 20131090.

Popper, A., Hawkins, A., & Fay, R. (2014). *Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI.*

Reid, J., Evans, P., & Northridge, S. (2003). *Atlas of cetacean distribution in north-west European waters* . JNCC.

Robertson, F., Koski, W., Thomas, T., Richardson, W. W., & A., a. T. (2013). Seismic operations have variable effects on dive-cycle behavior of bowhead whales in the Beaufort Sea. Endangered Species Research. 21: 143–160.

Santos, M., & Pierce, G. (2003). The diet of Harbour porpoise (Phocoena phocoena) in the Northeast Atlantic. *Oceanography and Marine Biology: An annual review*, pp. 41, 355-390.

Sarnocińska, J., Teilmann, J., Balle, J. D., van Beest, F. M., Delefosse, M., & Tougaard, J. (2020). Harbor Porpoise (Phocoena phocoena) reaction to a 3D seismic airgun survey in the North Sea. *Frontiers in Marine Science*, pp. 6, 824.

Sonntag, R., Benke, H., Hiby, A., Lick, R., & Adelung, D. (1999). Identification of the first harbour porpoise (Phocoena phocoena) calving ground in the North Sea. *Journal of Sea Research*, pp. 41(3), 225-232.

Southall, B. L., Bowles, A., Finneran, J. J., Reichmuth, C., Nactigall, P., Ketten, D., . . . Tyack, P. (2019). Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. *Aquatic Mammals*, pp. 45:125-232.

SPE International. (2020). *Marine mammal biodiversity around oil and gas platforms -challanges and successes of long-term monitoring.* Society of Petroleum Energies.

Stimpert, A., D. S., Southall, B., Moretti, D., Falcone, E., Goldbogen, J., . . . Calambokidis, J. (2014). Acoustic and foraging behavior of a Baird's beaked whale, Berardius bairdii, exposed to simulated sonar. Scientific Reports. 4: 7031.

Sundby, S., Kristiansen, T., Nash, R., & Johannesen, T. (2017). *Dynamic Mapping of North Sea spawning.* Report of the KINO Project. Fisken og Havet nr. 2-2017.

Sveegaard, S., Galatius, A., Dietz, R., Kyhn, L., Koblitz, J., Amundin, M., . . . Teilmann, J. (2015). Defining management units for cetaceans by combining genetics, morphology, acoustics and satellite tracking. *Global Ecology and Conservation*, pp. 3, 839-850.

Sveegaard, S., Nabe-Nielsen, J., & Teilmann, J. (2018). *Marsvins udbredelse og status for de marine habitatområder i danske farvande.* Aahus Universitet, DCE -Nationals Center for Miljø og Energi, 36 s. -Videnskabelig rapport nr. 284.

Søgaard, B., Wind, P., Sveegaard, S., Galatius, A., Teilmann, J., Therkildsen, O., . . . Bladt, J. (2018). *Arter 2016. Novana.* . Videnskabelig rapport fra DCE - Nationalt Center for Miljø og Energi.

Teilmann, J., Larsen, F., & Desportes, G. (2007). Time allocation and diving behaviour of harbour porpoises (Phocoena phocoena) in Danish and adjacent waters. *J Cetacean Res Manag*, pp. 9, 201-210.

The Sea Watch foundation. (2012). Minke whales in UK waters.

Thompson, P., Brookes, K., Graham, I., Barton, T., Needham, K., Bradbury, G., & Merchant, N. (2013). Short term disturbance by a commercial two-dimensional seismic survey does not lead to long-term displacement. *Proceedings of the Royal Society B: Biological Sciences*, pp. 280(1771), 20132001.

Tougaard, J. (2014). *Vurdering af effekter af undervandsstøj på marine organismer -Del 2 -Påvirkninger.* Aarhus University, DCE .

Tougaard, J. (2016). *Input to revision of guidelines regarding underwater noise from oil and gas activities - effects on marine mammals and mitigation measures.* Aarhus University, DCE - Danish Centre for Environment and Energy. Scientific report No. 202.

Tougaard, J. (2021). Thresholds for behavioural responses to noise in marine mammals. Background note to revision of guidelines from the Danish Energy. Aarhus University, DCE – Danish Centre for Environment and Energy, 32 pp. Technical Report No. 225 http://dce2.au.dk/pub/TR2. *Technical Report from DCE – Danish Centre for Environment and Energy No. 225* .

Tougaard, J. (2021). *Thresholds for noise induced hearing loss in marine mammals. Background note to revision of guidelines from the Danish Energy Agency.* Aarhus University, DCE - Danish Centre for Environment and Energy, 34 s.

Tougaard, J., Sveegaard, S., & Galatius, A. (2021). *Marine mammal species of relevance for assessment of impulsive noise sources in Danish waters. Background note to revision of guidelines from the Danish Energy Agency.* Aarhus University, DCE - Danish Centre for Environment and Energy.

Waggitt, J. J., Evans, P. G., Andrade, J., Banks, A. N., Boisseau, O., Bolton, M., & ... & Hiddink, J. G. (2019). Distribution maps of cetacean and seabird populations in the North-East Atlantic. *Journal of Applied Ecology*, pp. 57(2), 253-269.

Wardle, C. S., Carter, T. J., Urquhart, G. G., Johnstone, A. D., Ziolkowski, A. M., Hampson, G., & & Mackie, D. (2001). Effects of seismic air guns on marine fish. *Continental shelf research, 21(8-10), 1005-1027*.

Weilgart, L. A. (2007). Brief review of known effects of noise on marine mam-mals. *International Journal of Comparative Psychology*, s. 20(2), 159-168.

Wiemann, A., Andersen, L. W., Berggren, P., Siebert, U., Benke, H., Teilmann, J., . . . Tiedemann, R. (2010). Mitochondrial Control Region and microsatellite analyses on harbour porpoise (Phocoena phocoena) unravel population differentiationin the Baltic Sea and adjacent waters. *Conservation Genetics*, pp. 11(1), 195-211.
Wisniewska, D., Johnson, M., Teilmann, J. S., Galatius, A. D., & Madsen, P. (2018). High rates of vessel noise disrupt foraging in wild harbour porpoises (Phocoena phocoena). Proceedings of the Royal Society B 285: 20172314.

APPENDIX 1

NOISE MODELLING FOR DAGNY CCS SITE SURVEY BY GENESIS (2024)

REPORT

Noise Modelling for Dagny CCS Project

Prepared for: **TotalEnergies EP Danmark A/S**

Prepared by: **Genesis**
www.genesisenergies.com

Project Title: **Noise Modelling for Dagny CCS Project**
Document/Rev No: J75955A-215546C001-RT-6200-0001/3
Date: March 2024

Rev	Date	Description	Issued by	Checked by	Approved by	Client Approval
1A	04/12/2023	Issued for internal review	RFr	MLa		
A	07/12/2023	Issued for client review	RFr	MLa	MLa	
0	19/12/2023	Issued for use	RFr	MLa	MLa	
1	07/02/2024	Issued for use (additional summer modelling included)	RFr	CHi	MLa	
2	29/02/2024	Issued for use (updated with responses to DEA comments)	RFr	CHi	MLa	
3	06/03/2024	Issued for use (updated with responses to DEA comments)	RFr	CHi	MLa	

Contents

Figures & Tables

Figures

Tables

ABBREVIATIONS

2DHR	Two-Dimensional High-Resolution
2DUHR	Two-Dimensional Ultra-High-Resolution
BMU	Bundesministerium für Umwelt, Naturschutz und Reaktrosicherheit
CCS	Carbon Capture and Storage
cu. in	Cubic inch
dB	Decibels
dB re 1 µPa	Decibels relative to one micro Pascal
dB re 1 µPa^{2}s	Decibels relative to one micro Pascal square second
dB re 1 µPa^2 m^2 s	Decibels relative to one micro Pascal square metre square second metre
dB re 1 µPa m	Decibels relative to one micro Pascal metre
DEA	Danish Energy Agency
EC	European Commission
ED	European Datum
EEC	European Economic Community
EEZ	Exclusive Economic Zone
EMODnet	European Marine Observation and Data Network
EPS	European Protected Species
ESD	Energy Spectral Density
EU	European Union
FARAM	Faunal Acoustic Risk Assessment Model
GWA	Greater Working Area
HF	High Frequency
Hz	Hertz
ICES	International Council for the Exploration of the Sea
JNCC	Joint Nature Conservation Committee
kg/m^3	Kilograms per cubic metre

kHz	Kilohertz
km	Kilometres
km^2	Square kilometres
LF	Low Frequency
m	Metres
m/s	Metres per second
MBES	Multi-Beam Echosounder
MERP	Marine Ecosystems Research Program
MMO	Marine Mammal Observer
NMFS	National Marine Fisheries Service
OSPAR	Oslo and Paris Convention
PAM	Passive Acoustic Monitoring
PTS	Permanent Threshold Shift
PVA (SVO)	Particularly Vulnerable Area (Særlig verdifulle og sårbare områder)
RMS	Root Mean Square
s	Seconds
SAC	Special Area of Conservation
SBES	Single-Beam Echosounder
SBP	Sub-Bottom Profiler
SCANS	Small Cetacean Abundance in the North Sea
SEL	Sound Exposure Level
SONAR	Sound Navigation and Ranging
SPA	Special Protection Area
SPL	Sound Pressure Level
SSS	Side-Scan Sonar
TEPDK	TotalEnergies EP Danmark A/S
TTS	Temporary Threshold Shift
UK	United Kingdom

UTM	Universal Transverse Mercator
WOA	World Ocean Atlas
VHF	Very High Frequency

1.0 INTRODUCTION

1.1 Survey Details

TotalEnergies EP Danmark A/S is planning to conduct a geophysical (seismic) survey in the Dagny Carbon Capture and Storage (CCS) license area (Oligocene aquifer). This is part of the Bifrost CCS project in the Danish sector of the North Sea (see Figure 1-1).

The proposed site survey will be conducted over a 3.8 km x 3.8 km (14.4 km^2) area. The survey area is located within the 6.5 km x 6.5 km (42.3 km^2) greater working area (GWA) shown in Figure 1-1. There are two options for the proposed survey location. The GWA for survey location option 1 lies approximately 191 km from the nearest coastline (the Danish coast) and 24 km from the nearest median line (the Denmark/Norway median line). The GWA for survey location option 2 lies approximately 196 km from the nearest coastline (the Danish coast) and 23 km from the nearest median line (the Denmark/Norway median line). Both survey options have been modelled, and the results are presented in Section 5.0.

Two-dimensional high-resolution (2DHR) and ultra-high-resolution (2DUHR) seismic data will be acquired over the site survey area using a 160 cubic inch (cu. in) airgun array and 24 cu. in airgun array, respectively. Data will also be acquired using a sub-bottom profiler (SBP), multi-beam echosounder (MBES), single-beam echosounder (SBES) and side scan sonar (SSS).

The site survey is expected to be completed in a maximum of 45 working days (including downtime) with a total of 24 days airgun use. The survey will be conducted between March and October depending on vessel availability. Modelling has been undertaken for winter (during the month of March) and summer (during the month of August) for both survey options.

This report assesses the potential impacts that the proposed survey will have on marine mammals and fish in the area. Potential impacts to plankton are also discussed.

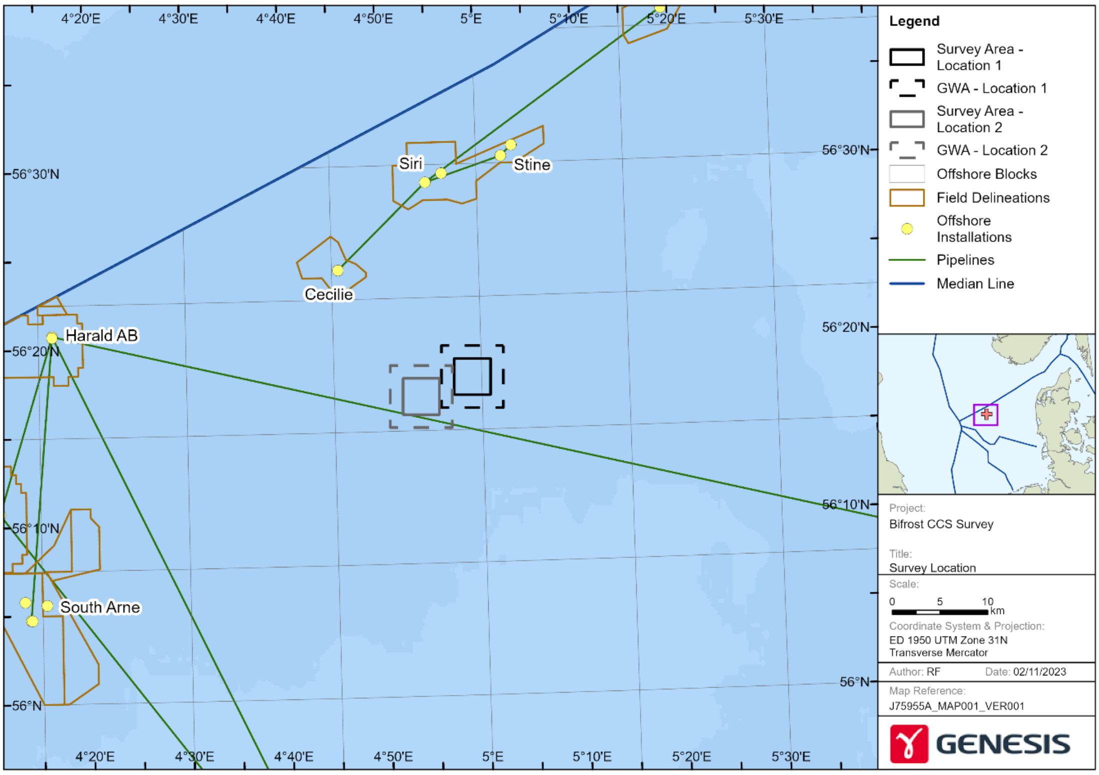

Figure 1-1: Location of the proposed options for the Dagny CCS survey.

1.2 Survey Equipment

1.2.1 Airgun Arrays

The survey will acquire 2DHR seismic data using a 160 cu. in airgun array comprising four TI Sleeve airguns and 2DUHR seismic data using a 24 cu. in airgun array comprising two Mini-G-Gun airguns. Parameters for the airgun arrays that will be used during the survey, including zero-to-peak sound pressure level (SPL), root mean square (rms) SPL, and sound exposure level (SEL) source levels, have been calculated using Gundalf (Oakwood Computing, 2023). Source levels and other properties of the airgun arrays are summarised in Table 1-1. Further details of the airgun arrays are provided in Section 3.1.

Table 1-1: Properties of the airgun arrays that will be used during the survey.

Parameter		160 cu. in Airgun Array (2DHR Survey)	24 cu. in Airgun Array (UHR Survey)
Source		Airgun array comprising four TI Sleeve airguns	Airgun array comprising two Mini-G-Gun airguns
Total volume (cu. in)		160	24
Source levels (single pulse) [1]	Zero-to-peak SPL (dB re 1 µPa m)	245.5	239.6
	Peak-to-peak SPL (dB re 1 µPa m)	249.6	245.1
	Rms SPL [2] (dB re 1 µPa m)	222.3	216.3
	SEL (dB re 1 $\mu Pa^2\ m^2\ s$)	213.2	207.3
Peak frequency (Hz)		*c.* 10	*c.* 12
Tow depth (m)		3	1
Tow speed (knots)		4	4
Shot point interval (m)		6.25	3.125

[1] Source levels for single pulses have been computed using Gundalf airgun array modelling software (Oakwood Computing, 2023) over a frequency range of 0 Hz to 50 kHz. The source levels quoted here are unweighted i.e., do not include any frequency weighting.

[2] The rms SPL source level has been calculated over a 125 ms time window.

1.2.2 Sub-Bottom Profiler

SBP data will be acquired during the Dagny CCS survey. The SBP source that will be used is the EdgeTech 3300 hull-mounted CHIRP (Compressed High-Intensity Radar Pulse) system (EdgeTech, 2017). This SBP comes in different configurations and many of the properties (such as signal type, frequency range, pulse length, duty cycle) are variable or user selected (EdgeTech, 2017). During the Dagny survey, the SBP will generate frequency modulated CHIRP signals sweeping from 3 kHz to 7 kHz. Source levels and other properties of the SBP are summarised in Table 1-2. The SBP will generate lower sound levels than the airgun arrays. SBPs are also highly directional (much more so than the airgun array) and as such their acoustic footprint is very small (Crocker and Fratantonio, 2018).

Table 1-2: Properties of the SBP that will be used during the survey.

Parameter		Value
Source		EdgeTech 3300 7 transducer hull-mounted CHIRP SBP
Source levels	Zero-to-peak SPL (dB re 1 µPa m)	212.0
	Rms SPL (dB re 1 µPa m)	209.0
	SEL (dB re 1 µPa^2 m^2 s)	199.0
Frequency range (kHz) [1]		3 – 7
Tow depth (m)		Hull-mounted
Tow speed (knots)		4
Pulse length (ms)		20
Duty cycle		0.1
Pulse rate		5 Hz (5 pulses per second)
Beam width		3 dB beamwidth: 16º 16 dB beamwidth: 29º

[1] The majority of sound energy will be contained between 3 kHz and 7 kHz. However, sound energy will also be produced outside of this range.

1.2.3 Other Survey Equipment

MBES, SBES and SSS equipment will be used during the survey. MBES, SBES and SSS operate at very high frequencies and the sound generated by this equipment is typically outside the main hearing ranges of marine mammals and well outside the hearing ranges of fish species. Furthermore, these devices are highly directional and therefore have a small acoustic footprint (Crocker and Fratantonio, 2016; Crocker *et al.,* 2018; Pace *et al.,* 2021). The impact of this equipment on marine receptors will therefore be low.

SSS can be operated in conjunction with an ultra-short baseline (USBL) high-precision positioning system. The USBL is an omnidirectional source. The addition of a USBL positioning system can cause the impact range of SSS to be greater than the impact range of SBP (Pace *et al.*, 2021). However, even with the use of USBL, the SSS will generate lower sound levels than the airgun arrays.

2.0 ENVIRONMENTAL BASELINE

This section discusses the local environment in the region of the survey, focussing on the aspects of the physical environment that influence how sound propagates, and on the specific biological receptors in the area that are sensitive to underwater noise.

2.1 Physical Environment

2.1.1 Bathymetry

Bathymetry can strongly influence sound propagation. Sound propagating in shallower waters interacts with the seabed, which typically results in stronger attenuation. In deeper waters, there is less sound interaction with the seabed and attenuation due to bottom loss is generally lower than in shallow waters, which can result in longer range sound propagation (Jensen *et al.,* 2011).

Bathymetry in the region of the proposed survey is provided by the European Marine Observation network (EMODnet) and is shown in Figure 2-1 (EMODnet Bathymetry Consortium, 2020). Water depth in each survey area option is approximately 60 m.

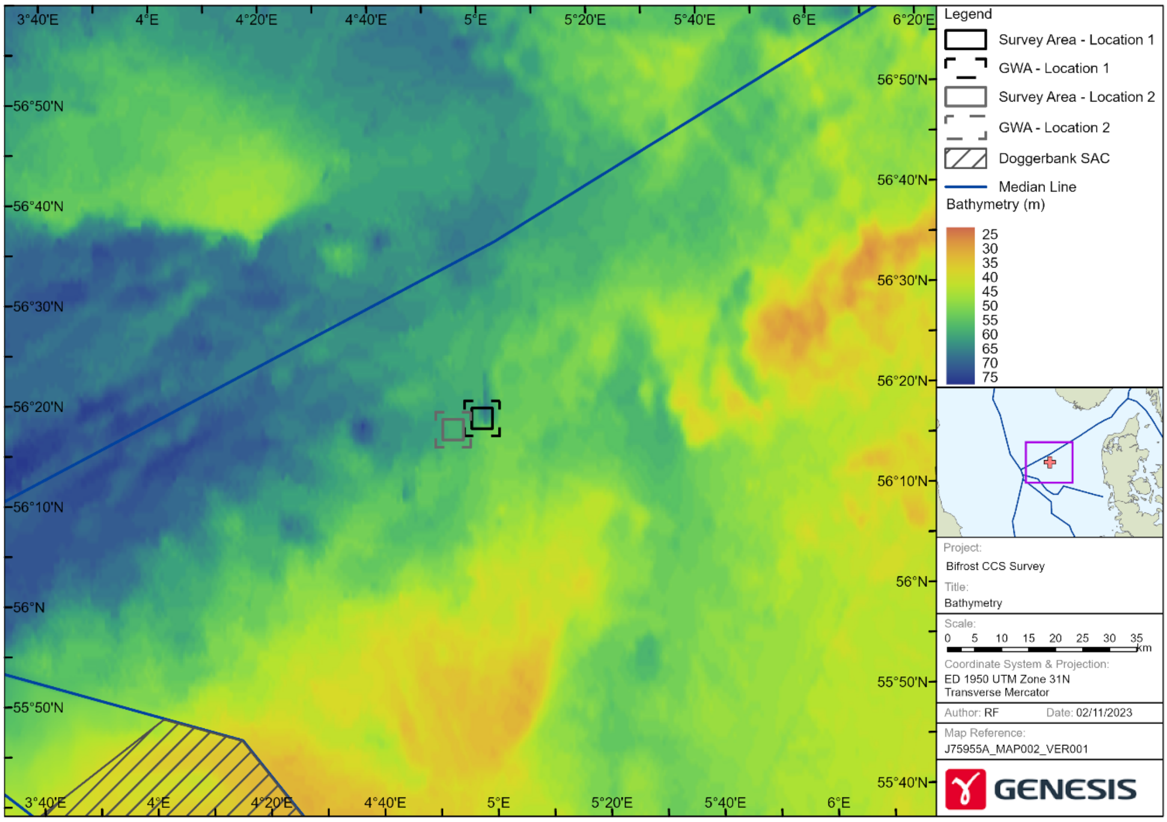

Figure 2-1: Bathymetry in the region of the survey area.

2.1.2 Sediments

The type of sediments in an area can affect sound propagation through reflection, attenuation, and scattering effects (Jensen *et al.,* 2011). An understanding of sediment distribution is therefore important for propagation modelling. The sediments in the region of the proposed survey are shown in Figure 2-2 (Vasquez *et al.,* 2021). Sediments in the survey area are expected to be mixed and comprised of sands and muds.

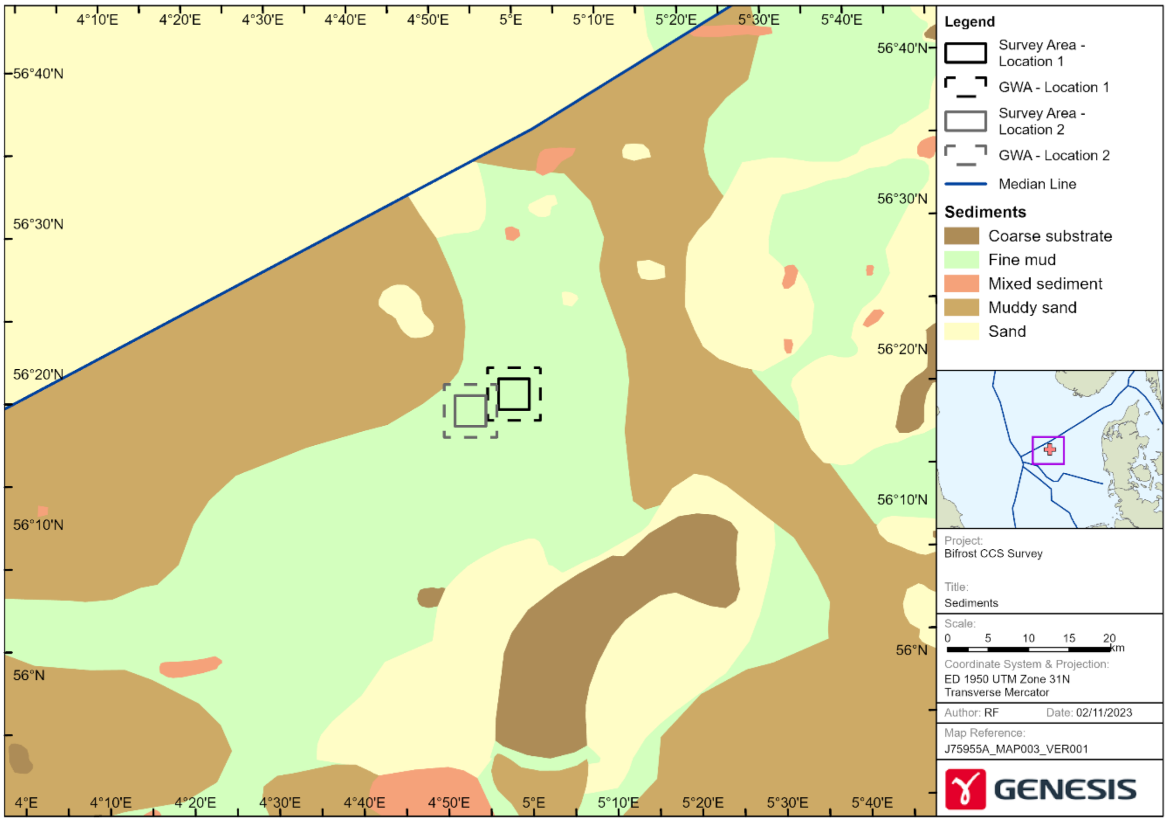

Figure 2-2: Sediments in the region of the survey area.

2.2 Biological Environment

2.2.1 Cetaceans

The Marine Ecosystems Research Program (MERP) has produced monthly distribution maps for cetaceans in the North-East Atlantic (Waggitt *et al.,* 2019). These distribution maps were generated from species distribution models using survey data taken between 1980 and 2018. The distribution maps produced by Waggitt *et al.* (2019) suggest that harbour porpoise (*Phocoena phocoena*) are the most abundant species in the region of the proposed survey area. Other species that could be present in the area in lower numbers include white-beaked dolphin (*Lagenorhynchus albirostris),* common dolphin *(Delphinus delphis*) and minke whale (*Balaenoptera acutorostrata*). Figure 2-3 shows the maximum yearly distribution of these species across the North Sea (Waggitt *et al.,* 2019).

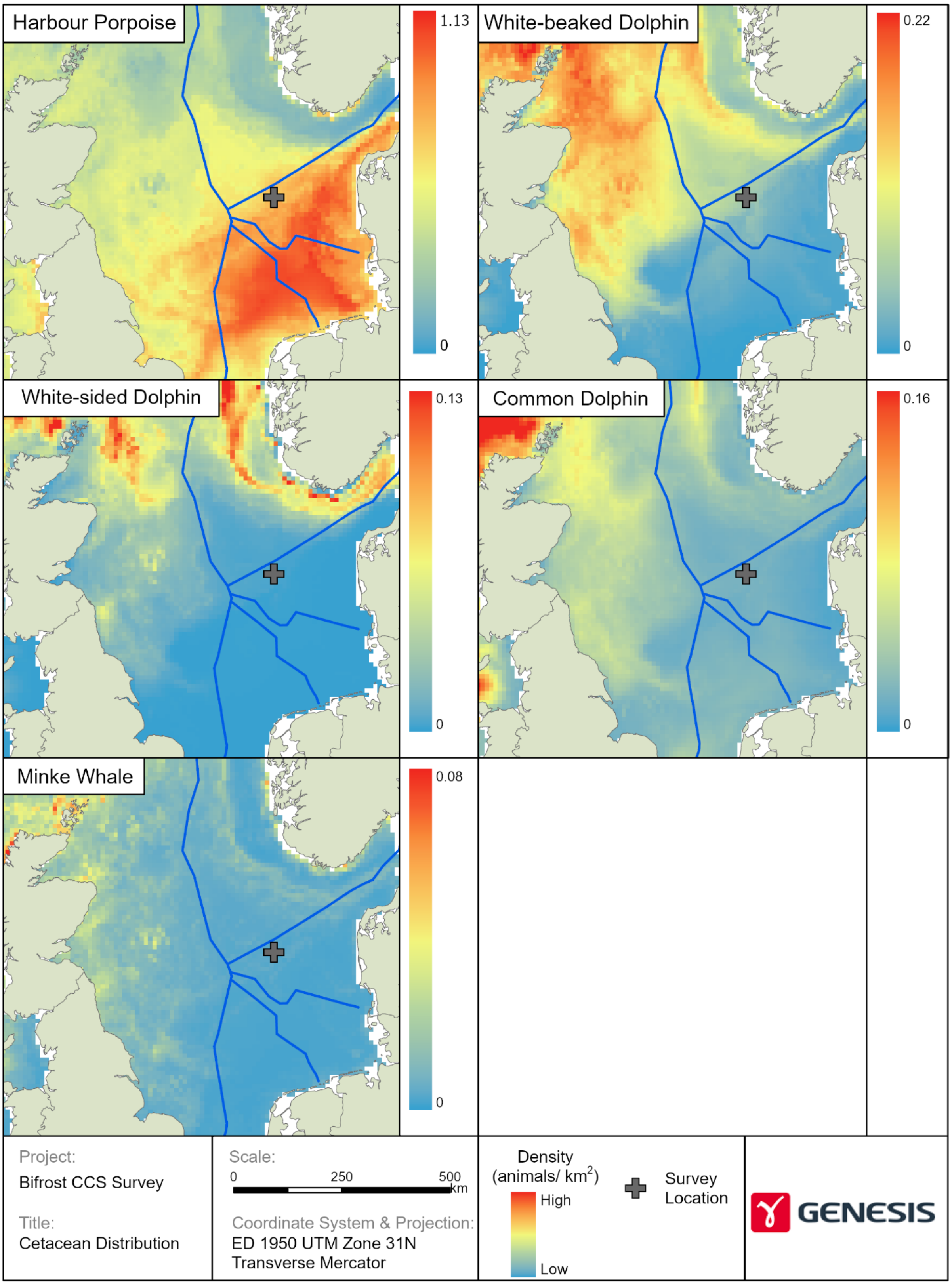

Figure 2-3: Maximum yearly distribution of cetacean species in the North Sea (Waggitt *et al.*, 2019).

Monthly densities of cetacean species that may be present in the region of the survey area are shown in Figure 2-4. These densities were obtained by interrogating the Waggitt *et al.* (2019) distribution data around the survey area. Cetacean species with monthly densities of less than 0.001 individiuals/km^2 are not shown in Figure 2-4.

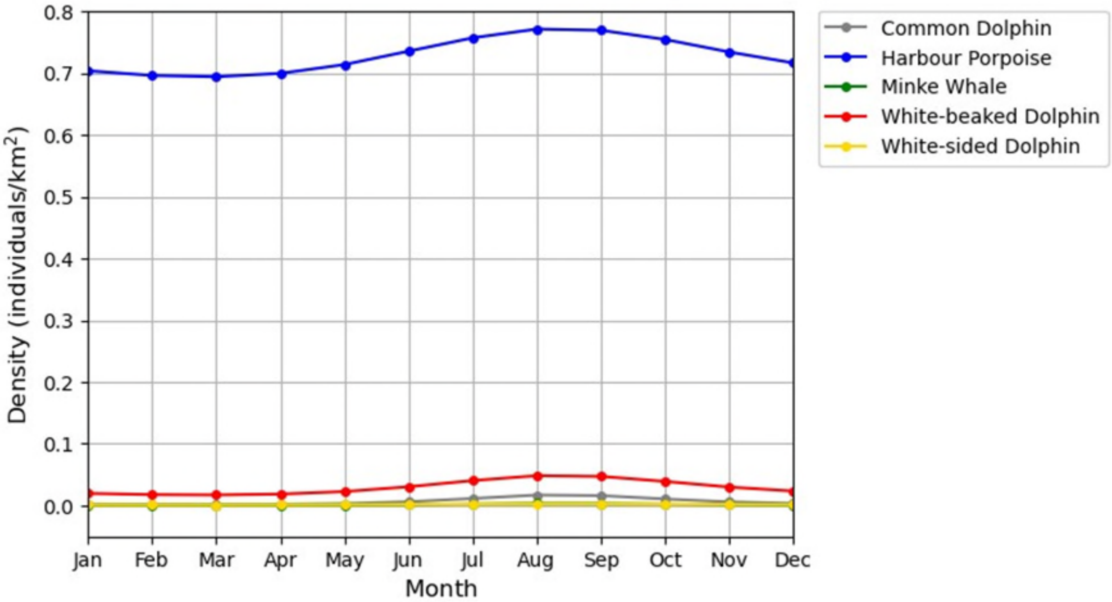

Figure 2-4: Monthly maximum densities of cetacean species in the region of the survey area (calculated from Waggitt *et al.* (2019) data).

The Joint Nature Conservation Committee (JNCC) has compiled an Atlas of Cetacean Distribution in Northwest European Waters (Reid *et al.,* 2003). Similar to Waggitt *et al.* (2019), the Reid *et al.* (2003) data shows that harbour porpoises, white-beaked dolphins, and minke whales have been sighted in the region of the survey area at different times throughout the year with harbour porpoise being the most sighted species.

Sightings around oil and gas installations in Danish waters reported by Delefosse *et al.* (2017) also indicate that harbour porpoise are the most sighted cetacean species in the region. Delefosse *et al.* (2017) also reported sightings of white-beaked dolphins, minke whales, killer whales, and pilot whales (*Globicephala* spp.) in the region of the survey area.

A series of Small Cetacean Abundance in the North Sea (SCANS) surveys have been conducted to obtain estimates of cetacean densities in the North Sea and adjacent waters, the most recent of which is SCANS-IV (Giles *et al*., 2023). The survey area is located in SCANS Block NS-J. During the SCANS-IV survey, harbour porpoises, white beaked dolphins, white-sided dolphins, minke whales and common dolphins were sighted in SCANS Block NS-J. Table 2-1 shows the estimated densities of these species from the SCANS-IV survey.

Table 2-1: Cetacean densities in SCANS-IV survey blocks.

SCANS-III Survey Block	Species	Density (animals/km^2)
NS-J	Harbour porpoise	0.4729
	White-beaked Dolphin	0.0622
	White-sided Dolphin	0.015
	Common Dolphin	0.0165
	Minke Whale	0.01

The Danish Centre for Environment and Energy (DCE) has published a background note containing recommendations for which species should be included in environmental impact assessments (Tougaard *et al.,* 2021). The document recommends that white-sided dolphin and common dolphin can be excluded from the impact assessment as they are uncommon in the region.

All cetacean species are included in Annex IV of the Habitats Directive (European Commission, 1992), implying that they are protected wherever they occur, and are awarded European Protected Species (EPS) status. Harbour porpoises are also granted further protection under Annex II of the EU Habitats Directive.

Cetaceans may be more susceptible to underwater noise during breeding and rearing seasons when mothers have dependant calves (Tougaard, 2016). Harbour porpoise calving and mating occurs from May to August and peaks in June and July (Sørensen and Kinze, 1994). Calves remain dependent on their mother for many months after birth (Lockyer, 1995).

There is very little information on the reproductive biology of minke whales and it is unknown when they mate or give birth. There is also little known about the reproduction of white-beaked dolphins, although it is suspected that they calve during summer months (Galatius and Kinze, 2016).

2.2.2 Pinnipeds

Two relevant species of seal (pinnipeds) are resident and breed in European waters: the grey seal (*Halichoerus grypus*) and the harbour seal (*Phoca vitulina*). Both species are listed under Annex II of the Habitats Directive. Grey seals and harbour seals have been observed in the region of the survey area (Delefosse *et al.*, 2017).

An estimated 40,000 harbour seals occur within the Wadden Sea area (which stretches along the coastline from Den Helder in the northwest of the Netherlands to its northern boundary at Skallingen in Denmark). Approximately 14,000 of the harbour seals in this area occur in Danish waters (Hansen *et al,* 2021). Harbour seals generally have a coastal distribution (Tougaard *et al.*, 2008; Herr *et al.*, 2009) but can be encountered across the entire North Sea. Tracking studies undertaken on harbour seals in the Wadden Sea indicate that most movements are within 50 km of the coast. The proposed survey area is approximately 191 km from nearest landfall and therefore beyond the range where harbour seals are more likely to be present.

An estimated 1,600 grey seals occur in Danish waters (Hansen *et al,* 2021) out of a wider population of 5,445 individuals in the Wadden Sea (Brasseur *et al.*, 2018). Grey seals tend to forage further offshore than harbour seals. Tracking studies undertaken in the Wadden Sea recorded the most movement within 60 km from shore. However, four of the sixteen tagged seals were recorded travelling more widely (Brasseur and Kirkwood, 2016).

Seals may pass through the region of the proposed survey area, but they are unlikely to occur in significant numbers.

Ringed seals, harp seals, hooded seals and walrus have been recorded in Danish waters. These species have been excluded from the assessment as they are considered not relevant by the DCE (Tougaard *et al.*, 2021).

2.2.3 Fish

The survey area is in International Council for the Exploration of the Sea (ICES) Rectangle 41F4 and 41F5. Fisheries sensitivity maps have been used to identify spawning and nursery grounds (Coull *et al.,* 1998; and Ellis *et al.,* 2012) for commercial fish species in ICES Rectangle 41F4 and 41F5. A summary of spawning and nursery activity in the area is provided in Table 2-2. Known spawning and nursery grounds for these species are shown in Figure 2-5.Cod, lemon sole, mackerel, plaice, sprat and whiting may be spawning in the region of the survey area between March and October.

Table 2-2: Summary of spawning and nursery activity for species known to be present in the region of the survey area.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Anglerfish	N	N	N	N	N	N	N	N	N	N	N	N
Blue whiting	N	N	N	N	N	N	N	N	N	N	N	N
Cod	SN	S*N	S*N	SN	N	N	N	N	N	N	N	N
European hake	N	N	N	N	N	N	N	N	N	N	N	N
Herring	N	N	N	N	N	N	N	N	N	N	N	N
Lemon sole				S	S	S	S	S	S			
Ling	N	N	N	N	N	N	N	N	N	N	N	N
Mackerel	N	N	N	N	S*N	S*N	S*N	SN	N	N	N	N
Plaice	S*N	S*N	SN	N	N	N	N	N	N	N	N	SN
Sandeel	SN	SN	N	N	N	N	N	N	N	N	SN	SN
Spotted ray	N	N	N	N	N	N	N	N	N	N	N	N
Sprat	N	N	N	N	S*N	S*N	SN	SN	N	N	N	N
Spurdog	N	N	N	N	N	N	N	N	N	N	N	N
Tope shark	N	N	N	N	N	N	N	N	N	N	N	N
Whiting	N	SN	SN	SN	SN	SN	N	N	N	N	N	N

S = Spawning

S* = Peak spawning

N = Nursery

Blue highlight indicates the period within which the survey may be conducted. The survey is expected to be completed within 45 days within this period.

Orange highlight indicates that high intensity spawning has been identified in the area.

Green highlight indicates that high intensity nurseries have been identified in the area.

Note: Ellis *et al*. (2012) reported that there was insufficient evidence to derive spawning grounds for sandeel and spotted ray but that these are likely to overlap with known nursery grounds.

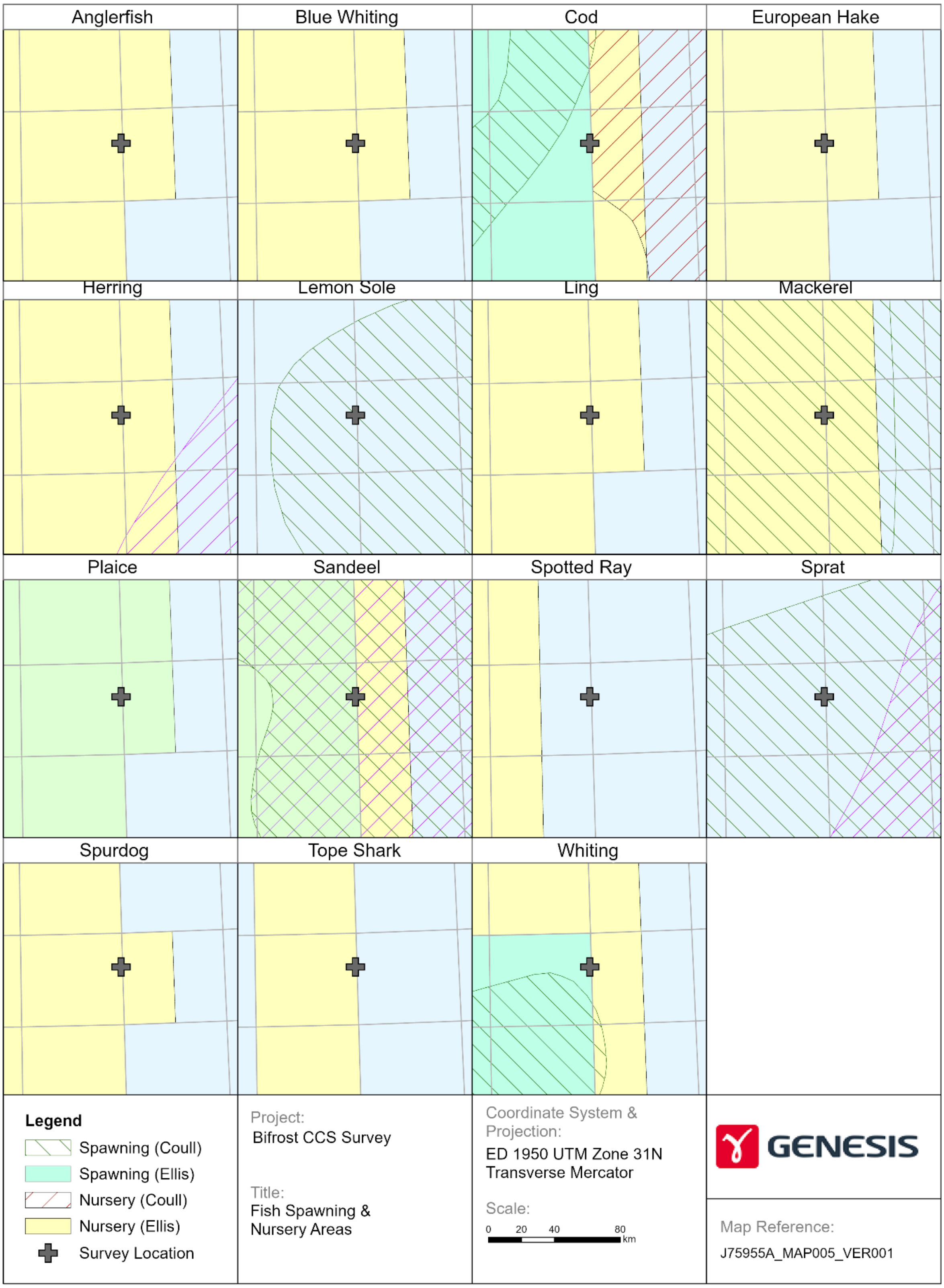

Figure 2-5: Fish spawning and nursery grounds in the region of the survey area.

2.2.4 Plankton

Plankton are drifting organisms that inhabit the pelagic zone of a body of water and include single celled organisms such as plants (phytoplankton) and animals (zooplankton), as well as organisms which have a temporary planktonic life stage (meroplankton). Phytoplankton are primary producers of organic matter in the marine environment and form the basis of marine ecosystem food chains. They are grazed upon by zooplankton and larger species such as fish, birds, and cetaceans. Therefore, the distribution of plankton directly influences the movement and distribution of other marine species. Meroplankton includes the eggs, larvae, and spores of non-planktonic species (fish, benthic invertebrates, and algae).

The composition and abundance of plankton communities vary throughout the year and are influenced by several factors including depth, tidal mixing, temperature stratification, nutrient availability, and the location of oceanographic fronts. Species distributions are directly influenced by temperature, salinity, water inflow and the presence of local benthic communities (Robinson, 1970; Colebrook, 1982; Johns and Reid, 2001).

2.2.5 Protected Areas

A network of marine protected areas (collectively known as Natura 2000 sites) are in place to aid the protection of vulnerable and endangered species and habitats through structured legislation and policies. These sites include Special Areas of Conservation (SAC) and Special Protection Areas (SPA) designated under the EC Habitats Directive (92/43/EEC), Particularly Vulnerable Areas (PVA/SVO) and EC Birds Directive (2009/147/EC), respectively. Figure 2-6 illustrates the nearest protected areas to the proposed survey area.

The closest protected areas to the proposed survey area are the SVO Tobisfelt sjr PVA and Dogger Bank SAC, which are located approximately 46 km and 67 km, respectively, from the survey GWA. The SVO Tobisfelt sjr is protected for the spawning of sandeel. Dogger Bank is a shallow sandbank that extends across the Danish, German, Dutch and UK Exclusive Economic Zones (EEZs), although the Danish region is not designated as a Natura 2000 site. The German, Dutch and UK Dogger Bank SACs are all designated for the Annex I habitat ‘Sandbanks which are slightly covered by sea water all the time’. The German SAC and Dutch SAC also list the Habitats Directive Annex II species harbour porpoise, grey seals, and harbour seals as qualifying features.

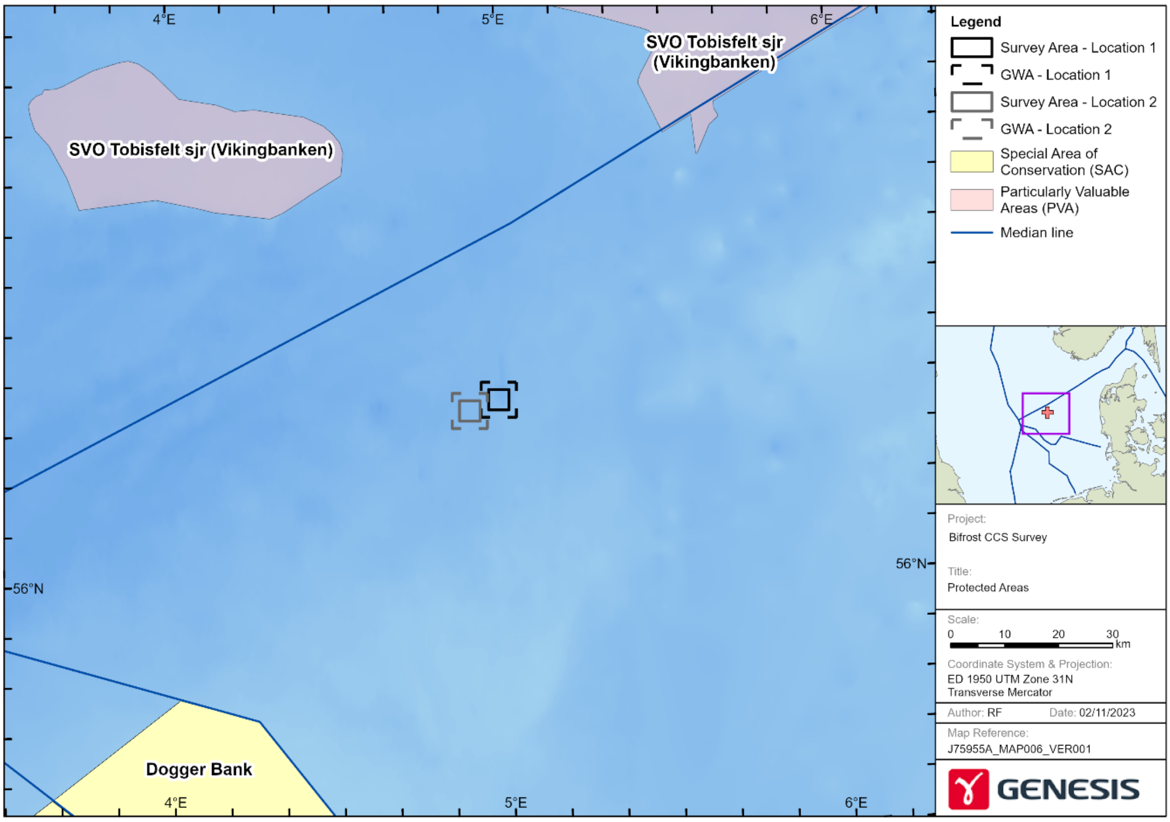

Figure 2-6: Protected sites in the region of the survey area.

3.0 MODELLING METHODOLOGY

This section discusses the modelling methodology adopted for estimating received sound levels generated during the proposed Dagny CCS survey. As discussed previously (see Section 1.2.2), the SBP that will be used during the survey will generate lower sound levels than the airgun arrays and will therefore have less impact on receptors. The MBES, SBES and SSS equipment operate at very high frequencies that are mainly outside the hearing range of most marine mammals and are highly directional (Crocker and Fratantonio, 2016; Crocker *et al.,* 2018). The high frequency and small acoustic footprint mean that these systems are unlikely to have a significant impact on marine mammals and other marine receptors. The modelling therefore focuses on the airgun arrays that will be used during the survey. Source modelling for the airgun arrays is discussed in the following sections.

3.1 Source Modelling

2DHR data will be acquired during the survey using a 160 cu. in airgun array and 2DUHR data will be acquired using a 24 cu. in airgun array. Sound levels generated by the airgun arrays are dependent on specific details such as the number and type of airguns deployed, individual airgun volumes, firing pressures and array geometry. Accurate prediction of sound levels produced by airgun sources therefore requires detailed modelling of the source.

3.1.1 Source Configuration

The modelled 160 cu. in airgun array comprises four 40 cu. in TI Sleeve airguns, whilst the modelled 24 cu. in airgun array comprises two 12 cu. in Mini G-gun airguns. The configurations of the airgun arrays are detailed in Table 3-1.

Table 3-1: Airgun source configurations.

Airgun ID	Airgun Type	Airgun volume (cu. in)	X (m)	Y (m)	Z (m)	Pressure (psi)
160 cu. in Airgun Array (2DHR)						
1	TI Sleeve	40	0	0.23	2.77	2000
2	TI Sleeve	40	0	0.23	3.23	2000
3	TI Sleeve	40	0	-0.23	3.23	2000
4	TI Sleeve	40	0	-0.23	2.77	2000
24 cu. in Airgun Array (2DUHR)						
1	Mini G-gun	12	2.5	-0.3	1	2000
2	Mini G-gun	12	2.5	0.3	1	2000

3.1.2 Source Signatures

Time domain and frequency domain signatures for the 160 cu. in and 24 cu. in airgun arrays have been predicted from the Gundalf modelling. The predicted far-field pressure signatures vertically below the airgun arrays are shown in the time domain in Figure 3-1. Figure 3-2 and Figure 3-3 show deci-decadal band SEL source levels (otherwise known as deci-decadal band energy source levels) for the 160 cu. in and 24 cu. in airgun arrays, respectively. These figures show both unweighted and weighted source levels. The source levels have been weighted using the Southall *et al.* (2019) auditory weighting functions for low frequency (LF) cetaceans, high frequency (HF) cetaceans, very high frequency (VHF) cetaceans, and phocid pinnipeds (see Section 4.1.1).

Source levels for the airgun arrays in terms of zero-to-peak SPL, rms SPL, and SEL been calculated based on the far-field vertical signatures estimated by Gundalf and are summarised in Table 3-2. The source levels quoted in Table 3-2 (and the signatures shown in Figure 3-1) are predicted by Gundalf based on back propagated far-field estimates of sound levels vertically below the airgun sources. As discussed in the following section, the directivity of airgun arrays is such that the highest sound levels are emitted vertically downwards and sound in other directions can be substantially lower. It is observed from the Gundalf modelling results that the 160 cu. in airgun array generates higher peak sound levels than the 24 cu. in array. The deci-decadal band SEL source levels are also higher for the 160 cu. in array over the majority of the deci-decadal bands up to 50 kHz, which is due to it comprising more individual airguns and having a larger overall volume.

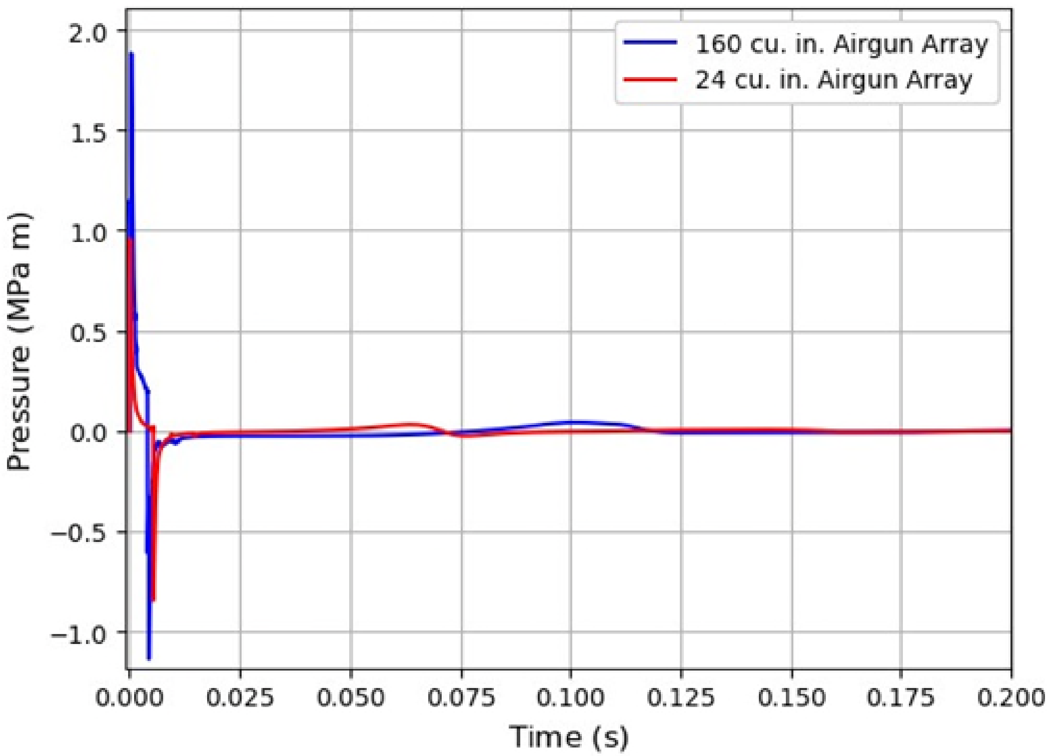

Figure 3-1: Time domain far-field signatures at 1 m vertically below the airgun arrays.

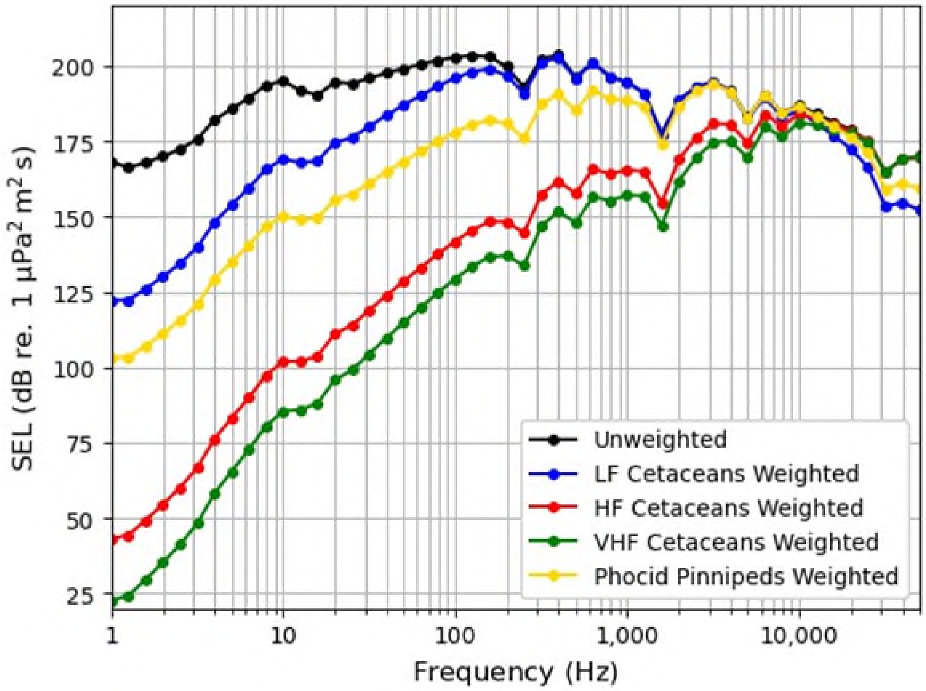

Figure 3-2: Deci-decadal band SEL source levels vertically below the 160 cu. in airgun array.

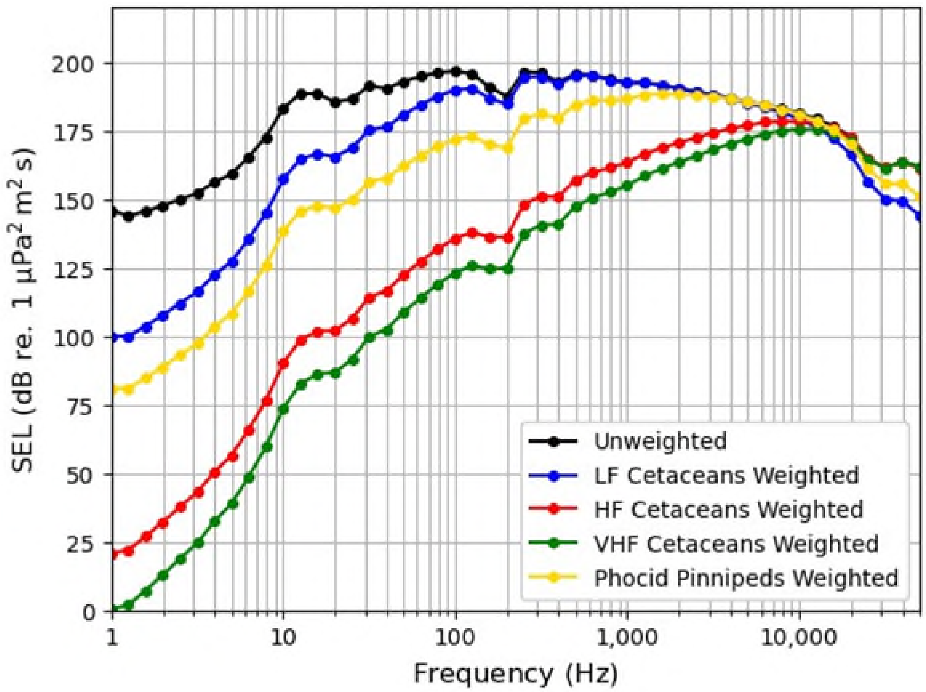

Figure 3-3: Deci-decadal band SEL source levels vertically below the 24 cu. in airgun array.

Table 3-2: Source levels and peak frequencies of the airgun arrays.

<table>
<tr><th colspan="3">Parameter</th><th>160 cu. in Airgun Array (2DHR Survey)</th><th>24 cu. in Airgun Array (UHR Survey)</th></tr>
<tr><td rowspan="11">Source level [1,2,3]</td><td colspan="2">Zero-to-peak SPL (dB re 1 µPa m)</td><td>245.5</td><td>239.6</td></tr>
<tr><td rowspan="5">Rms SPL (dB re 1 µPa m)</td><td>Unweighted</td><td>222.3</td><td>216.3</td></tr>
<tr><td>LF cetaceans[4]</td><td>218.8</td><td>213.6</td></tr>
<tr><td>HF cetaceans[4]</td><td>200.4</td><td>195.9</td></tr>
<tr><td>VHF cetaceans[4]</td><td>197.2</td><td>192.4</td></tr>
<tr><td>Phocid pinnipeds</td><td>210.7</td><td>207.3</td></tr>
<tr><td rowspan="5">SEL (dB re 1 $\mu Pa^2 m^2 s$)</td><td>Unweighted</td><td>213.2</td><td>207.3</td></tr>
<tr><td>LF cetaceans</td><td>209.7</td><td>204.6</td></tr>
<tr><td>HF cetaceans</td><td>191.3</td><td>186.9</td></tr>
<tr><td>VHF cetaceans</td><td>188.2</td><td>183.4</td></tr>
<tr><td>Phocid pinnipeds</td><td>201.6</td><td>198.2</td></tr>
<tr><td colspan="3">Peak frequency (Hz)</td><td>c. 10</td><td>c. 12</td></tr>
<tr><td colspan="5">[1] Source levels have been calculated by the Gundalf airgun array modelling software (Oakwood Computing, 2023) for single pulses over a frequency range of 0 Hz to 50 kHz. The source levels are calculated from far-field sound levels vertically below the array back propagated to 1 m from the airgun source.
[2] Zero-to-peak SPL source levels are unweighted, whilst rms SPL and SEL source levels are either unweighted or weighted according to the Southall et al. (2019) marine mammal hearing group auditory weighting functions.
[3] The rms SPL source levels have been calculated using a 125 ms time window.
[4] See Section 4.1.1 for full details of marine mammal hearing groups.</td></tr>
</table>

3.1.3 Directivity

Airgun arrays are designed to direct a large proportion of acoustic energy vertically downwards to maximise energy into the seabed and underlying geology. Sound levels emitted in horizontal directions can be significantly lower than those emitted vertically downwards (Richardson *et al*., 1995; Duren, 1988; Caldwell and Dragoset, 2000).

Directivity patterns have been predicted by Gundalf for different frequencies, azimuthal angles, and elevation angles, and incorporated into the propagation modelling. Example directivity patterns predicted by Gundalf for the 160 cu. in and 24 cu. in airgun arrays are shown in Figure 3-4 and Figure 3-5, respectively. These plots show the energy spectral density (ESD) as a function of frequency and elevation angle for a given azimuthal angle (the figures show the inline directivity pattern of the airgun arrays). An elevation angle of 0° corresponds to vertically below the array, whilst elevation angles of -90° and 90° correspond to horizontal directions. Most of the acoustic energy is directed downwards (at an 0° elevation angle), but some acoustic energy is released horizontally. The ESD is greatest at approximately 10 Hz as this is the centre frequency of the airgun arrays.

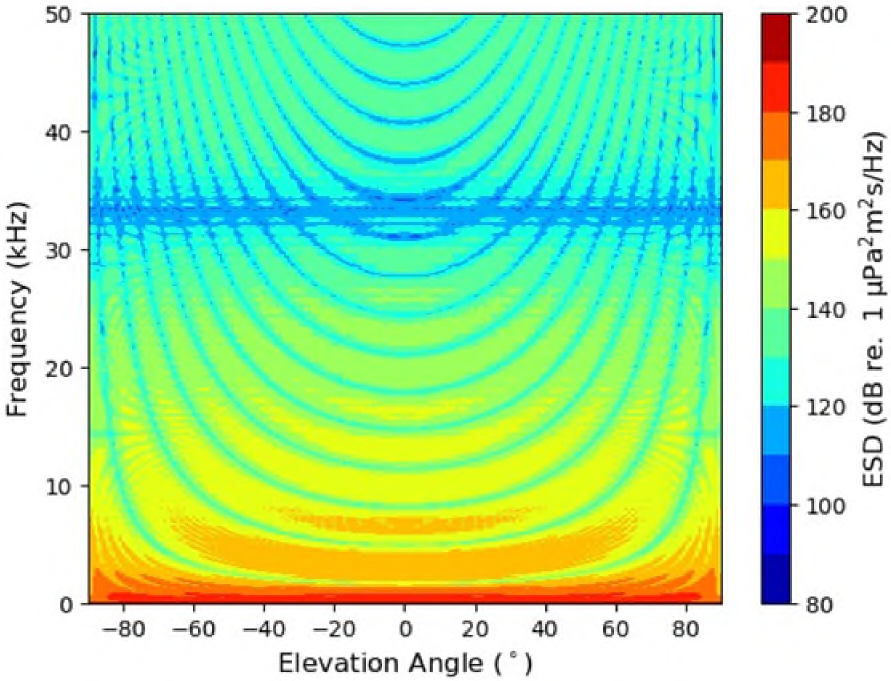

Figure 3-4: Predicted inline ESD for the 160 cu. in airgun array.

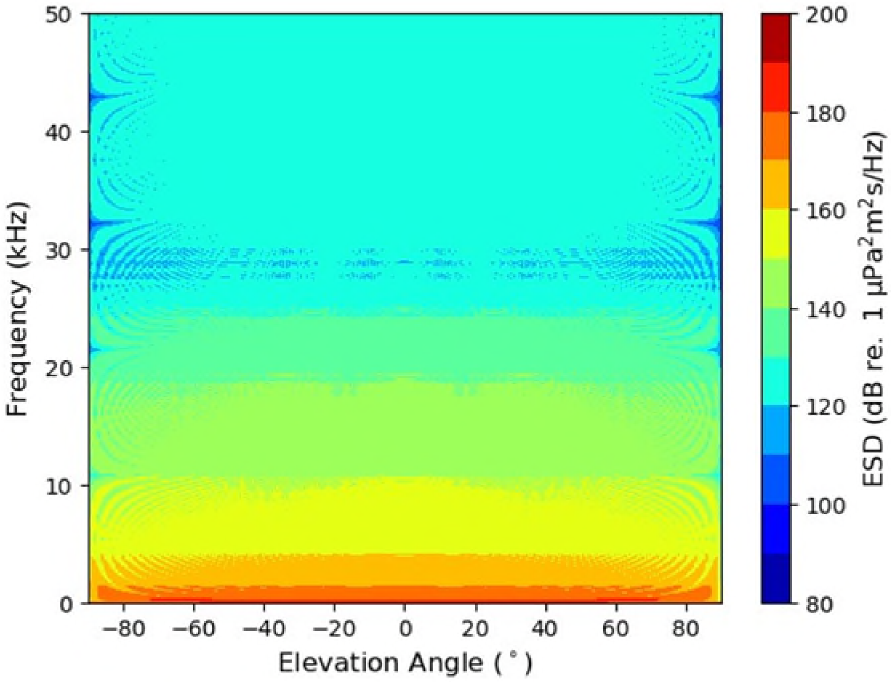

Figure 3-5: Predicted inline ESD for the 24 cu. in airgun array.

3.2 Noise Propagation Modelling

3.2.1 Propagation Model

Various underwater noise models can be used for propagation modelling e.g., parabolic equation, ray tracing, normal mode, wavenumber integration, energy flux density and semi-empirical models (Jensen *et al.,* 2011). The Genesis in-house model FARAM (Faunal Acoustic Risk Assessment Model) has been used in this assessment.

For this propagation modelling study and impact assessment, the FARAM implementation of the Bellhop Gaussian beam ray tracing model has been used (Porter and Liu, 1994). The adopted propagation model satisfies the requirements suggested by Tougaard (2016) for propagation modelling. Specifically, the model:

- Employs range and depth dependent sound speed profiles based on modelled hydrological conditions;
- Employs a bathymetric grid to account for the influence of varying bathymetry;
- Accounts for acoustic properties of the predominant sediments in the modelling area;
- Accounts for frequency-dependent propagation effects (e.g., volume attenuation, reflection, scattering at different frequencies);
- Accounts for various properties of the sound source (e.g., frequency content, directivity, pulse interval, movement of mobile sound sources); and
- Accounts for the movement of receptors when calculating received cumulative SEL (e.g., incorporates swim speed, depth and trajectory).

3.2.2 Environmental Data

FARAM accounts for site-specific environmental properties including a bathymetric grid, geographically and depth varying sound speed profiles, and geo-acoustic properties of the sediment.

3.2.2.1 Bathymetry

Accurate bathymetry data is important for sound propagation modelling since the seabed strongly influences the propagation characteristics of sound. In shallow water regions, there is significant interaction of the sound with the seabed through reflections and scattering effects, and strong attenuation may occur as sound penetrates the seabed. In deep water regions, there is typically less interaction of sound with the seabed and attenuation due to bottom loss is small, which can result in longer propagation distances.

The bathymetry data that has been used in the propagation model is provided by EMODnet (Figure 2-1), which is a high-resolution digital terrain model for European Seas (EMODnet Bathymetry Consortium, 2020). The bathymetry is based on almost 10,000 datasets obtained from bathymetric surveys, with data provided at a spatial resolution of 1/16 arc minutes.

3.2.2.2 Seabed Properties

The implemented propagation model accounts for attenuation effects due to interactions with the seabed. The main sediment types in the region of the survey area are classified as mixed sands and muds (Figure 2-2). However, the propagation model is limited to a single sediment type for the seabed. A sandy seabed has been assumed in the modelling. This is likely to be conservative since harder sediments such as sands typically result in longer range propagation compared to softer sediments such as muds (Jensen *et al.*, 2011). The geo-acoustic properties associated with the seabed substrate that have been used in the modelling are shown in Table 3-3 (Jensen *et al.*, 2011).

Table 3-3: Geo-acoustic parameters that have been used in the model.

Seabed Property	Value
Sound speed in sediment	1,650 m/s
Sound attenuation in sediment	0.8 dB/wavelength
Sediment density	1,900 kg/m^3

3.2.2.3 Sound Speed

A major factor that influences sound propagation in water is the speed of sound through the water column, which affects how sound refracts as it propagates through the water. The model used in this study allows for geographically and depth varying sound speed profiles. Sound speed data can be derived from water column temperature and salinity data (Jensen *et al.*, 2011). Sound speed profiles for the model are derived from temperature and salinity profiles taken from the World Ocean Atlas (WOA) from 2013 (WOA, 2013). Modelling has been undertaken both in winter (March) and in summer (August). The temperature, salinity and sound speed profiles used in the modelling are shown in Figure 3-6 and Figure 3-7.

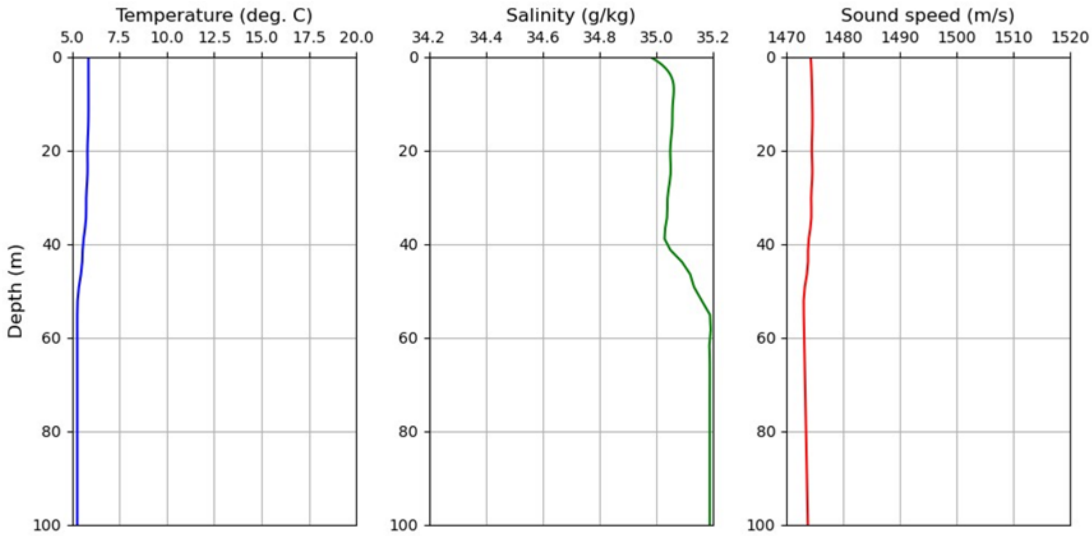

Figure 3-6: Example sound speed profile used in the winter modelling.

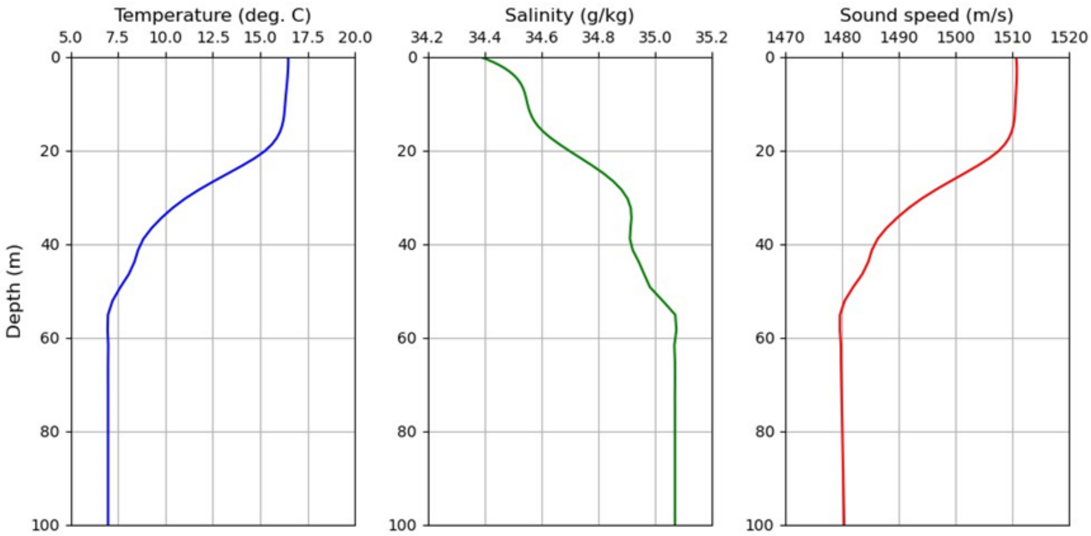

Figure 3-7: Example sound speed profile used in the summer modelling.

4.0 IMPACT ASSESSMENT METHODOLOGY

It has become increasingly evident that noise from human activities can potentially impact marine species (e.g., Oslo and Paris Convention (OSPAR), 2009; Richardson, *et al*., 1995; Tougaard, 2016; Southall *et al*., 2007, 2019, 2021; National Marine Fisheries Service (NMFS), 2018). Sound is important for marine mammals for navigation, communication, and prey detection. Therefore, the introduction of anthropogenic noise could impact/disturb marine mammals. This section discusses the impact criteria/thresholds that have been adopted to assess potential impacts to marine mammals.

4.1 Marine Mammals

4.1.1 PTS and TTS Thresholds

It is generally accepted for marine mammals that the auditory system is the most sensitive organ to acoustic injury, meaning that injury to the auditory system can occur at lower sound levels than injuries to other tissues (Tougaard, 2016; Southall *et al*., 2007, 2019; NMFS, 2018). Noise-induced hearing impairment includes permanent threshold shift (PTS) and temporary threshold shift (TTS). PTS is a permanent change in hearing threshold from which marine mammals do not recover, whilst TTS is a temporary change in hearing threshold that mammals recover from over time depending on the severity (the larger the initial TTS the longer the recovery period). Marine mammals will recover from small amounts of TTS within minutes, whereas it could take hours to days to recover from severe TTS (Tougaard, 2016).

Numerous studies have been conducted to estimate the sound levels required to cause auditory injury to marine mammals (e.g., Tougaard, 2016; Finneran, 2013, 2015; Kastelein *et al.,* 2013; Lucke *et al.,* 2009; Southall *et al*., 2007, 2019; NMFS, 2018). Various thresholds for PTS and TTS have been proposed using different metrics (e.g., zero-to-peak SPL, peak-to-peak SPL, unweighted and weighted single-pulse SEL and cumulative SEL). A distinction is generally made between impulsive and non-impulsive sound when establishing thresholds for PTS and TTS (Southall *et al*., 2019; NMFS, 2018). Although there is no clear agreement on the definition of impulsive and non-impulsive sound (Ruppel *et al.,* 2022), impulsive sound is generally characterised as being transient, brief (less than 1 second), broadband, and consisting of high zero-to-peak sound pressure with rapid rise time and rapid decay (NMFS, 2018). Seismic sources such as airgun arrays, sparkers, and boomers are generally classified as impulsive sources. Non-impulsive sound can be broadband, narrowband or tonal, brief or prolonged, continuous or intermittent) and typically do not have a high peak sound pressure with rapid rise/decay time that impulsive sounds do (NMFS, 2018). Sound pulses from high-resolution geophysical survey equipment such as SBPs, MBESs, and SSSs can share some attributes similar to impulsive sounds (e.g., the sound pulses from these types of equipment are transient, brief, and broadband). However, they typically do not have the same high zero-to-peak levels associated with impulsive sounds. Sound from SBPs, MBESs, and SSSs can therefore be classified as intermittent non-impulsive sound sources (Ruppel *et al.,* 2022; Guan *et al.,* 2021).

The thresholds adopted in this assessment are those according to Energistyrelsen (2022a) for assessing potential impacts to marine mammals in Danish waters. According to Energistyrelsen (2022a,) the cumulative SEL thresholds proposed by Southall *et al.* (2019) should be used for assessing potential PTS and TTS impacts to marine mammals. The Southall *et al.* (2019) cumulative SEL thresholds are summarised in Table 4-1. The cumulative

SEL thresholds proposed by Southall *et al.* (2019) have been established for impulsive and non-impulsive noise. In this assessment the impulsive thresholds are used to assess potential impacts from the airgun array that will be used during the Dagny CCS survey.

Southall *et al.* (2019) established thresholds for different marine mammal hearing groups. The hearing groups that are relevant for this assessment are low frequency (LF) cetaceans, high frequency (HF) cetaceans, very high frequency (VHF) cetaceans, and phocid pinnipeds. Table 4-1 shows the marine mammal species that are most likely to be present in Danish waters categorised according to these hearing groups.

Table 4-1: Marine mammal PTS and TTS thresholds adopted in this assessment.

Hearing Group	Relevant Species	Cumulative SEL Thresholds [1] (dB re 1 μPa^{2}s)	
		PTS	TTS
LF cetaceans	Minke whale	183	168
HF cetaceans	White-beaked dolphin, White-sided dolphin, Common dolphin, Killer whale, Pilot whale	185	170
VHF cetaceans	Harbour porpoise	155	140
Phocid pinnipeds	Harbour seals, Grey seals	185	170

[1] In this assessment the impulsive thresholds are used to assess potential impacts to marine mammals from the airgun arrays that will be used the survey.

The thresholds shown in Table 4-1 are based on the cumulative SEL metric, which accounts for the hearing capabilities of different marine mammal hearing groups and for exposure time (Southall *et al.*, 2019; Tougaard, 2021). Received sound levels are frequency-weighted according to the generalised auditory weighting functions shown in Figure 4-1 (Southall *et al.,* 2019), and the resulting weighted sound levels are integrated over the duration of exposure to calculate the cumulative SEL. The effect of the auditory-weighting functions shown in Figure 4-1 is to reduce received sound levels at frequencies for which a hearing group is less sensitive.

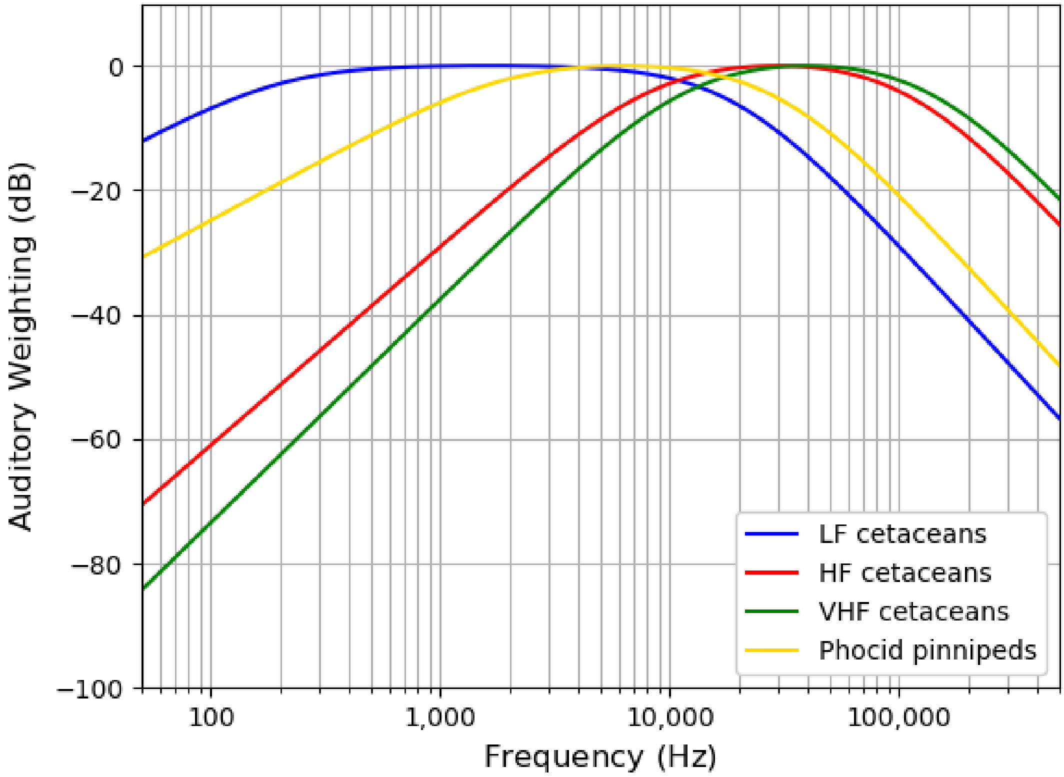

Figure 4-1: Auditory weighting functions for different marine mammal hearing groups.

4.1.2 Behavioural Disturbance Thresholds

Sound at lower levels than those required to induce PTS or TTS to marine mammals can still have an adverse impact since it may alter their normal behaviour i.e., cause behavioural disturbance. Marine mammals can exhibit varying behavioural responses to underwater sound depending on the level and duration of the sound. The most immediate effects are flight reactions which can potentially lead to mortality e.g., due to mammals beaching in coastal waters (D'Amico *et al.*, 2009; Balcomb and Claridge, 2001) or calves becoming separated from their mothers. However, the more probable behaviour effects caused by the proposed seismic survey activities will be displacement (Sarnocinska *et al.*, 2020; Thompson *et al.*, 2013; Bejder *et al.*, 2006; Pirotta *et al.*, 2014), or disturbance to feeding behaviours (Stimpert *et al.*, 2014; Isojunno *et al.*, 2016; Wisniewska *et al.*, 2018). At lower sound levels, less severe behavioural effects may include changes in swimming behaviour and vocalisation (van Beest *et al.*, 2018; Robertson *et al.*, 2013). Any long-term changes in normal behaviour can have implications for the long-term survival and reproductive success of individuals and in extreme cases may have consequences at a population level.

Southall *et al.* (2007) concluded that thresholds for behavioural disturbance were difficult to conclusively define since behavioural responses to sound are highly variable and context specific. Southall *et al*. (2007) therefore recommended assessing whether sound from a specific activity could cause disturbance by comparing the circumstances of the situation with empirical studies reporting similar circumstances.

In order to calculate the extent of disturbance to marine mammals from an activity, it is necessary to know reaction thresholds for noise impact for the various species. The empirical basis is not extensive in the area and the Danish guidelines (Energistyrelsen, 2022a; 2022b) only includes a generalized threshold of 103 dB re. 1 µPa calculated as rms average over 125 ms and frequency weighted with the VHF weighting function for harbour porpoises. This threshold has been derived from observations of displacement of harbour porpoises (VHF cetaceans) from noise from piling (Energistyrelsen, 2022b). For other species of marine mammals there are no generalised thresholds for behavioural disturbance, i.e., thresholds expressed as a frequency-weighted received sound level. Instead, observations of displacement of other marine mammal species during similar activities should be considered if possible.

Tougaard (2016) suggests that behavioural disturbance to harbour porpoises from seismic surveys using airgun arrays should be assessed using an unweighted single-pulse SEL threshold of 145 dB re 1 µPa^{2}s. This threshold was derived based on noise measurements and observations of disturbance to harbour porpoise during a seismic survey with a 470 cu. in airgun array (Thompson *et al.,* 2013; Lucke *et al.,* 2009). In lieu of specific data for other marine mammals, Tougaard (2016) also suggested that this threshold should be used for assessing impacts to other species of marine mammals. This will likely be conservative since it is suspected that harbour porpoises are more sensitive to noise than most other species (Tougaard, 2016). The threshold from Tougaard (2016) is used in this report to estimate potential behavioural disturbance to all marine mammals from the proposed survey using the airgun array (Table 4-2).

The marine mammal behavioural disturbance thresholds adopted in this assessment are summarised in Table 4-2.

Table 4-2: Marine mammal behavioural disturbance thresholds adopted in this assessment.

Behaviour Disturbance Threshold	Source	Application
145 dB re 1 µPa^{2}s (single-pulse unweighted SEL)	Tougaard (2016) Thompson *et al.,* (2013) Lucke *et al.,* (2009)	This threshold has been derived from observations of displacement of harbour porpoises during seismic surveys. In this assessment it is used to estimate displacement of all marine mammals from sound generated from the airgun arrays during the proposed site survey.
103 dB re 1 µPa (rms SPL over a time window of 125 ms weighted for VHF cetaceans)	Energistyrelsen (2022a) Energistyrelsen (2022b)	This threshold has been derived from observations of behavioural disturbance to harbour porpoises from piling during wind farm site construction. In this assessment it is used to inform the estimation of displacement of all marine mammal species from the sound generated by the airgun arrays during the proposed survey.

4.2 Fish

4.2.1 Injury Thresholds

Popper *et al*. (2014) have defined criteria for injury to fish based on a review of publications related to impacts on fish, fish eggs, and larvae from various high-energy sources including airgun arrays. Popper *et al.* (2014) is the most comprehensive review available for potential impacts on fish species. The hearing capability of fish largely depends on the presence or absence of a swim bladder. Popper *et al*. (2014) derived different injury thresholds for:

- Fishes with no swim bladder or other gas chamber;
- Fishes with swim bladders in which hearing involves a swim bladder or other gas volume;
- Fishes with swim bladders in which hearing does not involve the swim bladder or other gas volume; and
- Fish eggs and larvae.

The thresholds proposed by Popper *et al*. (2014) for mortality and potential mortal injury to fish species from seismic surveys are shown in Table 4-3, which are used in this assessment for assessing potential impacts from the airgun arrays used during the survey.

Table 4-3: Thresholds for potential injury to fish.

Fish Group	Injury Thresholds [1]	
	Zero-to-peak SPL (dB re 1 μPa)	Cumulative SEL (dB re 1 μPa^{2}s)
Fishes with no swim bladder	213	219
Fishes with swim bladder involved in hearing	207	207
Fishes with swim bladder not involved in hearing	207	210
Fish eggs and larvae	207	210

[1] In this assessment the seismic survey thresholds are used to assess potential impacts to fish from the airgun arrays that will be used during the survey.

4.2.2 Behavioural Disturbance Thresholds

Documented behavioural effects of sound on fish behaviour are variable, ranging from no discernible effect (Wardle *et al.,* 2001) to startle reactions followed by immediate resumption of normal behaviour (Wardle *et al.,* 2001; Hassel *et al.,* 2004). Avoidance of airgun array sound has also been observed (Hassel *et al.,* 2004). However, there are no well-established thresholds for assessing behavioural disturbance to fish. Popper *et al*. (2014) concluded that there lacked sufficient evidence to recommend specific thresholds that correspond to behavioural disturbance for fish. Disturbance to fish is therefore not assessed in this report.

4.3 Other Relevant Thresholds

The Dagny CCS survey area is located approximately 64 km from the German EEZ and German region of the Dogger Bank SAC, (see Section 2.2.5). The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety issued the 'Sound Protection Concept' which provides guidelines on sound levels in the German EEZ and nature conservation areas (Bundesministerium für Umwelt, Naturschutz und Reaktrosicherheit (BMU), 2014). The thresholds proposed by BMU (2014) are summarised in Table 4-4. The thresholds are based on a single-pulse unweighted SEL of 140 dB re 1 μPa^2s, which is more conservative than the marine mammal behavioural disturbance threshold of 145 dB re 1 μPa^2s proposed by Tougaard (2016). The Tougaard (2016) threshold is used in this report for assessing the impact of behavioural disturbance to marine mammals since it is based on evidence of displacement of marine mammals to impulsive noise (Tougaard, 2016; Thompson *et al.,* 2013; Lucke *et al.,* 2009). However, the noise modelling is also conducted to assess if the BMU (2014) threshold is exceeded in German waters. The German thresholds shown in Table 4-4 were developed primarily for assessing impacts from piling but may also be applicable for other impulsive sound sources such as airgun arrays.

Table 4-4: Sound level restrictions in the German EEZ.

Threshold	Restrictions
Single-pulse unweighted SEL of 140 dB re 1 μPa^2s	Sound levels above this threshold must not cover more than 10% of the German EEZ area at any time.
	Sound levels above this threshold must not cover more than 10% of the Dogger Bank SAC area from September to April.
	Sound levels above this threshold must not cover more than 1% of the Dogger Bank SAC area from May to August.

5.0 MODELLING RESULTS AND IMPACT ASSESSMENT

This section presents the noise modelling and impact assessment results for the proposed survey at Dagny. The impacts of both survey options have been assessed. As discussed in Section 3.0, the 160 cu. in airgun array that will be used during the survey will have the biggest impact to marine mammals and other marine receptors. The noise modelling therefore focuses on predicting impacts from this source. Winter and summer modelling has been undertaken using environmental data from the months of March and August respectively.

5.1 Marine Mammals

5.1.1 PTS and TTS

5.1.1.1 Stationary Marine Mammals

The 160 cu. in airgun array has been modelled being towed along single representative seismic lines over the survey area and firing at a regular shot point interval. The cumulative SEL received in the marine environment has then been calculated and weighted using the marine mammal auditory weighting functions shown in Figure 4-1. Thus, the weighted cumulative SEL received by stationary marine mammals belonging to the different marine mammal hearing groups has been estimated.

Figure 5-1 to Figure 5-4 show the maximum predicted cumulative SELs received by the LF cetacean, HF cetacean, VHF cetacean, and phocid pinniped hearing groups, respectively, from the airgun array operating over a single seismic line for the proposed survey option 1 during winter. Figure 5-5 to Figure 5-8 show the maximum predicted cumulative SELs received by the LF cetacean, HF cetacean, VHF cetacean, and phocid pinniped hearing groups, respectively, from the airgun array operating over a single seismic line for the proposed survey option 1 during summer. The contours highlighted in these figures show the adopted marine mammal PTS and TTS thresholds. The cumulative SELs have only been shown for survey option 1, as the cumulative SEL results for survey option 2 are the same as survey option 1.

Figure 5-1 to Figure 5-8 show the estimated cumulative SELs received by the different marine mammal hearing groups assuming that marine mammals remain stationary during the acquisition of data along the seismic line. The maximum distances to threshold are detailed in the figures. The results only indicate areas where PTS and TTS may occur if marine mammals remain stationary as the survey vessel traverses the seismic line, which is a highly conservative assumption but provides a robust base scenario with which further assessment and comparison of moving animals can be conducted. Cumulative SELs received by marine mammals as they swim away from the survey vessel are calculated in the following section.

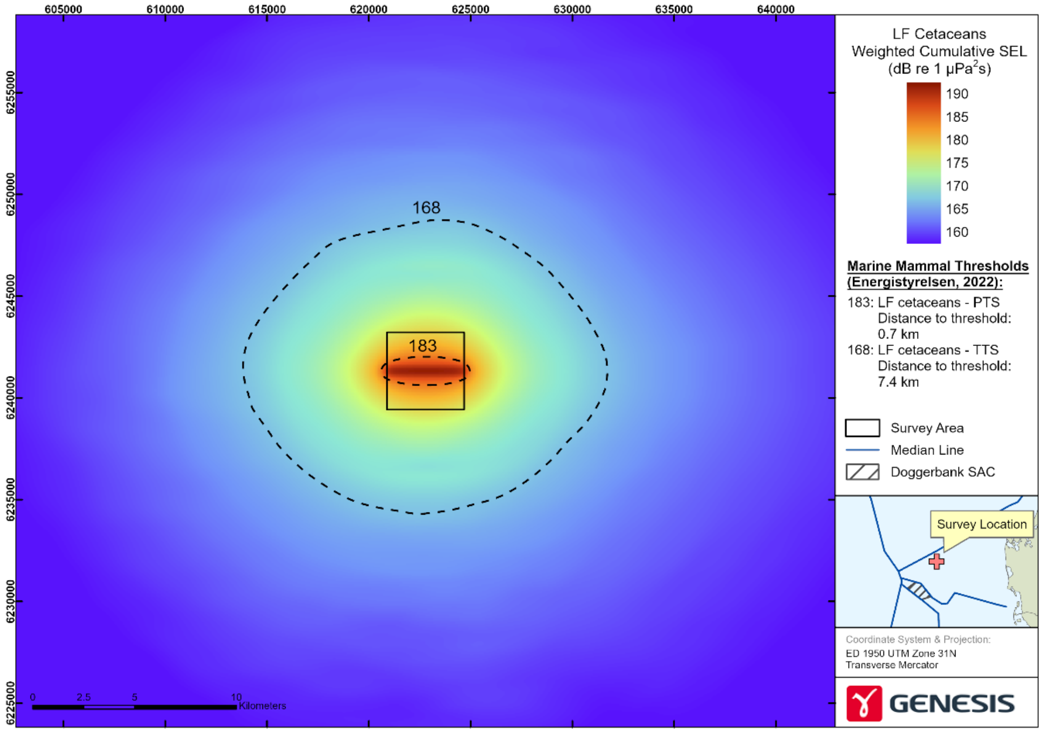

Figure 5-1: Cumulative SEL (weighted for LF cetaceans) received by stationary marine mammals from the airgun array operating over a single seismic line for survey area option 1 during winter.

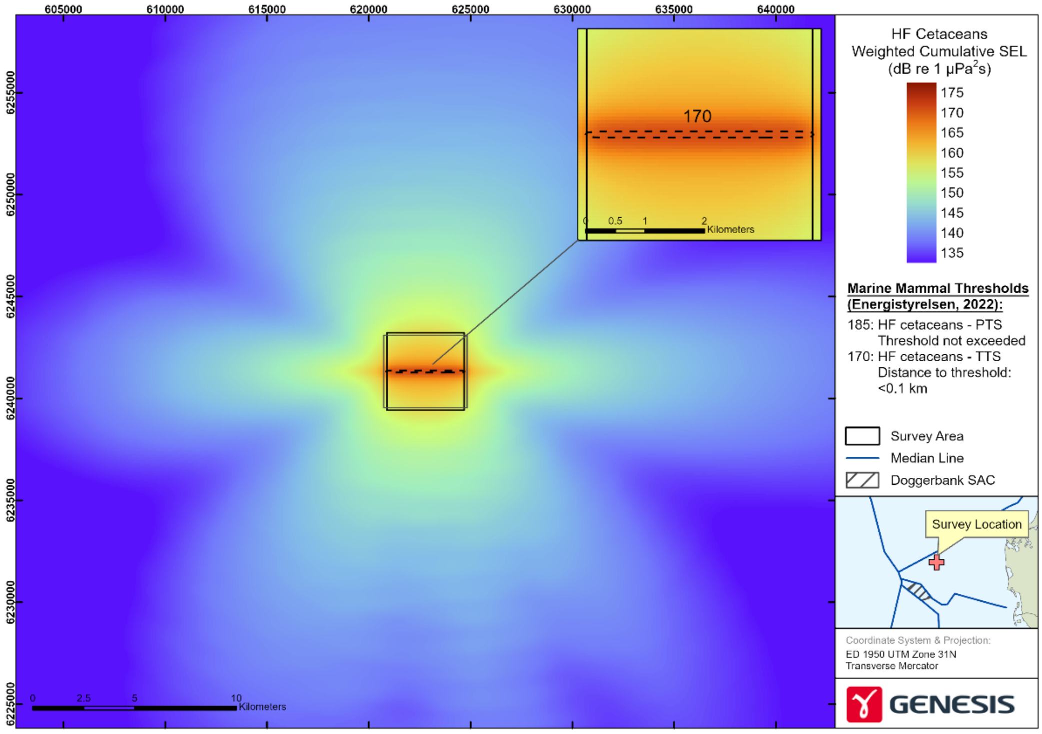

Figure 5-2: Cumulative SEL (weighted for HF cetaceans) received by stationary marine mammals from the airgun array operating over a single seismic line for survey area option 1 during winter.

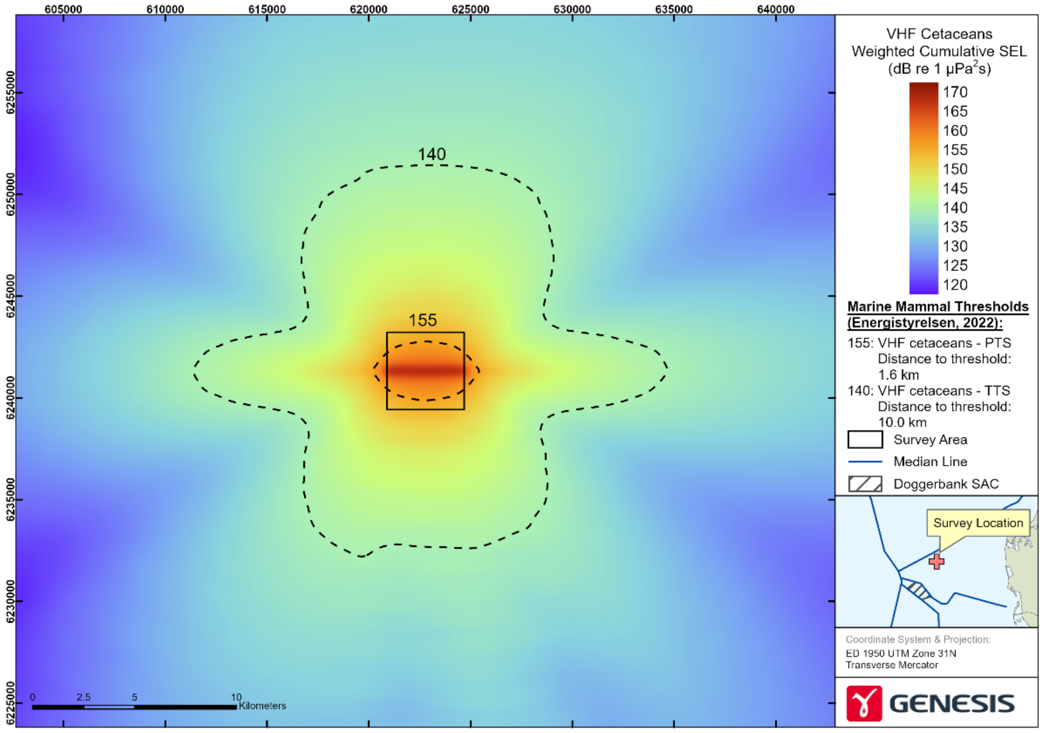

Figure 5-3: Cumulative SEL (weighted for VHF cetaceans) received by stationary marine mammals from the airgun array operating over a single seismic line for survey area option 1 during winter.

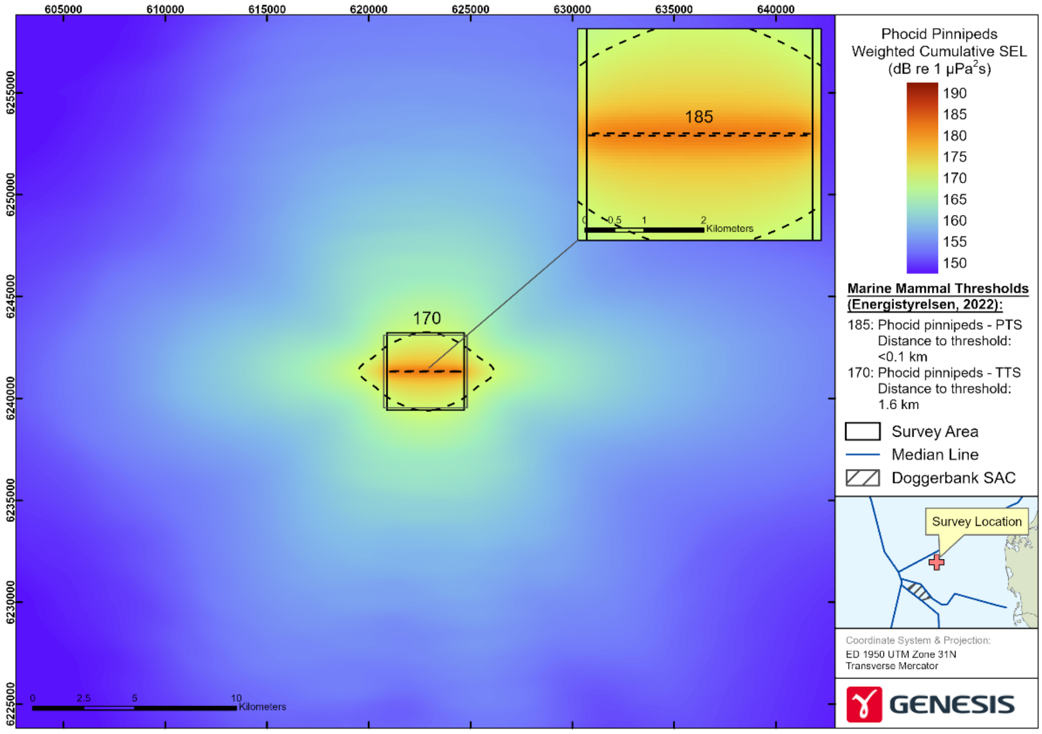

Figure 5-4: Cumulative SEL (weighted for phocid pinnipeds) received by stationary marine mammals from the airgun array operating over a single seismic line for survey area option 1 during winter.

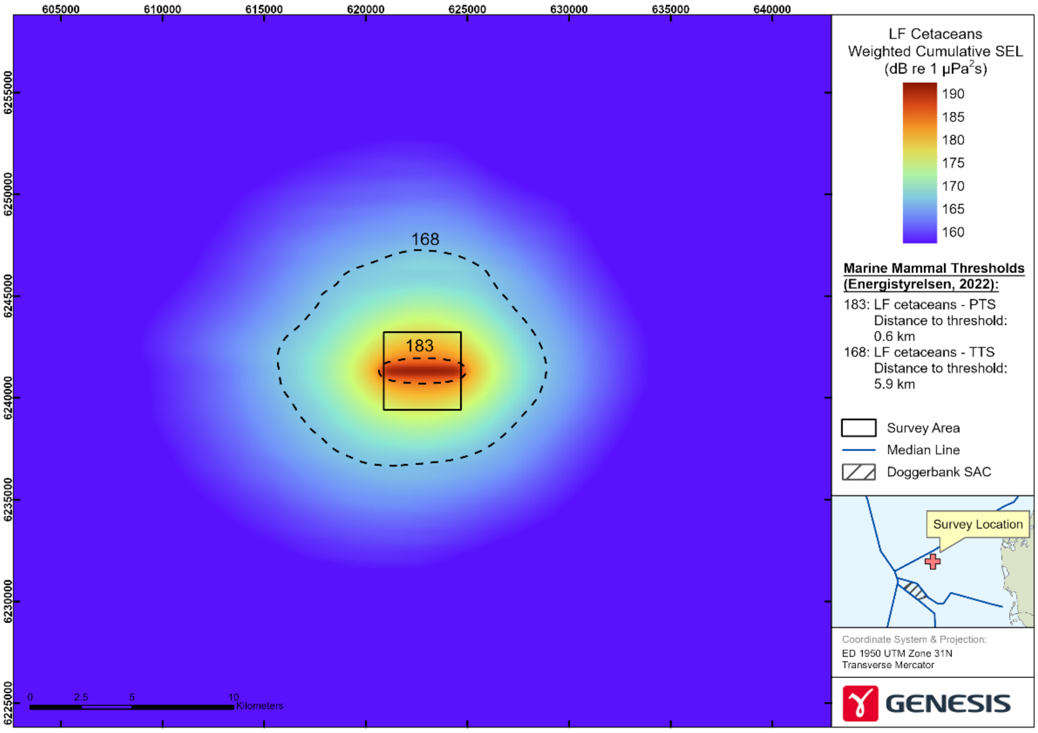

Figure 5-5: Cumulative SEL (weighted for LF cetaceans) received by stationary marine mammals from the airgun array operating over a single seismic line for survey area option 1 during summer.

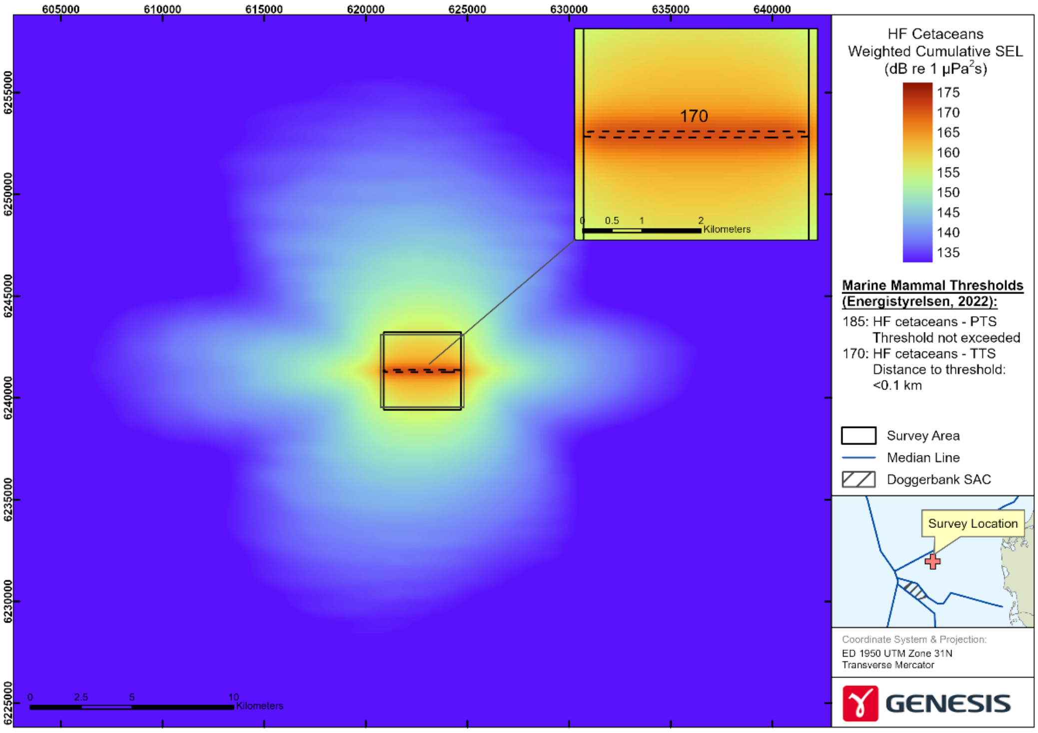

Figure 5-6: Cumulative SEL (weighted for HF cetaceans) received by stationary marine mammals from the airgun array operating over a single seismic line for survey area option 1 during summer.

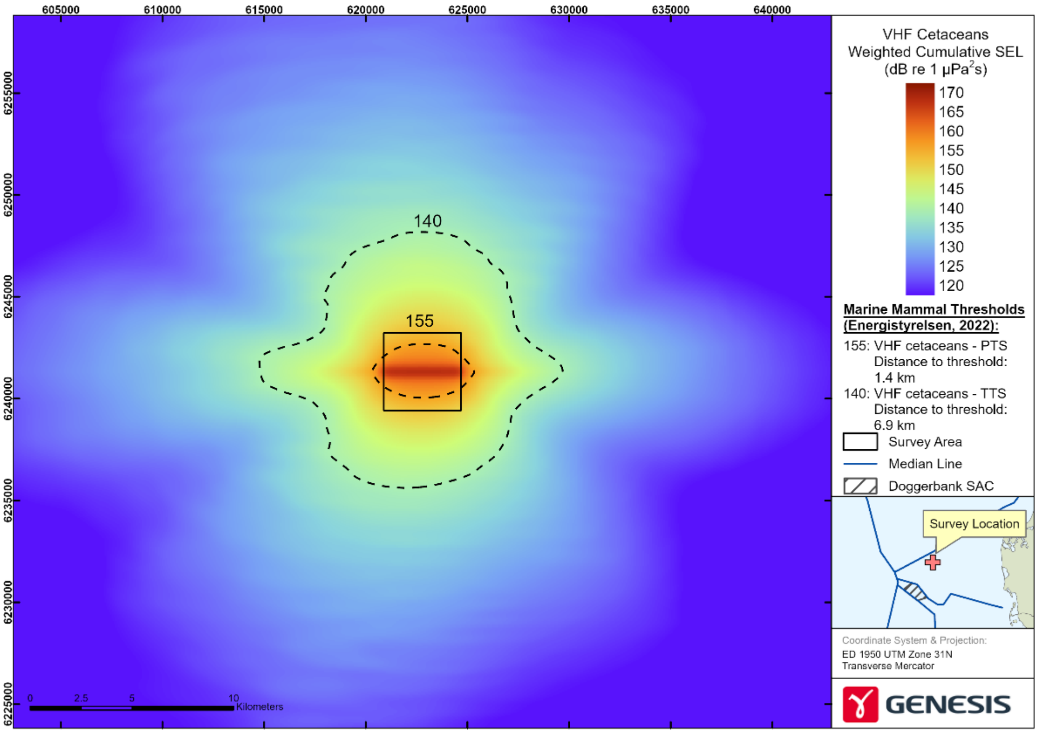

Figure 5-7: Cumulative SEL (weighted for VHF cetaceans) received by stationary marine mammals from the airgun array operating over a single seismic line for survey area option 1 during summer.

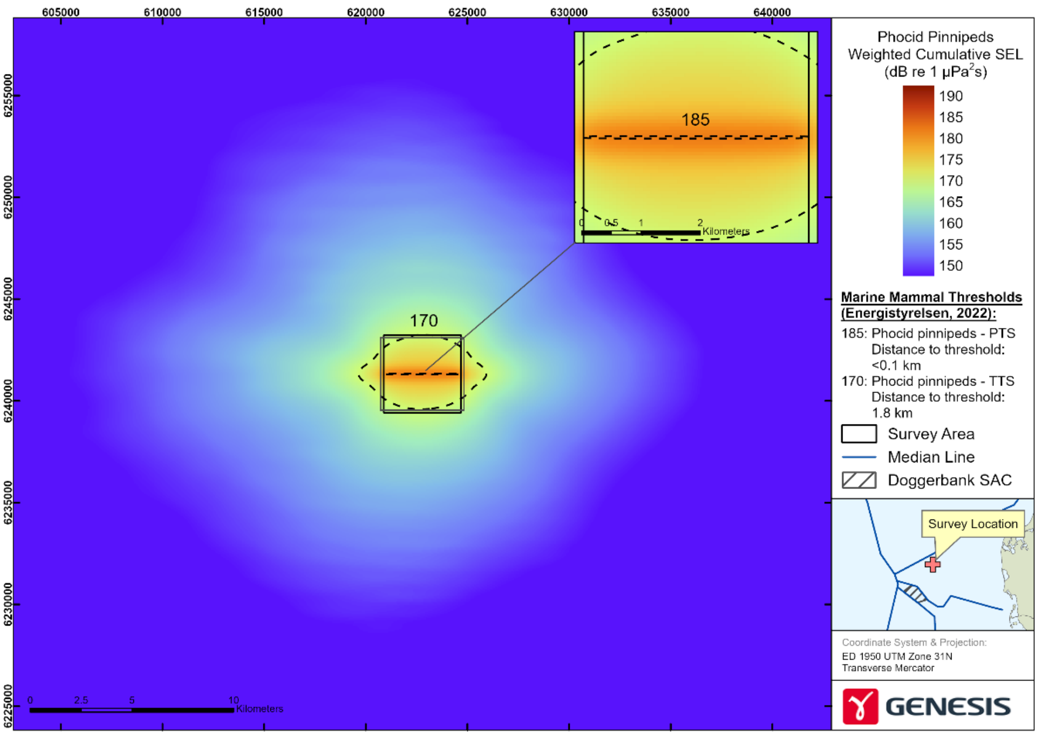

Figure 5-8: Cumulative SEL (weighted for phocid pinnipeds) received by stationary marine mammals from the airgun array operating over a single seismic line for survey area option 1 during summer.

5.1.1.2 Marine Mammals Swimming Away

The cumulative SELs received by marine mammals belonging to the different hearing groups when they swim away from the airgun array have been calculated. Marine mammals have been simulated swimming away from the seismic line (in a direction perpendicular to the seismic line) at different swim speeds and from different initial starting distances from the seismic line. As the marine mammals swim away, their swim depth is allowed to change such that upon receiving sound from each airgun array pulse they are at the depth where sound levels are highest (note that the predicted received sound levels vary with depth). This is a conservative measure and will result in the highest predicted cumulative SEL received by the marine mammals as they swim away.

The predicted initial start distances that marine mammals must be at in order not to be exposed to weighted cumulative SELs sound levels exceeding the PTS and TTS thresholds during winter and summer are summarised in Table 5-1. The distances in Table 5-1 are applicable to both survey location options, as the start distances predicted in the modelling were the same for survey location option 1 and option 2.

The modelling predicts that the marine mammal PTS thresholds will not be exceeded (Table 5-1) provided that the airgun array is activated with a soft start and marine mammals swim directly away from the airgun array. During the survey, marine mammal observers (MMOs) will observe a 500 m exclusion zone before the start of the airgun array. If any marine mammals are observed within 500 m, the airgun activation will be delayed until all mammals have vacated the exclusion zone. The airgun array will also commence with a soft start activation. (A soft start of 40 minutes has been used in the calculation of predicted distances equating to cumulative SEL threshold exceedance.) Given these measures, which are standard best practices employed by TEPDK, it is not expected that any marine mammals will be exposed to sound levels that will cause PTS.

The modelling predicts that the TTS threshold for LF cetaceans (e.g., minke whales) and VHF cetaceans (harbour porpoise) may be exceeded at distances of over several kilometres during winter (Table 5-1). The distances to threshold exceedance are greater during winter than during summer because the water temperature is colder in winter which causes the underwater noise to propagate further distances. However, TTS is a temporary change in hearing and any mammals that could potentially suffer TTS will recover over time.

Table 5-1: Predicted initial starting distances from the airgun array where the adopted weighted cumulative SEL thresholds for PTS and TTS are exceeded for marine mammals swimming away from the airgun array at different swim speeds.

Hearing Group	Relevant Species	Cumulative SEL[1] Threshold (dB re 1 µPa²s)		Winter (March) Distance to Threshold Exceedance [2] (m)		Summer (August) Distance to Threshold Exceedance [2] (m)	
		PTS	TTS	PTS	TTS	PTS	TTS
Swim speed of 1.5 m/s							
LF cetaceans	Minke whale	183	168	Not exceeded	5,800	Not exceeded	2,000
HF cetaceans	White-beaked dolphin, Pilot whale	185	170	Not exceeded	Not exceeded	Not exceeded	Not exceeded
VHF cetaceans	Harbour porpoise	155	140	Not exceeded	6,300	Not exceeded	2,400
Phocid pinnipeds	Harbour seals, Grey seals	185	170	Not exceeded	Not exceeded	Not exceeded	Not exceeded
Swim speed of 2.0 m/s							
LF cetaceans	Minke whale	183	168	Not exceeded	4,400	Not exceeded	1,300
HF cetaceans	White-beaked dolphin, Pilot whale	185	170	Not exceeded	Not exceeded	Not exceeded	Not exceeded
VHF cetaceans	Harbour porpoise	155	140	Not exceeded	5,200	Not exceeded	2,000
Phocid pinnipeds	Harbour seals, Grey seals	185	170	Not exceeded	Not exceeded	Not exceeded	Not exceeded

[1] PTS and TTS thresholds are in terms of auditory weighted cumulative SEL.
[2] Predicted distances have been rounded to the nearest 10 m.

5.1.2 Behavioural Disturbance

To estimate potential behavioural disturbance that the proposed site survey may have on marine mammals, the sound levels generated by the airgun array have been estimated as it traverses every seismic line over the survey area. The behavioural disturbance thresholds adopted in this assessment are based on unweighted single-pulse SEL (Tougaard, 2016) or VHF cetaceans weighted rms SPL calculated over a time window of 125 ms (see Table 4-2).

The maximum predicted unweighted single-pulse SEL from the airgun array operating over the entire survey area for survey option 1 during winter and summer is shown in Figure 5-9 and Figure 5-10.The results shown for survey option 1 are the same as the results obtained for survey option 2 and therefore option 2 results have not been shown. The 145 dB re 1 µPa²s contour highlighted in Figure 5-9 and Figure 5-10 is the threshold proposed by Tougaard (2016) for assessing the potential displacement of marine mammals. This threshold has been derived from observations of displacement of harbour porpoises during seismic surveys (Thompson *et al.* 2013) and is considered the most appropriate threshold for assessing displacement of marine mammals from the airgun array that will be used during the proposed site survey.

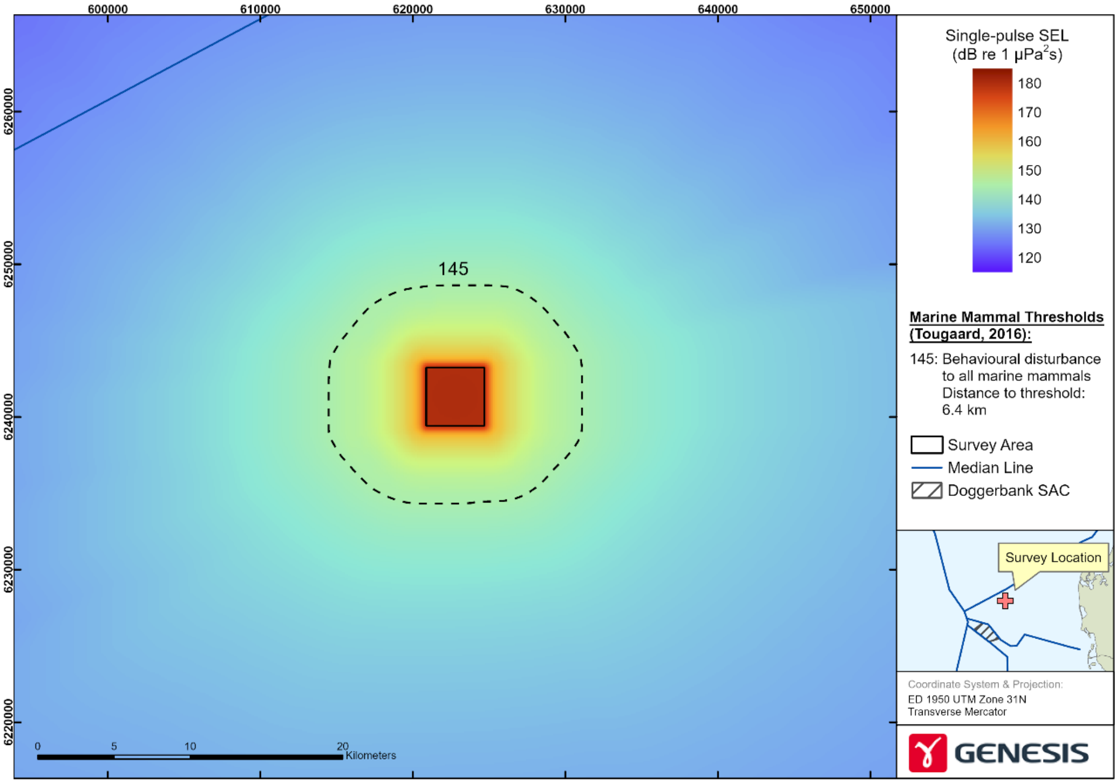

Figure 5-9: Unweighted single-pulse SEL from the airgun array operating over the whole of survey area option 1 during winter in relation to the Tougaard (2016) marine mammal disturbance threshold.

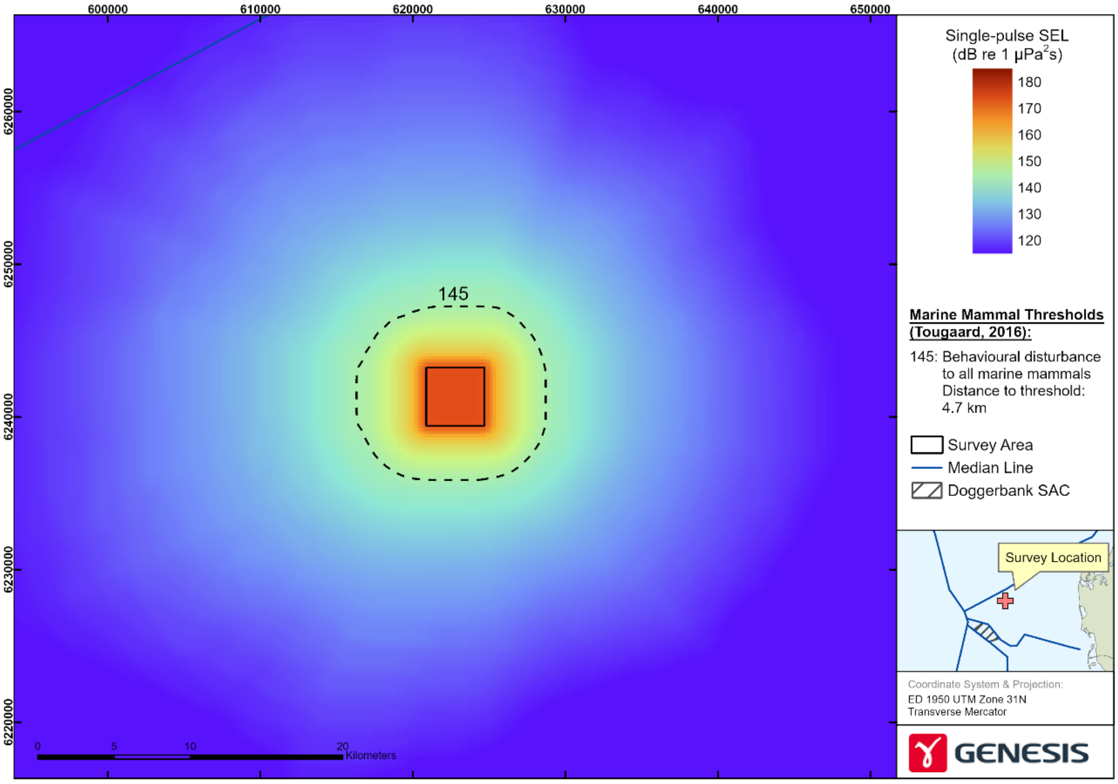

Figure 5-10: Unweighted single-pulse SEL from the airgun array operating over the whole of survey area option 1 during summer in relation to the Tougaard (2016) marine mammal disturbance threshold.

Energistyrelsen (2022a; 2022b) suggest the use of a rms SPL (calculated over a time window of 125 ms) threshold of 103 dB re 1 µPa weighted using the Southall *et al.* (2019) VHF cetaceans auditory weighting function for assessing behavioural disturbance to harbour porpoises from impulsive noise. This threshold has been adopted for informing the assessment of potential disturbance to all marine mammal species from the airgun array used during the proposed site survey. Figure 5-11 and Figure 5-12 show the rms SPL from the airgun array operating over the entire survey area during winter for survey option 1 and survey option 2, respectively, weighted using the Southall *et al.* (2019) VHF cetaceans auditory weighting function. Figure 5-13 and Figure 5-14 show the rms SPL from the airgun array operating over the entire survey area during summer for survey option 1 and survey option 2, respectively. The results for both survey option 1 and survey option 2 are included in this instance so that the difference in the extent of potential transboundary behavioural disturbance can be seen.

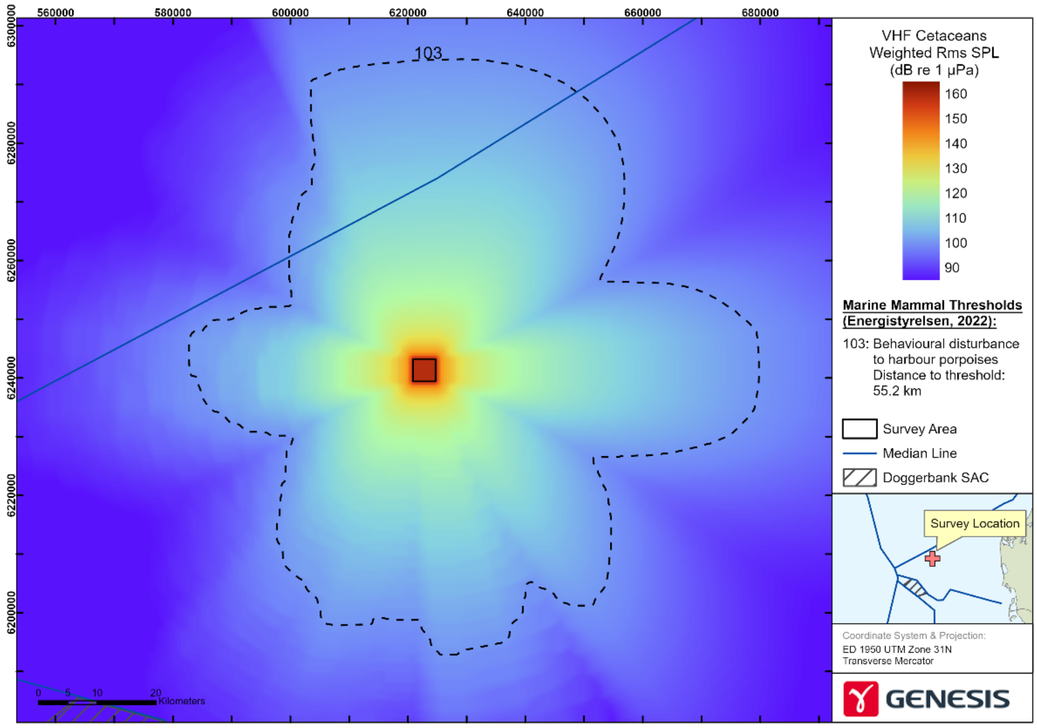

Figure 5-11: VHF cetaceans weighted rms SPL from the airgun array operating over the whole of survey area option 1 during winter in relation to the Energistyrelsen (2022a; 2022b) disturbance threshold.

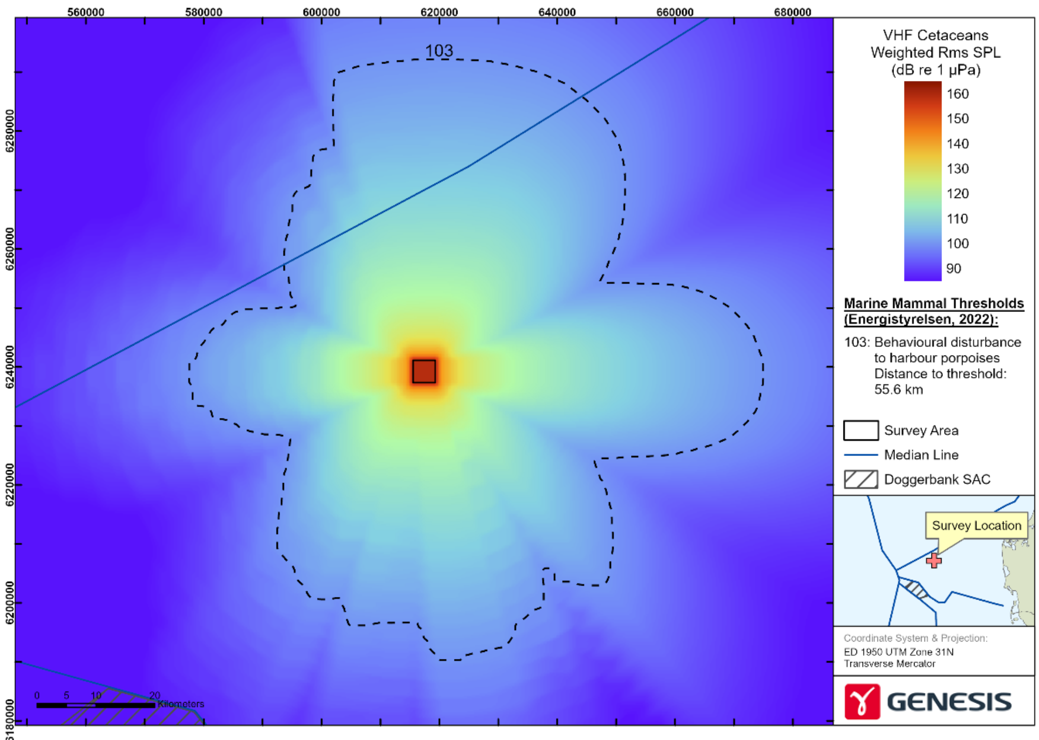

Figure 5-12: VHF cetaceans weighted rms SPL from the airgun array operating over the whole of survey area option 2 during winter in relation to the Energistyrelsen (2022a; 2022b) disturbance threshold.

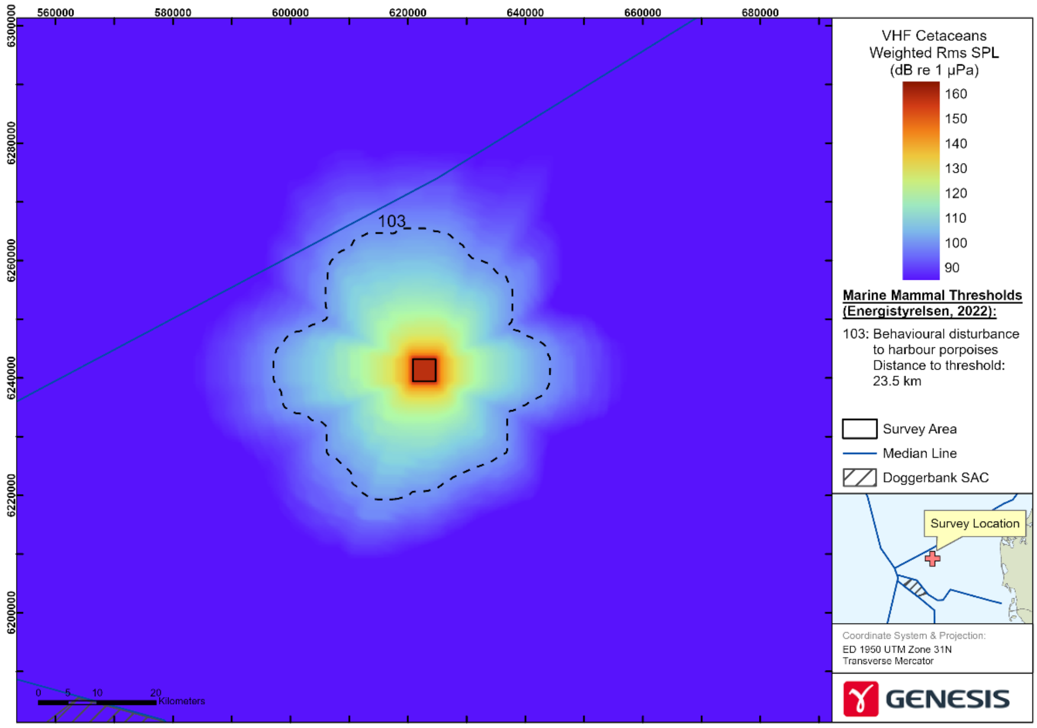

Figure 5-13: VHF cetaceans weighted rms SPL from the airgun array operating over the whole of survey area option 1 during summer in relation to the Energistyrelsen (2022a; 2022b) disturbance threshold.

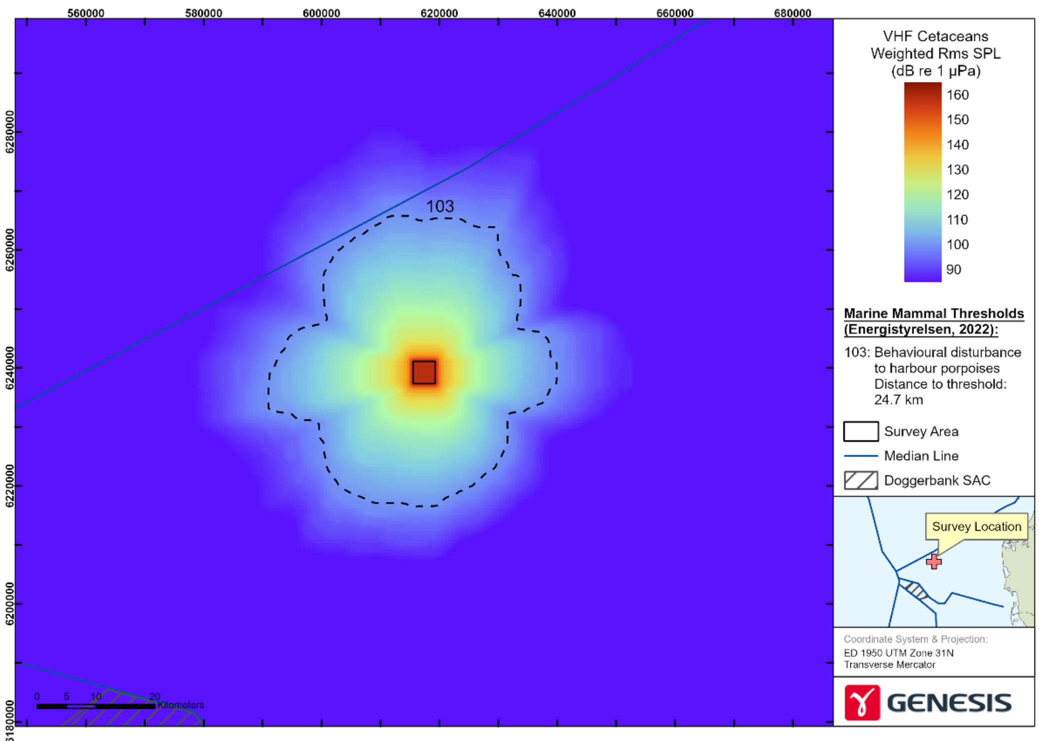

Figure 5-14: VHF cetaceans weighted rms SPL from the airgun array operating over the whole of survey area option 2 during summer in relation to the Energistyrelsen (2022a; 2022b) disturbance threshold.

The predicted distances and areas where the Tougaard (2016) and Energistyrelsen (2022a; 2022b) behavioural disturbance thresholds are exceeded are summarised in Table 5-2. The Tougaard (2016) threshold predicts that disturbance to marine mammals during winter may occur within 7 km from the airgun array. The Energistyrelsen (2022a; 2022b) threshold predicts that disturbance may occur during winter to marine mammals within 56 km from the airgun array. This is substantially higher than what has been observed during seismic surveys in the field.

The Tougaard (2016) threshold predicts that disturbance to marine mammals during summer may occur within 5 km from the airgun array. The Energistyrelsen (2022a; 2022b) threshold predicts that disturbance may occur during winter to marine mammals within 25 km from the airgun array. This is also higher than what has been observed during seismic surveys in the field.

Measurements made during a seismic survey conducted in the Moray Firth with a 470 cu. in array showed that harbour porpoise were displaced at distances of 5 to 10 km (Thompson *et al.,* 2013). Water depths in the region of the Moray Firth survey were typically less than 50 m, and the peak-to peak source levels of the 470 cu. in airgun array were estimated to be 242 - 253 dB re 1 µPa m. The modelling results compared with the Tougaard (2016) threshold (6.5 km and 4.8 km) therefore align with the observations of displacement made by Thompson *et al.* (2013). The predicted distance using the Energistyrelsen (2022a; 2022b) threshold (56 km and 25 km) appears to be overly conservative given the observations of displacement of harbour porpoise during the seismic survey made by Thompson *et al.* (2013). The Energistyrelsen (2022a; 2022b) threshold has been derived based on measurements made during piling activities and it may not be appropriate as a threshold for seismic surveys. The modelling results using the Tougaard (2016) threshold much better aligns with the observations of harbour porpoise displacement in Thompson *et al.* (2013) and therefore seems to be the most appropriate threshold to use.

Table 5-2: Predicted distance and area where the adopted marine mammal behavioural disturbance threshold is exceeded during the survey.

Behavioural Disturbance Threshold	Source	Winter		Summer	
		Distance to Threshold [1] (km)	Area of Threshold Exceedance [2] (km^2)	Distance to Threshold [1] (km)	Area of Threshold Exceedance [2] (km^2)
Dagny CCS Survey Option 1					
145 dB re 1 μPa²s (single-pulse unweighted SEL)	Tougaard (2016) Thompson *et al.,* (2013) Lucke *et al.,* (2009)	6.4	201	4.7	121
103 dB re 1 μPa (rms SPL over a time window of 125 ms weighted for VHF cetaceans)	Energistyrelsen (2022a) Energistyrelsen (2022b)	55.2	5,998	23.5	1,448
Dagny CCS Survey Option 2					
145 dB re 1 μPa²s (single-pulse unweighted SEL)	Tougaard (2016) Thompson *et al.,* (2013) Lucke *et al.,* (2009)	6.5	206	4.8	130
103 dB re 1 μPa (rms SPL over a time window of 125 ms weighted for VHF cetaceans)	Energistyrelsen (2022a) Energistyrelsen (2022b)	55.6	5,912	24.7	1,628

[1] Predicted distance has been rounded to the nearest 0.1 km.

[2] Predicted area has been rounded to the nearest 1 km^2.

Any marine mammals disturbed from the area by the proposed survey will likely return after cessation of activities (Sarnocinska *et al.,* 2020; Thompson *et al.,* 2013). Thompson *et al.* (2013) observed that harbour porpoise displaced by a survey in the Moray Firth returned to the survey area within one day after the survey finished. Similar studies based on impacts arising from pile-driving noise have indicated that marine mammals displaced by noise return to the area within relatively short periods of time, usually within three days once the activity causing the displacement has ceased (Brandt *et al.,* 2016). It is therefore expected that any marine mammals disturbed from the area by the proposed survey will return after the survey has been completed. TEPDK have observed marine mammals return to platforms following previous seismic surveys and piling operations in the area.

5.2 Fish

To quantitatively assess any potential injury to fish from the proposed survey, received sound levels in terms of unweighted zero-to-peak SPL and unweighted cumulative SEL have been predicted and compared to the Popper *et al*. (2014) thresholds for injury for seismic surveys (Table 4-3).

Figure 5-15 shows the maximum predicted zero-to-peak SPL from the airgun array during winter for proposed survey area option 1. The zero-to-peak SPL has only been shown for survey option 1, as the zero-to-peak SPL results for survey option 2 are the same as survey option 1. The zero-to-peak SPL has also only been shown for winter, as the zero-to-peak SPL results for winter are very similar to the results for summer. The contours in this figure highlight the Popper *et al*. (2014) zero-to-peak SPL thresholds for potential injury to fish species. The maximum predicted distances where the zero-to-peak SPL sound levels exceed the Popper *et al*. (2014) thresholds for fish injury are shown in Table 5-3. Figure 5-15 and the distances in Table 5-3 are applicable to both winter and summer, and survey option 1 and survey option 2 as the start distances predicted in the modelling were the same for summer and winter for both survey options. The modelling predicts that zero-to-peak SPL sound levels will be below threshold values associated with injury to the most sensitive fish beyond a maximum distance of 80 m from the airgun array. Predicted distances are lower for less sensitive fish species. It is expected that the soft start of the airgun array will likely disperse any mobile fish away from the sound source to further distances where injury impacts are unlikely to occur. Fish eggs and larvae that are immobile will not be able to move away from the airgun array and will be more susceptible to injury. However, given the estimated small area of potential impact and the large areas of fish spawning in the North Sea (see Figure 2-5), it is not predicted that the proposed survey will have a significant impact on any fish populations.

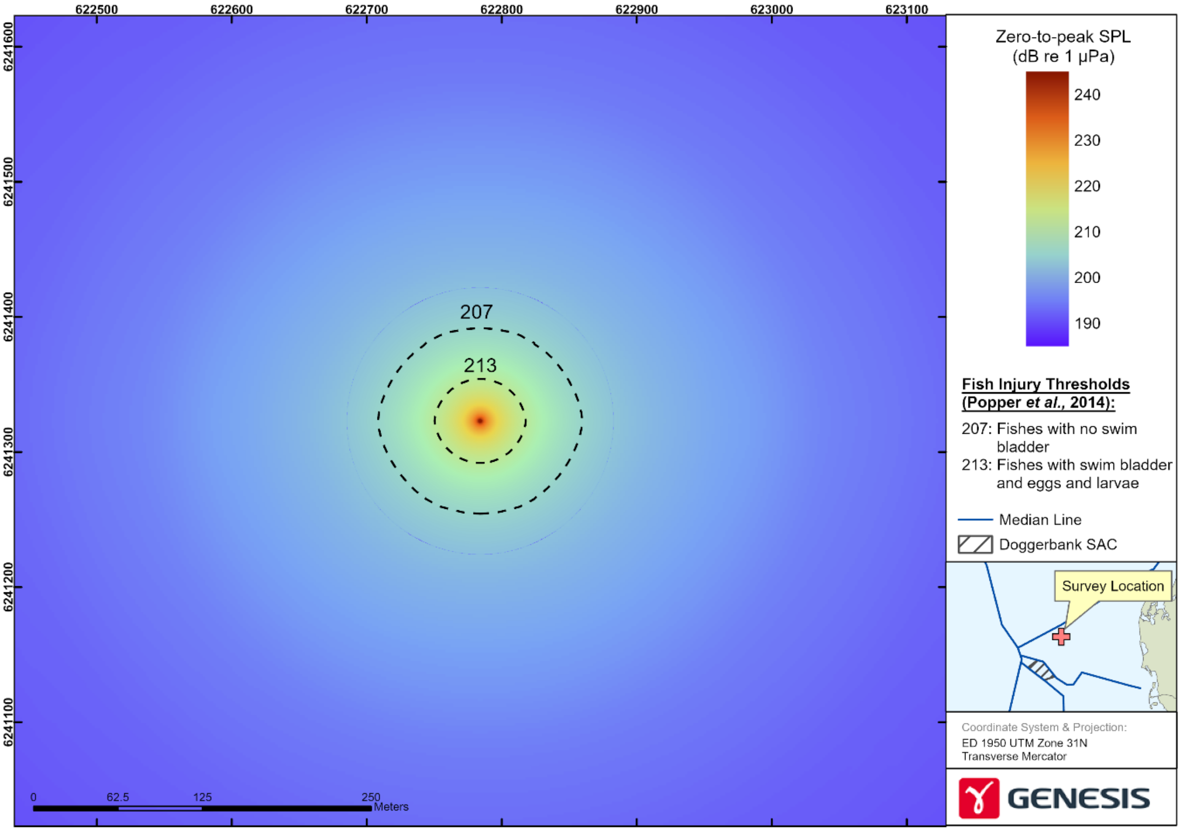

Figure 5-15: Maximum zero-to-peak SPL received by fish species from the airgun array during winter for survey area option 1.

Table 5-3: Predicted distances from the airgun array where the Popper *et al.* (2014) zero-to-peak SPL thresholds for injury to fish are exceeded.

Fish Group	Injury Threshold [1] (dB re 1 µPa)	Maximum Distance to Threshold Exceedance [2] (m)
Fishes with no swim bladder	213	30
Fishes with swim bladder involved in hearing	207	80
Fishes with swim bladder not involved in hearing	207	80
Fish eggs and larvae	207	80

[1] Injury thresholds are in terms of unweighted zero-to-peak SPL.

[2] Predicted distances have been rounded to the nearest 10 m.

5.3 German EEZ and Protected Areas

German authorities have proposed guideline threshold criteria for sound levels in the German EEZ and Doggerbank SAC (Table 4-4). The German authorities suggest that sound levels exceeding an unweighted single-pulse SEL of 140 dB re 1 μPa^{2}s should

- not cover more than 10% of the German EEZ;
- should not cover more than 10% of the Doggerbank SAC during the months of September to April (inclusive); and
- should not cover more than 1% of the Doggerbank SAC during the months of May to August (inclusive).

The predicted maximum distance from the proposed survey location at which the German Doggerbank SAC thresholds are exceeded are summarised in Table 5-4. The modelling predicts that sound levels above 140 dB re 1 μPa^{2}s will not extend into the Doggerbank SAC or the German EEZ.

Table 5-4: Predicted Maximum distance from the proposed survey location to the German Doggerbank SAC

Proposed Survey Area	Distance to German Doggerbank SAC (km)	Winter	Summer
		Maximum Distance to Threshold Exceedance (km)	Maximum Distance to Threshold Exceedance (km)
Survey Area Option 1	71.3	13.7	10.1
Survey Area Option 2	66.8	13.8	8.3

5.4 Plankton

Research on the impacts of underwater noise to plankton is limited. Some research has shown that zooplankton can suffer various anatomical impacts because of noise exposure. Impacts can include internal cellular damage, disorientation, hearing loss and in some cases death (McCauley *et al.,* 2017; Weilgart, 2018). Noise exposure can also cause elevated levels of stress hormones, which can have subsequent impacts on a variety of homeostatic processes (Nedelec *et al.,* 2015). McCauley *et al.* (2017) showed that the use of a single airgun could prove to be fatal to microscopic zooplankton. The impact to zooplankton was shown to extend beyond 1.2 km from the airgun source, with the potential to cause a 64% reduction in abundance within one hour from the airgun pulses (McCauley *et al.,* 2017; Tollefson, 2017). Fields *et al.* (2019) assessed the effect of seismic airguns on *Calanus spp.* The results suggested that noise exposure from airguns has limited effect on the mortality of *Calanus spp.* within 10 m of the airgun source. The proposed survey could therefore impact on plankton within the region of the survey area. However, given the abundance of plankton in the North Sea and the short duration of the survey, it is not expected that the survey will have a significant overall impact.

6.0 BEST-PRACTICE MEASURES

The following best-practice measures recommended by the Danish Environmental Agency Strategic Environmental Assessment (DEA, 2013) and the JNCC (2017) 'Guidelines for minimising the risk of injury to marine mammals from geophysical surveys' are suggested. The following measures are adopted by TEPDK as standard during airgun array surveys:

- The airguns used are the most appropriate and are no more powerful than necessary to conduct the survey;
- The airguns will not be used outside the proposed seismic lines, except in the soft start procedure immediately prior to arrival of the vessel in the survey area and in connection with short transit lines (line turns) and for the strictly necessary testing of equipment. The soft start procedure will be followed during the testing of any equipment;
- Two properly qualified, trained and equipped MMOs will be deployed onboard the survey vessel;
- The MMOs will carry out a 30-minute pre-data acquisition survey of a 500 m exclusion zone and, if a marine mammal is detected, the soft start of the airgun array will be delayed for at least 20 minutes following the last marine mammal sighting;
- A soft start activation of the airgun array will be employed over a period of at least 40 minutes. This will allow any marine mammals to move away from the source and reduce the likelihood of exposure to sounds that could potentially cause injury. A soft start will be employed whenever the airgun array is used;
- The airgun array will be shut down when the transit time between lines exceeds 40 minutes. Before the next line is commenced, the airgun array will be started again following the soft start procedure. If the transit time is less than 40 minutes, the airgun array will remain on but will be operated at reduced power;
- If the airgun array has been inactive for a period of 10 minutes, the MMO will perform a visual inspection of the 500 m exclusion zone. If a mammal is detected, the start of the airgun array will be delayed for at least 20 minutes following the last marine mammal sighting; and
- Passive Acoustic Monitoring (PAM) will be operated during the pre-data acquisition survey, during the soft start procedure and during seismic acquisition in association with the MMOs to detect marine mammal presence.

7.0 CONCLUSIONS

This assessment has considered the potential impacts from proposed survey at Dagny CCS. Underwater noise modelling has been conducted to assess the potential noise levels that may be generated during the proposed activities. The modelling results were used to assess any potential impacts to marine mammals based on a comparison of estimated received sound levels with the cumulative SEL thresholds for PTS and TTS suggested by Southall *et al.* (2019). These thresholds have been implemented as the appropriate thresholds for assessing potential impacts to marine mammals from underwater noise in Danish waters (Energistyrelsen, 2022a). Potential impacts to fish species were also assessed using the Popper *et al.* (2014) injury thresholds.

The loudest sound sources associated with the Dagny CCS survey is the 160 cu. in. airgun array that will be used. The modelling showed that the marine mammal PTS thresholds would not be exceeded during the site survey provided that soft starts of the airgun arrays are employed and marine mammals swim away from the airgun arrays. It is expected that most marine mammals will move away from the area when the site survey commences, and the risk of PTS will be low. During the proposed site survey, a 500 m exclusion zone will be implemented. If any marine mammals are observed by an MMO within this zone, the commencement of the airgun arrays will be delayed until all marine mammals have vacated the exclusion zone and will not recommence for at least 20 minutes following the last marine mammal sighting. Furthermore, soft starts of the airgun arrays will be employed where the power of the airgun arrays are ramped-up over a period of at least 40 minutes. This will allow any marine mammals in the area to move away to safe distances where sound levels will be at lower levels. Given these best practice measures, the risk of PTS to marine mammals is expected to be low. PAM will be operated during the pre-data acquisition survey, during the soft start procedure and during seismic acquisition in association with the MMOs to detect marine mammal presence.

The modelling showed that airgun arrays used during the survey may result in the TTS thresholds for LF cetaceans (e.g., minke whales) and VHF cetaceans (harbour porpoise) being exceeded at larger distances of several kilometres during winter. However, TTS is a temporary change in hearing and any mammals that could potentially suffer TTS will recover over time.

The proposed survey could lead to behavioural disturbance of marine mammals including harbour porpoises, white-beaked dolphins, minke whales, bottlenose dolphins, common dolphins, grey seals and harbour seals. Comparison of modelling results with the disturbance threshold suggested by Tougaard (2016) suggests that disturbance to marine mammals could occur at distances of 6.5 km during winter, and 4.8 km during summer from the airgun array used during the site survey. Comparison of modelling results with the threshold given by Energistyrelsen (2022a; 2022b) suggests that disturbance could occur at distances of 56 km during winter and 25 km during summer. The threshold proposed by Tougaard (2016) has been derived from observations of displacement of harbour porpoises during seismic surveys whilst the threshold suggested by Energistyrelsen (2022a; 2022b) is mainly for use of estimating disturbance from piling activities.

Any marine mammals disturbed during the proposed site survey are expected to return to the area within a short period of time (one to three days) once the survey has been completed (Sarnocinska *et al.,* 2020; Thompson *et al.,* 2013). The site survey will therefore not cause a long-term impact on any marine mammal population.

The modelling predicts that injury to fish species during the site survey will be localised. It was predicted that the most sensitive fish species could potentially suffer injury within a maximum distance of 80 m of the airgun array. It is expected that the soft start of the airgun array will allow mobile fish time to move to distances where injury will not occur. Fish eggs and larvae that are not mobile and cannot move away from the airgun array will be more susceptible to injury. However, given the localised area of potential impact, it is not expected that the site survey will have a significant impact on any fish populations.

German authorities stipulate thresholds on the area of the Doggerbank SAC and German EEZ that may be exposed to sound levels above 140 dB re 1 μPa^2s (BMU, 2014). The modelling predicts that the proposed site survey will not result in sound levels above 140 dB re 1 μPa^2s in the Doggerbank SAC or German EEZ during either the summer or winter.

There are no established thresholds for assessing potential impacts that the proposed site survey could have on plankton species. McCauley *et al.* (2017) showed that impacts from airguns could have an impact to zooplankton beyond 1.2 km from the airgun source, with the potential to cause a 64% reduction in abundance within one hour of the airgun pulses (McCauley *et al.,* 2017; Tollefson, 2017). If the proposed site survey does have an injurious impact on plankton, it will likely be very localised. Given the abundance of plankton in the North Sea, it is not expected that the survey will have a significant impact on plankton.

Overall, it is concluded that the Dagny CCS survey will not have a significant impact on any marine mammal, fish, or plankton populations.

REFERENCES

Balcomb, K. C., and Claridge, D. E. (2001). A mass stranding of cetaceans caused by naval sonar in the Bahamas. Bahamas Journal of Science. 5: 2-12.

Bejder, L., Samuels, A., Whitehead, H., Gales, N., Mann, J., Connor, R. and Krutzen, M. (2006). Decline in relative abundance of bottlenose dolphins exposed to longterm disturbance. Conservation Biology. 20: 1791-1798.

BMU (2014). Concept for the protection of harbour porpoises from sound exposures during the construction of offshore wind farms in the German North Sea (Sound Protection Concept).

Brandt, M., Dragon, A., Diederichs, A., Schubert, A., Kosarev, V., Nehls, G., Wahl, V., Michalik, A., Braasch, A., Hinz, C., Ketzer, C., Todeskino, D., Gauger, M., Laczny, M. and Piper, W. (2016). Effects of offshore pile driving on harbour porpoise abundance in the German Bight: Assessment of noise effects. Report by BioConsult SH, IBL Umweltplanung GmbH, and Institute of Applied Ecology (IfAO). pp. 262.

Brasseur, S., Cremer, J., Czeck, R., Galatius, A., Jeß, A., Körber, P., Pund, R., Siebert, U., Teilmann, J. and Klöpper, S. (2018). TSEG grey seal surveys in the Wadden Sea and Helgoland in 2017-2018. Common Wadden Sea Secretariat, Wilhelmshaven, Germany.

Brasseur, S. M. J. M. and Kirkwood, R. J. (2016). Seal monitoring and evaluation for the Gemini offshore windpark: T-construction - 2015 report. C043/16 pp. 52. IMARES, Den Burg.

Caldwell, J. and Dragoset, W. (2000). A brief overview of seismic air-gun arrays. The leading edge 19(8): 898 – 902.

Colebrook, J. M. (1982). Continuous plankton records: seasonal variations in the distribution and abundance of plankton in the North Atlantic Ocean and the North Sea. Journal of Plankton Research. 4: 435-462.

Coull, K. A., Johnstone, R. and Rogers, S. I. (1998). Fisheries sensitivity maps in British waters. UKOOA Ltd.

Crocker, S.E., and Fratantonio, F. D. (2016). Characteristics of high-frequency sounds emitted during high-resolution marine geophysical surveys. Nav. Undersea Warfare Center, Newport, RI USA, NUWC-NPT Tech. Rep. 12,203, 2016. [Online]. Available: http://www.data.boem.gov/PI/PDFImages/ESPIS/5/5551.pdf

Crocker, S., Fratantonio, F., Hart, P. Foster, D., Brien, T., and Labak, S. (2018). Measurement of sounds emitted by certain high-resolution geophysical survey systems. IEEE Journal of Oceanic Engineering. PP. 1-18. 10.1109/JOE.2018.2829958.

D'Amico, A., Gisiner, R. C., Ketten, D. R., Hammock, J. A., Johnson, C., Tyack, P. L., and Mead, J. (2009). Beaked whale strandings and naval exercises. Aquatic Mammals. 35(4): 452-472.

DEA (Danish Energy Agency). (2013). Strategic Environmental Assessment in connection with licensing rounds west of 6° 15' e in the Danish part of the North Sea for exploration and production of hydrocarbons, and licensing of permits for injection of CO_2 in existing oil fields for the purpose of EOR. Summary Report. Danish Environment Agency. August 2013.

Delefosse, M., Rahbek, L., Roesen, L., and Tubbert Clausen, K. (2017). Marine mammal sightings around oil and gas installations in the central North Sea. Journal of the Marine Biological Association. 98: 993–1001. Doi: 10.1017/S0025315417000406.

Duren, R.E. (1988). A theory for marine source arrays. Geophysics 53(5): 650-658.

Ellis, J. R., Milligan, S. P., Readdy, L., Taylor, N. and Brown, M. J. (2012). Spawning and nursery grounds of selected fish species in UK waters. Science Series Technical Report, Cefas Lowestoft, 147: 56 pp.

EMODnet Bathymetry Consortium (2020). EMODnet Digital Bathymetry (DTM 2020). https://doi.org/10.12770/bb6a87dd-e579-4036-abe1-e649cea9881a

Energistyrelsen (2022a). Guidelines for underwater noise, Prognosis for EIA and SEA assessments.

Energistyrelsen (2022b). Guideline for underwater noise, Installation of impact or vibratory driven piles.

European Commission (1992). Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.

Fields, D. M., Handegard, N. O., Dalen, J., Eichner, C., Malde, K., Karlsen, Ø., Skiftesvik, A. B., Durif, C. M. F., Browman, H. I. (2019). Airgun blasts used in marine seismic surveys have limited effects on mortality, and no sublethal effects on behaviour or gene expression, in the copepod Calanus finmarchicus, ICES Journal of Marine Science, Volume 76, Issue 7, pp 2033–2044. https://doi.org/10.1093/icesjms/fsz126

Finneran, J. J. (2015). Noise-induced hearing loss in marine mammals: A review of temporary threshold shift studies from 1996 to 2015. The Journal of the Acoustical Society of America. 138: 1702-1726.

Finneran, J. J. and Schlundt, C. E. (2013). Effects of fatiguing tone frequency on temporary threshold shift in bottlenose dolphins (*Tursiops truncatus*). Journal of the Acoustical Society of America. 133: 1819-1826.

Galatius, A. and Kinze, C. C. (2016). *Lagenorhynchus albirostris* (Cetacea: Delphinidae). Mammalian Species. 48: 35-47.

Gilles, A, Authier, M, Ramirez-Martinez, NC, Araújo, H, Blanchard, A, Carlström, J, Eira, C, Dorémus, G, Fernández Maldonado, C, Geelhoed, SCV, Kyhn, L, Laran, S, Nachtsheim, D, Panigada, S, Pigeault, R, Sequeira, M, Sveegaard, S, Taylor, NL, Owen, K, Saavedra, C, Vázquez-Bonales, JA, Unger, B, Hammond, PS (2023). Estimates of cetacean abundance in European Atlantic waters in summer 2022 from the SCANS-IV aerial and shipboard surveys. Final report published 29 September 2023. 64 pp. https://www.tiho-hannover.de/fileadmin/57_79_terr_aqua_Wildtierforschung/79_Buesum/downloads/Berichte/20230928_SCANS-IV_Report_FINAL.pdf

Guan, S., Brookens, T., Vignola, J. Use of underwater acoustics in marine conservation and policy: Previous advances, current status, and future needs. (2021). J. Mar. Sci. Eng. 2021, 9, 173. https://doi.org/10.3390/jmse9020173

Hansen J.W. & Høgslund S. (2021). Marine områder 2020. NOVANA. Aarhus Universitet, DCE – Nationalt Center for Miljø og Energi, 192 s. - Videnskabelig rapport fra DCE nr. 475. http://dce2.au.dk/pub/SR475.pdf. Gengivelse tilladt med tydelig kildeangivelse

Hassel, A., Knutsen, T., Dalen, J., Skaar, K., Løkkeborg, S., Misund, O., Østensen, Ø., Fonn, M. and Haugland, E.K. (2004). Influence of seismic shooting on the lesser sandeel (*Ammodytes marinus*). Journal of Marine Science. 61: 1165-1173.

Herr, H., Scheidat, M., Lehnert, K. and Siebert, U. (2009). Seals at sea: modelling seal distribution in the German bight based on aerial survey data. Marine Biology. 156: 811-820.

Isojunno, S., Curé, C., Kvadsheim, P.H., Lam, F-PA., Tyack, P.L., Wensveen, P.J., Miller, P.J.O. (2016). Sperm whales reduce foraging effort during exposure to 1–2 kHz sonar and killer whale sounds. Ecolological Applications. 26: 77–93.

Jensen, F. B., Kuperman, W. A., Porter, M. B. and Schmidt, H. (2011). Computational ocean acoustics. Second edition. Springer. Modern Acoustics and Signal Processing. pp. 794.

JNCC (2017). Guidelines for minimising the risk of injury to marine mammals from geophysical surveys.

Johns, D. G. and Reid, P. C. (2001). An overview of plankton ecology in the North Sea. Technical Report TR_005. Technical report produced for Strategic Environmental Assessment – SEA2. Produced by SAHFOS, August 2001.

Kastelein, R. A., Gransier, R. and Hoek, L. (2013). Comparative temporary threshold shifts in harbour porpoise and harbour seal, and a severe shift in a seal (L). Journal of the Acoustic Society of America. 134: 13-16.

Lockyer, C. (1995). Aspects of the biology of the harbour porpoise, *Phocoena phocoena*, from British waters. In: Blix, A.S., Walløe, L. and Ulltang, Ø (eds). Whales, seals, fish and man. Elsevier, London, pp. 443-457.

Lucke, K., Siebert, U., Lepper, P. A. and Blanchet, M. A. (2009). Temporary shift in masked hearing thresholds in a harbour porpoise (*Phocoena phocoena*) after exposure to seismic airgun stimuli. Journal of the Acoustical Society of America. 125 (6): 4060-4070.

McCauley, R., Day, R.D., Swadling, K.M., Fitzgibbon, Q.P., Watson, R.A., and Semmens, J.M. (2017). Widely used marine seismic survey air gun operations negatively impact zooplankton. Nature Ecology & Evolution. 1: 1-8.

Nedelec, S.L., Simpson, S.D., Morley, E.L., Nedelec, B., and Radford, A.N. (2015). Impacts of regular and random noise on the behaviour, growth and development of larval Atlantic cod (*Gadus morhua*). Proceedings of the Royal Society B 282 (1817): 20151943.

NMFS (National Marine Fisheries Service). (2018). Revision to: Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing: underwater acoustic thresholds for onset of permanent and temporary threshold shifts (Version 2.0). U.S. Dept. of Commer. NOAA. NOAA Technical Memorandum NMFS-OPR-55, pp. 178.

Oakwood Computing (2023). Gundalf: Marine Seismic Airgun Modelling Software Package. https://www.gundalf.com/theproduct/.

OSPAR (2009). Overview of the impacts of anthropogenic underwater sound in the marine environment. OSPAR Commission. Biodiversity Series.

Pace, F., Robinson, C., Lumsden, C.E., and Martin, S.B. (2021). Underwater sound sources characterisation study: Energy Island, Denmark. Document 02539, Version 2.1. Technical report by JASCO Applied Sciences for Fugro Netherlands Marine B.V.

Pirotta, E., Brookes, K.L., Graham, I.M., and Thompson, P.M. (2014). Variation in harbour porpoise activity in response to seismic survey noise. Biology Letters. 10: 20131090.

Popper, A. N., Hawkins, A. D., Fay, R. R., Mann, D., Bartol, S., Carlson, T., Coombs, S., Ellison, W. T., Gentry, R., Halvorsen, M. B., Lokkeborg, S., Rogers, P., Southall, B. L., Zeddies, D. G., Tavolga, W. N. (2014). Sound Exposure Guidelines for Fishes and Sea

Turtles: A Technical Report by ANSI-Accredited Standards Committee S3/SCI and registered with ANSI. Springer Briefs in Oceanography.

Porter, M. B. and Liu, Y-C. (1994). Finite-element ray tracing. In Theoretical and computational acoustics, Vol. 2, World Scientific Publishing Co.

Reid, J., Evans, P. and Northridge, S. (2003). Atlas of Cetacean distribution in north-west European waters., Available from: http://jncc.defra.gov.uk/page-2713.

Richardson, W. J., Greene, C. R. Jr., Malme, C. and Thomson, D. H. (1995). Marine mammals and noise. Academic Press, California. pp. 576.

Robertson, F., Koski, W., Thomas, T., Richardson, W., Würsig, B., and Trites A. (2013) Seismic operations have variable effects on dive-cycle behavior of bowhead whales in the Beaufort Sea. Endangered Species Research. 21: 143–160.

Robinson, G. (1970). Continuous plankton records: Variations in the seasonal cycle of phytoplankton in the North Atlantic. Bulletin of Marine Ecology. 6: 33-345.

Ruppel, C.D., Weber, T.C., Staaterman, E.R., Labak, S.J. and Hart, P.E. (2022). Categorizing Active marine acoustic sources based on their potential to affect marine animals. J. Mar. Sci. Eng. 2022, 10, 1278. https://doi.org/10.3390/jmse10091278

Sarnocinska, J., Teilmann, J., Balle, J. D., van Beest, F. M., Delefosse, M., and Tougaard, J. (2020). Harbor porpoise (*Phocoena phocoena*) reaction to a 3D seismic airgun survey in the North Sea. Frontiers in Marine Science. 6: 824.doi: 10.3389/fmars.2019.00824.

Sørensen, T.B. and Kinze, C.C. (1994). Reproduction and reproductive seasonality in Danish harbour porpoises, *Phocoena phocoena*. Ophelia. 39: 159-176.

Southall, B. L., Bowles, A. E., Ellison, W. T., Finneran, J. J., Gentry, R. L., Greene, C. R. Jr., Kastak, D., Ketten, D. R., Miller, J. H., Nachtigall, P. E., Richardson, W. J., Thomas, J. A. and Tyack, P. L. (2007). Marine mammals noise exposure criteria: initial scientific recommendations. Marine Mammals. 33(4).

Southall, B. L., Bowles, Finneran, J. J., Reichmuth, C., Nactigall, P.E., Ketten, D.R., Bowles, A.E., Ellison, W.T., Nowacek, D.P. and Tyack, P.L. (2019). Marine mammal noise exposure criteria : Updated scientific recommendations for residual hearing effects. Aquatic Mammals. 45(2): 125-232.

Southall, B. L., Nowacek, D.P., Bowles, A.E., Senigaglia, V., Bejder, L. and Tyack, P.L. (2021). Marine mammal noise exposure criteria : Marine mammal noise exposure criteria: Assessing the severity of marine mammal behavioral responses to human noise. Aquatic Mammals. 47(5): 421-464.

Stimpert, A.K., DeRuiter, S.L., Southall, B.L., Moretti, D.J., Falcone, E.A., Goldbogen, J.A., Friedlaender, A., Schorr, G.S., Calambokidis, J. (2014) Acoustic and foraging behavior of a Baird's beaked whale, *Berardius bairdii*, exposed to simulated sonar. Scientific Reports. 4: 7031.

Thompson, P.M., Brookes, K.L., Graham, I.M., Barton, T.R., Needham, K., Bradbury, G. and Merchant, N.D. (2013). Short term disturbance by a commercial two-dimensional seismic survey does not lead to long-term displacement. Proceedings of the Royal Society B, Biological Sciences. http://rspb.royalsocietypublishing.org/content/280/1771/20132001.

Tollefson, J. (2017). Airgun blasts kill plankton. Nature. 546: 586-587.

Tougaard, J. (2016). Input to revision of guidelines regarding underwater noise from oil and gas activities – effects on marine mammals and mitigation measures. Aarhus University, DCE – Danish Centre for Environmental and Energy, 52 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 202. http://dce2.au.dk/pub/SR202.pdf.

Tougaard, J. (2021). Thresholds for noise induced hearing loss in marine mammals. Background note to revision of guidelines from the Danish Energy Agency. Aarhus University, DCE - Danish Centre for Environment and Energy, 34 s. – Scientific note no. 2021|28 https://dce.au.dk/fileadmin/dce.au.dk/Udgivelser/Notater_2021/N2021|28.pdf.

Tougaard, J., Teilmann, J. and Tougaard, S. (2008). Harbour seal spatial distribution estimated from Argos satellite telemetry – overcoming positioning errors. Endangered Species Research. 4: 113-122.

Tougaard, J., Sveegaard, S. & Galatius, A. (2021). Marine mammal species of relevance for assessment of impulsive noise sources in Danish waters. Background note to revision of guidelines from the Danish Energy Agency. Aarhus University, DCE – Danish Centre for Environment and Energy, 13 s. – Scientific note no. 2020|19

van Beest, F.M., Teilmann, J., Hermannsen, L., Galatius, A., Mikkelsen, L., Sveegaard, S., Balle, J.D., Dietz, R. and Nabe-Nielsen, J. (2018). Fine-scale movement responses of free-ranging harbour porpoises to capture, tagging and short-term noise pulses from a single airgun. Royal Society Open Science. 5: 170110. http://dx.doi.org/10.1098/rsos.170110.

Vasquez, M, Allen, H, Manca, E, Castle, L, Lillis, H, Agnesi, S, Al Hamdani, Z, Annunziatellis, A, Askew, N, Bekkby, T, Bentes, L, Doncheva, V, Drakopoulou, V, Duncan, G, Gonçalves, J, Inghilesi, R, Laamanen, L, Loukaidi, V, Martin, S, McGrath, F, Mo, G, Monteiro, P, Muresan, M, Nikilova, N, O'Keeffe, E, Pesch, R, Pinder, J, Populus, J, Ridgeway, A, Sakellariou, D, Teaca, A, Tempera, F, Todorova, V, Tunesi, L, and Virtanen , E. (2021). EUSeaMap 2021. A European broad-scale seabed habitat map. D1.13 EASME/EMFF/2018/1.3.1.8/Lot2/SI2.810241 – EMODnet Thematic Lot n° 2 – Seabed Habitats EUSeaMap 2021 - Technical Report. https://doi.org/10.13155/83528.

Waggitt, J.J., Evans, P.G.H., Andrade, J., Banks, A.N., Boisseau, O., Bolton, M., Bradbury, G., Brereton, T., Camphuysen, C.J., Durinck, J., Felce, T., Fijn, R.C., Garcia-Baron, I., Garthe, S., Geelhoed, S.C.V., Gilles, A., Goodall, M., Haelters, J., Hamilton, S., Hartny-Mills, L., Hodgins, N., James, K., Jessopp, M., A.S. Kavanagh, Leopold, M., Lohrengel, K., Louzao, M., Markones, N., Martínez-Cedeira, J., Cadhla, O.O., Perry, S.L., Pierce, G.J., Ridoux, V., Robinson, K.P., Begoña Santos, M., Saavedra, C., Skov, H., Stienen, E.W.M., Sveegaard, S., Thompson, P., Vanermen, N., Wall, D., Webb, A., Wilson, J., Wanless, S., and GeertHiddink, J. (2019). Distribution maps of cetacean and seabird populations in the North-East Atlantic. Journal of Applied Ecology. 57: 253-269.

Wardle, C. S., Carter, T. J., Urquhart, G. G., Johnstone, A. D. F., Ziolkowski, A. M., Hampson, G. and Mackie, D. (2001). Effects of seismic air guns on marine fish. Continental Shelf Research. 21: 1005-1027.

Weilgart, L. (2018). The impact of ocean noise pollution on fish and invertebrates. Report for OceanCare, Switzerland. PhD Thesis. Oceancare and Dalhousie University.

Wisniewska, D.M., Johnson, M., Teilmann, J., Siebert, U., Galatius, A., Dietz, R., Madsen, P.T. (2018). High rates of vessel noise disrupt foraging in wild harbour porpoises (*Phocoena phocoena*). Proceedings of the Royal Society B 285: 20172314.

WOA (World Ocean Atlas) (2013). World Ocean Database and World Ocean Atlas Series. https://www.nodc.noaa.gov/OC5/indprod.html.

APPENDIX 2

CHANGES TO DAGNY SEISMIC SURVEY LOCATION (2024)

CHANGES TO DAGNY SEISMIC SURVEY LOCATION

Since the underwater noise modelling was completed for Dagny, the proposed location for the Dagny seismic survey has been changed. The survey will now be centered around the P11 well. This well is located between the two locations for which modelling has been undertaken and is sited within the greater working area of one of these. The new survey site has the same dimension (3.8 x 3.8 km) as the survey area for which modelling has been completed for. The survey area of the new survey location relative to the modelled survey locations is shown in Figure 1.

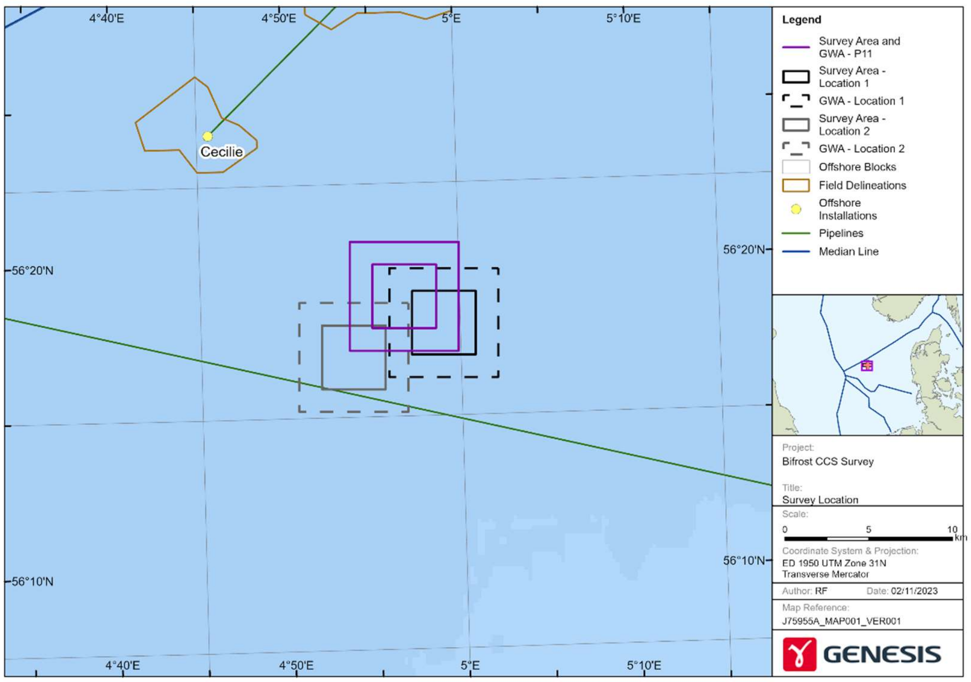

Figure 1: Dagny P11 Survey Location

The equipment used at the new location would be the same as that used for the modelled locations. The bathymetry, seabed sediment type and sound speed profile at the new location are the same or very similar to those modelled. The bathymetry and sediments in the region of the survey area are shown in Figure 2 and Figure 3.

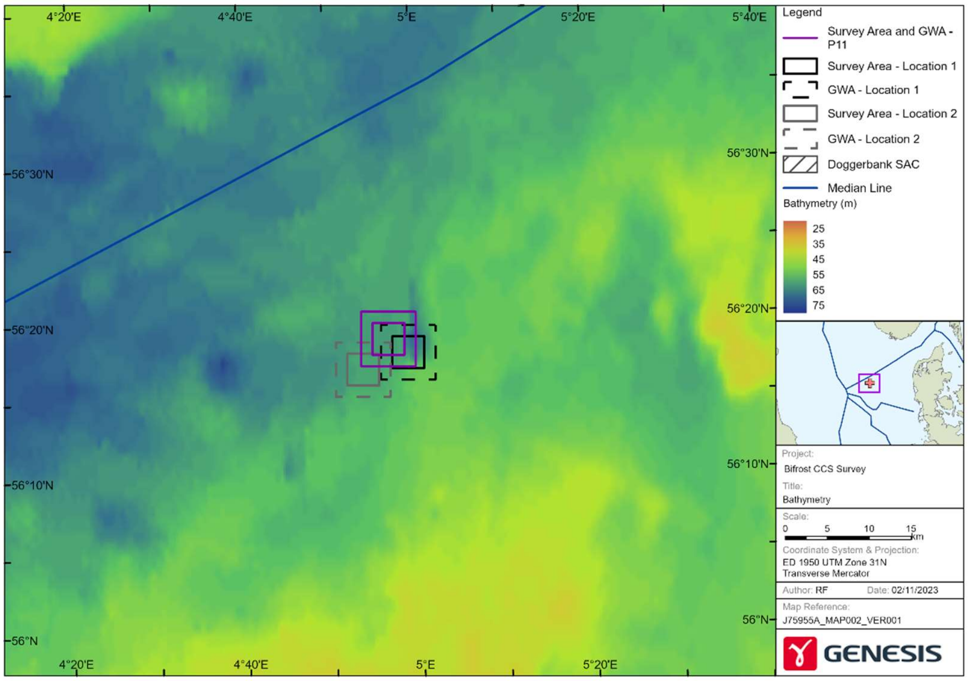

Figure 2: Bathymetry in the region of the survey area.

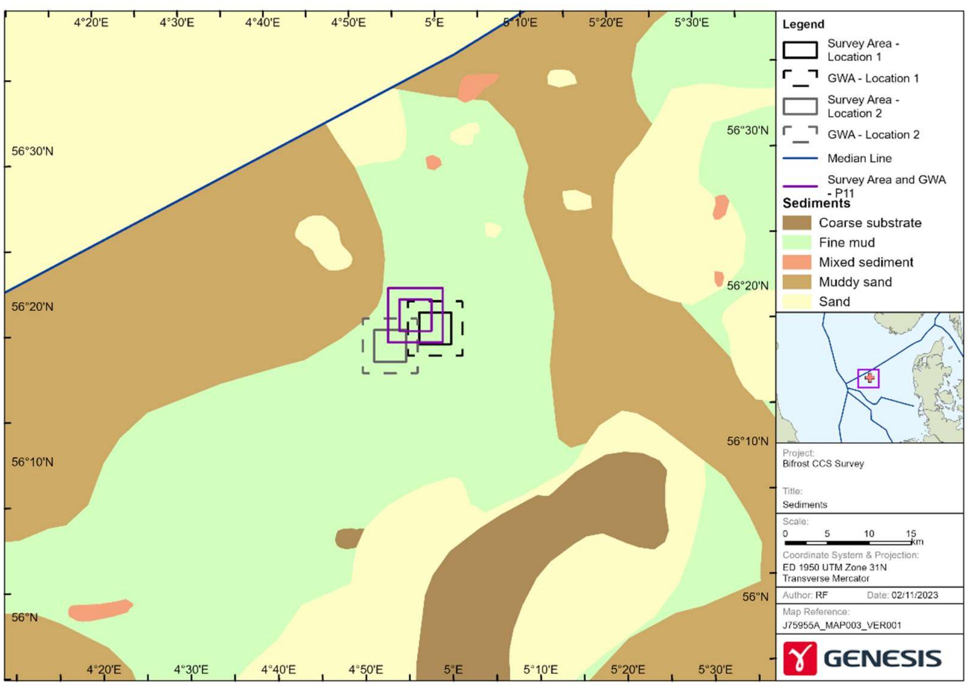

Figure 3: Sediments in the region of the survey area.

Therefore, additional underwater noise modelling at the new P11 location has not been sought, as the noise modelling results would be very similar at the P11 centered location. The recent Dagny noise modelling is therefore considered to provide representative results for the new survey location.