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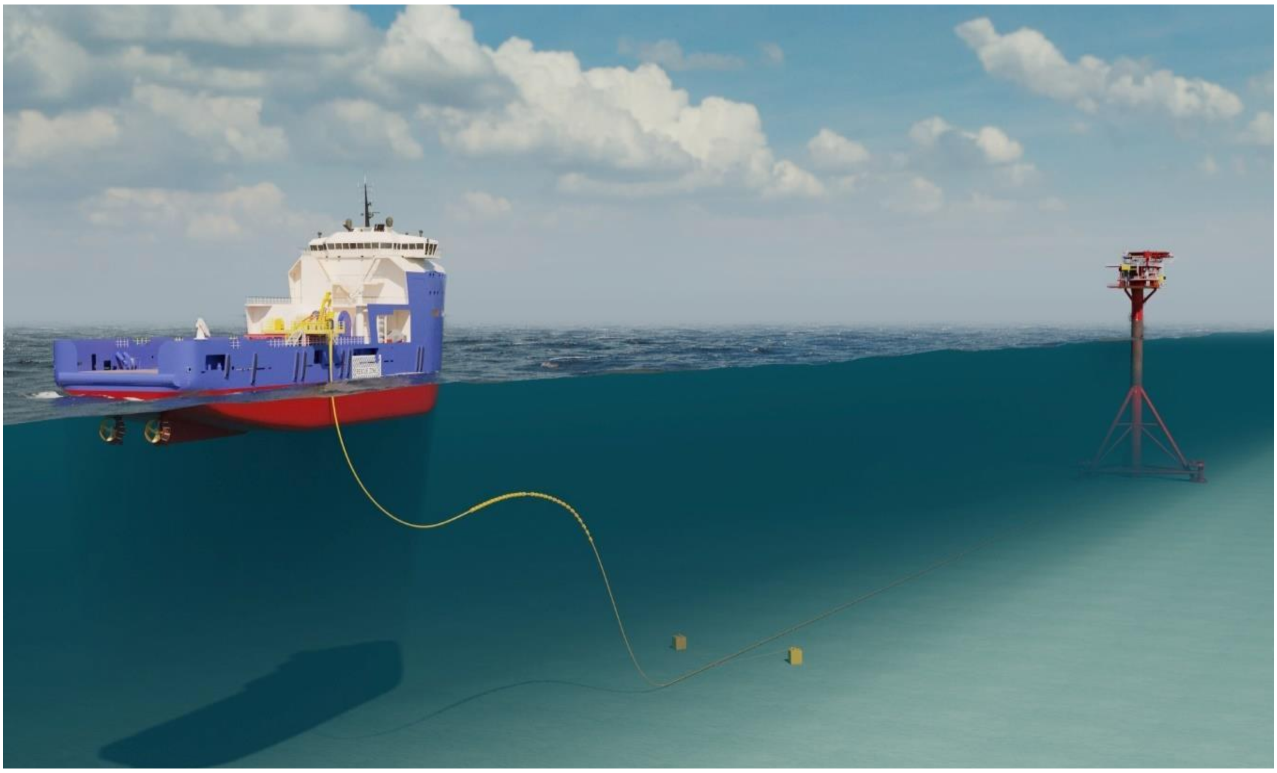
PROJECT GREENSAND FUTURE

ENVIRONMENTAL IMPACT ASSESSMENT REPORT



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PROJECT GREENSAND FUTURE
ENVIRONMENTAL IMPACT ASSESSMENT REPORT

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CONTENT

LIST OF ABBREVIATIONS

The following abbreviations are used in the report:

AIS	Automatic Identification System
AUV	Autonomous underwater vehicle
BAT	Best Available Technique
BEP	Best Environmental Practice
BOP	Blowout Preventer
CCS	Carbon Capture and Storage
CO_2e	CO_2 equivalents
COP	Cease of production
COLREG	International Regulations for Preventing Collisions at Sea
CHO	Cultural Heritage Object
DEA	Danish Energy Agency
DEPA	Danish Environmental Protection Agency
DIC	Dissolved Inorganic Carbon
ECAS	Emission Control Areas
EEA	European Environment Agency
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EOR	Enhanced Oil Recovery
EQS	Environmental Quality Standards
ERL	Effect Range Low
EUDP	Energy Technology Development and Demonstration Program
FID	Final Investment Decisions
FMSY	Fished Above the Maximum Sustainable Yield
GES	Good Environmental Status
HELCOM	Helsinki Commission
IBA	Important Bird Area
ICES	International Council for The Exploration of The Sea
IMO	International Maritime Organization
LSMGO	Low Sulphur Marine Gas Oil
LULUCF	Land Use, Land-Use Change and Forestry
MARPOL	International Convention for The Prevention of Pollution from Ships
MMV	Monitoring, Measurement and Verification plan
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive
MSP	Maritime Spatial Planning

MT	Million Ton
mtpa	Million-Ton per Annum
nmVOC	Non-methane Volatile Organic Compound
NOVANA	National Monitoring and Assessment Program for The Aquatic and Terrestrial Environment
NUI	Normally Unmanned Installation
OWF	Offshore Wind Farm
PAHs	Polycyclic Aromatic Hydrocarbons
PAM	Passive Acoustic Monitoring
PCBs	Polychlorinated Biphenyls
PCW	Phocid Carnivores in Water (seals)
PDO	Plan for Development and Operation
PLONOR	Pose Little or No Risk
PSV	Platform Supply Vessel
PTS	Permanent Threshold Shift
PW	Phocid Water
RBMP	River Basin Management Plan
SEL	Sound Exposure Level
SCI	Site Of Community Importance
SPA	Special Protected Area
SSB	Spawning Stock Biomass
SVO	Særlig Værdifulde Og Sårbare Områder
TEL	Target Effect Level
TTS	Temporary Threshold Shift
VHF	Very High Frequency
VMS	Vessel Monitoring Systems
WFD	Water Framework Directive
WW	Wet Weight
w/w %	Weight/weight %

1. INTRODUCTION

This document is an Environmental Impact Assessment (EIA) for a permanent carbon storage project within a segment of the Iris license in the Danish sector of the North Sea. The project is called *Project Greensand Future*.

The objective of *Project Greensand Future* is to use existing oil and gas infrastructure at the Nini A offshore platform for safe permanent storage of carbon dioxide (CO_2 hereafter). *Project Greensand Future*'s operational scope encompasses both the maritime transport of CO_2 from Esbjerg to Nini A, and the storage of CO_2 in the Nini West (Frigg) reservoir.

The partners of the Iris license (C2023/01) are:

- INEOS E&P A/S (Operator) 40%
- Wintershall Dea International GmbH (Non-Operator) 40%
- Nordsøfonden (Non-Operator) 20%

The carbon storage project was initiated in 2018, with the first assessments of the storage potential in depleted offshore oil and gas fields. In 2019 a consortium was formed, which in Q2 2020 filed a grant application to the Energy Technology Development and Demonstration Programme (EUDP), for co-funding of what was referred to as Project Greensand Phase 1. This grant application was approved, and the work initiated in Q2 2020 was finalized in Q3 2021.

In Q3 2021, a new consortium to initiate Phase 2 of Project Greensand was established and filed a grant application to the EUDP for co-funding which was approved in December 2021. The Greensand project Phase 2 included a CO_2 injection pilot into the Nini West reservoir utilizing the water disposal well NA-5 at Nini A. The pilot injection project concluded operations safely in Q1 2023 after a total of 4,000 tons CO_2 injected and having successfully demonstrated full value chain carbon capture and storage (CCS) operations.

The present EIA covers *Project Greensand Future* which is Phase 3 with planned first injection in 2025. The project plan to provide a total storage capacity of 2.4 million tons CO_2 with injection of 0.3 million tons per annum (mtpa) in 8 years. As part of the permitting process, INEOS E&P A/S must submit an EIA to the Danish Energy Agency (DEA) in which potential impacts to the environment are assessed in accordance with the Environmental Assessment Act (Consolidation Act no. 4 of 03/01/2023 §15 and annex 1 no. 23). Furthermore, Danish legislation in connection with administration of international nature conservation areas and protection of certain species (Offshore Habitats Order, No. 846 of 26/06/2024), demands that a Natura 2000 screening and assessment of potential impacts on species included in Annex IV (strictly protected species) of the European Union Habitats Directive must be conducted to determine if significant impacts can be ruled out or if a step two assessment (a so-called appropriate assessment) of Natura 2000 sites and Annex IV species is required.

Rambøll was commissioned by INEOS E&P A/S to write this EIA with the purpose to provide the required EIA documentation, screening of impacts on Natura 2000 and an assessment of Annex IV species in compliance with current legislation. The following reading guide presents the content of this EIA.

As described above, the present EIA covers the environmental impacts associated with the establishment of a storage facility for CO_2 in the Nini West reservoir. The establishment of the storage facility is based on a host-solution using one of the existing wells in Nini West. In this regard, it is noted that there is no longer production of hydrocarbons from the Nini West reservoir and that the injection of CO_2 into Nini West will not mean an increased production of oil and gas from either Nini West or the other reservoirs produced through the Nini installation.

Taking into account the existing EIA for the Nini license and given that the establishment of a storage facility for CO_2 would have only a limited impact going beyond what is covered by this existing EIA, the impact that has not already been addressed in the existing EIA of the Nini license is addressed in the EIA for the Iris license (Nini West). However, a brief description and impact assessment of historical activities in the project area are included.

2. READING GUIDE

This chapter briefly describes the reading guide of the environmental impact assessment report. The report contains a general *introduction* (chapter 1) to the project and a *reading guide* (chapter 2). The following list of chapters in the report are outlined with reference to the Danish Environmental Assessment Law (Miljøvurderingsloven Consolidation Act no 4 of 03/01/2023). The report then contains the following chapters:

- *Non-technical summary* (chapter 3, §20, stk. 2, nr. 5 and annex 7 no. 9) is a summary of the environmental impact assessment report, where the most important information and assessments are highlighted to provide a quick overview of the project and its environmental impacts.

- *The oil & gas production phase* (chapter 4) provides a description of the projects history, including location and facilities, historical activities and major production events, a brief description of discharges, emissions and impacts as well as a short assessment, based on the available knowledge of historical activities and impacts.

- *Project description* (chapter 5, §20, stk. 2, nr. 1 and annex 7 no.1) provides a detailed description of the project, including where and how it will be carried out. This includes a description of existing and new facilities, the construction and operation phases, decommissioning and resource consumption.

- *Alternatives* (chapter 6, §20, stk. 2, nr. 4 and annex 7 no.2) describes the situation where the CO_2 storage in not carried out at the planned project site (the zero-alternative) and the related consequences.

- *Legislative context* (chapter 7) describes the international laws, international conventions and national legislation that the planned CO_2 storage project must comply with and are relevant for the environmental assessment.

- *Environmental impact assessment method* (chapter 8, §20, stk. 3 and annex 7 no. 6) describes the method used to carry out a systematic assessment of the environmental impacts caused by the project.

- *Scope of impact assessment* (chapter 9, §20, stk. 4 and §23 and annex 7 no. 4) describes the environmental receptors and impacts and social receptors and that can be expected to be significantly affected for both planned activities and accidental events.

- *Existing environmental and social status* (chapter 10, §20, stk. 2, nr. 6 and annex 7 no. 3) provides a description of the relevant aspects of the current environmental and social status (the reference or baseline scenario). These includes a description of climate and air quality, hydrographic conditions, water quality, sediment conditions, biodiversity, protected nature, material assets, cultural heritage and fisheries.

- *Assessment of environmental and social impacts of planned activities* (chapter 11-12, §20, stk. 2, nr. 2 and nr. 3 (also covered by chapter 20) and §20, stk. 4) and annex 7 no. 5 and 7 provides the environmental impact assessment and the social impact assessment of planned activities. This includes a description and an evaluation of the expected significant effects on the receptors defined in chapter 8 and 0.

- *Assessment of accidental events* (chapter 13, §20, stk. 5 and annex 7 no.8) describes the project's expected harmful effects on the environment as a result of accidental events.

- *Assessment of accordance with EU Directives* (chapter 14-16) describes the project's potential impacts to the EU Water Framework Directive, the EU Marine Strategy Framework and the EU Maritime Spatial Planning Directives.

- *Natura 2000 Assessment* (chapter 17) provides a screening of whether the project may result in significant impacts on nearby Natura 2000-sites.

- *Decommissioning* (chapter 18) provide an overview of the decommissioning process and its impacts.

Finally, the report contains chapters for monitoring (chapter 19), mitigation measures (chapter 20 and annex 7 no. 7), cumulative effects (chapter 21 and annex 7 no. 5e), gaps and limitations (chapter 22 and annex 7 no.6), transboundary impacts (chapter 23) and a summary of the environmental impact assessment (chapter 24). At the end of the environmental impact assessment report, there is a comprehensive list of all references applied to write the report (according to Miljøvurderingsloven (2023) §20 and annex 7 no. 10) as well as an Appendix covering a supporting technical note to the EIA.

3. NON-TECHNICAL SUMMARY

3.1 The project

The goal of *Project Greensand Future* is to use the depleted reservoir in the Nini West field for storage of captured carbon dioxide (CO_2). *Project Greensand Future* plans to provide a total storage capacity of 2.4 million tons CO_2 with injection of 0.3 million tons per year (mtpa) in 8 years. The project covers transportation from Esbjerg (quay side) to the Nini A platform and injection of CO_2 into an existing well in the Nini West reservoir.

The Nini field is located in the Danish North Sea, about 170 km (direct route) off the Danish west coast and consists of three segments: Nini West, Nini Main and Nini East, as shown in Figure 3-1. Only Nini West is considered for CO_2 storage in this project.

Detailed design, procurement and fabrication is planned in 2024. The execution phase is scheduled to commence in 2025 including offshore installation, commissioning and initiating the CO_2 injection.

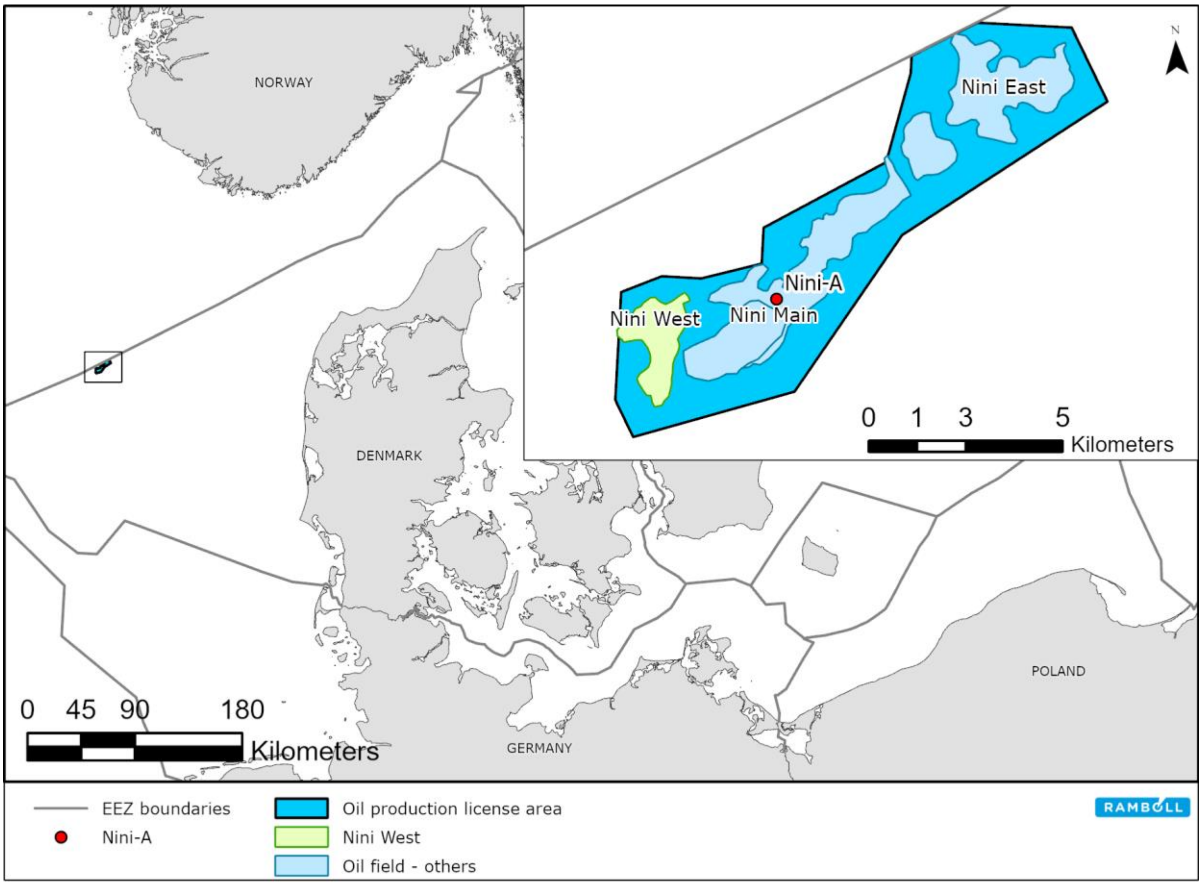


Figure 3-1: Location of the Nini A platform and the three Nini segments: Nini West, Nini Main and Nini East.

The Nini site is part of a larger area with oil reservoirs called the Siri Canyon. The Siri Canyon is a large underwater depression in the North Sea that was formed millions of years ago due to movements in the earth's crust. The rock overburden and mudstone seals above the Nini West reservoir have been well documented to effectively hold back CO_2, and they have been found to be stable and chemically inert. Therefore, it is a highly effective barrier for containing CO_2 and has a large safety margin for storing it and preventing leakage through the seabed.

3.1.1 *Construction phase*

To adapt the existing equipment to its new function, some minor adaption to current above-water components is required. The existing platform-riser will be reused, replacing a flowline to the injection well. The offloading system is illustrated in Figure 3-2. Further details regarding installation method can be found in section 5.4. A new offloading system is required for transferring the CO_2 from the vessel to the Nini A platform consisting of:

- A 6” fixed pipeline connected to Nini A.
- Concrete mattresses covering subsea pipeline.
- Flexible riser with buoyancy element, and hose end valve.
- 2 Anchor blocks – supporting the stability of the pipeline end.
- Inspections of the new facilities will continue throughout the operation phase.

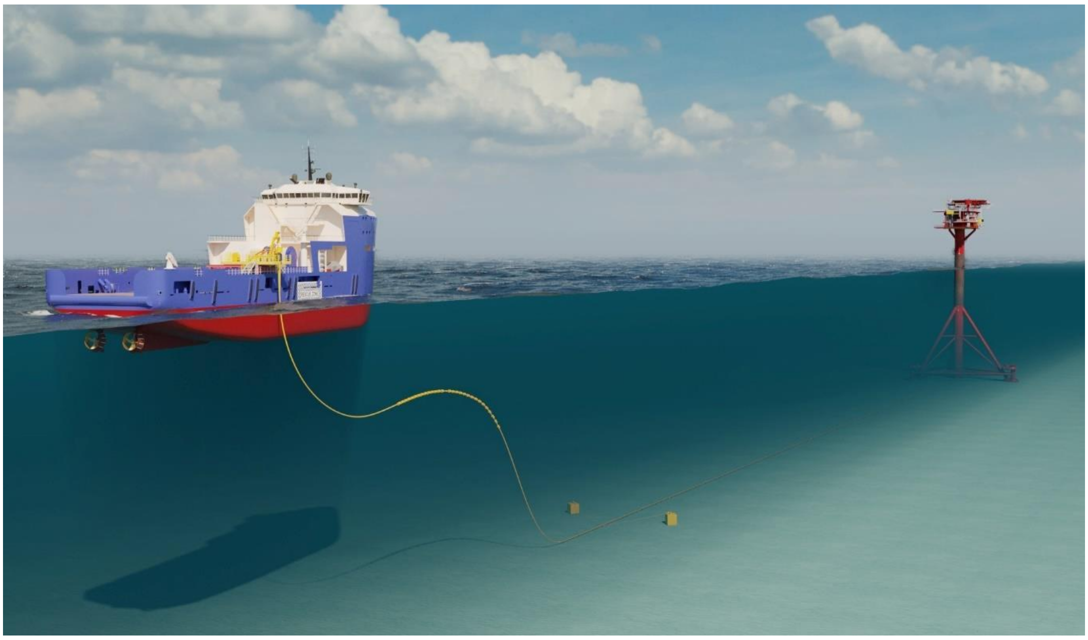


Figure 3-2: Illustration of the offloading system at Nini A.

Seismic survey and deployment of OBSs and Lander is also part of the construction phase. Thus, further offshore activities in Q3/Q4 2025:

- Installation of flowline on Nini A Platform
- Installation of CO_2 offloading system
- Wireline work on CO_2 injection well on Nini A Platform
- Seismic survey Q4 2025
- Deploy ocean bottom stations (OBS) for continuous seismicity data acquisition Q4 2025
- Deploy CO_2 leakage monitoring system (lander) for continuous monitoring Q4 2025

3.1.2 *Operation phase*

The overall expected lifetime of the injection period is 8 years, followed by 20 additional years of monitoring of the site. Onshore capture of CO_2 and transport to port is not part of this EIA. The platforms are equipped with a helipad for transportation via helicopter, which will be the main form of commuting for staff. The main activities are described as following:

Transportation of CO_2 from Esbjerg harbour to the offloading system at Nini A platform
CO_2 will be loaded onto a modified platform support vessel (CO_2 vessel) in Esbjerg harbour, and hereafter transported to the Nini A platform. The CO_2 is loaded in tanks on the deck of the CO_2 vessel and is kept at a liquefied state by maintaining high pressure and sub-zero temperatures. The sailing distance from Esbjerg to Nini A platform is approximately 127 nm (235 km) and a maximum of 130 injection cycles is expected per year.

Injection of CO_2 into the reservoir
The CO_2 vessel will be modified for this specific purpose and have equipment for pumping CO_2 on and off the vessel. The injection will be done from the vessel through a flexible hose that is connected to a pipeline which leads to the Nini A well.

Monitoring of the CO_2 injection into the reservoir
A seismic reservoir monitoring program with 2D seismic is designed to monitor the presence and movement of CO_2 in the reservoir.

Key features for the seismic monitoring activities:

- Baseline: A 2D baseline seismic survey is planned prior to first injection: Vessel transit to and from the survey area, deploy and retrieve airgun and streamers or ocean bottom nodes (OBNs) (Figure 5-19 as further described below), shoot seismic on defined lines across the area.
- First seismic monitor: The first 2D seismic monitoring campaign is planned 2 years after first injection: Vessel transit to and from the survey area, deploy and retrieve airgun and streamers or OBNs, shoot seismic on defined lines across the area.
- The second 2D seismic monitoring campaign will be reassessed and updated based on results and learnings from the initial two surveys. The current plan is to repeat the baseline and first monitor with seismic in year 4, 6, 8 and 10 to ensure verification that the model describes the CO_2 plume movement and lateral distribution accurately.

Monitoring of potential leaks
A CO_2 leakage monitoring system will be installed on the seabed to detect accidental leakage from the reservoir and from the legacy well (Nini 4). The system will be installed on a metal frame (lander) and deployed during the construction phase. The system consists of a sonar system for CO_2 gas bubble detection, chemical sensors (pH, total alkalinity, nitrate and O_2) to detect changes in water chemistry due to CO_2 leakage. Further the system includes a current meter to support the analysis of the other data collected.

Seismicity monitoring
Seismicity data is collected to monitor natural and CO_2 injection-induced subsurface movements, necessitating continuous monitoring according to the established plan, which involves the use of OBSs (deployed in the construction phase). The offshore seismicity monitoring technology is evolving, and the existing plans and equipment may undergo changes based on ongoing development.

3.1.3 Decommissioning

The decommissioning scope of this EIA covers the entire Nini A installation, including pipelines to Siri, CO_2 offloading system and plug and abandonment of the Nini A wells. Decommissioning will be performed as a reversed installation for components to be removed and includes activities very similar to the construction phase. A future decommissioning EIA will be assessing the activities in further detail and will be submitted as part of the authority approval of the decommissioning plans.

3.1.4 Material and resource use

The project will require some material and resource consumption as part of the construction and operation phase. For the construction phase both fuel and material consumption are assessed, however for the operation phase only fuel consumption is assessed, as the only material usage would be for minor maintenance or replacement of components. This is assessed to have an insignificant contribution to the overall assessment of impacts on environmental and social receptors and therefore not part of the scope.

<u>Materials and chemicals</u>

One of the primary materials used is the fixed pipeline as part of the offloading system to Nini A. The pipeline leading to the platform is expected to be at a length of 100-300 m, with a connected flexible hose of an additional 120 m. Regarding protection of the pipeline, a conservative estimate is to install concrete mattresses of 300 m pipeline, in total 45 mattresses as worst case. The new components added at Nini A are listed in the project description in section 5.7.1.

During hydrostatic testing and well preparation, is it planned to use 2 chemicals, both classified as "yellow" according to the Danish Environmental Protection Agency (DEPA) colour coding (substances exhibiting some degree of environmental hazard). More details can be found in the project description (section 5.7.1).

Chemicals will be used for plug and abandonment of the Nini A wells. Only green and yellow chemicals will be discharged. More details can be found under decommissioning (chapter 18).

<u>Fuel consumption</u>

During the construction phase, a support vessel and other vessel and activities will be required, consuming in total ~600 m^3 fuel. During the operation phase various activities will be required which sum up to ~4,000 m^3 fuel, where the major fuel consumption will be related to the transportation of CO_2. The fuel consumption for each voyage of the transport vessel has been estimated to be approximately 29.4 m^3 fuel, and in total around 3,800 m^3 fuel annually. Decommissioning activities contribute with ~16,000 m^3 fuel consumed.

3.2 The oil & gas production phase

The Nini A platform was commissioned in 2003 and consists of a topside and a jacket. The topside refers to the above water sections, and the jacket is the construction used for fastening the platform to the seabed. In 2009, 6 years after Nini A was commissioned, the Nini field was further developed by the additional satellite platform Nini B.

Drilling activities at Nini A are related to the period from 2003 until 2010:

- Ensco 70: February 2003 - November 2014 (NA-1, NA-2, NA-3, NA-4, NA-5, and NA-6)
- Ensco 101: April 2005 - May 2005 (NA-7)
- Noble George: June 2007 - August 2007 (NA-8)
- Maersk Resolute: January 2009 - January 2010 (NA-9 and NA-10)

The following sections describe historical discharges, emissions and impacts and give a short assessment based on the available knowledge.

3.2.1 Underwater noise

The following activities related to the construction and operation of the Nini A platform and the associated pipelines may potentially have generated noise impacts on marine organism:

- Installation of the Nini A platform incl.
    - High frequency noise from survey equipment e.g. debris survey
    - Piling to secure and anchor the subsea jacket and topside module to the seabed
- Establishment of wells
    - Machinery noise from drilling rig during drilling of wells
    - Conductor ramming
- Vessel activity
    - Machinery and propulsion noise from survey and support vessels

The legal regulation regarding protection of marine mammals has changed significantly throughout the service years of Nini A. When required an authority permit for noise emitting operations has been granted. Measures to protect marine mammals has been adhered to in line with the permit and good current practises at the time of the activity.

3.2.2 Physical footprint

The Nini A platform has a physical footprint of approx. 1,500 m^2 (the area within the three legs of the jacket).

- The jack-up rigs used for drilling operations at Nini A, have three spud-cans that each have a footprint of 200 m^2 on the seabed. (Bokalis Offshore AS, 2003)
    - It is expected that the physical footprint and sediment resuspension and deposits from the activities would have been minimal (no dredging or trenching activities). Consequently, there would have been no significant impact on the surrounding sediment composition or fauna.
- The pipelines used for transport of produced oil, water and gas between Siri and Nini A are all trenched.
    - The trenched pipelines do not contribute to the physical footprint as they do not take up space on the seabed, they are however protected by rock dumping or concrete mattresses.
    - 10 concrete mattresses are installed near the Nini A platform (within 500 m) (DONG, 2017). Near the Siri platform, another 10 concrete mattresses cover the pipeline running between Nini A and Siri (COWI, 2023a).
- Rock dumping was performed on spool ends, pipeline crossings and bends for protection and in total 1,600 m of the pipeline between Nini A and Siri is covered by rocks (INEOS, 2013). The width of the rock dumps on the pipeline is approx. 2 meters wide at each side.
    - Trenching, rock dumping and placement of concrete mattresses result in suspension of sediment near the seabed. The baseline survey report on sediment conditions found that the project area is highly homogenous (DHI and Rambøll, 2023a). Seabed intervention activities such as trenching, and rock dumping would most likely have led to dispersion of sediments with similar characteristics to those in the area where the material was deposited.

No planned installation of platforms, pipelines or activities that result in physical footprint or physical disturbance of the seabed have been identified between 2024 until the start of the *Project Greensand Future*.

3.2.3 Discharges

The production of oil, gas and water from the Nini A platform is exported to the Siri where the three phases, crude oil, gas, and water are separated, and the **produced water** is further treated to meet discharge requirements. During normal operation produced water will not be discharged. Abnormal or upset conditions may result in discharges of produced water at the Siri Complex. In recent years approximately 1% of the ~5,000,000 Sm^3 produced water annually generated at the Siri complex has been discharged. Nini A contributes with approximately 10-20% of the produced water generated equal to a discharge of 5,000-10,000 Sm^3 per year. The potential impact from produced water discharge at the Siri complex on marine organisms is generally restricted to a water volume less than 100 meters away from the discharge point. Consequently, the impact from produced water originating from Nini A platform is negligible.

During the **drilling** of the 10 wells at Nini A in the period from 2003 until 2010, the major part of chemical discharges to sea are in the green category, and thereby having low toxicity and low impacts on the marine environment. The more toxic compounds (red and to some extend the yellow chemicals) are typical left in the well and not discharged.

There have been yearly **wellhead maintenance** activities on the Nini A platform and occasional well interventions if required. The used chemicals are disposed into the well and not discharged to sea. All the chemicals used are ranked as Green or Yellow and environmental impact related to the use of these chemicals have not been identified.

3.2.4 Solid waste

Any waste generated at Nini A are transported to shore where it is recycled, incinerated, or landfilled in accordance with applicable legislation. Further all vessels follow the standards and procedures for the management and control of ships' ballast water and sediments in accordance with the Ballast Water Management Convention, which ensure all waste is shipped to shore and treated according to current legislation. This is valid for both the historical activities and until the start of *Project Greensand Future*.

3.2.5 Emissions

During the construction phase, emissions are assumed to be relatively similar to the estimate given for the decommissioning phase covering pipelines removed by reverse reeling, where the topsides and jacket are removed by a single-lift method.

During operation a number of activities are required to ensure safe operation (yearly emissions described in section 4.4.5):

- Power generation
- Maintenance of topside
- Fuelling and pigging operations
- Maintenance of equipment and breakdown repair

3.2.6 Light

Safety lights have been present on Nini A since installation. Vessels used for installation of the platform and pipelines, maintenance and safety inspections are illuminated while operating in dark hours. Light can have an effect on fish, marine mammals and birds as these can be attracted to illuminated areas which allow for better prey detection. Illumination may also disorient migratory birds. Since the impact from the illuminated vessels are temporary and the permanent safety lights from Nini A are of low intensity, the impact from light is expected to have been negligible. No impacts are expected to occur from 2024 until the start of *Project Greensand Future*.

3.2.7 Resource use

As part of the Nini A facilities a number of materials are used for construction of the jacket, pipelines and wells, this consist mainly of metals, concrete and polymers. Metals are the dominant fraction, especially steel in different alloys. The resource use is further specified in the chapter covering decommissioning in chapter 18.

3.2.8 Restricted zones

Safety and restriction zones around the Nini A platform and its pipeline to Siri aim to prevent marine traffic and fishing activities that could lead to collisions or other disturbances. With a 500 m safety zone around the platform and 200 m restriction zones along the pipeline, the impact on fishing and shipping is considered minimal due to the low fishery intensity and the distance from major and minor shipping lanes. No significant effects on fisheries or marine traffic are anticipated until the commencement of Project Greensand Future in 2024.

3.2.9 Accidental discharges

A major accidental event during the history of production was a rupture of the 10” water injection pipeline in 2007. The pipeline ruptured 2 km from the Siri installation due to pitting corrosion, which was a result of poor water management. The pipeline was at that time repaired and temporary back in service for 2 years before a new pipeline was established in continuation with installation of the Nini B in 2009.

The rupture resulted in a release of maximum 3.000 m^3 **produced water**. However, the quality of the released produced water is similar in quality to the water release to sea at Siri. The produced water released at the Siri platform is treated to meet discharge requirements. Consequently, the impact from produced water released at the rupture is negligible.

3.3 Alternatives

The alternative to the execution of *Project Greensand Future* is to follow standard procedures for decommissioning for the current equipment in the Nini Complex, within its current Nini license. The final decommissioning of the Nini A platform and related structures is covered in a separate EIA (COWI, 2023b).

3.4 Environmental impact assessment method

The significance of the consequence of different project activities and risks (unplanned events) have been assessed according to the following criteria in Table 3-1.

Table 3-1 Assessment criteria and categories

Assessment criteria	Impact categories
Vulnerability of the environmental and social receptor, describing how sensitive a receptor is to an impact	Low Medium High Very high
Geographical extent of the impact	Immediate vicinity (0-1 km) Local (>1-10 km) Regional (>10-50 km) National / international (>50 km) Global
Intensity of the impact, describing the force or strength of an impact	Negligible Low Medium High Very high
Duration of the impact	Very short-term (hours to less than one week/6 days) Short-term (7 days to 30 days) Medium-term (one month/31 days to several months, less than one year) Long-term (one to less than five years) Permanent (entire operation phase or >5 years)

By combining these criteria, the overall consequence of each activity and impact has been assessed for all relevant receptors in the following categories: None/negligible, limited, moderate and significant. Positive impacts that have a beneficial effect on the environmental subject in question have been assessed as either insignificant (insignificant to moderately positive impact) or significant (significantly positive impact). The assessment of the consequence is an overall professional assessment and thus not a mathematical sum of the criteria mentioned.

3.5 Scoping of environmental impact assessment

The scoping describes which environmental and social receptors as listed in the Environmental Assessment Act (Consolidation Act no. 4 of 03/01/2023) are assessed in this EIA. Following, environmental receptors and potential impact mechanisms are listed, and the relevance marked in Table 3-2and Table 3-3

Environmental Receptors

- Climate and air quality
- Hydrographic condition
- Water quality
- Sediment conditions
- Plankton
- Benthic fauna
- Fish
- Marine mammals
- Seabirds
- Annex IV species
- Protected areas

Social Receptors

- Material assets
- Cultural heritage
- Fisheries

Relevant Directives

- Water Framework Directive
- Marine Strategy Framework Directive
- Maritime Spatial Plan
- Natura 2000

Potential impact mechanisms

- Underwater noise
- Disturbance from vessels
- Physical footprint
- Physical disturbance of seabed
- Chemical discharges
- Solid waste (only onshore - decommissioning)
- Emissions
- Light
- Resource use
- Restricted zones

Planned activities and potential impacts

An overview of the planned activities and related the potential impact mechanisms is provided in Table 3-2

Table 3-2 Planned activities and potential impact mechanisms of *Project Greensand Future*. "X" marks the relevance for the impact assessment.

Phase	Potential impact mechanism	Retrofitting of topside equipment	Offloading system	Helicopter shuttling and boat manning	Seismic and seismicity monitoring	CO_2 leakage monitoring	Transportation of CO_2/other vessels	Removal of structures
Construction	**Underwater noise**		X		X		X	
	Disturbance from vessels		X		X		X	
	Physical footprint		X					
	Physical disturbance of seabed		X					
	Chemical discharges		X					
	Solid waste	X	X					
	Emissions	X	X	X	X		X	
	Light	X	X		X		X	
	Resource use	X	X	X	X		X	
	Restricted zones	X	X					
Operation	**Underwater noise**		X		X		X	
	Disturbance from vessels		X		X	X	X	
	Physical footprint		X			X		
	Emissions			X	X		X	
	Light	X	X		X	X	X	
	Resource use			X	X		X	
	Restricted zones	X	X					
Decommissioning	**Underwater noise**						X	X
	Disturbance from vessels						X	X
	Physical disturbance of seabed							X
	Emissions						X	X
	Solid waste							X

Relevant environmental and social receptors

The relevant receptors have been assessed based on the project description and the potential impact mechanisms. Relevant receptors for the impact assessment are summarized in Table 3-3.

Table 3-3 Potential impact mechanisms and relevant environmental and social receptors and directives of *Project Greensand Future.* "X" marks the relevance for the impact assessment.

	Potential impact on environmental/social receptor	Underwater noise	Disturbance from vessels	Physical footprint	Physical disturbance of seabed	Chemical discharges	Emissions	Light	Resource use	Restricted zones
Environmental Receptors	**Climate and air quality**						X		X	
	Hydrographic condition			X						
	Water quality					X				
	Sediment conditions			X	X					
	Plankton					X				
	Benthic fauna			X	X	X				
	Fish	X		X	X			X		
	Marine mammals	X	X					X		
	Seabirds		X					X		
	Annex IV species	X	X					X		
	Protected areas	X								
Social Recep.	**Material assets**									X
	Cultural heritage			X	X					
	Fisheries									X
Relevant Directives	**Water Framework Directive**					X				
	Marine Strategy Framework Directive	X	X	X	X			X		
	Maritime Spatial Plan									X
	Natura 2000	X	X					X		

3.6 Description of existing conditions in the project area

This section provides a description of the current environmental and social status of the relevant receptors in the project area (Figure 3-3).

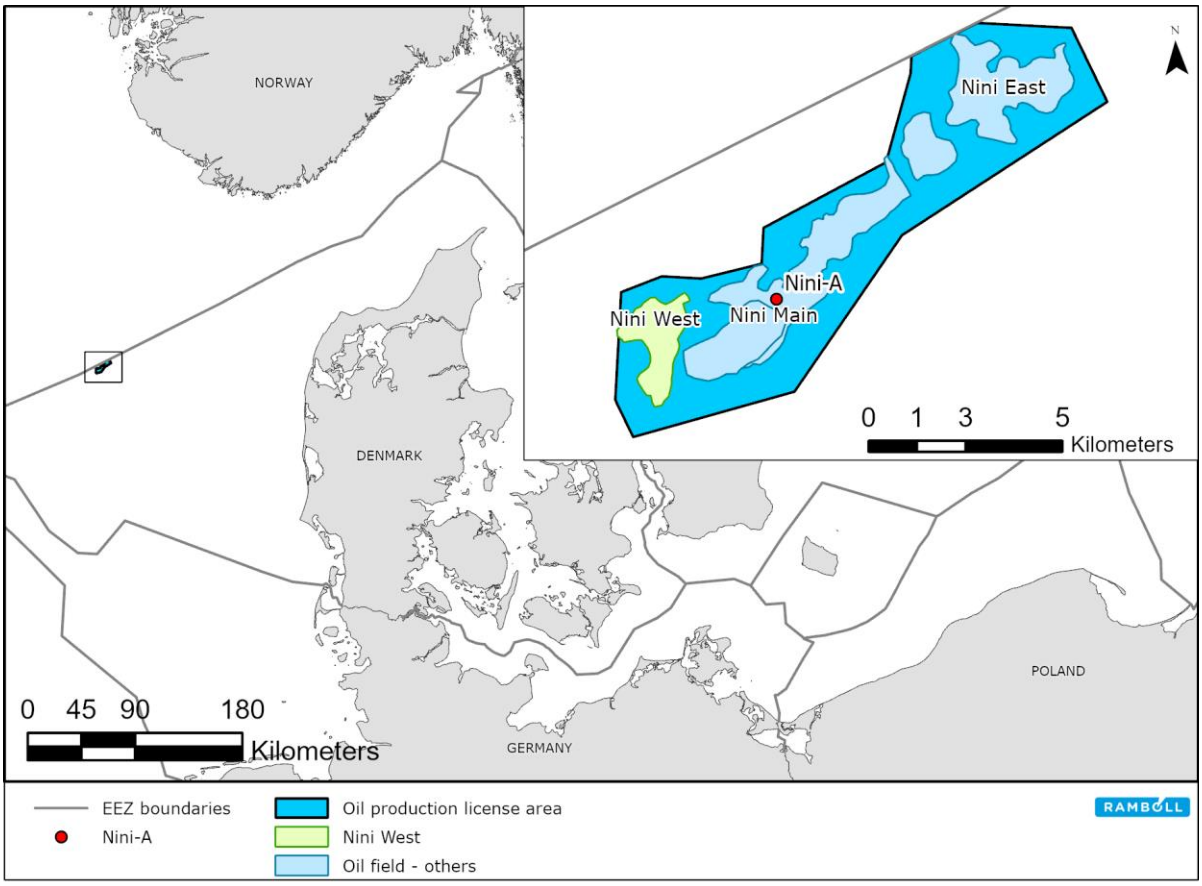


Figure 3-3 Location of Nini-A platform and the three Nini segments: Nini West, Nini Main and Nini East.

3.6.1 Climate and air quality

The project area is located centrally in the North Sea and air pollution is low in this region. Most of the emissions in the North Sea area are related to cargo ships, and the concentration of man-made emissions decrease with distance from the coast. CO_2 is the main greenhouse gas, and emissions of CO_2 contributed 67.9% of national total emissions (excluding land use) of greenhouse gases in 2021. The most important sectors in terms of greenhouse gas emissions in 2021 are estimated to be energy (61.8%), agriculture (26.2%), land use (5.3%), industrial processes and product use (4.0%) and waste (2.7%).

3.6.2 Hydrography and water quality

The project area is located outside important hydrographic pathways and is generally characterized by weak currents and relatively shallow water depths of about 60 m. The project area is classified as having good environmental status with regard to eutrophication (nutrient enrichment) but as most of the Central North Sea, the chemical status of the area is classified as a problem-area with regard to contaminants. However, over the past 30 years the concentrations of metals, polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) have decreased substantially, and the level of PAHs is assessed to only pose a low risk to the marine biological community.

3.6.3 Sediment conditions

Sediment samples were collected as a part of the baseline survey (DHI and Rambøll, 2023a) and used to address to physical and chemical characteristics of the sediment. Sediments were muddy sands or sands with means of fine sands or very find sands. These findings align with the dominant habitat types found in the western part of the Danish Exclusive Economic Zone (EEZ). The chemical analyses showed that concentrations of both heavy metals and hydrocarbons were generally found to be lower than the target levels. Only for one sample station, M7, the concentration of Arsenic was above the low range for possible toxicological effect. For another station, T06, the samples showed elevated levels of the hydrocarbon’s anthracene and ΣPAH16 (polycyclic aromatic hydrocarbons).

3.6.4 Biodiversity - Plankton

The project area is located in an area with an average biomass and abundance of phytoplankton comparable to the rest of the North Sea. The phytoplankton community is dominated by dinoflagellates and diatoms, while the zooplankton communities in the North Sea are dominated by copepods (small crustaceans) (Rambøll, 2015).

3.6.5 Biodiversity - Benthic fauna

The benthic fauna in the project area was investigated as part of the baseline survey report (DHI and Rambøll, 2023a). The dominant groups of benthic fauna were: Bristle worms as the largest group with 39 species, Molluscs with 20 species, Crustaceans with 12 species and Echinoderms with 10 species. The all-dominant species were the small tube-dwelling bristle worm with > 2,000 individuals / m^2. The burrowing brittlestar counted over 200 individuals / m^2. No red listed organism for the Norths Sea was found.

A bacterial eDNA analysis revealed that the detected microorganisms generally belonged to well-known groups of marine bacteria, that are expected to be widespread in North Sea sediments. The bacterial communities were relatively homogeneous across the 20 sampling stations.

3.6.6 Biodiversity - Fish

The most common fish species found in and around the project area are American plaice, Atlantic mackerel, sand eel, cod, common dab, European plaice, haddock, grey gurnard, herring, lemon sole, sprat and whiting. The fish species that are found spawning in the project area are characterized by spawning in the free water masses (pelagic spawning). The bottom-spawning sand eel, is found spawning in an area located about 11 km north of the project area in Norwegian waters.

3.6.7 Biodiversity - Marine mammals

Harbour porpoise, white-beaked dolphin and minke whale are the most common marine mammals in this part of the North Sea. The biology and distribution of these species as well as their habitat preference is related to the food availability. Harbour porpoise, white-beaked dolphin and minke whale are considered most vulnerable within their breeding and mating periods. However, the project area has not been identified as a potential breeding area for white-beaked dolphin or minke whale and is not an important breeding area for harbour porpoise.

Harbour seals and grey seals could use the area and appear sporadically. Haul-out sites for seals constitute important areas for resting, moulting and breeding. The closest haul-out site for harbour seal and grey seal is located approx. 178 km from the project area. Based on the fact that grey seals travel across long distances, it is likely that grey seals can be encountered foraging within the project area, but less likely that harbour seals are encountered, as they normally forage 20-25 km from their haul-out.

3.6.8 Biodiversity - Seabirds

The most common seabird species found in or near the project area are the black-legged kittiwake, common guillemot, northern gannet, razorbill, northern fulmar, lesser black-backed gull and herring gull. As Nini A is located relatively far (approximately 100 km) from the closest Important Bird Area (IBA) and offshore from the continental shelf, the waters around the platform are not an important area for seabirds.

3.6.9 Annex IV species

The whale species harbour porpoise, minke whale and white-beaked dolphin are the only Annex IV species listed in the Habitats Directive that naturally occur in the project area. The three whale species are native to the North Sea and protected across their entire range. The project area has not been identified as an important feeding or breeding site for these species. The population status of all three species has been assessed as favourable in the Danish part of the North Sea in 2019.

3.6.10 Protected nature

Protected areas close to the project areas include Natura 2000 sites, Ramsar sites, Important Bird Areas (IBA's), Valuable and Vulnerable Areas (Særlig Verdifulle og Sårbare Områder - SVOs), Marine Protected Areas (MPAs) and areas designated under the Marine Strategy Framework Directive. The nearest MPA-area is located > 75 km and SVO-area approx. 11 km from the project area.

3.6.11 Material assets

Material assets around the project area include existing oil and gas infrastructure, offshore wind farms, subsea cables and pipelines as well as ship traffic.

3.6.12 Cultural heritage

Ship and plane wrecks are the most likely cultural heritage objects to be found in and near the project area. Considering the extensive activity around the Nini Complex over the past 20 years, where no wrecks have been identified, the project area is not expected to have any significant importance concerning cultural heritage. The closest object registered is located 20 km southeast of the project area. However, no archaeological surveys of the project area exist, thus the presence of cultural heritage objects in the project area cannot be ruled out completely.

3.6.13 Fisheries

The North Sea is an important area for commercial fisheries. Around 6,600 fishing vessels are active in the Greater North Sea, which encompasses the North Sea, English Channel, Skagerrak, and Kattegat. Here, the landings peaked in the 1970s with 4 million tons and have since declined to about 2 million tons today. The spatial distribution or preference of fishing gear varies in the North Sea. The fish stocks harvested in the North Sea are being fished in accordance with achieving good environmental status, under the EU's Marine Strategy Framework Directive, but the reproductive capacity of the stocks has not reached this level. The greatest physical disturbance of the seabed is caused by mobile bottom-contacting gear. The project area mainly consists of sand eels (54.3%), European plaice (36.9%), lemon sole (2.4%), Atlantic cod (1.8%) and turbot (1.1%).

3.7 Environmental and social impacts

The following section summarizes the potential environmental and social impacts associated with *Project Greensand Future*, as written in detail in this EIA Report. The overall impact on climate is assessed to have moderate consequences in both the construction and operation phase. The impact from the entire CCS loop is however assessed to have significant positive consequences on the climate system.

Table 3-4 Summary of potential impacts

Receptor	Overall consequence	Summary of the potential impacts
Construction Phase		
Climate and air quality	Moderate	**Emissions – climate** As the project is of relatively small scale, the intensity of emissions is assessed as medium and therefore resulting in moderate consequences. The impact from the entire CCS loop is assessed to have significant positive consequences on the climate system, because it is planned to store 0.3 MT CO_2e (CO_2 equivalents) annually, which is higher than the emissions from construction (1,833 t CO_2e) and operation (~11,000 t CO_2e/year)
	Limited / negligible	**Emissions – air quality** The activities related to the construction phase will result in emissions of gasses and particles to the air. The vulnerability of the air quality offshore shore is assessed low. As the intensities of emissions are low, the combined consequences of the planned activities are assessed limited.
Hydrographic conditions	Negligible	**Physical footprint** New structures are expected to result in a physical footprint in the construction phase when they are installed, and they will remain throughout the operation phase. The presence of physical structures that leave a footprint on the seafloor and occupy space in the water column may result in minor hydrographic changes that could affect prevailing currents, inhibiting flow and potentially causing changes to salinity and temperature regimes at/near the seabed. As the hydrographic conditions are controlled by forces working on a large-scale basis, the consequences are assessed as negligible.
Water quality	Negligible	**Chemical discharges** Potential impacts to water quality from the project include chemical discharges which is assessed under plankton and benthic fauna. Consequences from chemical discharge are assessed to be negligible.
Sediment conditions	Negligible	**Physical footprint** The installation of new structures that leave a physical footprint on the seafloor results in loss of substrate under the structures and change the physical and chemical compositions of the sediment. The permanent placement of structures on the seabed introduces hard-substrate habitats to the predominantly soft-bottom environment in the project area, changing the physical characteristics of the seabed. Due to the vast area of homogenous sediment, the loss of about 850 m^2 does not impact the overall function or structure of the seabed.
		Physical disturbance of the seabed During the construction phase, the physical disturbance of the seabed is related to potential resuspension of sediments during installation of the offloading system. Potential resuspension of sediment will not change the physical aspects of the sediment and minor physical or chemical changes are expected to quickly return to their original state once the activities cease.

Receptor	Overall consequence	Summary of the potential impacts
Plankton	Negligible	**Chemical discharges** Chemical discharges are only associated with the leak testing of the offloading system and discharge of the hydrotest water. Some plankton may show a quick response to a toxic effect, but plankton has a short turnover time, which enables it to recover rapidly to its pre-impact status once the environmental impact ceases. The discharge volumes are small (13 m^3 of hydrotest water) and dilution of the chemical discharge will result in non-detectable levels.
Benthic fauna	Negligible	**Physical footprint** The installation of new structures that leave a physical footprint on the seafloor results in loss of substrate under the structures and the benthic fauna living on the affected substrate. A small area of about 850 m^2 will be impacted in the overall homogenous habitat and large extent of near-identical benthic community.
		Physical disturbance of the seabed Installation of the subsea pipeline and concrete mattresses may lead to an impact on the benthic fauna if surrounding top sediments are disturbed or organisms are displaced or experience increased mortality. The community is expected to recover and the existence of similar benthic communities in the surrounding seabed will allow for recolonization of the disturbed sediments. The colonization capabilities of the benthic community vary between species.
		Chemical discharges The chemical discharges related to the leak testing of the offloading system could result in a toxic effect on benthic fauna. The discharge volumes are small (13 m^3 of hydrotest water) and dilution of the chemical discharge will result in non-detectable levels. The chemicals have been approved for discharge by the DEPA and are not considered to pose a long-term effect on marine organisms. The benthic environment has the ability to recover from chemical discharges.
Fish	Limited / negligible	**Underwater noise** The ways in which fish can be impacted by underwater noise of a relatively high intensity are largely reversible over time or cease as the noise exposure is terminated, thereby attributing fish low sensitivity to underwater noise. Fish that have evolved a swim bladder, like herring have better hearing and are therefore more sensitive to noise that for example flatfish that does not have a swim bladder. The overall vulnerability of fish to underwater noise is therefore assessed as low, causing reversible impacts to fish as they are expected to return to the area once the impact ceases.
		Physical footprint The structures installed (offloading system and CO_2 leakage monitoring system) will result in a permanent loss of habitat. However, the loss of habitat is relatively small as they only occupy around 850 m^2 of the vast homogenous habitat of the seabed. Due to the small dimensions of the physical footprint in a vast and homogenous area, there will not be an impact on fish populations
		Physical disturbance of the seabed Potential impacts to fish caused by physical disturbance of the seabed, such as resuspension of sediment, can impact fish species that rely on the seabed for spawning and foraging. The amount of resuspended sediment from placing structures, mainly the concrete mattresses, on the seabed is expected to be very small and restricted to the footprint area of 850 m^2. It is expected that the seabed impacted by resuspension of sediment will revert to its pre-impact state within a relatively short time span. There are no important demersal spawning areas for fish within the project area.
		Light Safety lights are present at all satellite platforms and vessels throughout the construction and operation phase. Safety lights are generally low-intensity light sources, the impact from safety lights is expected to have a smaller extent than the illuminated vessels. Illuminated structures may be providing an enhanced foraging environment for fish by providing sufficient light to locate and capture prey. For juvenile fish there is probably a trade-off between foraging in an artificially illuminated nocturnal environment and the increased risk of predators. Since fish are highly mobile and the area does not constitute important spawning grounds for fish, impacts are expected to be negligible.

Receptor	Overall consequence	Summary of the potential impacts
Marine mammals	Limited / negligible	**Underwater noise** Underwater noise is expected from vessels and ROV equipment, diving operations, seismic surveys and vessels. Hearing is the primary sense for many marine mammals for detecting prey, predators, communication, and navigation and underwater noise can therefore cause severe impacts. Marine mammals are expected to avoid the area and they are assessed to be insensitive to small displacement, avoidance behaviour for harbour porpoise is modelled to be up to 6.1 km. With the initial disturbance from vessels and the application of a soft start procedure, there will be a very limited risk of injury from underwater noise on marine mammals.
		Disturbance from vessels Impact from disturbance is up to 200-400 m from the vessels, but since marine mammals are expected to avoid vessels at this distance, no impact is expected.
		Light Light on the Nini A platform and vessels and may locally attract fish, serving as prey for marine mammals, but it has no direct impacts.
Seabirds	Negligible	**Disturbance from vessels** Disturbance from vessels is not expected to cause significant a risk-avoidance response in seabirds that could affect the time available for resting or foraging.
		Light Light emissions from safety lights on the Nini A platform and vessels are limited and although some individuals may be impacted by these light sources, impacts are not expected to cause adverse effects at the population level.
Annex IV	Limited / negligible	The three Annex IV species in the project area are whales, which are native to the North Sea: harbour porpoise, white-beaked dolphin and minke whale (see section 11.8Marine mammals for further description). As described above there will be a limited risk of injury from underwater noise on marine mammals, with the appropriate slow and soft start procedures in place. The project does not include deliberate capture or killing of appendix IV species. The ecological functionality of breeding and/or resting sites is maintained.
Protected nature	None	**Underwater noise** The SVO area is the NS2 "the sand eel fields". Research on impacts on fish from underwater noise is relatively scarce and has only been carried out for a few fish species. Underwater noise only causes an impact in the immediate vicinity of the vessels and construction activities. Considering the distance of 11 km from the project area to the SVO-area and 4.6 km to the monitoring OBS (seismicity), no impact is expected in this protected area.
Cultural heritage	Limited	**Physical footprint** Physical footprint on the seabed during construction and operation phase has the potential to damage cultural heritage sites/objects (CHO) or render these inaccessible for future research during the operational lifetime of the project. The area has previously been surveyed without detecting CHOs. A geophysical site survey will provide verification on whether protection measures of findings need to be in place. In the case of chance finds, these will be reported to the relevant authorities and further action identified and coordinated, if needed.
		Physical disturbance of the seabed CHOs are often fragile and sensitive to physical disturbance. The potential resuspension of sediment is small due to the small dimensions of the installed structures and because the pipeline will be laid on the seabed. The area has been scanned and commercially utilised prior to this project and due to the very low likelihood of encountering cultural heritage in the project area, the consequences are assessed negligible.

Receptor	Overall consequence	Summary of the potential impacts
Operation Phase		
Climate and air quality	Moderate	**Emissions – air climate** During the operation phase fuel consumption of the CO_2 vessel is the largest climate footprint contributor and resulting in moderate consequences. As mentioned under the construction phase the impact from the entire CCS loop is assessed to have significant positive consequences on the climate system.
	Limited / negligible	**Emissions – air quality** The activities related to the operation phase will result in emissions of gasses and particles to the air. The vulnerability of the air quality offshore/near shore is assessed low/medium. As the intensities of emissions are low, the combined consequences of the planned activities are assessed limited.
Hydrographic conditions	Negligible	**Physical footprint** The offloading system and CO_2 leakage monitoring system will occupy space on the seafloor and in the water column. The installation will result in a physical footprint of about 850 m^2 in total with a max. height of approx. 0.5 m. The presence of these physical structures, may result in minor hydrographic changes that could affect prevailing currents, inhibiting flow and potentially causing changes to salinity and temperature regimes at/near the seabed. As the hydrographic conditions are controlled by forces working on a large-scale basis, it is expected, that once the structures are removed, the hydrographic conditions will be reversed naturally to their original state.
Sediment conditions	Negligible	**Physical footprint** The new structures leaving a physical footprint on the seafloor result in loss of substrate under the structures and change the physical and chemical compositions of the sediment. The permanent placement of structures on the seabed introduces hard-substrate habitats to the predominantly soft-bottom environment in the project area, changing the physical characteristics of the seabed. Due to the vast area of homogenous sediment, the loss of about 850 m^2 does not impact the overall function or structure of the seabed.
Benthic fauna	Negligible	**Physical footprint** The new structures that leave a physical footprint on the seafloor results in loss of substrate under the structures and the benthic fauna living on the affected substrate. A small area of about 850 m^2 will be impacted in comparison to the overall homogenous habitat and large extent of near-identical benthic community. The benthic fauna community is expected to recover and the existence of similar benthic communities in the surrounding seabed will allow for recolonization of the disturbed sediments. The colonization capabilities of the benthic community vary between species. Affected organisms are expected to be able to find suitable habitat in nearby sediments during the duration of the impact.
Fish	Limited / negligible	**Underwater noise** Underwater noise from seismic survey, the survey vessel and the CO_2 vessel is expected. Impacts from monitoring of the reservoir (seismic surveys) are assessed. Seismic emits high energy sounds which may potentially lead to mortality or mortal injury in fish. As soft start procedure is required by the authorities, the risk of non-reversible effects in fish (mortality and mortal injury) is prevented. Applying soft start procedure does not remove the risk of mortal injury to larvae at a range of 0.8 km (SELcum) (3D) and 0.9 km (SELcum) (2D) from the source. This is however unlikely to have repercussions for reproduction and stock recruitment. Impacts from vessels are related to behavioural and masking effects which are expected to cease once the impact ceases.
		Physical footprint The offloading system and CO_2 leakage monitoring system impose permanent structures which will persist throughout the lifetime of the project. Due to the small dimensions of the physical footprint in a vast and homogenous area, there will not be an impact on fish populations.
		Light Safety lights are present at all satellite platforms and vessels throughout the construction and operation phase. Since fish are highly mobile and the area does not constitute important spawning grounds for fish, impacts are expected to be limited.

Receptor	Overall consequence	Summary of the potential impacts
Marine mammals	Limited / negligible	**Underwater noise** Underwater noise can derive from the CO_2 vessel and survey vessel (continuous noise) but also from the use of airguns during seismic monitoring of the reservoir. With the application of soft start procedure and the disturbance from vessels, there will be a very limited risk of injury from underwater noise. During the 5-10 day seismic campaign, behavioural responses could occur up to 6.1 km for harbour porpoises and 28.9 km for seals.
		Disturbance from vessels Impact from disturbance is up to 200-400 m from the CO_2 vessel, but since marine mammals are expected to avoid vessels at this distance, no impact is expected.
		Light emissions The platform is unmanned, but safety light will be present, and the CO_2 vessel will be illuminated. Light may locally attract fish, serving as prey for marine mammals, but it has no direct impacts on them.
Seabirds	Negligible	**Disturbance from vessels** The frequent presence of the CO_2 vessel and annual presence of the seismic survey vessel will not result in physical impacts or changed function of the population of seabirds in the area, as impacted birds are expected to resettle again relatively quickly after the impact ceases or they get further away from the impact point.
		Light Light emissions from safety lights on the Nini A platform and vessels are limited and although some individuals may be impacted by these light sources, impacts are not expected to cause adverse effects at the population level.
Annex IV	Limited / negligible	The three Annex IV species in the project area are whales, which are native to the North Sea: harbour porpoise, white-beaked dolphin and minke whale (see section Marine mammals for further description). As described above there will be a very limited risk of injury from underwater noise on marine mammals. Avoidance behaviour could occur up to 6.1 km away from seismic locations. The project does not include deliberate capture or killing of appendix IV species. The ecological functionality of breeding and/or resting sites is maintained.
Protected nature	None	**Underwater noise** The closest SVO area is NS2 "the sand eel fields". Research on impacts on fish from underwater noise is relatively scarce and has only been carried out for a few fish species. Underwater noise only causes an impact in the immediate vicinity of the vessels. With 11 km from the project area to the SVO-area, no impact is expected in this protected area.
Material assets	Negligible	**Restricted zones** The offloading system is located within the already existing restriction zone of 500 m around the platform. Anchoring or trawling is restricted within the entire zone. This safety zone already applies and will remain throughout the entire operation phase. A new restriction point related to the CO_2-leakage monitoring system will be put in place.
Cultural heritage	Limited	**Physical footprint** Installed structures leave a physical footprint on the seafloor that can cause direct damage to CHOs, for example ship and plane wrecks, which are the most likely CHOs to be found within the project area. Physical footprint on the seabed during the construction and operation phase has the potential to damage cultural heritage sites/objects or render these inaccessible for future research during the lifetime of the project.
Fisheries	Negligible	**Restricted zones** The North Sea constitute important fishing grounds. No fishing is allowed within the restriction zones. For the subsea pipeline, no additional restriction zone will be applied, since the 200 m zone around the pipeline lies within the already existing restriction zone of 500 m around the platform. A new restriction point related to theCO_2-leakage monitoring system will be put in place. Fisheries will be no more impacted from this restriction p around the platform than they are today. Once structures imposing restricted zones are decommissioned the fishing ground will return to a pre-impact state.

3.8 Impacts from accidental events

3.8.1 Oil spill blowout

If a CO_2 blowout occurs, it could also result in the release of oil to the environment. A blowout is an extremely rare event and extensive preventive control measures are implemented to reduce the likelihood of such events. Blowouts may rarely occur during the CO_2 injection phase. In the unlikely event of a blowout, the oil is spread with the currents. Oil components and their breakdown product may affect marine and coastal habitats and species.

In general, the most severe impacts of an oil spill will occur if the oil slick passes flocks of seabirds or if the oil ends up in near coastal waters and on shorelines. An oil dispersion modelling from a blowout has previously been conducted for the NB-01 well on the Nini B platform located 8 km from the Nini A platform. A blowout occurring in *Project Greensand Future* one year after injection start is expected to result in an oil release rate of 100 m^3 per day, while a blowout occurring 10 years after injection start is expected to result in an oil release rate of 70 m^3 per day and a blowout occurring 20 years after injection start is expected to result in an oil release rate of 50 m^3 per day. The modelled scenario for the NB-01 well utilized in later sections of this EIA is therefore a very conservative estimate.
Regarding shore-line impact, the model showed that most of the oil (>99.5 %) is expected to stay offshore, with less than 0.5% reaching the shore. Denmark and Norway are the only two countries at risk of shoreline impact from a spill in winter, while a spill in summer could also impact the Swedish coastline.

The Natura 2000 sites, the Danish sites Lille Fiskebanke, Store rev, Gule Rev, Thyborøn Stenvolde, and Skagens Gren og Skagerrak, are closest to Nini in the prevailing direction of the oil slick drift and there is a relatively high likelihood that these sites will be affected by a blowout spill. While there is some risk of oil sedimentation and consequently impact on seabed habitats and associated flora and fauna there is negligible risk of harmful effects on Harbour porpoise and seal populations in these areas.

Additionally, the Norwegian SVOs to the north of the Nini A platform may be affected by an unmitigated blowout as concentrations of oil in this area are above 25 ppb and will be harmful to fish eggs and larvae and thereby affect spawning. Furthermore, the Sand eel field south is a valuable habitat for common guillemot and northern fulmar from April to December and there would be a risk of oiling and killing of birds in these areas.

Since the probability of an impact is low, since a blowout is very unlikely and can be stopped much faster than modelled, the overall consequence of the impact on the marine environment is assessed to be limited or moderate. The risk off impact on Natura 2000 sites and other protected areas is considered negligible.

3.8.2 CO_2 blowout

In the unlikely event of a blowout during or after the injection phase, this would result in a release of the injected CO_2 along with oil and water from the reservoir. Modelling results of a blowout show that the CO_2 gas will ascend rapidly and escape to the atmosphere. Only approximately a few percent of the released CO_2 will dissolve in the seawater and dissolution will mainly occur at the sea surface.

As the global climate system is vulnerable towards any additional climate gasses, the emission of CO_2 will affect the climate as a global impact. The probability of the worst-case event is assessed to be low. The impact from a blow out on the climate system is assessed to be negative, while the remaining stored CO_2 results in a positive impact.

The intensity of impact from a blow-out is declining in the period after completion of injection. Long-term reservoir modelling shows that in +10 years after completion of injection, the fraction of the free phase CO_2 is declining, and at that point the major fraction of CO_2 will be trapped either dissolved in the brine or mineralised as e.g., carbonates.

3.8.3 CO_2 leakage

The probability of CO_2 leakage from the reservoir is expected to be low based on the preliminary investigations and analyses of the geological layers. In the unlikely event of a CO_2 leakage from the reservoir, the main impacts are expected to affect fauna in or on the sea bottom as the dissolution of CO_2 gas bubbles will occur rapidly and within the first 2-5 m above the seabed. The CO_2 leak is expected to mainly impact immobile organisms or slowly moving organisms that are not able to migrate to unaffected areas.

CO_2 leakage from the reservoir is found highly unlikely based on the comprehensive preliminary investigations of the geological layers and only leakage from legacy wells might occur. The probability of a leakage is assessed to be very low. No significant impact on the North Sea benthic fauna community is expected as only a relatively small area will be affected consequently, no impact further up the food chain (fish and marine mammals) is expected.

During the offloading procedure from the vessel to the well there a number of potential accidental scenarios that could lead to emissions of CO_2 to the environment e.g., hose ruptur or accidental disconnection. The injection systems are designed with Emergency Shut Down Valves (ESDV's) at strategic locations that closes automatically. This prevents or reduces a release in case of accidental/unwanted events causing rupture and the release is limited to approximately 11.5 tonnes CO_2. The likelihood of such an accidental event is low and the overall consequence of the impact is assessed to be limited towards climate and negligible towards environmental receptors.

3.8.4 Ship collisions

It is assumed that CO_2 will be loaded onto a platform support vessel modified for CO_2 transport at Esbjerg harbour in Denmark. The sailing distance transported to the Nini A platform is expected to be 127 nm (235 km).

It is expected that one vessel will be used for the transports, and that it will perform a maximum of up to 130 injection cycles per year. Depending on the origin of the transports, shipping routes may change and hence represent different collision risks.

The 130 injection cycles per year are assessed to be insignificant compared to the ship traffic along the transport routes. The transport of CO_2 under pressure only occurs for the part of the trips towards the Nini A platform whereas the CO_2 vessel is in ballast when returning to port. Considering use of pilot where required and following ordinary COLREG rules for safe navigation, the additional ship collision risk imposed by the CO_2 vessel is assessed to be low.

3.9 Water Framework Directive

The overall objective of the Water Framework Directive (WFD) is to ensure the quality of surface waters (lakes, streams, transitional and coastal waters) and groundwater by achieving good ecological status and good chemical status by 2027. As the scope of this EIA contains exclusively offshore activities, therefore only impacts to coastal waters are relevant and were analysed.

The objective to achieve good ecological status applies within the 1 nm zone from shore while the objective to achieve good chemical status applies within the 12 nm zone from shore. For coastal waters, the ecological status is generally determined based on four quality elements (phytoplankton, macroalgae and angiosperms, benthic fauna, national specific environmentally hazardous substances in sediment and biota) and associated indicators (concentration of chlorophyll A, depth limit of rooted macrophytes (eelgrass or pond weed), Danish quality index for benthic fauna and the current legislation). Together, the ecological and chemical status make up the overall status of a water body.

For coastal waters along the coastline of Jutland, only phytoplankton and benthic invertebrates are used to assess the ecological status since growth of rooted macrophytes are inhibited by a high level of physical exposure in that area. The chemical status is determined based on concentrations of priority substances and their concentration thresholds.

Potential impacts to the WFD relate to impacts to water quality, which can be chemical discharges or accidental events, like oil spill. The drift time of oil after an oil spill from Nini A to the shoreline will be more than 20 days, in case of an oil spill lasting 90 days (worst case). The stranded oil will mostly be in the form of tar balls. The risk of a blow-out is very low and assessed to not be able to impact the quality elements phytoplankton, macroalgae and angiosperms and benthic fauna.

It is assessed that *Project Greensand Future* will not delay nor hinder the WFD's objective of achieving good ecological and good chemical status in Danish coastal waters.

3.10 Marine Strategy Framework Directive

The Marine Strategy Framework Directive (MSFD) aims to protect the marine environment through an ecosystem-based approach where the overall objective is to achieve good environmental status (GES) in the Member States' Sea areas. The descriptors embrace both receptors and sources of impacts for identifying human impact on marine ecosystems. This combination of causes and effects are described in rather general terms.

The nearest MSFD area is located approx. 17 km from the project area and 15.3 km from the nearest OBS for seismicity monitoring. The use of the area is required to comply with the objectives of the MSFD of achieving GES. Potential impacts from planned activities in Project Greensand are underwater noise, disturbance from vessels, physical footprint, physical disturbance of seabed, light emission and oil spill from accidental events.

The receptors identified in this EIA are especially related to the MSFD state descriptors which relate to biodiversity (seabirds, marine mammals, non-commercially exploited fish, and pelagic habitats i.e., plankton), the marine food web and benthic habitat types.

No prohibited activities take place inside Marine Strategy Areas and therefore *Project Greensand Future* comply with the directive. No significant impacts to any individual receptor have been identified. It is assessed that *Project Greensand Future* will not delay nor hinder the MSFD's goal of achieving Good Ecological Status for the descriptors contained in the MSFD.

3.11 Maritime Spatial Plan

The Marine Spatial Planning Directive has been established to ensure sustainable development of marine areas and promote sustainable development and sustainable use of marine resources. *Project Greensand Future* is located within an area designated for oil and gas exploration and extraction and for CO_2 storage according to the Maritime Spatial Plan (MSP). The project area does not intersect important shipping corridors and is located outside areas for renewable energy and energy islands and areas with protective measures for aviation. Potential impacts on marine spatial use are related to restricted zones, where no anchoring or fishing is allowed.

In the construction phase, an additional 300 m of subsea pipeline is planned in the current project which is within the 500 meters restricted zone of the Nini A platform. The lander for CO_2 leakage monitoring will have one navigation buoy to mark its location and protect against anchoring or trawling. This restricted point will apply once the lander have been placed and throughout the operation phase. The new restriction point does not interfere with other spatial usage zones according to the MSP. The new restriction point from the lander is assessed to have no significant impact on the spatial use of the area.

3.12 Natura 2000 assessment

The Natura 2000-network is the largest coordinated network of protected areas in the world, ensuring biodiversity by conserving natural habitats and wild fauna and flora in the territory of the EU. The purpose of Natura 2000-sites is to maintain or restore the favourable conservation status of habitats and species (both flora and fauna) in their natural range. The Natura 2000-network includes Special Protection Areas (SPAs), Special Areas of Conservation (SACs) and Sites of Community Importance (SCIs).

Four Natura 2000 sites have been identified closest to the project area (distance indicated): Jyske Rev, Lillefiskerbanke (71 km), Skagens Gren og Skagerrak (102 km), Thyborøn Stenvolde (142 km), Sydlige Nordsø (147 km), Dogger Bank (Germany, 121 km) and Dogger Bank (Netherlands, 156 km). No activities associated with *Project Greensand Future* are planned to occur within designated Natura 2000-sites and due to distance and the characteristics of the potential impacts from this project, no impacts are expected to extend into any Natura 2000-site.

Although none of the potential impact mechanisms are expected to extend into any Natura 2000-site, significant impacts to designated species happening outside Natura 2000-sites may cause impacts to the conservation objectives if species are impacted at the population level.

As summarized in section 3.7, significant impacts to marine mammals or Annex IV species on the designation basis of any Natura 2000 site from underwater noise generated in this project are ruled out. In conclusion, no impacts on marine mammals or Annex IV species on the designation basis of any Natura 2000 site from activities in the current project are expected.

Light emissions in the operation phase may cause an impact at a distance of up to 10 km from the source. Birds found on the designation basis of nearby Natura 2000 sites may potentially be attracted to these light sources resulting in a disruption of migratory behaviour. However, as effects are only temporary, no effects are expected at the population level for any species which may have implications for the conservation objectives of any Natura 2000-site.

3.13 Decommissioning

Decommissioning activities is described in high-level. A future decommissioning EIA will be assessing the activities in further detail and will be submitted as part of the authority approval of the decommissioning plans.
The potential impact mechanisms from decommissioning include underwater noise, disturbance from vessels, physical disturbance of the seabed, chemical discharges, emissions, light and solid waste. Potential impacted environmental receptors are limited to climate and air quality, water quality, sediment conditions, plankton, benthic fauna, fish, marine mammals and seabirds. The overall consequences, from decommissioning, are generally assessed as limited/negligible.

3.14 Monitoring program

As part of the *Project Greensand Future* a monitoring programme is designed to cover the major possible environmental impacts. As *Project Greensand Future* is the first CO_2 storage project (>100 kt) in Denmark, monitoring of the reservoir and leak monitoring are planned and have been assessed as an integrated part of the project. The programme is maintained and updated at in any case every five years to take account of changes to the assessed risk of leakage, changes to the assessed risks to the environment and human health, new scientific knowledge, and improvements in best available technology.

Since unplanned events, such as leaks of CO_2 from the sea floor can lead to impacts on benthic fauna, although not significant, regular monitoring of benthic fauna and sediment chemistry during the lifetime of the project may be considered. A regular monitoring program will give an understanding of possible impacts to the benthic communities including microbes as a result of CO_2 leakage to the seabed surface. Therefore, a monitoring program with a 5-year interval starting from the first injection, similar to the baseline survey is suggested (DHI and Rambøll, 2023a).

A post decommissioning survey will be performed to verify that the removal of all elements has been completed at the end of the project. The survey will include identification and recovery of debris within the 500 m zone around the platform.

None of the planned activities leads to significant negative impacts on environmental or social receptors and therefore no additional monitoring is required.

3.15 Mitigating measures

None of the identified impact mechanics from planned events have been assessed to result in significant negative impact on either the environmental or social receptors. Thus, no mitigation measures have been considered necessary in *Project Greensand Future*.

Measures like the soft start procedure to minimize harm to marine mammals during seismic surveys in the operation phase are considered standard procedures and described as part of the project description.

3.16 Cumulative effects

No other plans and/or projects have been identified to contribute to cumulative effects. Existing oil and gas activities in the North Sea are not expected to result in cumulative effects with *Project Greensand* Future due to distance from the project area and the characteristics of potential impacts from the current project and from other oil and gas activities. Additionally, impacts from other nearby planned projects do not temporally or geographically overlap with *Project Greensand Future*.

The baseline monitoring activities (seismicity and CO_2 leakage) are conducted in Q1-Q4 2025 and completed prior to first CO_2 injection. These activities are covered by separate application/permit. The baseline activity ends in Q4 2025 and the construction phase begins in Q3 2025, leading to a temporal overlap.

In Q1 2025 ocean bottom stations (OBS) for seismicity data acquisition baseline and the CO_2 leakage monitoring system (lander) for baseline monitoring will be deployed. OBSs and the lander will be retrieved in Q4 2025. Recovery of the baseline OBSs will require an ROV operation in which all 8 OBSs will be retrieved within 3 days. The retrieval of the baseline OBSs coincides with the deployment of OBSs for the continuous monitoring in the operation phase. Further offshore activities in Q3/Q4 2025 include installation of flowline on Nini A platform (1 month), installation of CO_2 offloading system (7 days + 1.5 days) and wireline work on CO_2 injection well on Nini A platform (1 month), which leads to an overlap in activities with the baseline monitoring activities.

Seismic survey and recovery of baseline OBSs are not planned to take place at the same time in proximity of each other. The impacts of the baseline monitoring activities are local, short-term, and temporary, and it is assessed that the risk of impact on Annex IV species and the integrity of Natura 2000 sites are not significant. Furthermore, the period where the baseline activities potentially coincide with other activities are very short (a few hours at the nearest station) and the impact is assessed negligible. Based on the above, it is concluded that there is no risk of cumulative effects from the activities.

3.17 Gaps and limitations

Overall, the gaps and limitation in assessing the impacts from *Project Greensand Future* considered to be limited. The overall assessment is considered to be sound as is it based on the best available knowledge from an area in the North Sea that is well studied. The impact paths are well known as the activities involved in the project are similar to those that take place in the oil and gas industry, therefore experience from decades of working with oil and gas can be transferred to the *Project Greensand Future*. The range of possible impacts is therefore well known and from an environmental perspective the planned part of the project and the impacts from these are considered simple. Impacts from unplanned activities always have some degree of uncertainty. For *Project Greensand Future* there has been put a lot of effort into identifying the risks to the environment and possible impacts have been modelled (oil spill and CO_2 release from blow out).

3.18 Transboundary impacts

One activity has been identified to cause potential transboundary impacts, which is the seismic survey. The seismic survey may have impacts on fish and marine mammals including Annex IV species as described in the following.

Fish

The Norwegian SVO-area “the sand eel fields” is located relatively near the Danish-Norwegian EEZ border approx. 11 km from the project area. Underwater noise from 2D/3D seismic surveys is the only impact mechanism which could potentially cause transboundary impacts. However, as soft start is applied to seismic, the expected impact ranges of non-reversible impacts are effectively reduced to 0 m. Applying soft start procedure does not remove the risk of mortal injury to larvae at a range of 0.8 km (SELcum) (3D) and 0.9 km (SELcum) (2D) from the source. This is however unlikely to have repercussions for reproduction and stock recruitment. An impact range of 1.5 km (3D) and 2 km (2D) resulting in TTS means that the Norwegian sand eel fields are not impacted.

Marine mammals and Annex IV species

Impacts in the construction phase are local and mainly related to vessels, diving operations and the use of ROV equipment using high frequency sound. Behavioural effects of marine mammals may occur up to 4.8 km from the Nini A platform and there could be a displacement of animals in Norwegian waters since the distance from the Nini A platform to the EEZ is approx. 4 km. However, since the impact is short-termed, reversible and only affects a very limited number of animals it is assessed to have negligible transboundary impacts.

In the operation phase underwater noise can derive from vessels and seismic monitoring of the reservoir. The reservoir monitoring takes place in a survey area where the closest distance is around 800 m from the Norwegian EEZ. Since the airguns used during the survey can cause avoidance behaviour for whales in a distance of up to 36.8 km there could be a displacement of animals in Norwegian waters. Since the impact is short-termed (5 days), reversible and only affects a very limited number of animals it is assessed to have negligible transboundary impacts. Likewise, the monitoring can displace seals in a 28.9 km radius, but since the distance to the Norwegian coast where haul-outs could occur is more than 100 km, it is assessed to not impact Norwegian seal populations.

4. THE OIL & GAS PRODUCTION PHASE

This chapter describes the historical activities related to installation, infrastructures and operation of the Nini A platform in the Nini field and covers the oil production phase since 2003 until cessation of production (CoP). COP is currently planned to be end of 2026. There has not been produced hydrocarbons from Nini West since 2018. The CCS project is described in chapter 5. The chapter summaries the activities related to the offshore installation and production phase to provide an overview of environmental impacts from this period.

4.1 Location

The Nini field is located in the Danish North Sea at the Siri Canyon. The Siri Canyon is a 15–20 km wide erosional depression in the Top Chalk surface stretching for about 150 km from the Stavanger Platform to the Central Graben along the Norwegian and Danish North Sea sector boundary (NO/DK EEZ border), see Figure 4-1.

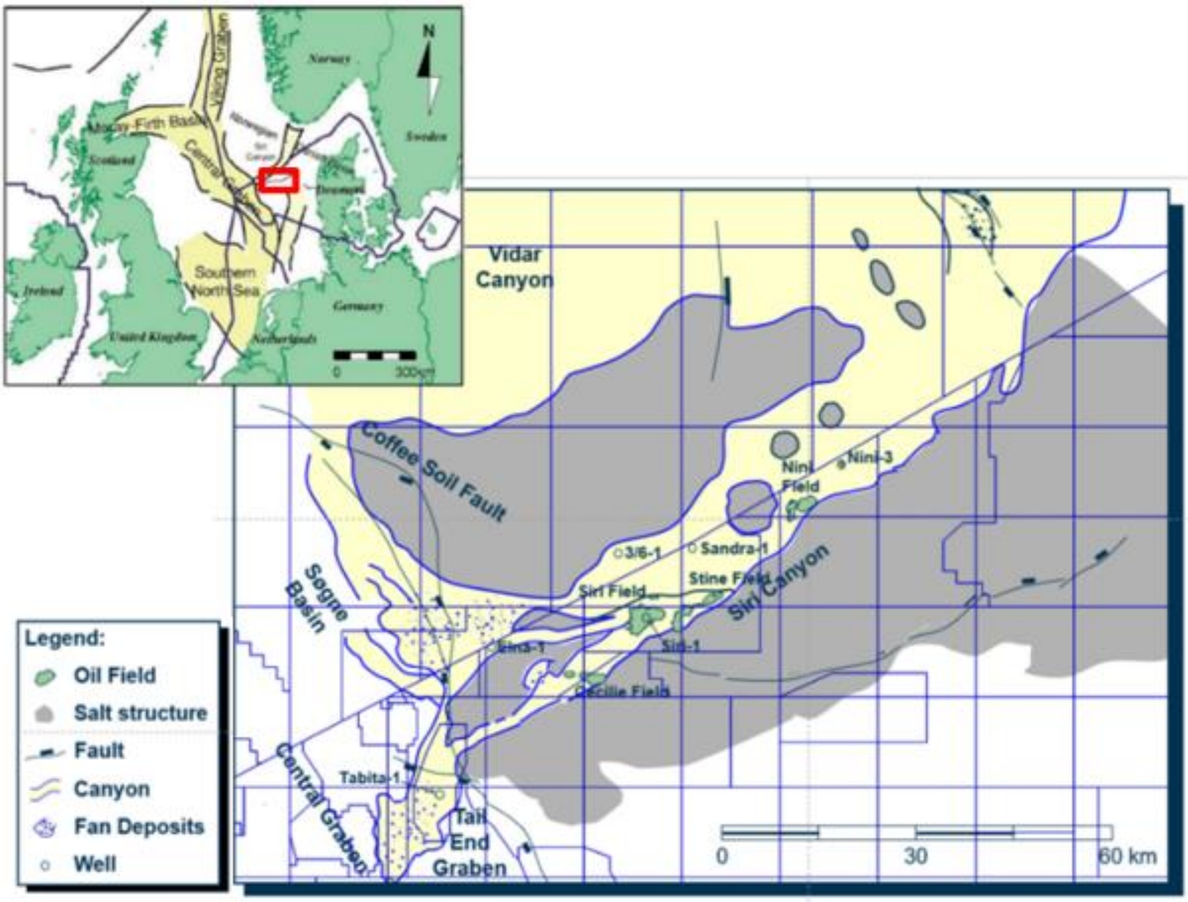


Figure 4-1 Location of the Siri Canyon and the fields within the Siri Canyon. The Nini Field is the north-eastern-most and shallowest field.

The oil fields and discoveries in the Siri Canyon (Figure 4-1) are all related to the Paleocene-Eocene succession consisting of clastic reservoirs deposited in a deep marine setting. The hydrocarbons found in the Siri Canyon fields was originally generated in the Tail End Graben to the south-west and migrated laterally along the southern edge of the Siri Canyon reaching the Nini area. The oil later became trapped in closures formed due to the salt movements in the layers below.

The Nini Field is located approximately 170 km from the Danish West Coast, and 32 km northeast of the Siri platform, see Figure 4-2. The Nini Field consists of three segments: Nini West, Nini Main and Nini East. Together, Nini West and Nini Main are produced from the Nini A platform whereas the Nini East is produced from Nini B.

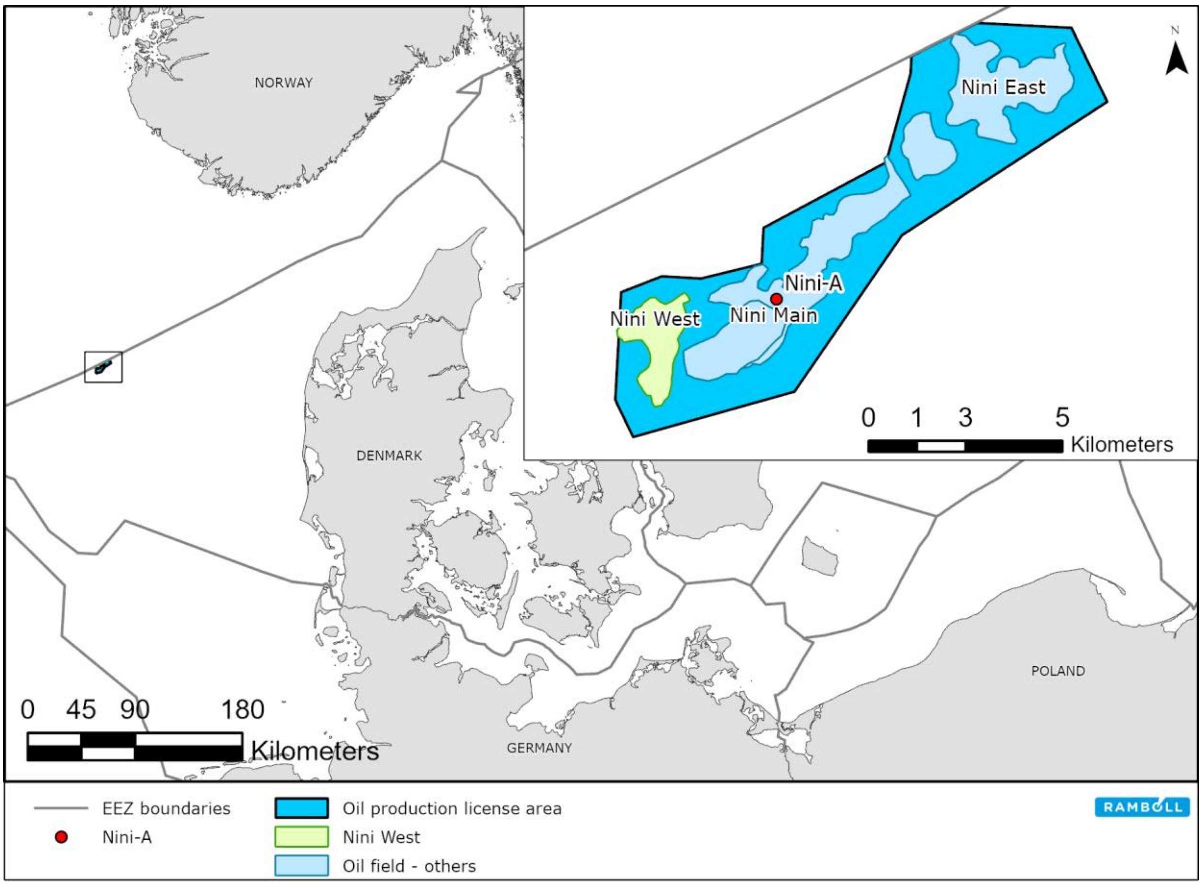


Figure 4-2 Location of Nini-A platform and the three Nini segments: Nini West, Nini Main and Nini East.

4.2 Facilities

Today the infrastructure in the Siri area consists of the main platform Siri, three normally unmanned installations (NUI), i.e. Nini A, Nini B and Cecilie, and two subsea wells with tie-backs, Stine, as shown in Figure 4-3. Only the Nini A platform and related tie-back to Siri are part of the scope in this report.

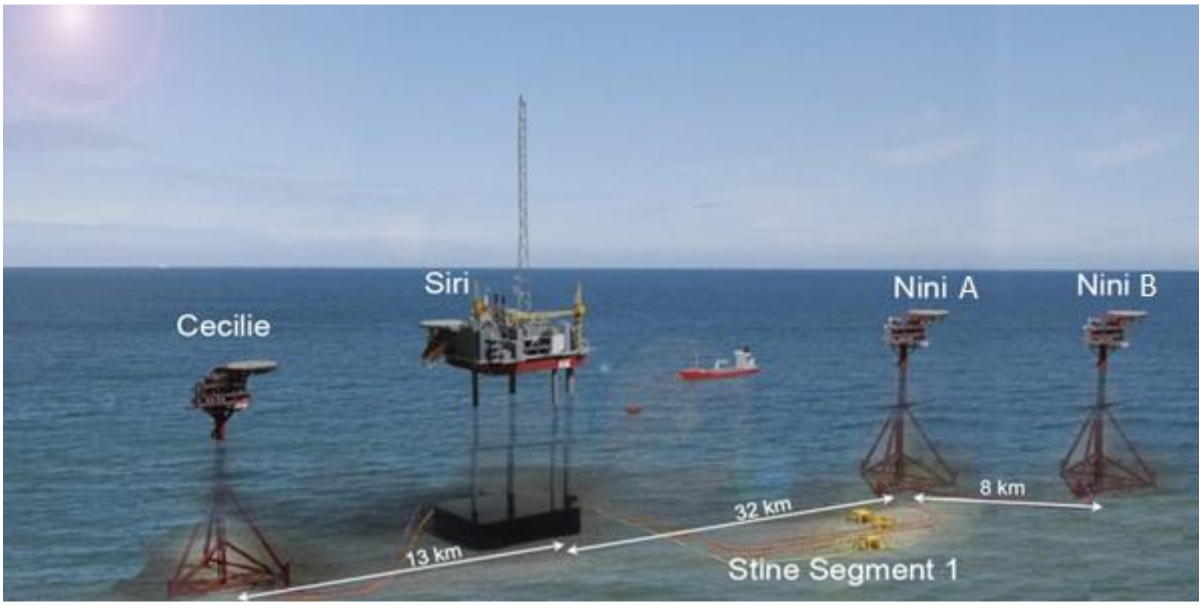


Figure 4-3 The four platforms located in the Siri area with Siri as the main platform and three satellite platforms.

The Nini A platform consists of a topside and a jacket (monotower), and reaches approximately 30 m above the sea surface, see Figure 4-4. The topside refers to the above water sections, primarily containing utilities, wellheads and Christmas trees, helicopter deck, containers, and facilities for staff. The jacket is the construction used for fastening the platform to the seabed, thus ensuring that the entire platform stays at its intended location. The platform is manned for process intervention, well service, maintenance and inspection work, but is otherwise unmanned. Remote supervision of the Nini A platform is carried out from the central control room (CCR) on Siri to where signals are transmitted via the telemetry system (Line of site, LOS). See the Decommissioning chapter for further description of the Nini A installation, including the infrastructure (subchapter 18.2 Installation for Decommissioning).

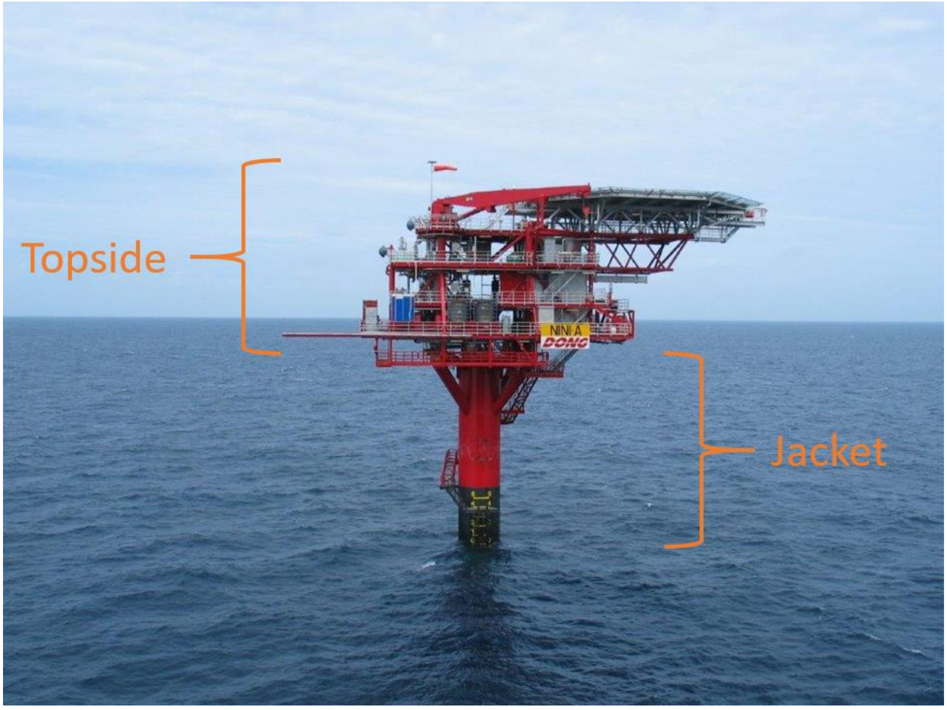


Figure 4-4 Topside and jacket extend to the seabed of the Nini A platform (water depth approx 60 m).

The platform is close to 90 m high and fastened to the seabed with three 50 m long 72" piles. All conductors and risers are located inside the centre column. The drilling template is placed underneath the centre column. The general jacket structure is shown in Figure 4-5.

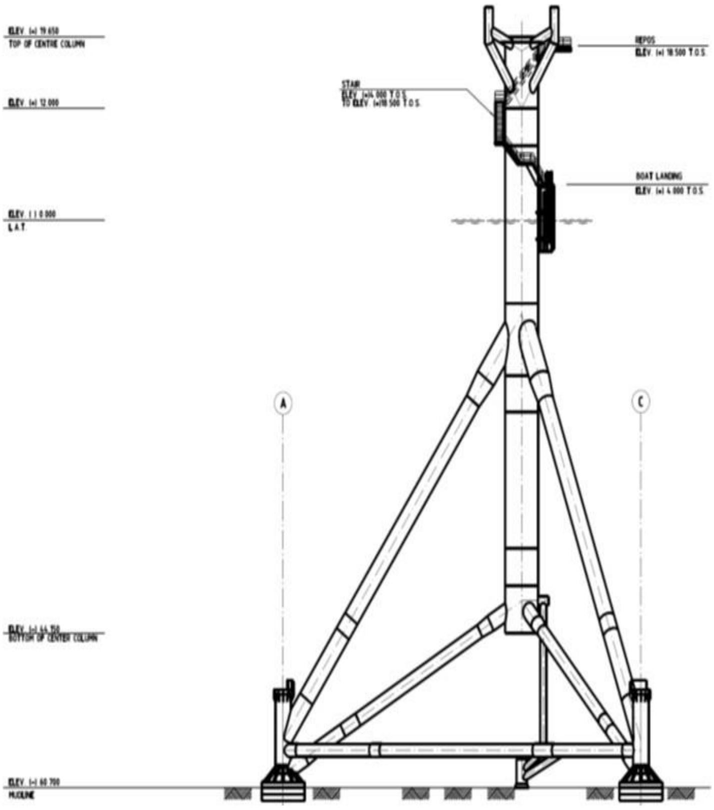


Figure 4-5 Jacket structure (general arrangement).

Wells
A total of 10 wells have been drilled from Nini A, including both oil producers and water injectors. These wells are further described in section 4.3.2.

Pipelines and raisers
In total 3 pipelines connect Nini A to Siri:
- One 10" water injection pipeline
- One 14" multiphase pipeline
- One 4" gas lift pipeline that is piggybacked (clamp) on the 10" water injection pipeline, see Figure 4-6

The pipeline lengths between Siri and Nini A are approximately 32 km.

In 2009, 6 years after Nini A was commissioned, the Nini field was further developed by the additional satellite platform Nini B. Pipelines from Nini B are routed to Nini A and the tie-ins from Nini A to Siri are utilized for both Nini platforms.

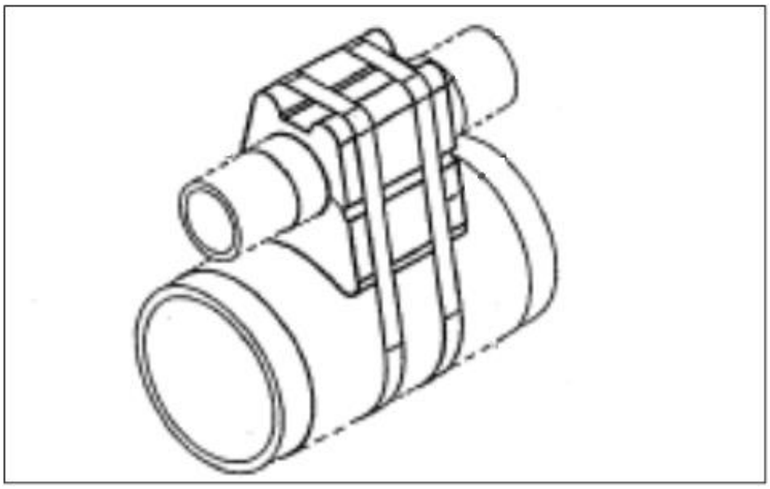


Figure 4-6 The 10" WI pipeline and the 4" gas lift pipeline (piggyback).

4.3 Historical activities

This section summaries the major production events since the installation of the Nini A and related pipelines. The main historical activities are listed in Table 4-1.

The Nini A offshore installation took place in the second half of 2003. The jacket structure – i.e., the centre pillar with three legs was sailed out to the location on a barge. A crane onboard the barge placed the jacket on the seabed above the drilling template - followed by a pile driving operation for fixation. The topside was transported to the offshore location on a barge as well and lifted on to the jacket.

As mentioned, the installed infrastructure consists further of 3 pipelines to Siri Main from Nini A. The water injection pipeline was trenched together with the gas pipe for gas lifting. The multi-phase pipeline was laid down in a separate trench. Tie-ins to platform raisers were established via one spool piece for each pipeline. Pipelines are protected with concrete tunnels (so-called GRP elements), concrete mattresses and rock dumps close the Siri and Nini A installations. Further to this pipeline crossings and bends are protected by rock dumping for prevention of seabed erosion due to the current.

An accidental event during the history of production was a rupture of the 10" water injection pipeline in 2007. The pipeline ruptured 2 km from the Siri installation due to pitting corrosion, which was a result of poor water management. The pipeline was at that time repaired and temporary put back in service for 2 years before a new pipeline was established in continuation with installation of the Nini B in 2009.

Table 4-1 Timeline of significant events of Nini A

Year	Event
Facilities and production	
2003	Nini A platform and pipeline installation (multiphase, injection water and lift gas) and tie-in to Siri
2003-2010	4 drilling campaigns, 10 wells completed
2007	Corrosion in water injection pipeline causes a rupture
2009	New water injection pipeline installed, and old water injection pipeline taken out of service.
2009	Nini B commissioned with "up-and-over" tie-in to Nini A platform /Siri
2018	Nini West (Nini A platform) production ended
2023	Greensand Pilot CO_2 injection in Nini West

4.3.1 Activities at Nini A topside facility

Prescheduled maintenance activities are required at Nini A during operation. The manning of the installation is either done by helicopter, by a vessel via fast rescue boat (FRB) or heave compensated "Walk to Work" gangway. Personnel are accommodated either on Siri or onboard the support/stand-by vessel.
The maintenance campaign activities comprise of:

- Maintenance – safety critical / non safety critical.
- Inspection of process systems and structural members.
- Fabric maintenance (painting / replacement of corroded piping and structural members).
- Minor construction projects and modifications.

During April 1st to September 30th 4 to 6 maintenance campaigns of up to 6 days duration are conducted. On top of that 2-day visits are planned every 4th week (12 times per year) for production related activities, typically fuelling of diesel generator and for chemical supplies. Whenever possible some general maintenance including well services activities are scheduled together with the monthly visits.

Finally, 5 one-day visits in average per year for repair and breakdowns are conducted. There will always be a standby vessel located at Nini A when manned.

4.3.2 Drilling Activities

Drilling activities at Nini A are related to the period from 2003 until 2010, these are summarised in Table 4-2.

Table 4-2 Timeline of drilling activities at Nini A

Year /Rig name	Well drilled
Ensco 70	
February 2003 – November 2014,	NA-1, NA-2, NA-3, NA-4, NA-5, and NA-6
Ensco 101	
April 2005 – May 2005	NA-7
Noble George	
June 2007 – August 2007	NA-8
Maersk Resolute	
January 2009 – January 2010	NA-9 and NA-10

Drilling chemicals applied during above listed well activities are presented in Table 4-3. Refer to section 4.4.3. for discharges of drilling chemicals and drill cuttings to sea.

Table 4-3 Chemical used for Nini A wells.

Year / SPUD	Well name	Use Red**	Use Yellow**	Use Green**
		Tons		
2003	NA-1	22.2	132	279
2003	NA-2	40.9	297	881
2003	NA-3	36.9	209	462
2004-5	NA-4	72.9	524	970
2004	NA-5	21.9	106	540
2004	NA-6	66.4	320	686
2005	NA-7	51.1	345	1,174
2007	NA-8	1.3	521	608
2008	NA-9*	31.4	246	546
2010	NA-10*	31.4	246	546

SPUD = start of drilling operations
* = Actual data cannot be retrieved. Values are average use for previously drilled wells
Chemicals are total for drilling, cementing, completion and testing.

**Chemicals are classified according to the Danish Environmental Protection (DEPA) colour coding system, which follows the OSPAR classification (substitution, ranking and PLONOR) and relates to the environmental hazard of offshore chemicals:

- Black chemicals are the most critical and not acceptable to be used offshore.
- Red chemicals (substitution) are environmentally hazardous to such an extent that they should generally be avoided and be substituted where possible. Substances that are inorganic and highly toxic and/or have a low biodegradation are classified as red.
- Green chemicals are considered not to be of environmental concern (so-called PLONOR-substances that ''Pose Little Or NO Risk'' to the environment)
- Yellow chemicals (Ranking) are those that do not fall into any of the above categories, i.e., substances exhibiting some degree of environmental hazard, which in case of significant discharges can give rise to concern. Substances that meet one of three criteria of low biodegradation, high bioaccumulation or toxicity are classified as yellow. If substances meet two or three criteria it will be classified as red.

4.3.3 Production operations including well services

During oil and gas production at Nini A chemicals are applied to support the operation, see typical consumption per year in Table 4-4. The well stream from Nini A is transferred in the multiphase pipeline to Siri. Due to the potential risk of wax- and scale formation, and corrosion in the multiphase pipeline, chemical application is required.

Table 4-4 Production chemicals used per year at Nini A.

Product type	Colour classification*	Yearly use (tons)
Corrosion Inhibitor	Yellow chemical	23.0
Scale Inhibitor	Yellow chemical	26.5
Wax dissolver	Yellow chemical	4.5
*See of chemical colour classification in footnote to Table 4-3.		

Further chemicals are applied as part of well intervention activities, the total usage is summarised in Table 4-5. The well maintenance includes the following:

- Regular yearly Wellhead Maintenance:
  - Typical 1 day per well per year.
  - Chemicals, a few kg of grease and < 100 litres MEG, per well.
  - All chemicals disposed in wells and covered in yearly offshore chemical reports to DEPA
- Regular ½ yearly SSSV inflow test (sub surface safety valve).
  - Typical ½ day per well per year.
  - No chemicals used.
- Well interventions from 2003 to 2023:
  - A total of only 9 wireline interventions – accumulated for all wells.
  - Typical 10 days duration per job.
  - Chemicals typical: MEG < 1000 litre/job, Friction Reducer < 100 litre/job, acid wash of SSSV job, and 1 chemical inhibition job. All disposed in wells and covered by yearly offshore chemical reports to DEPA.
  - Diesel fuel for power pack – provided by operations.

Combined the well maintenance activities are relatively limited and do not result in any discharges to sea.

Table 4-5 Well Service chemicals used during operations.

Chemical category - colour classification*	Total use 2003-2023 (tons)
Green chemicals	6.0
Yellow chemicals	1.0
*See of chemical colour classification in footnote to Table 4-3.	

Further production activities at Nini A are:

- Pigging operations: The water injection pipelines from Siri to Nini A and Nini B are cleaned once a week – no manning at Nini A required. Approximately 600 m^3 of injection water is discharged from Nini B during a cleaning operation. This water has produced water quality, cleaned at Siri and holds specification according to discharge permit. No water is discharged from Nini A.
- Diesel generator operations: To ensure power supply for Nini A operations, a diesel generator is installed.

4.4 Discharges, emissions, and impacts

In this section the major discharges, emissions and impacts from construction and oil and gas operations of the Nini A facilities are described.

4.4.1 Underwater noise

The following activities related to the construction and operation of the Nini A platform and the associated pipelines may potentially have generated noise impacts on marine organism:

- Installation of the Nini A platform incl.
  - High frequency noise from survey equipment e.g. debris survey
  - Piling to secure and anchor the subsea jacket and topside module to the seabed
- Establishment of wells
  - Machinery noise from drilling rig during drilling of wells
  - Conductor ramming
- Vessel activity
  - Machinery and propulsion noise from survey and support vessels

The legal regulation regarding protection of marine mammals has changed significantly throughout the service years of Nini A. When required an authority permit for noise emitting operations has been applied for and granted. Measures to protect marine mammals has been adhered to in line with the permit and good current practises at the time of the activity.

Survey and subsea operations (2003-COP)

Site surveys, inspection surveys and rig move surveys have been conducted around the Nini A platform. Many of them included the use of an USBL (ultra short baseline) underwater positioning system related to use of ROV (remotely operated vehicle) and other equipment to control and track their location under water. The equipment emits noise in a frequency band of 20 – 31 kHz i.e. within the detection range of harbour porpoises. The predicted sound source levels for the use of this equipment are described in section 5.4.2, along with the expected ranges for physical and behavioural impacts on marine mammals. The risk of physical injury was low as the vessel activity would have deterred individuals from being close to the activities before onset. It is most likely that there was a behavioural response up to a few kilometres away during the activity. Based on the number of expected harbour porpoises in the area, and the fact that they were able to return to the area after the survey activity had ceased, it is assessed that there was no permanent effect on individuals because of the activity. Consequently, the effect on harbour porpoise populations in the North Sea was insignificant.

Piling during jacket installation (year 2003)

The jacket of the Nini A platform has been fixed by three docking piles with a total weight of 522 tons. The piles have a diameter of 72" and have been driven approximately 50 meters into the seabed using a pneumatic/hydraulic impact hammer. The piling was initiated with low energy hammering and the duration of piling operation per pile were around 1.5 hour.
The underwater noise from impact piling is impulsive in character with multiple pulses occurring at blow rates in the order of 30 to 60 impacts per minute. Typical source levels range from SEL 170–225 dB re 1 μPa2·s for a single pulse, and peak level 190–245 dB re 1 μPa (Bailey et al., 2010). Most of the sound energy usually occurs at lower frequencies between 100 Hz and 1 kHz. Factors that influence the source level include the size, shape, length and material of the pile, the weight and drop height of the hammer, and the seabed material and depth.

Threshold levels for underwater noise that can cause physical harm to marine mammals or result in behavioural response are presented in section 11.8.3.
In-situ studies and measurements from pile driving have indicated that the risk of TTS for mid-frequency cetaceans may be confined to an area approximately 100 meters away from the piling of 1.8 m steel piles during installation of wind turbines (Bailey et al., 2010). Other studies indicate behavioural responses of cetaceans more than 20 km from the piling activity but that the animals returned to normal behaviour and numbers soon after the construction was completed (Graham et al., 2017).

The (Government of South Australia, 2012) established observation zones and shut-down zones for piling activities together with the estimated zone of behavioural response. Shut down zones defined areas where there was a risk of physical impact on cetaceans and was set at 1 km when the expected noise sound source would exceed SEL 150 dB(M) re 1 μPa^{2}s. Behavioural responses were expected up to 10 km from the piling location.
Tougaard (2021) identifies 103 dB re 1μPa as behavioural threshold limit for harbour porpoises based on several piling studies. Behavioural impact ranges of more than 10 km are reported in some of these studies (Tougaard, 2021b).

The piling at Nini A was completed within two days and the exposure of cetaceans to noise from this source was therefore short term. As described in section 10.5.4 several species of marine mammals can be encountered in the project area, however, not in significant numbers and the area has not been identified as an important feeding site. It cannot be excluded that there was a risk of physical injury to marine mammals in the immediate vicinity of the piling location. However, the risk of permanent hearing impairment was low as the vessel activity would have deterred individuals from being close to the piling. It is most likely that there was a behavioural response up to several kilometres away during the duration of the activity. Based on the number of expected marine mammals in the area, and the fact that they were able to return to the area after the piling activity had ceased, it is assessed that there was no permanent effect on marine mammal populations in the North Sea.

Drilling activities from 2003 to 2010 in four campaigns

The rotating equipment on the drilling rig and the other machinery related to e.g. energy production and drilling mud/cuttings treatment facilities will create under water noise emissions. Field studies around the drilling rig Noble Koskaya and associated support vessel Northern Seeker in the German sector of the Doggerbank have shown that activities at the rig and noise from shipping only affect the behaviour of harbour porpoise activity during rig-docking/rig departure manoeuvres (Todd et al., 2009; Todd, V.L.G. et al., 2007). The drilling noise at the well was measured at 120 dB re 1μPa, i.e., above the threshold for triggering potential change in behaviour of harbour porpoises (103 dB re 1μPa). Behavioural impacts of harbour porpoises could therefore occur during such activities. However, Bach et al. (2010) monitored harbour porpoise activity around two platforms in the North Sea using T-PODs and concluded that drilling activities in general did not affect small cetaceans (Bach et al., 2010).

Seals may potentially show behavioural response to noise levels above 160 dB re 1μPa (Tougaard, 2014). It is therefore assessed that behavioural responses would have been limited to a few hundred meters from the drilling rig.

Table 4-6 Underwater noise level at different distances from drilling rigs.

Sound levels at different distances from the source (dB re 1µPa)				References
At the source	100 m	125 m	400-500 m	
120	-	-	-	(Todd et al., 2009)
163	123	-	-	(Richardson et al., 1995)
145-190	-	-	-	(P. M. ; Thompson et al., 2010)
-	-	117	115	(McCauley, 1998)

Physical impacts on marine mammals or fish are not expected to have occurred in relation to drilling activities based on the sound levels presented Table 4-6 and the threshold impact levels described in section 11.8.3 and 11.7.3.

Conductor ramming (Between 2003 to 2010 divided in 4 campaigns)

The first section of the well casing, the conductor, is partly rammed into the seabed using a hydraulic hammer on the drilling rig. The 26" conductor is run in a pre-drilled hole and finally hammered to refusal +/- 170m true vertical depth below sea surface level, i.e. approximately 110 meters into the seabed, over a hammering period of approximately 1 hour for each well.

The noise impact from the ramming of conductor is less intense compared to the piling during the installation of the jacket due to the smaller diameter of the conductor. Nevertheless, it cannot be excluded that there was a risk of physical injury to marine mammals in the immediate vicinity of the conductor ramming site. However, the risk of permanent hearing impairment was low as the vessel and drilling rig activity would have deterred individuals from being close to the site. It is most likely that there was a behavioural response up to several kilometres away during the duration of the ramming. Based on the number of expected marine mammals in the area, and the fact that they were able to return to the area after the ramming activity had ceased, it is assessed that there was no permanent effect on marine mammal populations as a result of the activity.

Vessel activity (2003-COP)

Recent studies conducted in the Nort Sea indicate that harbour porpoises show behavioural response towards vessel traffic in 5-10% of the time even at longer distances (> 2 km) (Frankish et al., 2023). A study in the Black Sea has shown that harbour porpoises avoid vessels at a distance of 200-400 m (Bas et al., 2017). Earlier studies have documented that harbour porpoises avoid ships at distances up to 1 km, suggesting that radiated noise may incite negative reactions (Barlow, 1998; Palka & Hammond, 2001). Other whales and seals are estimated to have approximately the same avoidance distance from vessels.

A recent study from the Dan-F platform show high activity of harbour porpoise around the platform despite elevated under water noise levels (Clausen et al., 2021). This indicates that avoidance of structures and vessels depends on other factors as well. This is possibly due to increased prey availability created by the combined effect of the artificial reef formed by the underwater structure and the local protected area around all platforms where fishery is banned (Clausen et al., 2021).

Both during construction of the Nini A platform, the drilling of wells and during well service/ general maintenance, vessels have been present around the platform. Marine mammals are not considered sensitive to displacement from relatively small areas and the impact is reversible as the disturbance from vessels cease once the vessels leave the area (Dyndo et al., 2015) (Wisniewska et al., 2018). The short-term nature of the vessel activity in the area further suggests that behavioural impact on individuals would have been limited and the overall impact on marine mammal populations would have been insignificant. This is covering both the historical activities, and activities expected until the start of *Project Greensand Future*.

4.4.2 Physical footprint and physical disturbance of the seabed

Platform

The Nini A platform has a physical footprint of approx. 1,500 m^2 (the area within the three legs of the jacket). The jack-up rigs used for drilling operations at Nini A, have three spud-cans that each have a footprint of 200 m^2 on the seabed. (Bokalis Offshore AS, 2003)

It is expected that the physical footprint and sediment resuspension and deposits from the activities would have been minimal, as dredging and trenching activities were not taking place. Consequently, there would have been no significant impacts on the surrounding sediment composition or fauna as the area is homogenous and vast.

Pipelines

The pipelines used for transport of produced oil, water and gas between Siri and Nini A are all trenched. All pipelines are 31.7 km long each and are trenched to approx. 1 m depth into the seabed. The trenched pipelines do not contribute to the physical footprint as they do not take up space on the seabed. Pipeline spool pieces near the platform and pipeline crossings are protected by rock dumping or concrete mattresses.

10 concrete mattresses are installed near the Nini A platform inside the 500 m zone (DONG, 2017). Near the Siri platform, another 10 concrete mattresses cover the pipeline running between Nini A and Siri (COWI, 2023a).

Rock dumping was performed on spool ends, pipeline crossings and bends for protection and in total 1,600 m of the pipeline between Nini A and Siri is covered by rocks (INEOS, 2013). The width of the rock dumps on the pipeline is approx. 2 meters on both sides.

Trenching, rock dumping and placement of concrete mattresses result in suspension of sediment near the seabed. The baseline survey report on sediment conditions found that the physical characteristics of the sediment samples throughout the project area were highly homogenous and consisted primarily of fine sand and muddy sand (DHI and Rambøll, 2023a). Seabed intervention activities such as trenching, and rock dumping would most likely have led to dispersion of sediments with similar characteristics to those in the area where the material was deposited. The grain size distribution of the sediment in the project area is therefore not expected to have changed due to redistribution of sediments.

No planned installation of platforms, pipelines or activities that result in physical footprint or physical disturbance of the seabed will happen until the start of the *Project Greensand Future*.

4.4.3 Discharges

Chemical discharges have occurred both from produced water discharges at Siri and via discharges during drilling operation.

Produced water (2003-COP)

The production of oil, gas and water from the Nini A platform is exported to the Siri platform via the multiphase pipeline. At the Siri platform the three phases, crude oil, gas, and water are separated, and the produced water is further treated to meet discharge requirements i.e., the oil content is reduced to concentrations below 30 ppm. After treatment the produced water contains naturally occurring components such as heavy metals, traces of oil components and water-soluble chemicals that have been added to support the multiphase export and treatment process (Table 4-4).

The produced water is used for pressure support i.e., it is reinjected into the reservoir to enhance oil and gas recovery. During normal operation produced water will therefore not be discharged. Abnormal or upset conditions may result in discharges of produced water at the Siri Complex. Table 4-7 shows that in recent year approximately 1% of the ~5,000,000 Sm^3 produced water annually generated at the Siri complex has been discharged. Nini A contributes with approximately 10-20% of the produced water generated equal to a discharge of 5,000-10,000 Sm^3 per year.

Table 4-7 Produced water production from 2010-2023. The Nini A water production is included in the Siri total.

Year	Water Production (Sm^3)		Nini A fraction of Siri Total Water Production	Produced Water Reinjection Weighted Average
	Nini A	Siri Total		
2010	188,890	3,379,372	5.6%	100.0%
2011	330,504	3,380,436	9.8%	100.0%
2012	285,297	3,566,348	8.0%	100.0%
2013	153,666	1,825,716	8.4%	100.0%
2014	313,789	1,456,884	21.5%	98.7%
2015	452,693	3,815,742	11.9%	99.5%
2016	518,666	4,578,187	11.3%	99.2%
2017	367,930	4,961,566	7.4%	98.9%
2018	418,462	5,146,368	8.1%	98.9%
2019	660,347	5,798,348	11.4%	98.5%
2020	790,288	5,030,860	15.7%	98.8%
2021	888,571	4,840,833	18.4%	99.0%
2022	887,392	5,079,491	17.5%	99.1%
2023	702,127	4,234,702	16.6%	99.1%

As stipulated by the Danish Environmental Protection Agency (European Commission, 2003; Miljøministeriet, 2017) a Risk Based Approach (RBA) to Produced Water (PW) management is to be applied in accordance with the OSPAR Guidelines in support of Recommendation 2012/5 for a Risk Based Approach to the Management of Produced Water Discharges from Offshore Installations (OSPAR Agreement, 2012). The RBA is to evaluate the potential toxicity of each component present in the produced water discharge.

In 2021 NORCE prepared the latest report that presented the outcomes of the RBA for produced water discharges at Siri (NORCE, 2021). The report includes results from the Dose-Related Risk and Effect Assessment Model (DREAM) that is based on the produced water discharge volumes, the concentrations of components and their respective toxicity, and the hydrological conditions at the produced water discharge point (Rye et al., 2013). The simulation used a daily discharge of 136 Sm^3/day over a standardised 30-day period.

Chemicals that are added have been approved by the Danish Environmental Protection Agency and are ranked according to OSPAR recommendations (OSPAR, 2010). Yellow chemicals that are released with the produced water were included in the model. No red chemicals were discharged during 2021. In addition, PLONOR chemicals released in large quantities are also included in the simulations, as specified in the RBA guidelines (e.g., methanol). Chemicals used that are not discharged were excluded from the model.

The first step in the DREAM-model is the 3-dimensional fate modelling that calculates the Predicted Environmental Concentration (PEC) of all the components in the release. The fate modelling takes into account the physical properties either provided (for chemicals) or defined within the model (for the naturally occurring components) such as biodegradation rate and density. Following the fate modelling, a risk map is then generated by comparing the PEC with the Predicted No Effect Concentration (PNEC) for the components in the release. This includes the calculation of the Environmental Impact Factor (EIF) indicating the volume of water where there is potential for an environmental impact on marine organisms i.e. PEC/PNEC >1 (OLF, 2003). An EIF of 1 would indicate that the water volume where PEC exceeds the PNEC is restricted to a volume of 100x100x10 meters (Johnsen et al., 2000).

The DREAM-simulation conducted in 2021 showed that the EIF never exceeded 1 at any timepoint and was predominantly less than 0.1. The potential toxic effect of all the components in the discharged produced water was therefore confined to the water volume a few meters away from the discharge point.

During standard operation close to 100% of the produced water is reinjected into the reservoir. However, during such upset conditions up to 2,500 Sm^3 of produced water could be discharged in one day. The simulation therefore underestimates the peak daily discharge but overestimates the total discharge during a 30-day period. Overall, it is therefore assessed that the potential impact from produced water discharge at the Siri complex on marine organisms is generally restricted to a water volume less than 100 meters away from the discharge point. Furthermore, the Nini A contribution of produced water to the Siri platform was approximately 19% in 2021. Consequently, the impact from produced water originating from Nini A platform is negligible.

As presented in Table 4-7 the volume of produced water has increased from 2010 to 2021. The volumes of produced water have decreased since then and a 99 % reinjection rate is expected to continue until end of 2026 or the COP. Consequently, the RBA report from 2021 would be reflecting the highest potential impact related to the discharge of produced of water from the Siri complex and the Nini A platform both historically and until COP.

Drilling discharges (2003-2010)

During the drilling of the 10 wells at Nini A in the period from 2003 until 2010, the chemical discharged to sea were as seen in Table 4-8. The major part of chemical discharges to sea are in the green category, and thereby having low toxicity and low impacts on the marine environment. The more toxic compounds (red and to some extend the yellow chemicals) are typically left in the well and not discharged to sea.

Table 4-8 Chemical discharges per Nini A well.

Year / SPUD	Well name	Discharge red	Discharge yellow	Discharge green	Discharge cuttings
		Tons			
2003	NA-1	3.1	0.0	90	309
2003	NA-2	3.0	3.0	415	1,073
2003	NA-3	1.0	0.0	82.0	250
2004-5	NA-4	3.0	0.0	149	463
2004	NA-5	1.3	0.0	207	313
2004	NA-6	3.1	0.0	91.0	375
2005	NA-7	2.0	8.0	361	320
2007	NA-8	0.0	0.2	44.0	no data
2008	NA-9*	1.7	1.1	144	345
2010	NA-10*	1.7	1.1	144	345

SPUD = start of drilling operations

*) Actual data cannot be retrieved numbers are average of consumptions on previous drilled wells
Discharged cuttings are all WBM cuttings - drilling of top hole sections

Impact on sediment composition

The benthic fauna and physio-chemical composition of the seabed sediment in the Nini field were investigated as part of the baseline survey for the Greensand Future project (DHI and Rambøll, 2023a). The baseline survey was conducted in July 2022 using ROV and Van Veen sediment sampler and included 24 stations distributed along two transects stretching between 50 m and 3500 m northeast and southwest of the Nini A platform (section 10.4).

Chemical analyses included assessment of the following indicators:

- Organic content: Total organic carbon (TOC), total nitrogen (TN) and total phosphorus (TP)
- Metals: Silver (Ag), Aluminium (Al), Arsen (As), Barium (Ba), Beryllium (Be) Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Mercury (Hg), Manganese (Mn), Molybdenum (Mo), Nickel (Ni), Lead (Pb), Antimony (Sb), Selenium (Se), Tin (Sn), Thallium (Tl), Vanadium (V), and Zinc (Zn)
- BTEX: Benzene, Toluene, Ethylbenzene and Xylenes
- NPD: Naphthalene, C1-Naphtalene, C2-Naphtalene, C3-Naphtalene, C1-Phenantrene, C2-Phenantrene, C3-Phenantrene, Dibenzothiophene, C1-Dibenzotiophene, C2-Dibenzo-tiophene, C3-Dibenzotiophene
- 16 PAHs (polyaromatic hydrocarbons) (EPA16): Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benz(a)anthracene, Chrysene, Benz(b)fluoranthene, Benz(k)fluoranthene, Benz(a)pyrene, Dibenz(a,h)anthracene, Benzo(ghi)perylene and Indeno(123cd)pyrene
- THC: Total Hydrocarbons (C12 – C35)
- Aliphatic hydrocarbons (C5 – C35)

Compared to measurements at reference stations the sediment concentration of the above-mentioned contaminants can be regarded as low and close to background levels. The physical and chemical composition of the sediments in the project area are characterized by a very high degree of homogeneity between the sampled stations. Consequently, the Greensand baseline survey did not find trends or characteristics that could indicate increased contamination as a result of past activities and discharges. There were elevated levels level of barium, which is related to the use of barite in drilling mud, confirming that drilling discharges had taken place in the area. According the

OSPAR barite is categorised as a PLONOR/green substance (Posing Little or No Risk) and barium is considered to be biological inert and generally non-toxic to marine organisms. Barium is therefore primarily a historical tracer of drilling discharges rather than an indicator of harmful contaminations levels (DHI and Rambøll, 2023a). The above results and findings are further described in section 10.4.

Benthic fauna

The dominant groups of benthic fauna were Bristle worms as the largest group with 39 species, Molluscs with 20 species, Crustaceans with 12 species and Echinoderms with 10 species. The all-dominant species were the small tube-dwelling bristle worm with > 2,000 individuals / m^2. The burrowing brittlestar counted over 200 individuals / m^2. The composition of the benthic fauna was considered of species well-known to the North Sea and although oil and gas activities have taken place for decades, the current seabed is relatively natural and undisturbed. Sampling showed a high similarity of benthic fauna for all stations except one, where the substrate was coarse sand instead of muddy sand.

The video images from the ROV indicated a relatively varied epibenthic community. However, larger organisms (necto benthos) such as the brittle star *Ophiura albida* and decapods where rarely observed. Instead, smaller species such as the mud brittle star (*Amphiura filiformes*), small cumaceans and small burrowing sea urchins (*Echinocardium cordatum*) seemed to thrive. There were extensive signs in sediment surface suggesting high activity of burrowed organism (infauna) confirming the analysis of the sediment samples.

There was no significant change in species composition related to distance from the Nini A platform. Consequently, there was no indication of impact on the benthic fauna related to historical drilling discharges from the Nini A platform. The methods and findings of the of the benthic fauna survey are further described in section 10.4. Based on the colour and smell of the sediment, the oxygen conditions seemed good. And since the chemical conditions did not indicate any notable contamination in the area.

The physiochemical conditions in the investigated area are further described in section 10.4.

Additional wells for oil and gas production are not planned for Nini A. Consequently, there will be no further drilling discharges in the period from 2024 to 2026. After the expected cease of production in 2026 the wells related to oil and gas production will be plugged and abandoned (P&A). The P&A activities are described in chapter 18.

Wellhead Maintenance and Well intervention (2003-COP)

As described in section 4.3.3 there have been yearly Wellhead Maintenance activities on the Nini A platform and occasional well interventions if required. The used chemicals are described in Table 4-5. All the chemicals are disposed into the well and are not discharged to sea. All the chemicals used are ranked as Green or Yellow and environmental impact related to the use of these chemicals have not been identified.

Yearly wellhead maintenance will continue in the period from 2024 to COP. Well intervention will be conducted if required but are not expected or planned.

4.4.4 Solid waste

Any waste generated at Nini A are transported to shore where it is recycled, incinerated, or landfilled in accordance with applicable legislation. Further all vessels follow the standards and procedures for the management and control of ships' ballast water and sediments in accordance with the Ballast Water Management Convention, which ensure all waste is shipped to shore and treated according to current legislation. This is valid for both the historical activities and until the start of *Project Greensand Future*.

As part of the drilling activities as described previously, drill cutting waste is generated, which is shipped onshore for further handling. The 10 wells at Nini A have generated the waste amounts as listed in Table 4-9.

Solid waste generated from decommissioning is described in chapter 18.

No marine litter is therefore expected from the project.

Table 4-9 Cuttings shipped to onshore from the different Nini A wells.

Year / SPUD	Well name	Cuttings shipped onshore (Tons)
2003	NA-1	439
2003	NA-2	873
2003	NA-3	769
2004-2005	NA-4	968
2004	NA-5	607
2004	NA-6	1,183
2005	NA-7	845
2007	NA-8	no data
2008	NA-9*	632
2010	NA-10*	632

SPUD = start of drilling operations

* = Actual data cannot be retrieved numbers are average of consumptions on previous drilled wells
Cuttings shipped to onshore is OBM cuttings – mainly lower top-hole section and in reservoir

4.4.5 Emissions

Construction

During the construction phase, emissions are assumed to be relatively similar to the estimate given for the decommissioning phase covering pipelines removed by reverse reeling, where the topsides and jacket are removed by a single-lift method, Table 4-10.

Table 4-10 Emissions during construction from installation of platform and pipelines.

CO_2 [ton]	NO_x [ton]	SO_x [ton]	CH_4 [ton]	nmVOC [ton]
22-23,500	350-400	7-8	1-2	35-38

Operation

During operation a number of activities are required to ensure safe operation, these activities and related fuel consumptions are listed in Table 4-11. The activities are further described in section 4.3.

Table 4-11 Type of activity and fuel consumption required during operation per year

Operation	Type	No./year	Days per unit	Fuel consumption [m^3/day]	Comments
Power generation	Generator	Fuelling with 5m^3 diesel per month			
Maintenance of topside	Standby vessel	4-6	6	3	~5 campaigns of 6-day duration
	Helicopters*	8-12	6	0.15	
Fuelling and production activities	Standby vessel	12	2	3	Every 4. Week
	Helicopters*	24	2	0.15	
Maintenance of equipment and breakdown repair	Standby vessel	5	1	3	
	Helicopters*	10	1	0.15	10 helicopter supported campaigns of 1 days duration
*Helicopters are operating 0-15 min/trip, Fuel: Kerosene/Jet A					

The above activities correspond to the yearly emissions listed in Table 4 11. Further during the year of well developing at the Nini A field results in emissions as listed in Table 4 12. From the presented in this section it's obvious that the construction and decommissioning phase results in the largest emissions. In the phase from 2024 until the start of *Project Greensand Future*, only the emission as listed in Table 4-11 will have an impact on air quality and climate.

Table 4-12 Greenhouse gas and air pollutant emissions related yearly fuel consumption during operation

Vessel	CO_2e [tons]	NOx [tons]	SO_2 [tons]	nmVOC [tons]
Power generation	167	3.7	0.09	0.09
Maintenance of topside	273	5.5	0.15	0.27
Fuelling and pigging operations	218	4.4	0.12	0.22
Maintenance of equipment and breakdown repair	87	1.8	0.05	0.07
Total	**744**	**15**	**0.40**	**0.64**

Table 4-13 Air emissions related to drilling activities at Nini A.

Year / SPUD	Well name	CO_2 produced gas/oil flaring [ton]	CO_2 emission [ton]	NO_x emission [ton]	SO_2 Emission [ton]
2003	NA-1	527	2,228	45.5	6.7
2003	NA-2	n/a	1,085	21.3	2.6
2003	NA-3B	542	1,200	23.9	2.9
2004-5	NA-4	0.0	3,254	63	6.8
2004	NA-5	0.0	1,464	27.1	3.5
2004	NA-6	0.0	2,254	44.4	5.5
2005	NA-7	0.0	2,899	57.2	7.0
2007	NA-8	0.0	2,449	48.4	4.2
2008	NA-9*	0.0	1,944	38.4	4.7
2010	NA-10*	n/a	1,944	38.4	4.7

SPUD = start of drilling operations * = Actual data cannot be retrieved numbers are average of consumptions on previous drilled wells. n/a = data not available. Emissions are from rig, supply vessels helicopters and stand by vessel.

4.4.6 Light

Safety lights have been present on Nini A since installation. Furthermore, vessels used for installation of the platform and pipelines, maintenance and safety inspections are illuminated while operating in dark hours.

Light can have an effect on fish, marine mammals and birds as these can be attracted to illuminated areas which allow for better prey detection. Illumination may also disorient migratory birds. Since the impact from the illuminated vessels are temporary and the permanent safety lights from Nini A are of low intensity, the impact from light is expected to have been negligible. No impacts are expected to occur from 2024 until the start of *Project Greensand Future*.

4.4.7 Resource use

As part of the Nini A facilities a number of materials are used for construction of the jacket, pipelines and wells, this consist mainly of metals, concrete and polymers. Metals are the dominant fraction, especially steel in different alloys. The resource use is further specified in the chapter covering decommissioning in chapter 18.

4.4.8 Restricted zones

Restriction- and safety zones were implemented around the Nini A platform and along the pipeline from Nini A to Siri. The platform is surrounded by a 500 m safety zone where normal marine traffic is prohibited to prevent ship collision. On each side of the pipeline is a 200 m restriction zone where fishing and anchoring are prohibited. These restriction- and safety zones can have an impact on fisheries and marine traffic. The Nini A platform is located in an area with relatively low fishery intensity (see section 10.9). Major shipping lanes are situated far from the Nini A platform and minor shipping lanes are also not located near the platform (see section 10.7). Thus, it is not expected that restriction- and safety zones have had a significant impact on fisheries or marine traffic. Neither is it expected that there will be an impact on these receptors from 2024 until the start of *Project Greensand Future*.

4.4.9 Accidental discharges

Only one spill event during the history of production have impacted the environment. This was a major rupture of the 10” water injection pipeline in 2007, which resulted in a release of maximum 3.000 m^3 produced water. However, the quality of the released produced water is similar in quality to the water release to sea at Siri during a production upset, see also section 4.4.3. The produced water released at the Siri platform is treated to meet discharge requirements i.e., the oil content is reduced to concentrations below 30 ppm. Consequently, the impact from produced water released at the rupture is negligible.

5. PROJECT DESCRIPTION

The goal of *Project Greensand Future* is to use depleted reservoirs in the Nini West field for storage of captured CO_2. *Project Greensand Future* plans to provide a total storage capacity of 2.4 million tons CO_2 with injection of 0.3 million tons per year (mtpa) over 8 years. The project covers transportation from Esbjerg (quay side) to the Nini A platform and injection of CO_2 into an existing well in the Nini West reservoir. This chapter will provide an overall project description including a timeline and a description of the location, geology, and composition of the seabed at the chosen storage site. Subsequently a description of the existing facilities and new equipment required for the execution of the project is provided. The project description covers the construction phase, operation phase and decommissioning phase as well as the technical monitoring of reservoirs. Specifications of the required resources for the various phases is quantified, as detailed as possible, including both use of materials and vessels.

The project schedule is based on the Storage Site Application (incl. PDO & MMV plan) was submitted on the 5th of February 2024. It is expected that the investment decision is made in Q4 2024, and the first injection is initiated by Q4 2025. The subsequent operation phase is 8 years and post closure of site injection monitoring plan is approx. 20 years. The decommissioning phase is not shown in the time schedule. Figure 5-1 shows the project schedule covering the project activities during the construction phase.

The proposed time schedule for the *Project Greensand Future* up until first injection includes the following major milestones:

- Storage Site Application (incl. PDO, MMV plan and EIA) sent 05-02-2024
- Updated EIA sent July 2024
- Updated MMV plan submitted November 2024
- Updated EIA sent Q4 2024
- Expected final investment decision (FID) in Q4 2024
- Further offshore activities in Q3/Q4 2025:
    - Installation of flowline on Nini A Platform. Duration ~ 1 month.
    - Installation of CO_2 offloading system. Duration ~ 7 days installation + 1.5 days flange assembly.
    - Wireline work on CO_2 injection well on Nini A Platform. Duration ~ 1 month
- Seismic baseline survey Q4 2025. Duration ~ 5 days
- Deploy ocean bottom stations (OBS) for continuous seismicity data acquisition Q4 2025. Duration ~ 2 days
- Deploy CO_2 leakage monitoring system (lander) for continuous monitoring Q4 2025. Duration ~ 2 days
- Operation start in Q4 2025 with expected first injection 01-12-2025.

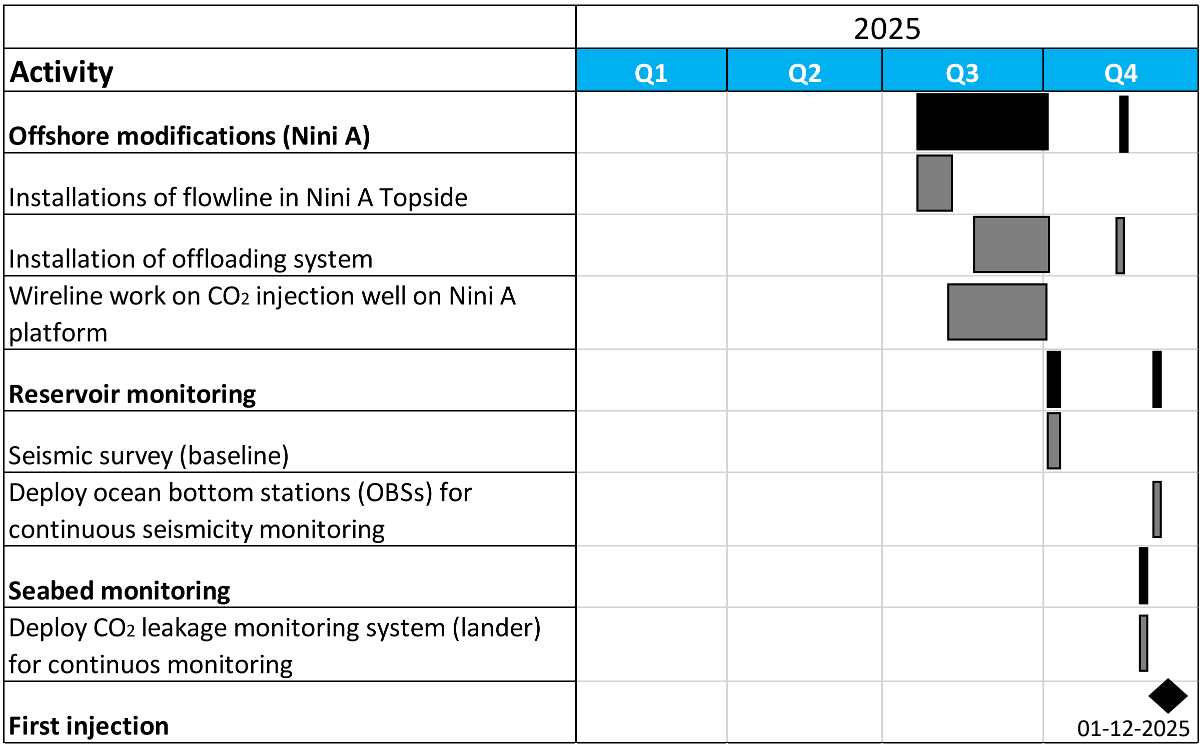


Figure 5-1 Project schedule.

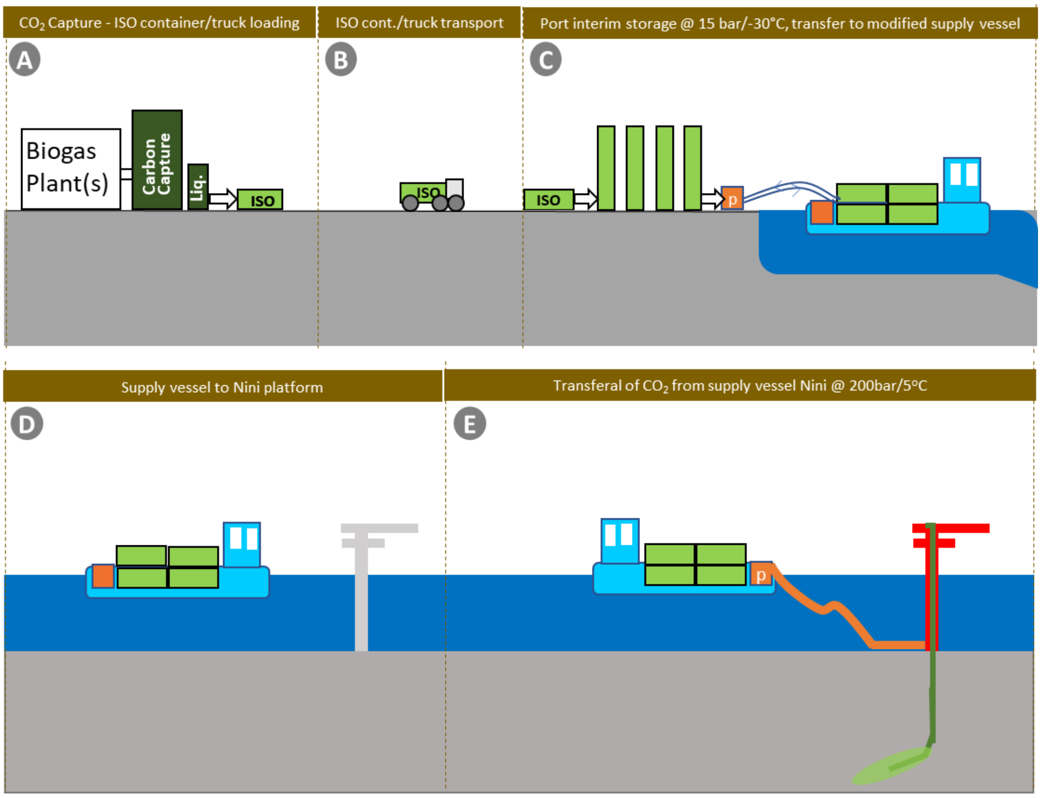


Figure 5-2 CCS chain from capture of CO_2 to injection at the storage facility. This EIA covers transportation from quay side to the platform and storage of CO_2.

The overall CCS chain is presented in Figure 5-2. The EIA is limited to storage (described in section 5.4) and transportation from quay side (described in section 5.5.1).

5.1 Location

The project area is defined by the Nini West storage complex shown in Figure 5-3, and the coordinates in Table 5-1. The location assessed as part of this EIA is further described in section 4.1.

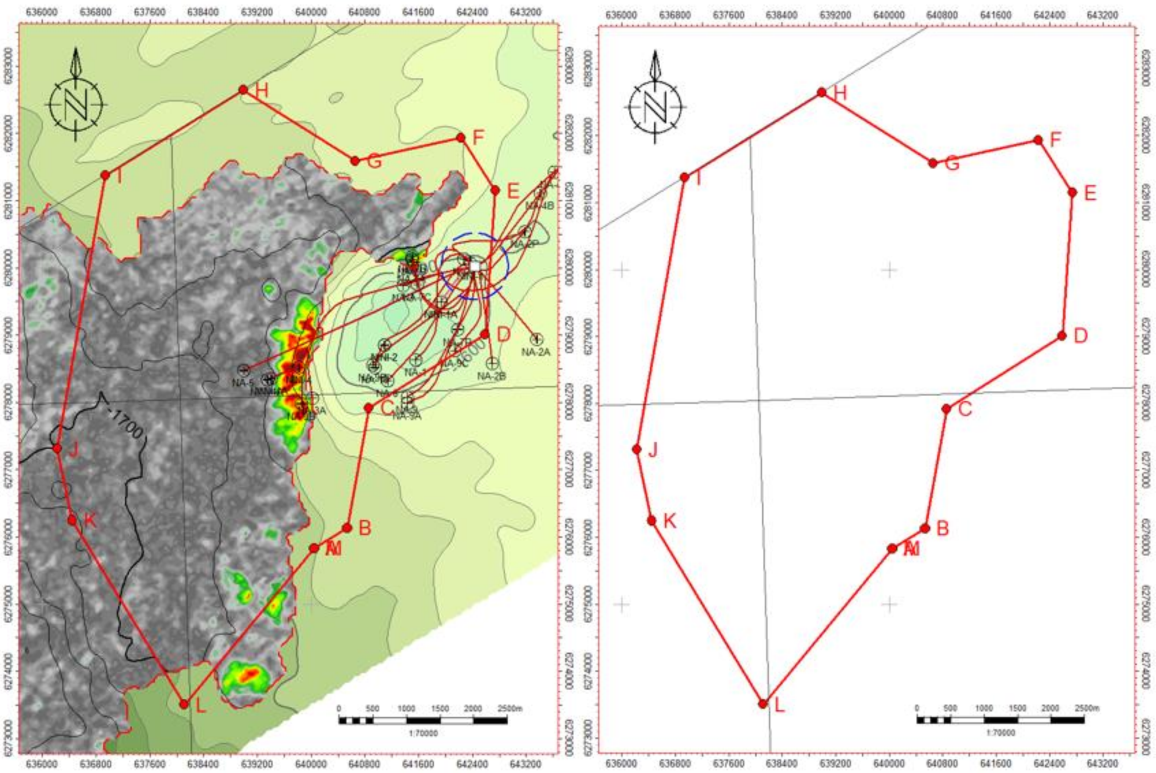


Figure 5-3 Project area (red line). Nini A platform is illustrated with a white square and the safety zone is the blue circle.

Table 5-1 Application area coordinates Lat/Lon and UTM (ED50-UTM31)

Name	Lat	Long	UTM X	UTM Y
A	56 36 16.134526 N	5 16 52.927322 E	640047,51	6275828,13
B	56 36 25.439131 N	5 17 22.185029 E	640536,71	6276132,36
C	56 37 22.744718 N	5 17 44.537764 E	640858,47	6277916,44
D	56 37 56.245391 N	5 19 28.233061 E	642590,34	6279011,48
E	56 39 5.206348 N	5 19 41.166657 E	642738,29	6281150,56
F	56 39 31.142155 N	5 19 13.057782 E	642232,54	6281936,02
G	56 39 21.651591 N	5 17 39.888074 E	640656,24	6281589,27
H	56 39 57.624745 N	5 16 4.056438 E	638987,89	6282646,94
I	56 39 18.687305 N	5 14 1.107797 E	636934,41	6281374,62
J	56 37 8.056267 N	5 13 11.587902 E	636222,02	6277309,27
K	56 36 33.479901 N	5 13 22.697793 E	636446,00	6276246,61
L	56 35 3.046639 N	5 14 55.132636 E	638113,33	6273502,61
M	56 36 16.134526 N	5 16 52.927322 E	640047,51	6275828,13

5.1.1 Geology

The Nini West storage complex is defined as consisting of the Nini West storage unit (Frigg Member reservoir) and the overlying primary and secondary seal (Horda and Lark formation). The Nini West storage unit (reservoir) is composed of sandstone that was deposited as deep marine sediments within the geological period of Paleocene-Eocene (65-33 million year ago). The sandstones formed reservoirs for oil and gas for millions of years and were the target for the Nini West oil field producing oil from 2003-2018. Following the stop of oil production from Nini West the reservoir was used for injection of water until March 2024. The reservoir sandstone is overlain by several thick shales i.e., very fine-grained rock composed mainly of clay minerals, about 900 m thick which can be divided into the primary seal and the secondary seal. These seals were deposited as marine mudstones and belong to the Eocene to Miocene geological periods (5-55 million years ago). The sealing units have a large regional extent and can be found in the North Sea and onshore Denmark.

The primary seal is defined as the shale unit that occurs above the Frigg reservoir and extends up to the first porous and permeable beds in the Mid Lark Formation. The primary seal in the Nini West Field is about 340 m thick (1,780-1,450 m). The Secondary seal is defined as starting from the base of the first porous and permeable beds in the Mid Lark Formation. In the Nini-4 legacy well this is from 1,450 m. The upper boundary is at the base of a sandy bed at 830 m, and it is about 550 m thick.

Overburden layers above the Nini West storage complex starts from a depth of approx. 800 m below the surface of the seabed and consists mostly of sandy and gravelly glacial deposits. The storage site is well known from 3D seismic data, well data including cores and the production history of the Nini West Field.
Nini A and B platforms with the wells, pipelines and elevation time is shown in Figure 5-4. The elevation time is an indicator of the depth of the top of the main reservoir. The grey areas show the initial oil fields, and the blue line shows a cross section of the Nini reservoirs with the colours indicating the initial water saturation (Figure 5-4).

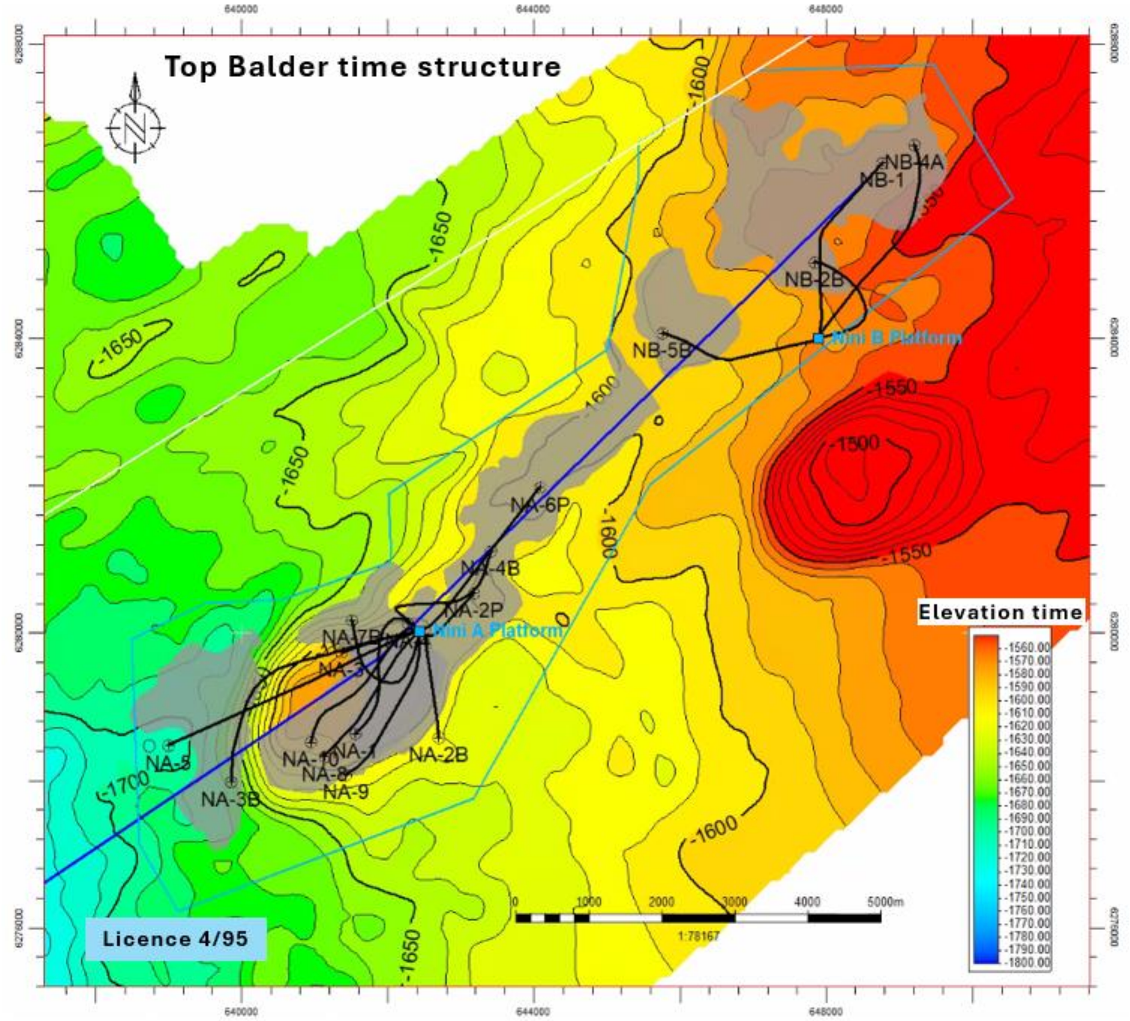


Figure 5-4 Map of the Nini field on the Top Balder time surface. Light blue squares show the location of the two platforms, Nini-A and Nini-B.

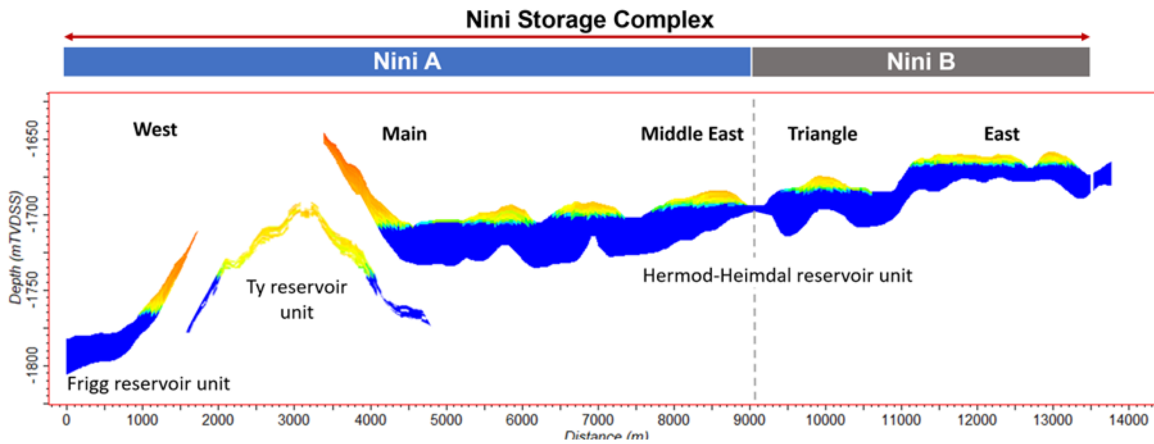


Figure 5-5 Cross-section showing the main reservoir units and initial water saturation in the Nini West, Nini-Main, and Nini East Segments. Blue = fully water saturated, green/yellow = transitional saturation, red/orange = fully oil saturated.

5.1.2 Characterisation of Reservoir and Seal

Seal

The sealing units are characterised by greenish grey shale and its integrity has been evaluated through semi-regional assessment and analysis of the actual cap rock formation at the Nini West site. Petroleum exploration and field development have secured a comprehensive database with full 3D seismic coverage as well as additional data including petrophysical logs and core section data from the cap rock. The sealing capacity in the Nini west area was studied by the Geological Survey of Denmark and Greenland (GEUS) and results have been published by (Petersen et al., 2022).

The primary seal in the project area has been tested and shown to be able to effectively hold back supercritical CO_2 ($scCO_2$) (Holmslykke et al., 2021a). In situ data on the seal's ability to retain CO_2 includes measurements that show no or very limited upward migration of gases from the Nini West area. This data suggests that the seal is able to effectively contain any gases that may be present in the area. In addition, there is no evidence of any migration of gases through the cap rock, and the presence of gas in the overburden above the cap rock is thought to be from non-moveable in situ generated biogenic gases (Petersen et al., 2022). These are generated from organic matter already existing in the sedimentary layers.

Mud gas logs shows that only very limited vertical gas migration has occurred from the reservoir into the basal part of the seal (Petersen et al., 2022). The key conclusion from the seal studies is that the general very low gas concentrations and the gas composition in the seal complex demonstrate that the cap rock has an efficient sealing capability that area-wise extends beyond the Nini West Field.

To further test the suitability of the primary seal for use in CCS, geochemical analysis of the mudstone seal when exposed to CO_2 was conducted (Holmslykke et al., 2021b). These tests showed that the seal is chemically stable and does not significantly react with CO_2, indicating that it is effectively chemically inert.

Other studies have also shown that the seal has very low permeabilities, which means that fluids or gases have difficulty passing through it. This, combined with its high sealing capacity, makes the primary seal in the project area an effective barrier to CO_2 migration and preventing leakage through to the seabed.

5.1.3 Reservoir

A reservoir is a term that describes a geological layer capable of storing fluids being either water, oil, gas or CO_2. A reservoir is typically composed of sand size grains and have porosities i.e., free space between the grains in the order of 20-30 % of the rock volume. It is also permeable meaning that the pore space is well connected and that the fluids and gasses can move within the rock. This is a requirement for oil to be produced but also for CO_2 to be injected.

The Nini West reservoir lies approximately 1,750 m below the seabed with wells operated from the Nini A platform. The placement of the legacy wells can be seen in Figure 5-6. As the reservoir has been used for hydrocarbon extraction, the properties of the reservoir are well known. Production stopped in 2018, and the legacy wells in the Nini West reservoir are further explained in Section 5.2. The Nini West reservoir has a high well injectivity that allows for a large flow into the reservoir, and thereby allows for an efficient process flow.

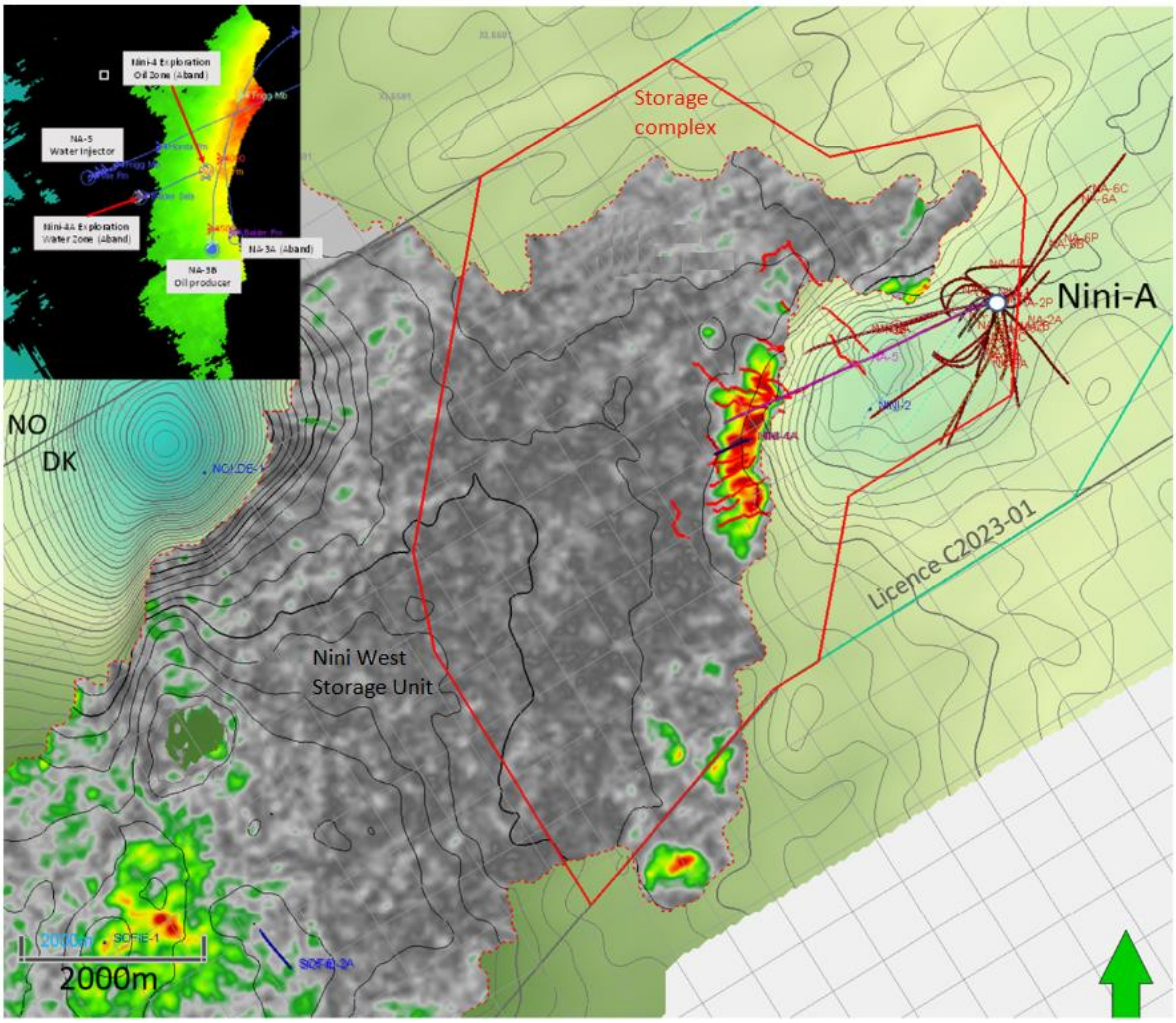


Figure 5-6 Extend of the Nini West storage unit (grey) and the outline of the storage complex (red polygon). Well trajectories of production and injection wells (Table 5-2) from the Nini-A platform is indicated by lines from Nini A.

The properties of the geology and the reservoir has been confirmed by pilot injection in the Nini West reservoir, when 4,000 tons CO_2 was injected in Q1 2023. The pilot injection demonstrated:

- No changes to the reservoir were observed during and after injection
- Injectivity performance was stable throughout 7 injection cycles
- Focused (spot) seismic data confirmed CO_2 location in reservoir at the end of the injection

The Nini reservoir is well described from seismic and well data and has been modelled as part of the production history. The production data has continuously been used to optimize the model matching the pressure development in the reservoir. The history matched simulation model forms the basis for the predictive simulation model for the CO_2 storage project. Based on this model the pressure development during and after injection and the migration of CO_2 in the subsurface can be predicted.

As part of the *Project Greensand Future* the migration of CO_2 in reservoir has been modelled, see Figure 5-7. The model illustrates the migration during the 8 years of injection at a rate of 0.3 million tons CO_2 per year and until 100 years after first injection. After 100 years the CO_2 is assessed to be kept mainly in the former oil trap and only migrated slightly into neighbouring areas of the reservoir.

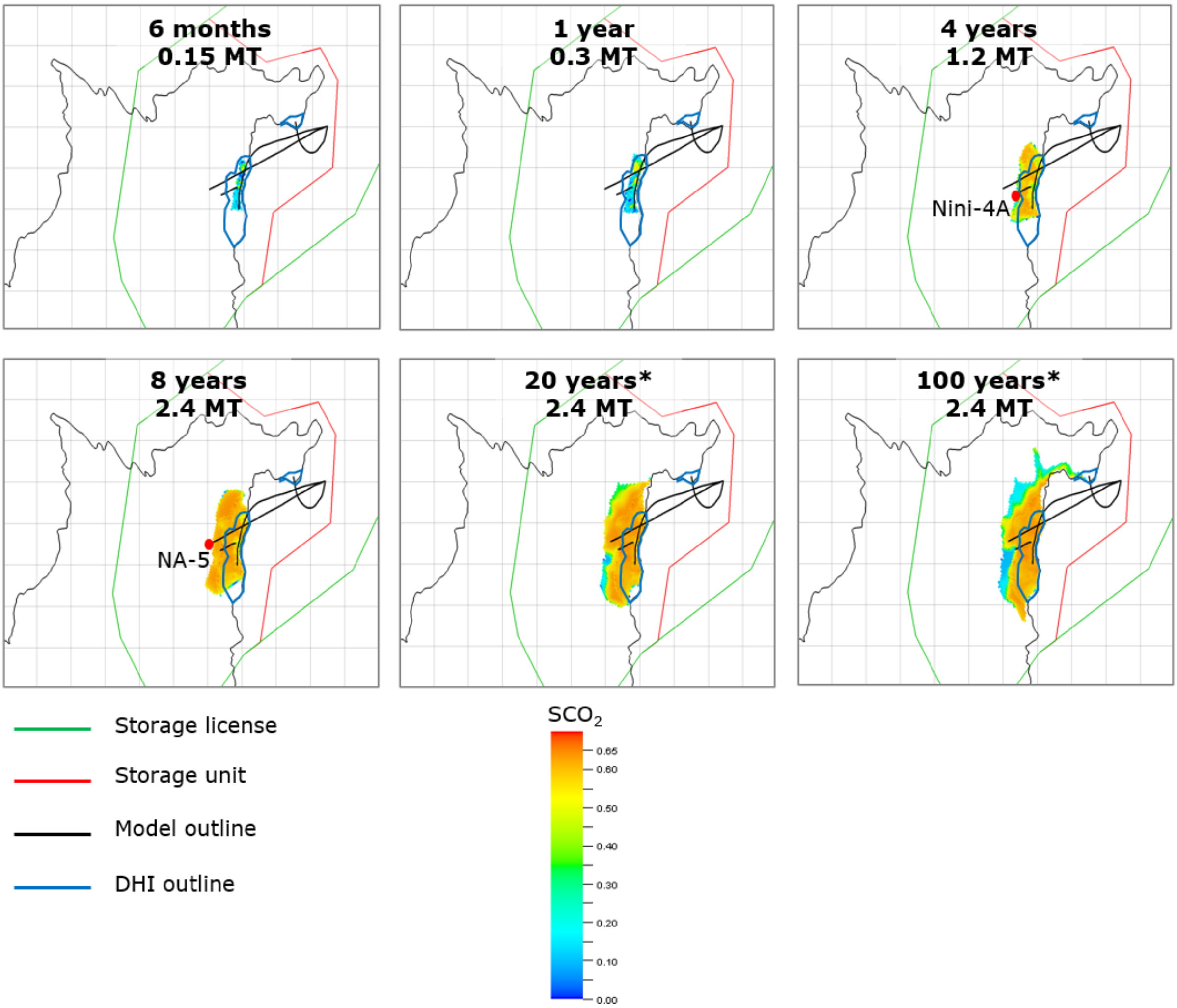


Figure 5-7 Predicted migration of CO_2 in reservoir during and after the 8-year period of injection (SCO_2=Supercritical carbon dioxide).

5.2 Existing facilities

The existing facilities at Nini A used for the CO_2 injection project is as described in section 4.2. Nini A has 4 legacy wells in the Nini West reservoir. Legacy wells are, in accordance with the ISO Standard guidance (ISO 27914, 2017), defined as "the pre-existing wells within the area of review of a CO_2 storage project that were drilled for a different purpose than CO_2 injection or monitoring of the respective CO_2 storage project". The Nini West legacy wells connected to the Nini A platform are shown in Table 5-2. The existing facilities require minor modifications as part of *Project Greensand Future*, see next sections.

Table 5-2 Legacy wells to the Nini West reservoir.

Name	Well type	Well Status	Reservoir
Nini-4/4A	Exploration	Plugged and abandoned	Nini West (Frigg)
NA-3A/B	Oil producer	Inactive (not used since 2018)	Nini West (Frigg)
NA-5	Water injector	Inactive (not used since March 2024)	Nini West (Frigg)
NA-7D	Oil producer	Frigg reservoir plugged	Nini West (Frigg)

5.3 New facilities

When converting the existing facilities to be used for CO_2 storage rather than oil extraction, a significant amount of equipment can be repurposed. This includes the platform itself as well as existing well infrastructure. An overview of the process can be seen in Figure 5-8, with detailed descriptions of each step described in section 5.4. For *Project Greensand Future*, only limited modifications are required to allow connection of the new offloading system to the well-setup. The offloading system will be new and is further described in section 5.4.1.

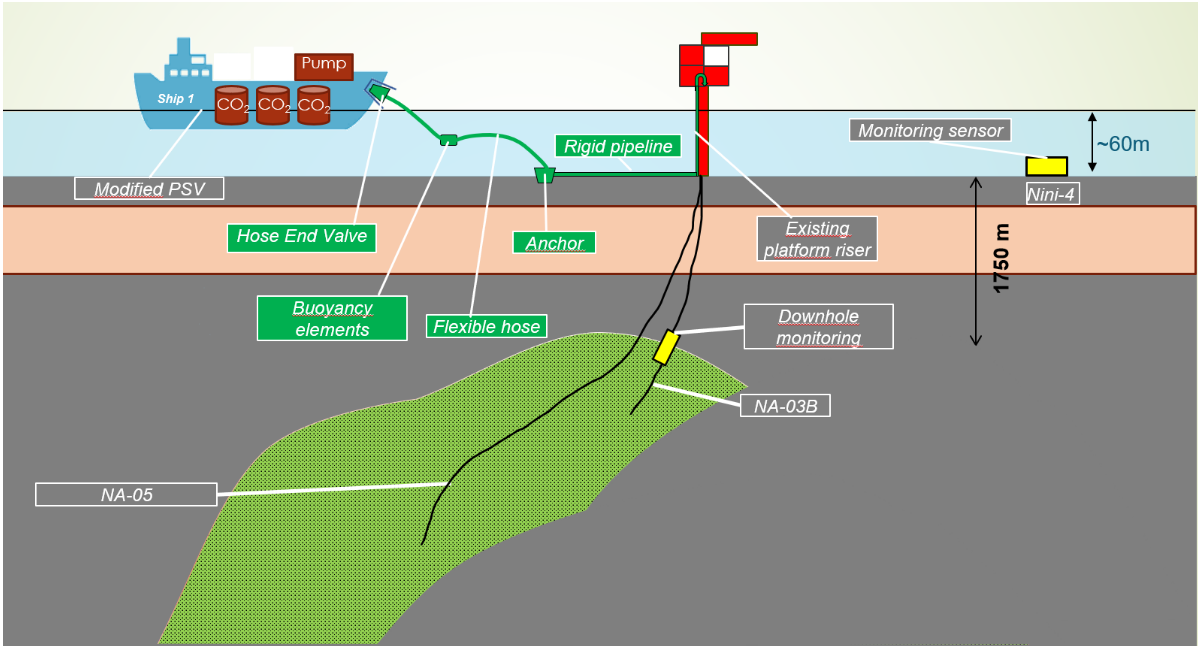


Figure 5-8 Conceptual illustration of the CO_2 storage process (not to scale). Liquified CO_2 onboard a vessel is transported to the Nini A platform through a newly constructed offloading system (green labels). From here, the fluid is pumped to the underground reservoir via a well.

The following (new) facilities are assumed to be outside the *Project Greensand Future* scope and thus are not part of the project scope from an EIA perspective:

- Capture, liquefaction, and purification of CO_2.
- Modification of PSV for CO_2 transport (CO_2 vessel).
- Any onshore scope related to transport of CO_2 from emitter to vessel loading, including any harbour modifications.

5.4 Construction phase

Detailed design, procurement and fabrication is planned in 2024. The execution phase is scheduled to commence in 2025 including offshore installation, commissioning and initiating the CO_2 injection. The main components to be installed in this period are described in this section.

To adapt the existing equipment to its new function, some minor adaption to current above-water components, is required. The existing platform-riser will be reused, just replacing the flowline that connects the new offloading system to the injection well. This activity will take approx. one month, and a support vessel will be present.

Several vessels will be present during the construction phase. Vessel noise from large dynamic positioning (DP) vessels is described as a mainly low frequency broadband sound, with tonal components generally ranging from 30 Hz to 3 kHz, and with sound pressure levels reported between 121 to 197 dB re 1 µPa at 1 m. The dominant frequency range is mostly between 100 to 1,000 Hz (Center for Marine Acoustics, 2023; MMO, 2015; Talisman Energy (UK) Ltd, 2006; Wyatt, 2008; Xodus, 2014). Noise from DP vessels does not vary significantly with speed, as a DP system relies on all thrusters working simultaneously, regardless of whether the vessel is moving or holding station. However, noise levels will vary with weather conditions, which affect a vessels ability to maintain position, since these factors change the amount of thrust required to keep the vessel in position. In moderate wind, sea state and current; the noise levels can be expected to be lower than in more challenging conditions.
Vessels operating within the 500 m safety zone are required to use DP. Vessels used for seismic surveys (section 5.5.4), deployment and maintenance of equipment used for the CO_2 leakage monitoring system (section 5.5.3) and seismicity monitoring (section 5.5.4) will also use DP during the activities.

5.4.1 New offloading system and monitoring equipment

A new offloading system is required for transferring the CO_2 from the vessel to the Nini A platform. All installations, in connection to the offloading system, will be within the existing 500 m zone at Nini A, located at: 56° 38.45' N, 005° 19.27' E. This concept can be seen in Figure 5-9 to Figure 5-12. All figures are at concept level not to scale and indicative only for describing solutions and principles.

As seen on figures the offloading system will consist of a flexible hose, a rigid pipe and anchor. The flexible hose has buoyancy elements to create a lazy wave configuration and anchors to keep a bottom stability. The anchor and tether will provide on-bottom stability for the lazy wave configuration, and also act as a protection against excessive loads at the tie-in point at Nini A in the event of an accidental drift-off case.

The flexible hose will be 4” and around 120 meter in total. At the end of the hose is installed a Riser End Valve to ensure failsafe closing. The valve and flexible hose will be connected to a floating messenger line connected to a buoy.

The riser handling equipment set-up onboard the vessel is illustrated in Figure 5-12. The set-up on the vessel is not part of the EIA scope.

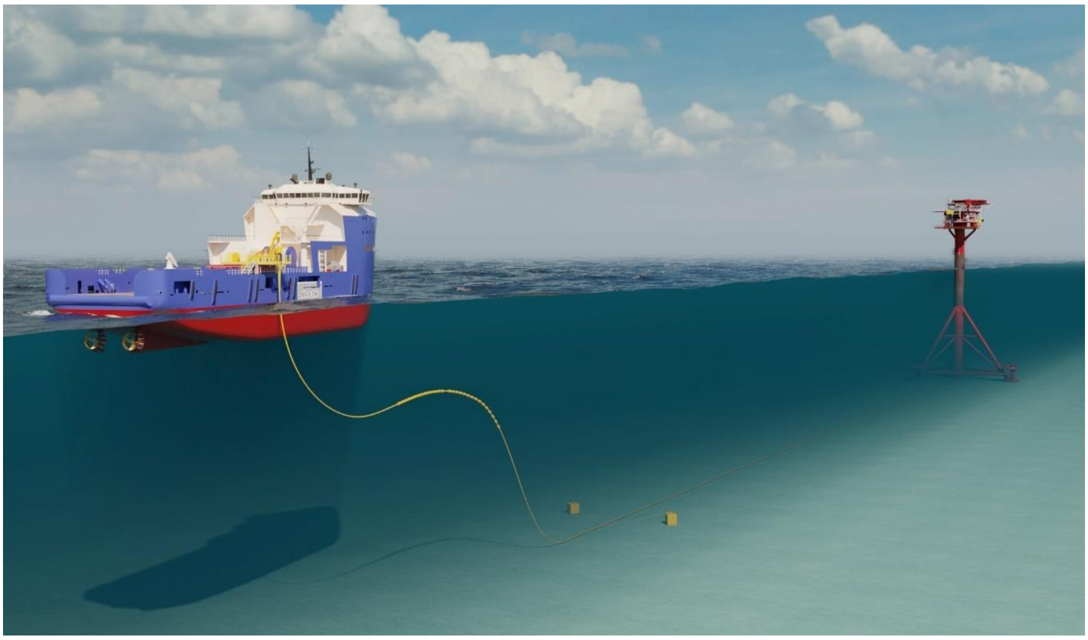


Figure 5-9 Illustration of an offloading system. The vessel is connected to the riser.

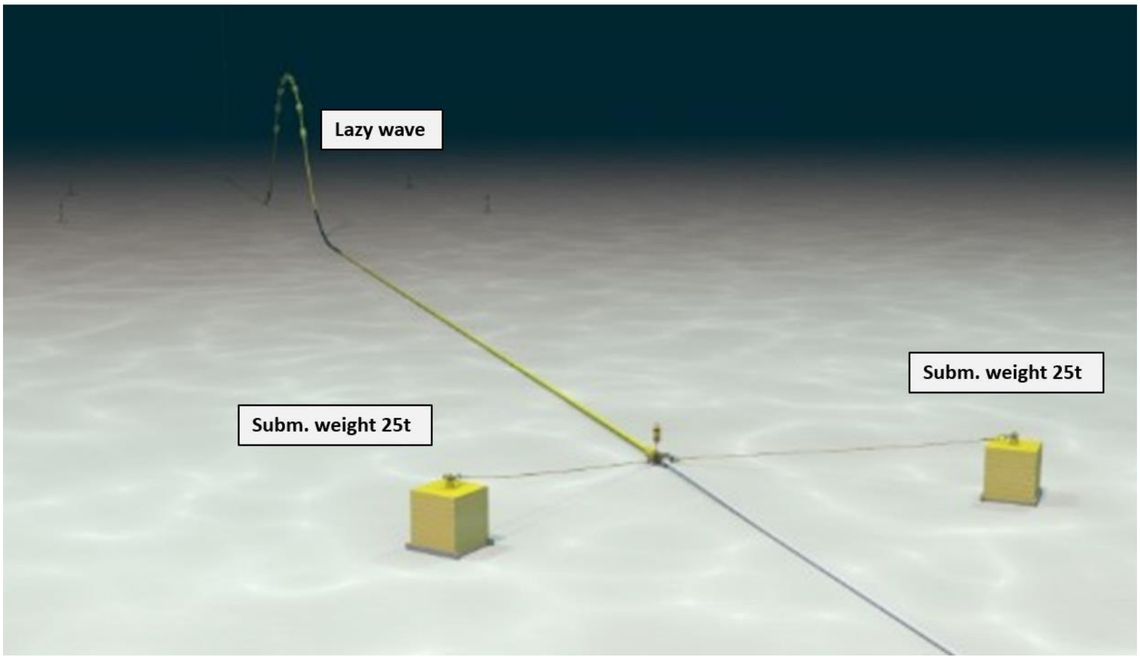


Figure 5-10 Anchors at flange between flexible riser and fixed subsea pipeline.

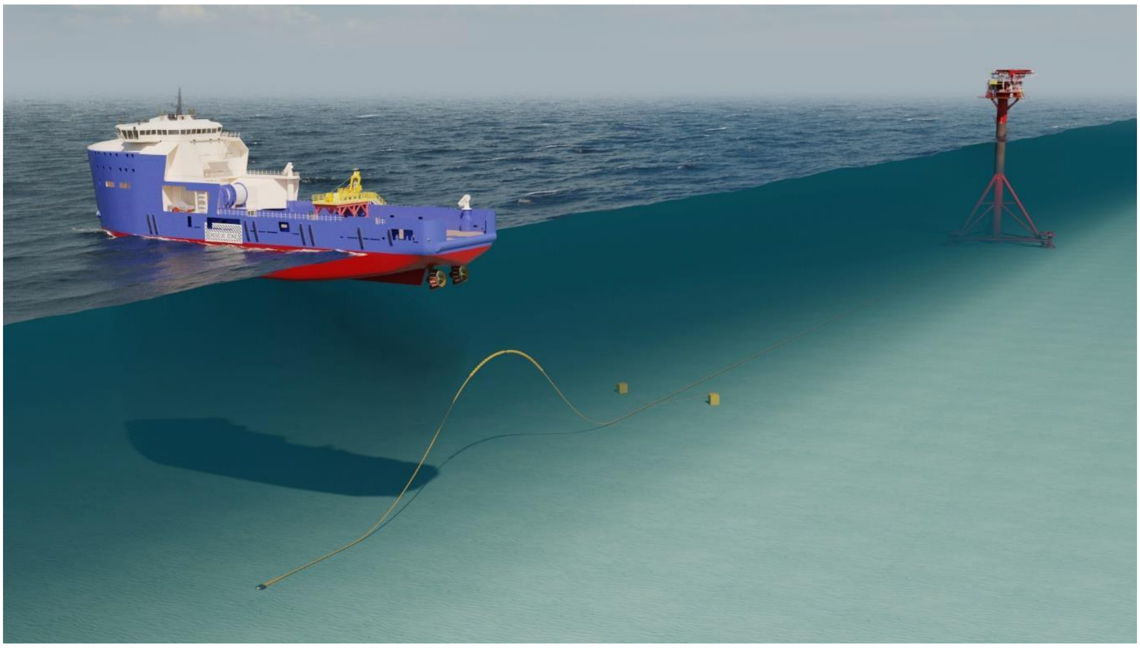


Figure 5-11 Riser in idle configuration (lazy wave).

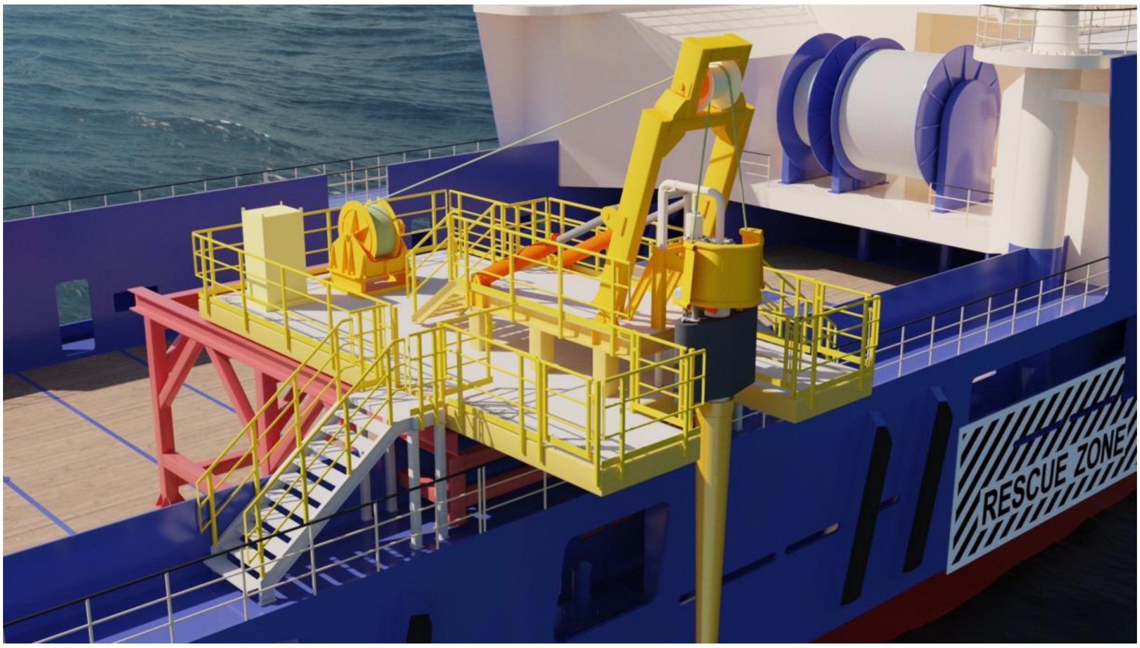


Figure 5-12 Riser Handling Equipment with HEV and Riser connected.

The offloading system's rigid pipeline will be covered with concrete mattresses to protect against falling objects. In Figure 5-13, the loading operation of concrete mattresses at a harbour is shown as well as how the concrete mattresses are installed on top of the pipeline. For installation of concrete mattresses, a vessel will be needed for an expected duration of 3-4 days, this is a relatively standard offshore operation. The installation of the concrete mattresses is included in the combined 7 + 1.5 days installation of the offloading system.

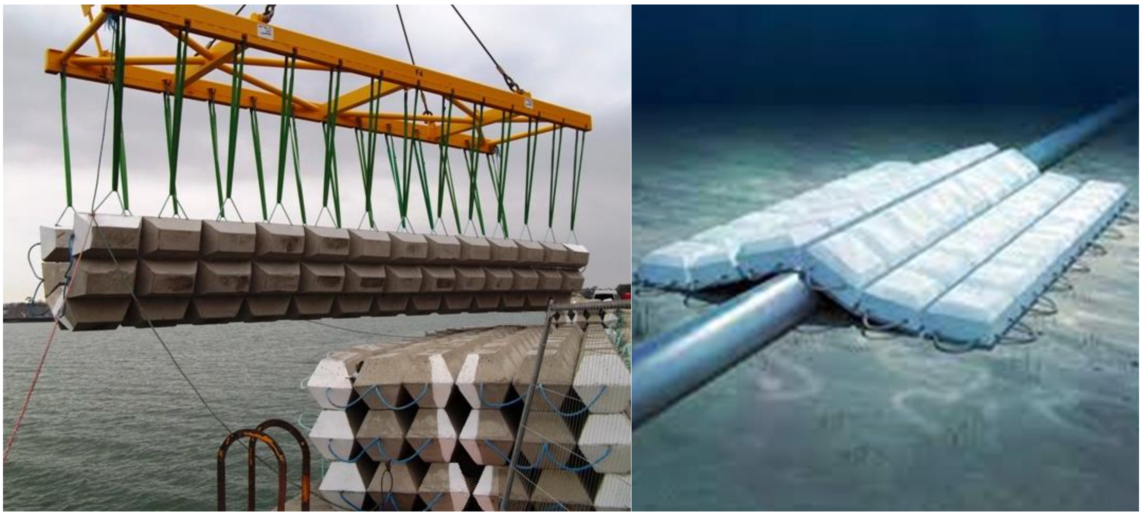


Figure 5-13 Illustration of concrete mattresses. Loading on vessel (left) and installed covering a pipeline (right).

An overview of the offloading system is found in Figure 5-14, and this can be compared with the existing facilities within the 500 m zone at Nini A in Figure 5-15.

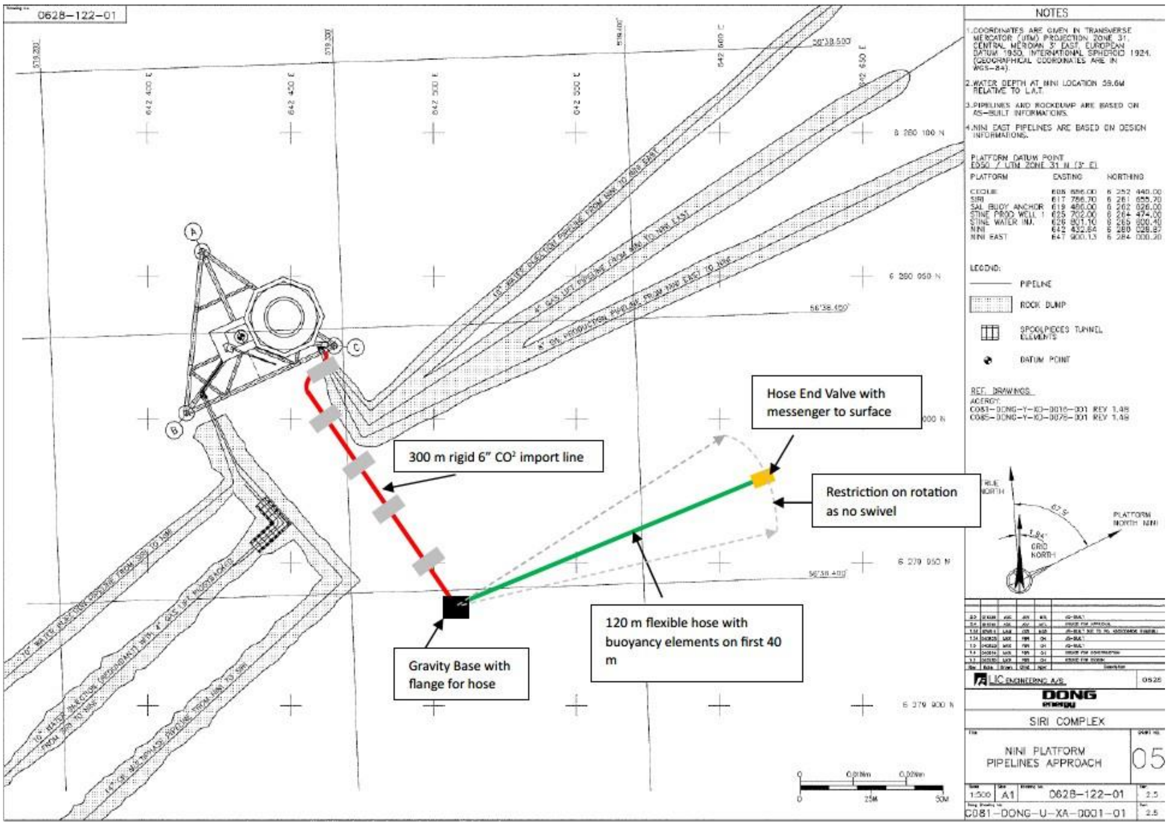


Figure 5-14 Schematic illustration of an offloading system and connection system.

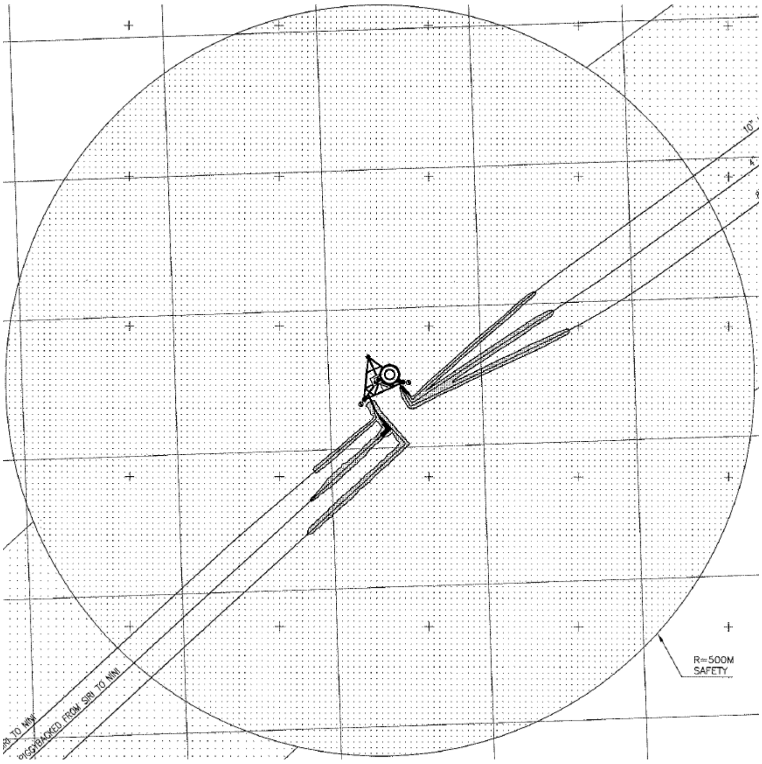


Figure 5-15 Existing infrastructure within the 500-meter safety zone at Nini A.

To verify the integrity of the offloading system, all piping and/or hoses will be pressure tested onshore. A leak test is performed offshore in accordance with NORSOK or similar standard. The leak test will be performed as a risk reducing measure to reveal any leakage as early as possible. As medium for the leak test, seawater mixed with corrosion inhibitor and fluorescent chemicals will be used (further detailed in 5.7.1). The final step before commissioning is dewatering and drying of the offloading system's elements by discharging the seawater and airdrying the system.
Annual inspection of the offloading system will be performed using an ROV, as described in section 5.5.3.

For the assessment, the occupied seabed areas (footprint) are summarized by the installed components, see Table 5-3. Note that certain installations (pipeline and concrete mattresses) overlap and are placed on top of one another. The CO_2 leakage monitoring system is installed on a metal frame, referred to as a lander, and further described in section 5.5.5 (seabed monitoring). Ocean bottom stations (OBS's) will be installed on the seabed for seismicity monitoring in Q4 2025. Their location for monitoring will be reassessed continuously as part of the monitoring plan. The activities require a support vessel.

The sea surface is also occupied in some areas due to the activities of the project. In the construction phase the installation of the offloading system requires activities within the 500-meter safety zone of the Nini A platform. Further, the lander for CO_2 leakage monitoring will be marked by one navigation buoy to mark the area (no restriction area). The seismicity and seismic systems will not result in additional restricted zones.

Table 5-3 Overview of the footprint of the installed structures on the seabed during the construction and operation phase.

Description	Dimensions* (m)	No. of units	Footprint	Comments
Anchor (pipeline end)	L: 2.2 x W: 2.2 x H: 2.2	2	10 m^2	See illustration of anchors in Figure 5-10. 25 tons each.
Concrete mattresses	L: 6 x W: 3 H: 0.3	45	810 m^2	See illustration in Figure 5-13
Pipeline	Ø: 0.168 x L: 100-300	1	79 m^2	The 6-inch pipeline will be covered. Area overlapping with concrete mattresses. 300 metres applied in estimate
CO_2 leakage monitoring system	Ø: 75 cm, H: 1.5 m	1	0.5 m^2 + 1 m^2	The diameter of the lander is 0.75 m with a height of 1.5 m above the seafloor. One anchor holds the lander and its marker buoy.
Ocean bottom stations (OBS)	Ø: ~50 cm	max. 8	~1-2 m^2	Seismicity monitoring with ocean bottom stations, system under development.
Optional ocean bottom nodes (OBN)	Ø: ~50 cm	8-30	~1-6 m^2	2D seismic surveys will use streamers or OBNs. Optional spot seismic surveys will use OBNs. OBNs are dropped onto seabed during the seismic campaigns and retrieved after.
*Dimensions: Best estimate at current engineering stage.				

5.4.2 Diving operation

During installation of the offloading system, divers will be present to facilitate and support this operation. An ROV will also be present during this operation. The divers and ROV will be deployed from a support vessel. All activities will take place over a period of 5 days in June to September. All activities will be conducted within the 500-meter safety zone of the Nini A platform.

Operating frequency and sound source levels of equipment, that is expected to be used during the installation, is presented in Table 5-4. Sound source levels have been estimated using data from the product specifications. The support vessel is equipped with an ultra-short baseline (USBL), which is an underwater acoustic positioning system, that uses a transceiver to track subsea targets such as ROV/diver/dive bell/dynamic positioning beacon. The targets are equipped with a transponder (beacon, WSM 6+ transponder Sondardyne type 8370). For this operation the transceiver is a Sonardyne type 8142 and the transponder (ROV) is a Sonardyne type 8262. The transponders operate at frequencies of 20-34 kHz and sound source levels of approx. 169 dB re 1 µPa2s@1m (SPLrms (re 1 µPa m) ~ 178-180 dB, SPLpeak (re 1 µPa m) ~184 dB).

Some of the equipment listed in Table 5-4 will operate at very high frequencies outside the hearing range of marine mammals (i.e. above 180 kHz) and is therefore not further assessed in this document.

Table 5-4 Equipment used during diving operation and their respective noise emission levels.

Source	Model (reference)	Equipment location	Operating frequency	Sound source level SEL ss (re 1 µPa2s@1m)	Frequency within marine mammal hearing range
Magnetometer	GMA 1000	ROV	N/A	-	N/A
Depth Sensor	Valeport Mini IPS	ROV	N/A	-	N/A
Side Scan	Edgetech 2205	ROV	600-1600 kHz	-	No
Multibeam Echosounder	EM2040D MBES	ROV	200-400 kHz (configuration planned for 340 kHz)	-	No
Doppler Velocity Log	Sonardyne Syrinx	ROV	400/600 kHz	-	No
Velocity Sensor	Valeport Sound Mini SVS	ROV	2.5 MHz	-	No
Altimeter	Kongsberg 1007 Altimeter	ROV	120-675 kHz (675 kHz to be used)	-	No
Obstacle Avoidance Sonar	Blueview M900	ROV	900/2250 kHz	-	No
Transceiver	HPT 5000/7000 USBL Transceiver Sonardyne Type 8142	Vessel	20-34 kHz	169 dB	Yes
Transponder	Nano Transponder Sonardyne Type 8262	ROV	20-34 kHz	169 dB	Yes
Transponders	Wideband Sub-Mini 6+ (WSM 6+) transponder Sonardyne Type 8370	- DP positioning beacon (seabed) - dive bell transponder - 3 diver transponders	20-34 kHz	169 dB	Yes

Slow start procedure

A slow start procedure will be applied for diving and ROV operations. Slow start is used to minimize underwater noise impacts on marine mammals and fish. A 5 minute and 15-minute slow start was modelled, where one single individual vessel transponder signal (ping) is emitted every 20 seconds for 5 or 15 minutes respectively. The ping is released at a low power setting. The 15-minute slow start is used for diving operations i.e. scenarios with multiple transponders on divers, ROV and supporting equipment. The calculated slow start periods are taking into account that the presence of the vessel will deter the animals to be at least 100 meters away from the sound source. For a detailed description it is referred to the underwater noise modelling report in the Appendix.

5.4.3 Well preparation for CO_2 injection

The well intervention in NA-3B (November 2023), have confirmed that the well is in healthy condition and can be used for CO_2 injection.

For the *Project Greensand Future* there will be a well intervention scope to further prepare the NA-3B for CO_2 injection. A wireline intervention is a simpler form of well intervention and does not require a drilling rig as it would be the case with a well workover. The well intervention equipment will be rigged up on the Nini A platform and connected to the well and is expected to include the following:

NA-3B Wireline intervention:

- Install Packer with Injection (Non-Return) Valve in tubing at Production Packer depth. The purpose of the packer is to provide a seal against the tubing wall for the non-return valve. The non-return valve will prevent flow back into the upper part of the tubing (Figure 5-16).
- Replace Gas Lift Valve with dummy valve. This will limit the potential leak pass from the tubing to the tubing / casing A-annulus.
- Circulate A-section annulus to a glycol rich mixture, while taking return of the fluids presently within the tubing /casing Annulus. The fluid is exported to the production facilities and there will be no discharges to sea.
- Install Bypass Valve (BPV) (plug at tubing hanger in wellhead) temporarily to enable redress of Christmas Tree Valves (XMT valves) including soft seals and packings.

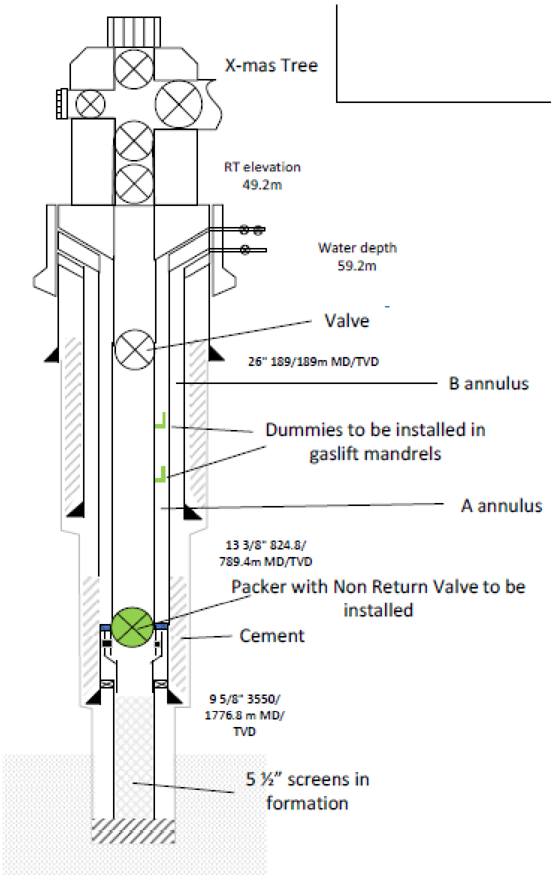


Figure 5-16 Preparation of NA-3B for CO_2 injection.

When preparing the NA-3B well, a glycol rich mixture (Methyl Ethylene Glycol, MEG) will be used to displace fluids in the tubing/casing A-annulus as mentioned above (see chemical inventory in section4.3.2). As an alternative it is considered to apply an oil-based fluid as contingency. In either case there will be no planned discharge to the environment as the fluids will be produced back to the production facilities at the platforms.

NA-5 Conversion to Observation Well:

The NA-5 pilot injection confirmed pressure interference between the NA-5 and NA-3B wells. During NA-5 injection, a clear pressure response was observed in NA-3B and NA-5 is therefore seen as a good candidate for an observation well for the NA-3B injection.

The NA-5 monitoring will consist of:

- Topside pressure and temperatures measured at the well head.
- Modelled downhole pressures based on the topside measurements, as performed during the pilot operation. The pilot confirmed a good predictability with this method and good correlation with modelled predictions.
-

The feasibility of installing a downhole gauge has been considered and will be further investigated.

Maintenance
Over the lifetime of the Nini Field injection, there will be some visits to the Nini A platform as part of a planned maintenance program. Regular Maintenance will be conducted as per ISO and API requirements, as well as defined by legislation and Company standards and procedures for Safety and Environmental Critical Elements (SECE)

- Half yearly inflow test of downhole valves
- Yearly maintenance of XMT valves and instrumentation
- Yearly maintenance of wellhead valves

Waste from the well operations is not expected to be generated.

5.5 Operation phase

The *Project Greensand Future* operation phase has a relatively simple set-up: The main activities are the transportation of liquefied CO_2 from a harbour to the offloading system, injection into the reservoir, monitoring of the CO_2 plume (section 5.5.4) and monitoring of potential leakage (section 5.5.5).

Several vessels will be present during the operation phase. Some of these will be using dynamic positioning (DP) which is further described in section 5.4.

5.5.1 Transportation of CO_2

CO_2 will be loaded onto a modified PSV vessel (CO_2 vessel) in Esbjerg harbour, and hereafter transported to the Nini A platform. The CO_2 is loaded in tanks on the deck of the vessel and is kept at a liquefied state by maintaining high pressure and sub-zero temperatures. The CO_2 vessel will be modified for this specific purpose and have equipment for pumping CO_2 on and off the vessel.

The distance from Esbjerg to Nini is approximately 127 nm (235 km) and a maximum of 130 injection cycles per year is expected. The injection operations are weather sensitive, and the actual number of cycles may be lower.

5.5.2 Helicopter shuttling and boat manning

Although Nini A is a NUI, operated and controlled from the Siri platform, some level of maintenance and supervision will be required during its operation. The platforms are equipped with a helideck for transportation via helicopter, which will be the main form of commuting for staff. Estimation of the frequency of these missions is based on prior experiences and presented in section5.7.

5.5.3 ROV operations

There will be several ROV operations during the operation phase:

- Maintenance of the offloading system
- Inspection of the subsea structure of Nini A
- Validation of the CO_2 leakage monitoring system and secondary bubble detection measure.

- Retrieval, data collection, and maintenance of ocean bottom stations (seismicity)
- Optional: Deployment and retrieval of OBNs (2D seismic survey or spot seismic surveys)

A support vessel will be used for these activities. The activities require an ROV and other equipment as described in Table 5-5. The vessel will be equipped with a USBL & positioning system. For this operation the transceiver is a high precision acoustic positioning system (HiPAP). The HIPAP emits signals within the frequency range of 21-31 kHz at a sound source level of approximately 167 dB re. 1 µPa at 1 m when in low power mode. During high power mode, the maximum sound source levels are expected to be approx. 182 dB rel. 1 µPa. The cNODE operates within the frequency range of 21-31 kHz at a maximum source level of approx. 173-188 dB re. 1 µPa at 1 m. During these activities, the HiPAP and cNODE will only be used in low power mode i.e., with a maximum peak sound source level of approx. 173 dB rel. 1 µPa.

The inspection of the subsea structure will take approx. 2 days and will be conducted biannually. The maintenance of the new offloading system will be conducted annually and completed within a time period of 24 hours.

Some of the equipment listed in Table 5-5 will operate at very high frequencies outside the hearing range of marine mammals (i.e. above 180 kHz) and is therefore not further assessed in this document.

Table 5-5 Equipment used during ROV operations and their respective noise emission levels.

Source	Model (reference)	Equipment location	Operating frequency	Sound source level SEL ss (re 1 µPa2s@1m)	Frequency within marine mammal hearing range
Magnetometer	GMA 1000	ROV	N/A	-	N/A
Depth Sensor	Valeport Mini IPS	ROV	N/A	-	N/A
Side Scan	Edgetech 2205	ROV	600-1600 kHz	-	No
Transponder	Kongsberg cNODE MiniS	ROV	21 – 31 kHz	173 dB	Yes
Tranceiver	Kongsberg HiPAP 501	Vessel	21 – 31 kHz	167 dB	Yes
Multibeam Echosounder	EM2040D MBES	ROV	200-400 kHz (configuration planned for 340 kHz)	-	No
Doppler Velocity Log	Sonardyne Syrinx	ROV	400/600 kHz	-	No
Velocity Sensor	Valeport Sound Mini SVS	ROV	2.5 MHz	-	No
Altimeter	Kongsberg 1007 Altimeter	ROV	120-675 kHz (675 kHz to be used)	-	No
Obstacle Avoidance Sonar	Blueview M900	ROV	900/2250 kHz	-	No

Slow start procedure

A slow start procedure will be applied for diving and ROV operations. Slow start is used to minimize underwater noise impacts on marine mammals and fish. A 5-minute and 15-minute slow start was modelled, where one single individual vessel transponder signal (ping) is emitted every 20 seconds for 5 or 15 minutes respectively. The ping is released at a low power setting. The 5-minute slow start applies for ROV activities using a USBL transmitter and one transponder placed on the ROV. The calculated slow start periods are taking into account that the presence of the vessel will deter the animals to be at least 100 meters away from the sound source. For a detailed description it is referred to the underwater noise modelling report in the Appendix.

5.5.4 Reservoir monitoring

Seismic monitoring

A seismic reservoir monitoring program is designed to monitor the presence and movement of CO_2 in the reservoir and to detect leakage of CO_2 from the reservoir to the overburden. The monitoring data will be compared to predictive dynamic modelling of the CO_2 behaviour and observed deviations may trigger additional monitoring activities or lead to changes to the injection plan.

The Nini West field was covered by 3D seismic acquired in 1997. The data was reprocessed in 2002 and again in 2024. Rock physics modelling (fluid substitution) implies that a CO_2 saturation exceeding ca. 4% in the reservoir will create an impedance contrast strong enough to detect a difference in seismic reflection and cause a measurable time shift for the base reservoir reflection.

The seismic monitoring data for the *Project Greensand Future* will be acquired by the use of a dedicated survey vessel. Seismic sources (airguns) will be provided by a commercial seismic vendor (to be selected). In the Greensand Pilot project (Q1 2023) the seismic acquisition set-up included airguns and the hydrophone ocean bottom nodes (OBNs) for the spot-seismic survey. The technical specifications for the airguns and OBNs are not known at the time of writing the EIA and will depend on the commercial vendor selected for the survey. For the evaluation two airgun sizes have been selected based on industry standards as they are expected to represent equipment similar to what is used in *Project Greensand Future*.

Key features for the seismic monitoring activities:

- Seismic baseline survey (Q4 2025): A 2D seismic baseline survey is planned prior to first injection: Vessel transit to and from the survey area, deploy and retrieve airgun and streamers or ocean bottom nodes (OBNs) (Figure 5-19 as further described below), shoot seismic on defined lines across the area.
- First seismic monitor: The first 2D seismic monitoring campaign is planned 2 years after first injection: Vessel transit to and from the survey area, deploy and retrieve airgun and streamers or OBNs, shoot seismic on defined lines across the area.
- The second 2D seismic monitoring campaign will be reassessed and updated based on results and learnings from the initial two surveys. The current plan is to repeat the baseline and first monitor with seismic in year 4, 6, 8 and 10 to ensure verification that the model describes the CO_2 plume movement and lateral distribution accurately.

A closeout 3D seismic monitoring campaign is planned before handover of the storage site to the Danish authorities. The final acquisition plan will be decided in collaboration with the authorities and based on the results of the collected monitoring data and modelling of the plume migration in the subsurface. For the EIA it is assumed that the 3D closeout survey will take place 18 years after first injection.

The initial predictive monitoring plan is to start with the final conformance model after re-processing datasets from seismic survey (1997) and the acquisition of the associated seismic baseline survey.

The exact locations of the 2D line locations will be determined based on the geophysical modelling and the results from the baseline and earlier monitoring campaigns. The monitoring thus utilizes the concept of predictive maintenance linking the monitoring data to the predictive modelling. The total shot numbers per seismic acquisition campaign will amount to approximately 2100 shots (Table 5-6).

Table 5-6 List of seismic monitoring program and planned seismic shots. The coordinates will be laid out in the seismic survey plan for permitting. The timing and design of the 3D closeout survey will be planned based on results and learnings from the initial surveys.

Monitor	Date	Nr. of lines	Line km's	Nr. of shots	Comment / objective
Seismic baseline	Q4 2025	8	50	2100	2D baseline
Monitor 1	March 2028	8	50	2100	2D monitor
Monitor 2	March 2030	8	50	2100	2D monitor
Monitor 3	March 2032	8	50	2100	2D monitor
Monitor 4	March 2034	8	50	2100	2D monitor
Site closure	March 3036	8	50	2100	2D monitor
Monitor	**Date**	**Area (km^2)**		**Nr. of shots**	**Comment/objective**
Closeout	March 2044	32		4000	3D monitor

By request from DEA or in case of significant irregularities such as deviations from modelled reservoir pressure, migration of the CO_2 plume away from the storage site or any indications of leakage detected by the monitoring activities, additional 2D or 3D seismic surveys might be triggered. The full definition of significant irregularities follows the EU directive guidelines and is described in the MMV plan.

Seismic surveys are planned to be carried out in the period from October to March, to minimize impacts that lead to displacement or disturbance of harbour porpoises and other marine mammals, which are less vulnerable to disturbance in this time (see section 9.5.4).

For the protection of marine mammals, the terms described in "Standardvilkår for forundersøgelser til havs, August 2018" (Energistyrelsen, 2018a) must be followed including soft start procedure, see Figure 5-17. The screening also follows the requirements of the Executive Order no. 846 of 26/06/2024 on the administration of international nature conservation areas and protection of certain species.

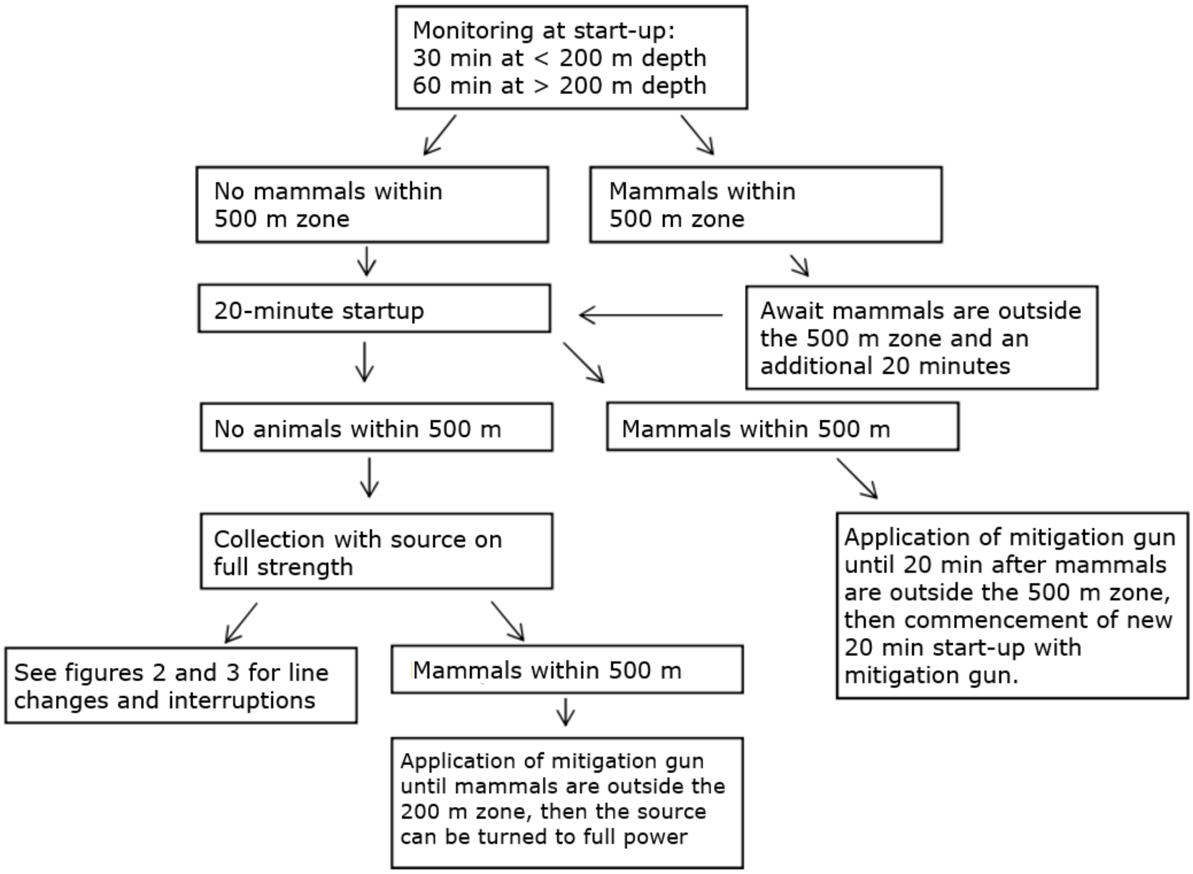


Figure 5-17 Soft start procedure for seismic monitoring. The box "see figures 2 and 3" refers to the line change and case of interruption procedure as described in "Standardvilkår for forundersøgelser til havs, August 2018" (Energistyrelsen, 2018).

Location

The intended area of the seismic activity is located west of the Nini A platform. The exact locations of the seismic sail lines will be selected based on the survey design and the pre-injection model predictions. The seismic survey area is shown in Figure 5-18. Details regarding the CO_2 leakage monitoring system at the Nini-4 well is described in section 5.5.5.

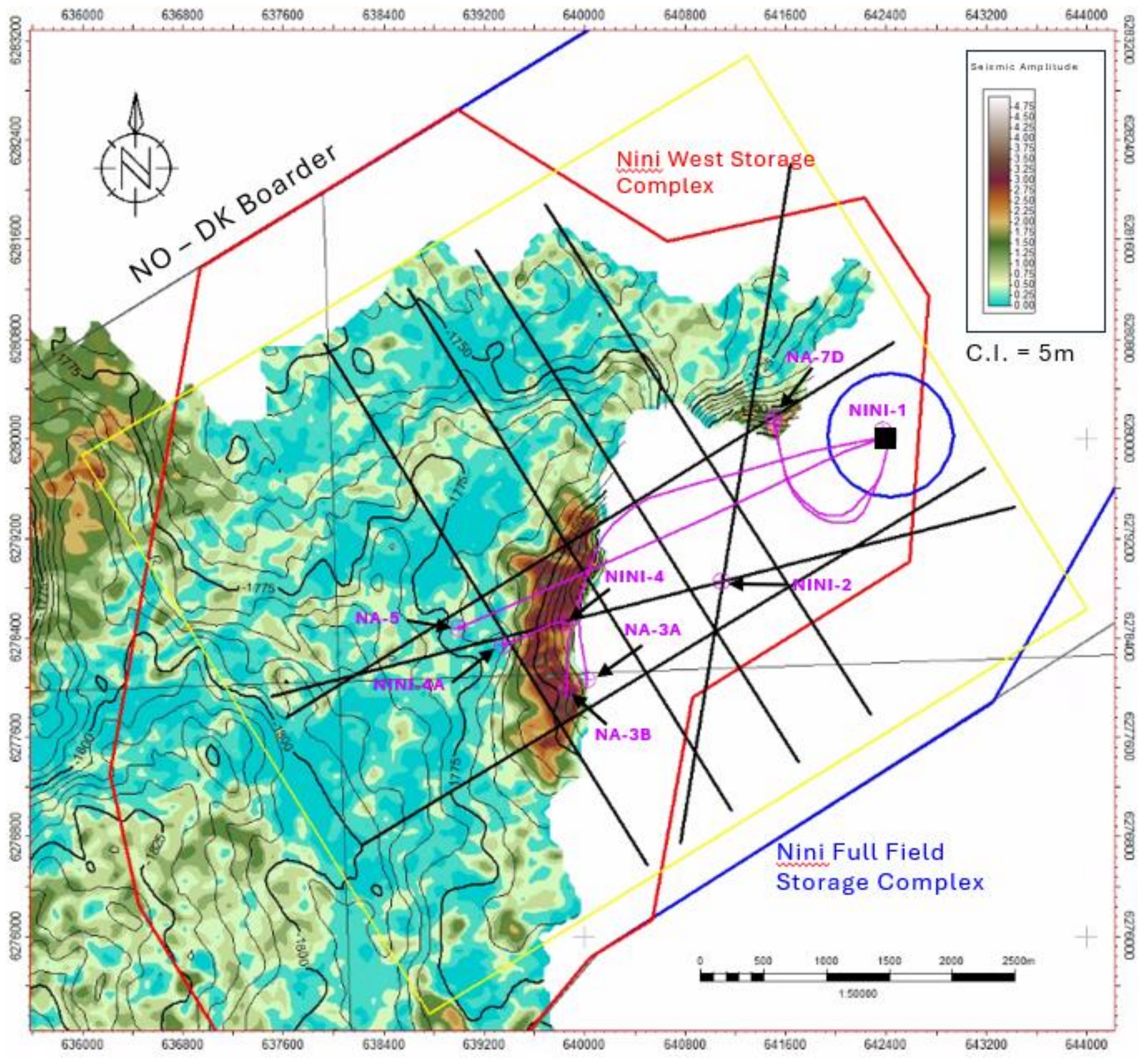


Figure 5-18 Top Frigg depth map with seismic amplitude overlay showing the seismic survey area (yellow rectangle, preliminary boundary), 500 m safety zone (blue circle) around the Nini-A platform (black square), and the wells in the area (pink).

Optional Spot seismic to replace 2D seismic

<u>Ocean Bottom Nodes (Hydrophones)</u>

Hydrophones will be industry standard ocean bottom nodes (OBN): MASS nodal system and ZXPRL with four components (x, y, z, P), ability to detect shear waves. OBNs used in the Greensand Pilot project are shown in Figure 5-19. All receivers will record data continuously during the deployment period, enabling passive acoustic monitoring.

The OBNs will be installed on the seabed at the receiver locations. Each receiver location will be equipped with at least one OBN, some locations may have two OBNs co-located. OBNs will be deployed from the ship by dropping from the side of the ship by a crane. Once the seismic surveys are completed, the OBNS will be retrieved using an ROV. An ROV, similar to what is described in section 5.4.2, will be used. The duration of the deployment will be approximately 5 days. It should be noted that a commercial drop and self-retrieving OBN system is under development and may be applied in the final project.

Figure 5-19 Example of ocean bottom node (OBN), size 30x20x8 cm.

The OBNs weigh approximately 10 kg each and are approximately 50 cm in diameter. The OBN are provided by a commercial seismic vendor and will be laid on the seabed during the seismic surveys. The locations of the OBNs will be determined based on detailed geophysical modelling and will be adjusted to reflect the results from previous monitoring campaigns.

Spot seismic Source (Airgun)

It is planned to use an industry standard of 3 airguns (200 in^3 – cubic inch) for a total 600 in^3 point source. The sound source level for the 600 in^3 airgun is estimated to be 240 dB re 1 µPa2s at 1 meter from the source. The sound frequency spectrum of the airgun contains mostly low frequency sounds, with the highest noise levels at 10-120 Hz.

The source equipment will fit into a 20 ft ISO container and will host the airgun compressor and control centre. The container will be installed on deck of the survey vessel. The compressor is connected to the airgun by a pressure hose. The nominal operating pressure of the compressor is 2000 PSI. Near-field OBN will record the shot signature. Mitigation airguns and passive acoustic monitoring (PAM) are available for environmental reasons incl. personnel (MMO) according to standard practice.

Shots will be fired maximum every 45 seconds, which is the time required to cycle the gun, meaning the airgun has a maximum capacity of 80 shots per hour. Each pulse has a duration of 200 milliseconds (ms).

The containerized small source (airgun) will be deployed by the crane of the survey vessel at the source locations in approximately 6 m water depth. The survey vessel will stay in dynamic positioning to perform the planned 80 shots for a total duration of approximatively 1-2 hours net productive time per source location (1 hour per location is a best estimate, up to 2 hours is planned to achieve the 80 shots, excluding possible interruptions).

The maximum operational time per campaign cumulates to maximum 5 daylight net operational days ('compressor days') taking interruptions, reshooting and repeated soft starts into account. The activities during non-daylight hours are foreseen for transits, laydown/retrieval of OBNs and data QC work.

Seismicity monitoring

The purpose of seismicity data acquisition is to monitor movements in the subsurface. This could either be natural small-scale earthquakes or the movement of a fault or fracture caused by the CO_2 injection. Seismicity will have to be monitored continuously in accordance with the monitoring plan. Monitoring is conducted using Ocean Bottom Stations (OBSs) as seen in Figure 5-20 and Table 5-7. The OBSs will have both geophones and hydrophones and will be dropped from the side of the ship with a crane. There will be no seismic source involved in this monitoring, as only measurements of the vibrations from the earth itself will be taken. In other words, the OBSs will be left on the seafloor to record. Underwater noise will be generated when deploying (general vessel noise e.g. DP system) and retrieving the OBSs (ROV operation and general vessel noise). A baseline seismicity monitoring will establish the natural level of seismicity in the area prior to injection operations start, in order to distinguish between natural and induced seismicity.

Figure 5-20 "NAMMU" ocean bottom station (OBS) for seismicity monitoring.

Table 5-7 Technical data for the NAMMU ocean bottom stations.

NAMMU technical specifications	
Weight with anchor	205 kg
Width	63.5 cm
Height	77.0 cm
Depth	80.0 cm
Anchor size	80 cm x 60 cm

A map of the survey layout can be seen in Figure 5-21 with station coordinates in Table 5-8.

For <u>monitoring during injection</u>, OBSs will be deployed to continuously monitor induced seismicity. The program is assumed to be adapted based on the collected seismicity data, as it will bring new knowledge that can improve the monitoring plans. The current plan is to install 8 OBSs on the seabed. Every 2 months, a 2-day ROV operation is required to retrieve the stations for data collection. A support vessel with ROV is used for this operation. Batteries will be changed when required, during these operations.

The technology for offshore seismicity monitoring is currently under development and the equipment and plans for the seismicity monitoring are assumed to change and the applied system will be developed. The seismicity monitoring program will be designed and developed together with GEUS and approved by the DEA.

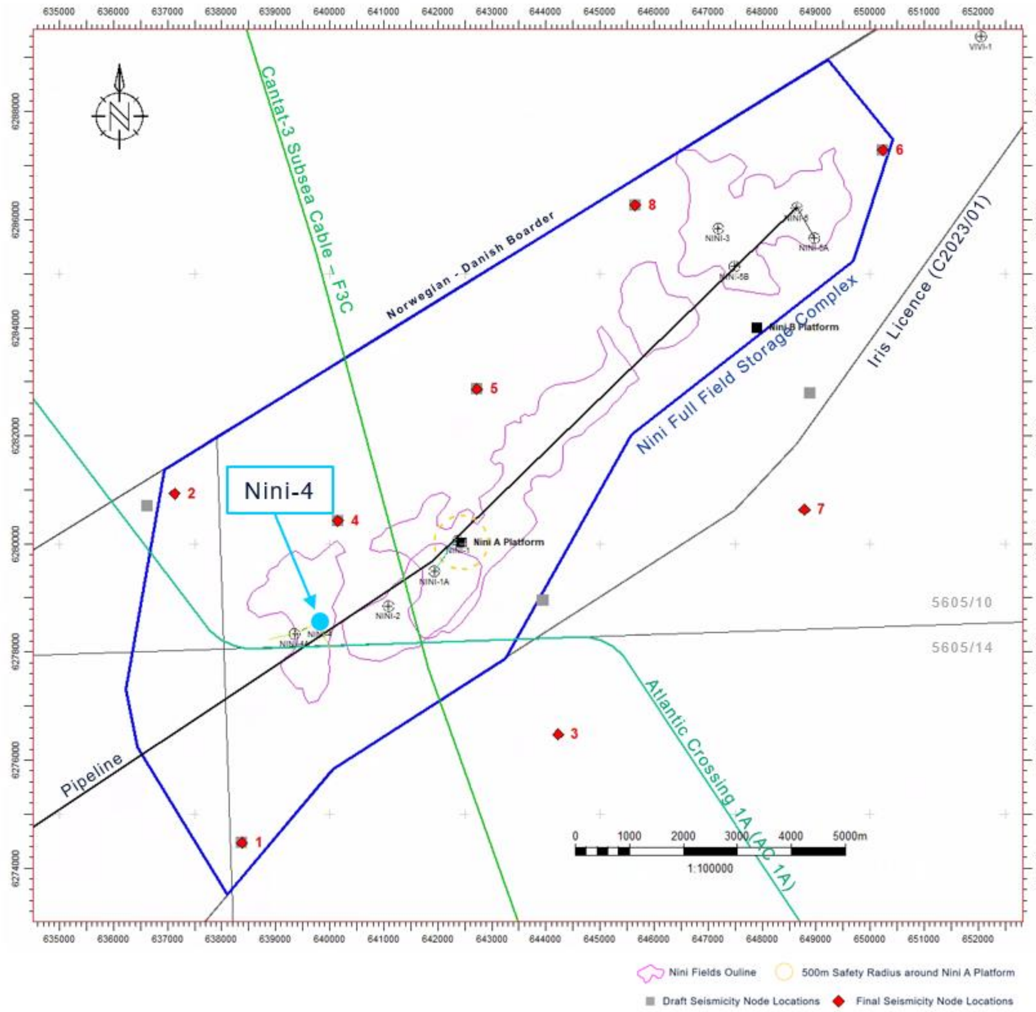


Figure 5-21 Map of locations of OBSs for seismicity monitoring.

Table 5-8 Coordinates of OBSs for seismicity monitoring. Reference coordinate system is ED50-UTM31.

Index	X	Y
1	638373.50	6274468.02
2	637128.78	6280931.27
3	644221.10	6276473.58
4	640150.65	6280432.10
5	642723.91	6282865.37
6	650234.38	6287284.05
7	648781.61	6280632.06
8	645651.34	6286271.85

Development of seismicity monitoring system

Seismicity monitoring with real-time data transmission from subsea is still under development with the various geophysical vendors. The most mature solutions have been identified, but the technology readiness level (TRL) is low and requires more testing. Three possibilities, that might be used in conjunction, are under consideration which are OBN's with data harvest by AUV, S-DAS cables deployed from a platform, and wellbore monitoring. The solution of choice will depend on results from the seismicity baseline, commercialization of technologies, feasibility with existing wells and facilities, and environmental impact.

As the seismicity monitoring system is still in development, the exact details cannot be assessed further at this stage and will not be included in the assessment chapters of the current EIA.

5.5.5 Seabed monitoring

If the injected CO_2 should accidentally leak from the reservoir or from installations this will be thoroughly monitored. The risk and probabilities of leaks has been thoroughly investigated and these unplanned events are described in Section 13.2 and 13.2.2.

A CO_2 leakage monitoring system will be installed on a metal frame, referred to as a lander, to be able to detect leakage of CO_2 from the reservoir or from the wells. The detection system is placed onto the seabed near the legacy well (Nini-4). The deployment does not require an ROV operation. Maintenance, battery exchange, data harvest, etc. will take place every 6 months by exchanging the lander with an identical lander. The lander will be recovered using the support vessels crane to retrieve the lander buoy and bring back the lander with the mooring line from the bouy. This operation will be repeated throughout the monitoring period from 2025 to 2033. The replacement will be coordinated with the similar activities related to the seismicity monitoring described in section 5.5.4.

On occasion, and in relation with other ROV activities in the same area, an ROV will be deployed to photograph the sea floor near the lander as a means of validation of the lander and as a secondary bubble detection measure. This is estimated to be once a year and last for 3 hours.

Schematic location of the CO_2 leakage monitoring system is shown in Figure 5-21 where Nini-4 is located. The CO_2 leakage monitoring system will be marked with 1 surface buoy.

The CO_2 leakage monitoring system is designed for placement on the seafloor and will house multiple chemical sensors, an active acoustics system, and local communication hub. The chemical lander also accommodates a central housing for batteries and communications to and from a surface buoy. Power and telemetry from the ocean surface buoy are enabled by an umbilical cable from the buoy (via anchor block) to the central battery housing (Figure 5-22). The diameter of a lander is approx. 0.75 m, with a height of 1.5 m above the seafloor. The CO_2 leakage monitoring system has a physical footprint of 0.5 m^2. The required anchor block has a footprint of 1 m^2 and a weight of 4.2 t.

Sonar – bubble detector

The CO_2 leakage monitoring system houses a high frequency sonar, Kongsberg, M3, that operates at a frequency of 500 kHz. The sonar system detects bubbles and is relevant if there is a leak where CO_2 is in gaseous form (bubbles) in the water column. The sonar fires a horizontal beam surveying an area of approx. 23,500 m^2 for potential leaks. The radius of the surveillance of the lander is 120° to maximum 150 m distance. As the sonar will send its maximum signal very close to the seafloor, it will continuously provide the highest sensitivity and is able to detect the modelled minimum leakage rate.

Figure 5-22 Schematics of the lander design (left) an image of the lander with sensors (right). The central white tube contains the battery.

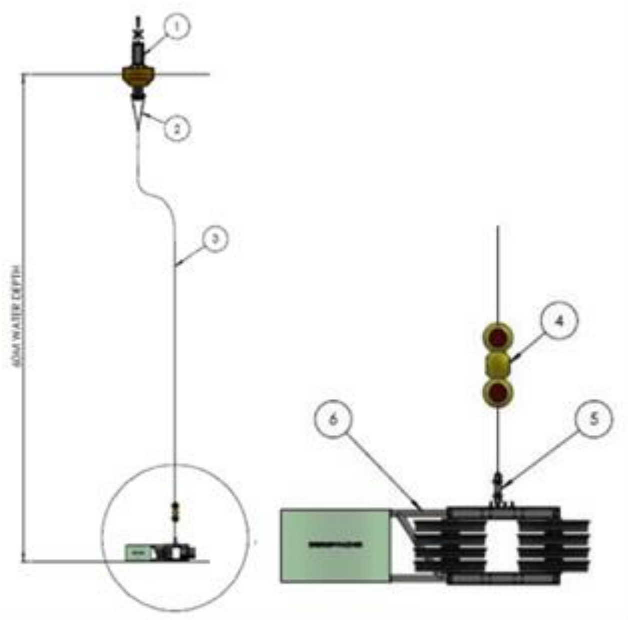


Figure 5-23 Schematics of the buoy-lander setup. 1) Surface buoy, 2.1 m diameter, 1.2 t weight, 2) Bridle assembly, 3) Wire mooring cable, 4) Subsea floatation, 5) Data swivel assembly, 6) Anchor block, 4.2 t weight. The lander is the green attachment.

Other sensors

The lander is equipped with a series of chemical sensors to assess the marine carbonate system by focusing on surveillance of pH-changes as an indicator of elevated CO_2-concentration beyond the natural baseline. The chemical sensors on the CO_2 leakage monitoring system are the following:

- pH – an indirect measure of dissolved CO_2 as the dissolution of CO_2 into seawater acidifies the water, decreasing its pH. A principal parameter to assess the carbonate system.
- Total alkalinity – the measurement of the concentration of all alkaline substances dissolved in the water. Illustrative of the buffering capacity of the water. An overall parameter to assess the carbonate system.
- Nitrate – a key nutrient in seawater. Used on the monitoring system to be able to differentiate dissolved CO_2 due to organic processes from dissolved CO_2 due to leaks.
- The SeapHOx sensor also measures pH and in addition temperature, pressure, and dissolved oxygen. This provides redundancy and higher frequency/lower accuracy pH readings as well as other essential contextual data.

The chemical sensors for pH, total alkalinity and nitrate all use wet reagents. All of these reagents (liquids) remain in the sensors and are recovered with the lander. An Aquadopp current meter from Nortek (Figure 5-24) will be installed on top of the lander (Figure 5-22). The current meter operates at 1 or 2 Mhz, depending on the specific model selected.

Figure 5-24 An Aquadopp profiler (black cylinder) will be mounted at the lander. Source: https://www.nortekgroup.com/products/aquadopp-profiler-1-mhz

5.6 Decommissioning

Decommissioning activities to be covered by the end of the CCS project is described and assessed in chapter 18. The decommissioning scope of this EIA will cover all Nini A facilities, platform, wells, pipelines and the CO_2 offloading system. Compared to the zero–scenario the scope of decommissioning in this EIA is then:

- Offloading system: Including subsea pipeline, anchors and flexible hose.
- Nini A platform incl. topside, jacket structure, risers, and subsea structures (drilling template and docking piles).
- The 10 wells connected to Nini A.
- The four pipelines between Nini and Siri: one 14" multiphase pipeline, one 10" water injection pipeline, one 4" gas lift pipeline piggybacked to the redundant 10" water injection.

5.7 Resource consumption

As in previous sections, the projects resource consumption will be considered for the construction and operation phase. When it comes to resource consumption though, material consumption will only be relevant for the construction phase. The operational phase will primarily include fuel consumption, and the only material consumption will be from potential minor maintenance or replacement of components. Minor materials, such as hand-operated valves on the platform or similar, is not considered. It is assessed that minor replacements and normal maintenance has an insignificant contribution to the overall assessment of impacts on environmental and social receptors and are therefore not part of the scope.

It should be noted that, due to uncertainties at this planning stage of the project, some numbers include a certain degree of uncertainty.

5.7.1 Materials and chemicals

One of the primary material components is the fixed pipeline as part of the offloading system to Nini A. The pipeline leading to the platform is expected to be at a length of 100-300 m, with a connected flexible hose of additional 120 m. Regarding protection, concrete mattresses will be installed onto 300 m pipeline, in total 45 mattresses as a conservative estimate. The new components required, consist of the elements listed in Table 5-9.

Table 5-9 Additional components required for the construction phase.

Description	Quantity	Unit	Comments
Pipeline (6'')	100-300 10-30	Meters piping Tons	For offloading system. Weight: ~100kg/m. For this EIA 300 m of pipeline is assumed.
Anchor blocks	50	Tons - 2 units	For offloading system
Flexible riser with buoyancy element on first 40 m	120 6	Meters Tons	For offloading system Weight: ~50 kg/m E.g. composite material
Hose End Valve with messenger line to surface	1	Tons	Valve at the end of the flexible riser made of sea resistant material
Concrete mattress	45 135	Units Tons (total)	For pipeline protection, approximately 3 tons each
Replaced flowline (at Nini)	3-4	Tons	Steel

During hydrostatic testing of the offloading system, a fluorescent chemical is used to identify potential leaks in the system. Table 5-10 gives an overview of the estimated amounts of chemicals planned to be used during the tests. The amount is based on a dosage rate of 500 ppm in the offloading system volume. The dosage rate of the fluorescent is estimated to be less than 10 % of the corrosion inhibitor, i.e., max. 50 ppm. As a conservative scenario, both chemicals will be released to the environment after completion of the hydrotest. Both chemicals are classified as yellow according to the Danish Environmental Protection Agency (DEPA) colour coding - substances exhibiting some degree of environmental hazard. The total discharged volume is assessed to be around 13 m^3.

Table 5-10 Estimated usage of pipelay chemicals.

Type	Planned total use [kg]	Ranking
Corrosion inhibitor	10	Yellow*
Fluorescent tracer chemical	1	Yellow*
*Chemicals are classified according to the Danish Environmental Protection Agency (DEPA) colour coding system, which follows the OSPAR classification (substitution, ranking and PLONOR) and relates to the environmental hazard of offshore chemicals.		

When preparing the wells, a glycol rich mixture (Methyl Ethylene Glycol, MEG) will be used, alternatively it is considered to apply an oil-based fluid. In either case there will be no planned discharge to the environment as the fluids are planned to be left in the well. The chemicals that are planned to be used as part of preparation of the well and later maintenance, are listed in Table 5-11.

Table 5-11 Estimated usage of well chemicals.

Functionality	Product name	Chemicals planned used for		Ranking
		preparation [tonnes]	maintenance [tonnes/year]	
Hydrate inhibitor	MEG 60 %	277.5	111	Green*
Wireline grease	Claretech V500 Wireline Fluid	0.8	0.8	Yellow*
Spacer	Escaid 120 ULA	205	82	Yellow*
*Chemicals are classified according to the Danish Environmental Protection (DEPA) colour coding system, which follows the OSPAR classification (substitution, ranking and PLONOR) and relates to the environmental hazard of offshore chemicals.				

5.7.2 Fuel

Fuel consumption as part of construction and operation phase is listed below (Table 5-12 and Table 5-13). Fuel consumption as part of decommissioning activities are described in chapter 18.

Construction phase

During the construction phase, several vessels will be present during the different construction activities related to the offloading system: rigid pipeline, installation of concrete mattress, connection of flexible hose incl. buoy etc. Vessels will also be present for placement of the CO_2 leakage monitoring system and OBSs as well as for flowline replacement and well intervention. The required vessels can be seen in Table 5-12 Type of vessels and fuel consumption required during construction phase., along with the expected days of use and fuel consumption.

Table 5-12 Type of vessels and fuel consumption required during construction phase.

Operation	Type	Numbers	Days per unit	Fuel consumption [m^3/day]	Comments
Installation of the offloading system	Support vessel	1	7 + 1.5	20	Diving operation with ROV
	Standby vessel	1	7 + 1.5	3	
	Helicopters*	1	7 + 1.5	1.0	Fuel: Kerosene/Jet A
Replacement of flowline at Nini A	Standby vessel	1	32	3	
	Helicopters*	1	32	1.0	Fuel: Kerosene/Jet A
Well Intervention Campaign	Standby vessel	1	30	3	
	Helicopters*	1	30	1.0	Fuel: Kerosene/Jet A
Baseline 2D seismic acquisition	Seismic survey vessel	1	5-10	20	Transport to and from survey location. Streamer or OBN seismic in local area.
CO_2 leakage monitoring, deployment (lander)	Support vessel	1	2	12	
Seismicity ocean bottom stations (OBS) deployment	Support vessel	1	2	12	ROV operation for recovery of OBSs.
*Helicopters are operating 2 hours/day					

Operation phase

During the operation phase, various activities will be required which consume fuel. There will also be fuel consumption related to the transportation of CO_2 to the offloading system. These are listed in Table 5-13.

Table 5-13 Type of vessels required during operation phase.

Activity	Type	No.	Days per unit	Fuel consumption [m^3/day]	Comments
CO_2 transport	Modified Vessel (PSV)	1	Max. 130 cycles per year	29.4 m^3 (25 tonnes) per cycle	Sailing distance: 127 nm (Esbjerg). 2½ days per round trip.
Continuous seismicity monitoring, deploy and retrieve OBSs	Support vessel with ROV	1	2 days for maintenance every 2 month	12	ROV needed for recovery during maintenance
2D seismic acquisition	Seismic survey vessel	1	5-10 days per campaign in year 2, 4, 6, 8 and 10	20	Transport to and from survey location. Streamer or OBN seismic in targeted Nini West area
Inspection of offloading system	Support vessel	1	1 day annually	12	ROV operation
Exchange of the continuous CO_2 leakage monitoring system (lander).	Support vessel	1	1 day deployment + 1 day maintenance and exchange every 6 months	12	
Validation of the CO_2 leakage monitoring system and secondary bubble detection measure with ROV.	Support vessel with ROV	1	Annually (3 hours)	12	On occasion, and in relation with other ROV activities in the Nini area, an ROV will be deployed to photograph the sea floor near the lander as a means of validation of the lander and as a secondary bubble detection measure. The activity will continue until the lander has proven its durability.
Inspection of the Nini A subsea structure	Support vessel with ROV	1	2 days biannually (jun-sep)	12	ROV operation
Triggered/closeout 3D seismic acquisition	Seismic survey vessel	1	7-14 days per campaign	20	Transport to and from survey location. Streamer or OBN seismic in targeted Nini West area
Optional spot seismic surveys	Support vessel	1	5 days	12	Transport to and from survey location. OBN retrieval.
	Airgun compressor at survey vessel	1	3 days	1	

Conservative estimates of the ship fuel consumption can be derived from prior experiences. The fuel consumption for each voyage of a transport vessel has been estimated to be approximately 29.4 m^3 (25 tons). The maximum number of injection cycles to be carried out is 130. This means that at the high end there is a fuel consumption of 3,800 m^3 (3,250 tons) fuel annually. The fuel type is Low Sulfur Marine Gas Oil (LSMGO), which is a light oil mixture frequently used in the shipping industry.

6. ALTERNATIVES

6.1 Zero – scenario

The project is dependent on both the usage of the Nini reservoirs as well as most of the existing offshore infrastructure for conversion to CO_2 storage. Simply put, this means that the alternative to the proposed project is to not convert the reservoirs into storage facilities. In this case, the Nini Complex would simply follow standard procedures for decommissioning, within its current Nini license. This scenario will be described in an EIA separate from this document (COWI, 2023b).

7. LEGISLATIVE CONTEXT

The *Project Greensand Future* is developed and implemented in a context of international and national law. This chapter provides an overview of key Directives and national regulation.

7.1 International Law

CCS Directive

The CCS Directive (2009/31/EC on the geological storage of carbon dioxide) provides a regulatory framework and guidelines for the safe geological storage of CO_2 and this is widely implemented national by the Executive Order No. 845 of 26/06/2024 on geological storage of CO_2 (CCS-bekendtgørelsen). The CCS Directive contains provisions on selection of sites, application, permitting, monitoring, closures and responsibility. The Directive prescribes permanent containment of CO_2 in such a way as to prevent and, where this is not possible, eliminate as far as possible negative effects and any risk to the environment and human health. As an example, the Directive prescribes that a geological formation shall only be selected as a storage site, if there is no significant risk of leakage under the proposed conditions of use, and if no significant environmental or health risks exist. The CCS Directive does not apply to geological storage of CO_2 with a total intended storage below 100 kilotons, undertaken for research, development or testing of new products and processes. Nationally, this is however covered by Executive Order No. 974 of 22/06/2022 on geological storage of CO_2 under 100 kt.

Environmental Impact Assessment (EIA) Directive

The EIA Directive (Directive 2011/92/EU as amended by 2014/52/EU) on the assessment of impacts of certain *public and private projects* on the environment and the Environmental Assessment Directive (Directive 2001/42/EC 27 June 2001) on the assessment of impact of certain *plans and programs* on the environment, have been implemented in a number of acts in Denmark with the act on environmental assessment of plans and programs and of specific projects (Miljøvurderingsloven Consolidation Act no. 4 of 03/01/2023) as the core act.

Habitat Directive (Chapter 17)

The Habitat Directive of 1992 (Council Directive 92/43/EEC on the conservation of habitats and wild animals and plants with later amendments) obliges EU members states to preserve selected habitat types and species that are characteristic, rare, or threatened in the EU.

Birds Directive (Chapter 17)

The Birds Directive (Council Directive 2009/147/EC) aims to protect all of the around 500 wild bird species naturally occurring in the European Union. It establishes a network of Special Protection Areas (SPAs) including all the most suitable territories for endangered and migratory species. Since 1994, all SPAs are included in the Natura 2000 ecological network, set up under the Habitats Directive.

Water Framework Directive (Chapter 14)

The Water Framework from 2000 (Council Directive 2000/60/EC) establishes a framework for the Community's water policy measures. The Water Framework Directive establishes the framework for the protection of rivers, streams, lakes, transitional waters (estuaries, lagoons), coastal waters and groundwaters in all EU countries. The framework includes both ecological status and chemical status. The ecological status is defined by biological elements (including fish, macro-invertebrates, macrophytes and diatoms); and supporting elements (made up of hydro morphology, ammonia, pH, phosphates, dissolved oxygen and 18 pollutants including some heavy metals and pesticides).

The chemical status of waters is determined based on concentrations of priority substances, and whether they exceed the relevant Environmental Quality Standards (EQS) established in the Environmental Quality Standards Directive 2008/105/EC (as amended by the Priority Substances Directive 2013/39/EU).

Marine Strategy Framework Directive (Chapter 15)
The Marine Strategy Framework Directive (Council Directive 2008/56/EC), which aims to ensure a good marine environment in the Member State's sea areas by achieving good environmental status by 2020 at the latest. The means to achieve this goal are the preparation and adoption of strategies for the marine areas. Marine strategies contain basic analyses, a description of what good environmental condition entails and the setting of environmental targets, monitoring and action programs, according to section 5 of the Marine Strategy Act.

Maritime Spatial Planning (Chapter 16)
This Directive establishes a framework for maritime spatial planning (Directive 2014/89/EU of 23 July 2014) aimed at promoting the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources. Maritime areas face many competing claims on their use and their development such as tourism, fishing and aquaculture, raw material extraction, sea transport routes, marine protected areas, etc. They also face common challenges such as fragile ecosystems, the impacts of climate change and pollution. Maritime spatial planning seeks to enable public authorities to organise human activities in marine areas so as to meet various ecological, economic and social objectives.

Waste Framework Directive
The Waste Framework Directive (2008/98/EC of 19/11/2008) defines key concepts such as waste, recovery and disposal and puts in place the essential requirements for the management of waste, notably an obligation for an establishment or undertaking carrying out waste management operations to have a permit or to be registered and an obligation for the Member States to draw up waste management plans. It also establishes major principles such as an obligation to handle waste in a way that does not have a negative impact on the environment or human health, an encouragement to apply the waste hierarchy and, in accordance with the polluter-pays principle, a requirement that the costs of disposing of waste must be borne by the holder of waste, by previous holders or by the producers of the product from which the waste came.

7.2 International conventions

Ramsar Convention
The Ramsar Convention on Wetlands of international importance from 1971 provides the framework for the conservation and sustainable use of all wetlands through local and national actions. Under this convention, wetland sites designated to be of international importance are protected in national regulation.

Espoo-Convention
The Espoo Convention of 25 February 1991 is a convention on transboundary environmental impacts. The purpose of the convention is to counteract the transboundary harmful effects of planned activities on the environment. The convention therefore contains provisions on environmental assessment of the transboundary environmental impacts, consultation of the public as well as concerned authorities and interest organizations and consultation between the involved countries to prevent, reduce and monitor noticeable harmful effects on the environment across national borders. At an Espoo consultation, the public as well as concerned authorities and interest

organizations in all the areas that may be assumed to be affected by an intended plan, program and/or project's environmental impacts, are consulted.

UNCLOS Convention

The United Nations Convention on the Law of the Sea of 10 December 1982 (UNCLOS) oblige Denmark to protect and preserve archaeological and historical objects found in maritime areas outside of its national jurisdiction. Disturbance to or alteration of protected submarine heritage is prohibited. Further obligations are prescribed by the Convention on the Protection of the Underwater Cultural Heritage from 2001. In this convention, underwater cultural heritage is defined as all traces of human existence of a cultural, historical or archaeological nature which, for at least 100 years, have been partially or totally immersed, periodically or permanently, under the oceans and in lakes and rivers.

Convention on the prevention of marine pollution by dumping of wastes and other matter

International maritime organization (IMO) convention on the prevention of marine pollution by dumping of wastes and other matter (London Convention) has been in force since 1975. Its objective is to promote the effective control of all sources of marine pollution and to take all practicable steps to prevent pollution of the sea by dumping of wastes and other matter.

MARPOL Convention

The International Convention for the Prevention of Pollution from Ships adopted in November 1973 at IMO (International Maritime Organization). The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. Annexes I – V regulates respectively prevention of pollution by oil, noxious liquid substances in bulk, harmful substances in packaged form, sewage from ships and garbage from ships.

International convention for the control and management of ships' ballast water and sediments (BWM)

The convention for the control and management of ships' ballast water and sediments (ballast water management convention) was adopted in 2004. The convention aims to prevent the spread of harmful aquatic organisms from one region to another, by establishing standards and procedures for the management and control of ships' ballast water and sediments.

Convention for the protection of the marine environment of the North-East Atlantic (OSPAR)

The convention for the protection of the marine Environment of the North-East Atlantic (the 'OSPAR Convention') entered into force in 1998. Contained within the OSPAR Convention are a series of Annexes which focus on prevention and control of pollution from different types of activities. OSPAR has a focus on application of the precautionary principle, and on use of best available technique (BAT), best environmental practice (BEP) and clean technologies.

Several strategies and recommendations from OSPAR are relevant to the *Project Greensand Future*, most notably:

- OSPAR Decision 2007/02 on the Storage of Carbon Dioxide Streams in Geological Formations (OSPAR Decision 2007/2, OSPAR 07/24/01, Annex 6)
- OSPAR Guidelines for Risk Assessment and Management of Storage of CO2 Streams in Geological Formations (OSPAR Agreement 2007/12).

- OSPAR Decision 2005/01 Amending OSPAR Decision 2000/2 on a Harmonised Mandatory Control System for the Use and Reduction of the Discharge of Offshore Chemicals (OSPAR decision 2005/1, OSPAR 05/21/1, Annex 11).
- OSPAR List of Substances Used and Discharged Offshore which Are Considered to Pose Little or No Risk to the Environment (PLONOR) – Update 2021 (OSPAR Agreement 2013-06)
- OSPAR Recommendation 2020/03 amending OSPAR Recommendation 2012/5 for a risk-based approach to the Management of Produced Water Discharges from Offshore Installations (OSPAR 20/12/1, Annex 14)
- OSPAR Decision 98/3 on the Disposal of Disused Offshore Installations

7.3 National legislation

Act on the use of the Danish Subsoil

The purpose of the Consolidation Act no. 1461 of 29/11/2023 on the use of the Danish Subsoil is to ensure appropriate use and exploitation of the Danish subsoil and its natural resources. This includes use of the subsoil for storage, and the act implements part of the CCS Directive in a Danish context. Section 23 regulates the granting of license for a defined part of the subsoil that gives the license an exclusive right of exploration and use of the subsoil for storage.

The Executive Order no. 845 of 26/06/2024 on geological storage of CO_2 (CCS-bekendtgørelsen) provides more detailed provisions on the application, permitting, operation, inspection, and closure of the storage location. The order is based on the Act on the use of the Danish Subsoil.

The Executive Order no. 846 of 26/06/2024 prescribes impact assessment regarding international nature conservation areas and the protection of certain species in connection with scientific studies, preliminary studies, exploration and production of hydrocarbons, underground storage, pipelines, etc. offshore.

Environmental Assessment Act

The Consolidation Act no. no. 4 of 03/01/2023 based on the Environmental Assessment Act set the framework for how environmental assessments must be carried out in Denmark. The order includes environmental assessment of plans and programs and environmental assessment of specific projects (EIA). This entails projects on geological storage of CO_2, and The Danish Energy Authority is the authority for this law for CO_2-storage projects. The order prescribes that the EIA authority must carry out a common procedure if assessments according to more than one EU Directives are obligatory. This can e.g., be the Environmental Impact Assessment Directive and the Habitats Directive.

Museum Act

The Consolidation Act no. 358 of 08/04/2014 based on the Museums Act aims to secure cultural and natural heritage in Denmark. Pursuant to Section 29 g of the Museums Act, no changes may be made to the condition of ancient monuments on the seabed, if they are in territorial waters or on the continental shelf, however not further than 24 nautical miles from the baselines from which the width of the outer territorial waters is measured. There must, according to subsection 2, not be made any changes to the condition of wrecks of ships or ship cargoes that must be assumed to have been lost more than 100 years ago, if they are in the areas mentioned in subsection 1, in streams or in lakes**.**

Environmental Targets Act
Consolidation Act no. 692 of 26/05/2023 of the Act on environmental objectives etc. for international nature protection areas, the rules on planning and monitoring of the international nature protection areas contain. Based on this, state and municipal nature planning has been carried out, which has resulted in nature plans for Natura 2000 areas. In the action plans,
the authorities determine the initiatives and measures that are planned to be implemented to ensure the protection of the designated areas.

Habitat Order
The Executive Order no. 1098 of 21/08/2023 on the designation and administration of international nature conservation areas and the protection of certain species contributes to the implementation of the habitat directive and the bird protection directive in Danish legislation. The Habitats Order designates international nature protection areas and lays down rules for the administration of these areas. The nature protection areas include bird protection areas, habitat areas and Ramsar areas. The bird protection areas and habitat areas are part of the European Natura 2000 network.

Nature Protection Act
Consolidation Act no. 927 of 28/06/2024 of the Nature Conservation Act protects, among other things, nature with its population of wild animals and plants and their habitats as well as the landscape, cultural history, natural science, and educational values.

Species Conservation Order
According to Executive Order no. 521 of 25/03/2021 on the conservation of certain animal and plant species and the care of injured game, the species conservation order, protected animals and plants may not be collected or killed, and plants may not be removed from the place, where they grow. All wild mammals and birds are protected, unless permission to hunt them has been granted in the Hunting Act. In the executive order, hunting times are set for the species that may be hunted. The animals that are not hunted are protected. Most bird species are protected, for example, all birds of prey and small birds as well as most waders. In addition, all reptiles and amphibians as well as 13 species of insects are protected by special protection. This also applies to some endangered plant species, for example, all orchids.

Water Planning Act
The Water Framework Directive has been implemented in Denmark in Consolidation Act No. 126 of 26/01/2017 on water planning. The Act contains general provisions on water districts, authorities' responsibilities, environmental targets, planning and monitoring, etc.
Pursuant to the law, a state water planning has been carried out, and water planning for the third planning period (2021-2027) is to be decided. The content of water planning is described in the watershed plans for each of Denmark's four watershed districts. Two executive orders on environmental targets and action programmes based on the Environmental Protection Act are described in the following.

Danish River Basin Management Plans
The Water Framework Directive (WFD) is implemented in Denmark by the Act on Environmental Objectives and the Act on Water Planning and detailed in the Danish River Basin Management Plans (RBMP). The RBMPs are not binding but are a communication tool. The binding water planning appears from the executive order on environmental objectives for surface water areas and groundwater sources (no. 819 of 15/06/2023) and from the executive order on programmes of initiatives for river basin districts (no. 793 of 13/06/2023).

Order on Environmental Targets for streams, lakes, transition waters, coastal waters, and groundwater

Executive Order no. 796 of 13/06/2023 on the determination of environmental targets for streams, lakes, transition waters, coastal waters and groundwater sets inter alia rules on determining environmental targets, including what is more precisely understood by good surface water condition (good ecological condition and good chemical condition for surface water). Annex 2 of the executive order contains environmental quality requirements for surface water. This concerns both nationally set environmental quality requirements for water, sediment and biota and EU-set environmental quality requirements.

Marine Strategy Act

The Marine Strategy Act, Consolidation Act no. 123 af 01/02/2024, implements significant parts of the EU's Marine Framework Strategy Directive. The means to achieve this goal are the preparation and adoption of strategies for the marine areas. Marine strategies contain basic analyses, a description of what good environmental condition entails and the setting of environmental targets, monitoring and action programmes, according to. Section 5 of the Marine Strategy Act.

The Marine Strategy Act and Denmark's Marine Strategy apply to the two Danish Sea areas, the North Sea, including the Kattegat and the Baltic Sea, which include all waters, including the seabed and subsoil, in the maritime territory and in the exclusive economic zones.

However, the Marine Strategy Act does not apply to internal and external territorial waters that extend to one nautical mile outside the baseline, to the extent that the waters are covered by water planning according to the Water Planning Act and/or efforts included in an adopted Natura 2000 plan according to the Environmental Objectives Act.

It follows from Section 18 of the Marine Strategy Act that state, regional and municipal authorities, when exercising their powers in accordance with the legislation, are bound by the environmental goals and action programs set out in the marine strategy(s) pursuant to Sections 10-13 of the Act. The current action programme, which also contains the set environmental targets for the two sea areas, is Denmark's Marine Strategy Action Program of 10 May 2017.

Marine Environment Act

Act on the Protection of the Marine Environment, Consolidation Act no. 147 of 19/02/2024, aims to protect nature and the environment so that social development can take place on a sustainable basis. The Act must prevent and limit pollution and other impacts on nature and the environment, including especially the marine environment. This applies to activities that may endanger human health, damage natural and cultural values, be a nuisance for the legitimate use of the sea or impair recreational values. Offshore platforms and offshore pipelines are specifically mentioned and regulated in terms of potential pollution.

Protection of Submarine Cables and Submarine Pipelines

There will be a protection zone of 200 meters on each side of the cable and/or pipeline route, which prohibits anchoring, dredging, rock fishing and the use of bottom trawling gear. The permanent protection zone is established by marking the submarine cable or pipeline on the nautical chart. The protection zone is established pursuant to Executive Order no. 939 of November 27, 1992, on the protection of submarine cables and submarine pipelines (the Cable Order), which, however, does not apply within the territorial waters of a port. The main purpose of the protection zone is to protect the interests of the submarine cable or pipeline owner. No underwater works or activities may be carried out within the protection zones of submarine cables or pipelines without prior agreement with the submarine cable or pipeline owner.

Environmental Protection Act and the approval order

Environmental Protection Act, Consolidation Act no. 1093 of 11/10/20244, must contribute to protecting nature and the environment, so that social development can take place on a sustainable basis in respect for human living conditions and for the preservation of animal and plant life. The law must prevent and combat pollution, provide rules of importance for the environment and for people, limit the use and waste of resources, promote the use of cleaner technology and promote recycling. Three executive orders on wastewater, discharge of pollutants, air quality and waste based on the Environmental Protection Act are described in the following.

Air Quality Order

Executive Order no. 1472 of 12/12/2017 on assessment and management of air quality is colloquially known as the air quality order. The order includes targets, assessment methods, etc. and covers the substances sulphur dioxide (SO_2), nitrogen dioxide (NO_2), nitrogen oxides (NO_X), particles (PM10 and PM2.5), lead (Pb), ozone (O_3), benzene, carbon monoxide (CO), polycyclic aromatic hydrocarbons (PAH), cadmium (Cd), arsenic (As), nickel (Ni) and mercury (Hg).

Natural Resources Act

Promulgation of the Natural Resources Act, Consolidation Act no. 1230 of 20/11/2024, aims, among other things, to ensure that the utilization of the resource deposits on land and sea takes place as part of sustainable development, the supply of raw materials in the long term and that natural raw materials in as far as possible is replaced by waste products.

Particularly valuable and vulnerable areas (Norwegian SVOs)

Particularly valuable and vulnerable areas (in Norwegian "Særlig Verdifulle og Sårbare Områder", SVOs) have been identified in the Norwegian Management Plans for the Barents Sea, Norwegian Sea and North Sea and Skagerrak. SVOs are identified based on criteria of biological productivity and diversity. SVOs do not directly impose restrictions on business activity, but it is an aim of the management plans that activities in SVOs must not threaten the ecological functionality or biodiversity in the areas.

7.4 Decommissioning

The decommissioning obligations as part of this project are assessed in chapter 18. Below are described the major regulation and guidance supporting decommissioning activities.

Act on the use of the Danish Subsoil

Decommissioning is regulated through Danish legislation in the Subsoil Act (Consolidation Act no. 1461 of 29/11/2023).

According to the subsoil act decommissioning plans for offshore oil and gas installations shall be prepared, submitted and approved by the DEA before the installations can be removed. DEA has prepared a guideline for these decommissioning plans "Guideline on decommissioning plans for offshore oil and gas facilities or installations" dated August 2018. The guideline explains the legal framework and the required contents of the plans.

Further the Marine Environment Act (Consolidation Act no. 147 of 19/02/2024) regulated discharges etc., see section 7.3.

Convention for the protection of the marine environment of the North-East Atlantic (OSPAR)

In addition, decommissioning is regulated through the following international conventions and declarations. Besides the international convention described in the previous the OSPAR conventions includes further details regarding decommissioning.

OSPAR Commission's OSPAR Convention (1992 and 1998), Annex III on Prevention and elimination of pollution from offshore sources, Decision 98/3 on Disposal of disused offshore installations, and recommendation 77/1 on Disposal of pipes, metal shavings and other material resulting from offshore petroleum hydrocarbon exploration and exploration operations. Regarding decommissioning, the Esbjerg Declaration states that more environmentally acceptable and controllable land-based solutions are preferred, and that decommissioned offshore installations therefore shall either be reused or be disposed on land.

The OSPAR commission establishes the framework for decommissioning including guidelines and procedures. Recommendation 77/1 states that dumping of bulky waste such as pipes and containers is prohibited without special permission excluding inter-field pipelines. All dumping or leaving wholly or partly in place of offshore installations in the North Sea is prohibited according to Decision 98/3. However, derogation from this regulation is possible when there are significant reasons why an alternative disposal is preferred. Decision 98/3 does not include decommissioning of pipelines.

8. ENVIRONMENTAL IMPACT ASSESSMENT METHOD

The chapter describes the overall method for mapping existing conditions and the assessment method used to analyse the project's environmental impacts. The method and extent of mapping and assessment of the individual environmental topics are described in detail under each receptor, including how mapping of existing conditions has been carried out, whether field surveys have been carried out and how data has been collected.

The description of each environmental topic in the environmental impact report is systematically structured with the same overall headings in each environmental chapter that appear in the reading guide in chapter 2.

The process of assessing impacts on environmental and social receptors are described in the following chapters. Assessment of impacts on indicators under the Water Framework Directive (chapter 14), Marine Strategy Framework Directive (chapter 15), Maritime Spatial Planning (chapter 16) and Natura 2000-sites (chapter 16.1) follows a different method defined by regulations relevant for the topic. The methods are described in the respective chapters.

8.1 Assessment of the method used

First, the methods, knowledge and data which are used as a basis for assessing the environmental impacts are described. Next, the quality of the methods used, knowledge and data are assessed based on the following scale. The sections are brought together for an overall assessment of lack of knowledge at the end of the report (chapter 22).

- Sufficient: There is available data, some field trials and documented knowledge that allows for a sound assessment of the environmental impact.
- Limited: There is only scattered data and poorly documented knowledge that can affect the quality of environmental assessments.

8.2 Assessment of Environmental Impact

An environmental impact assessment shall describe and analyse the direct effects and the indirect, secondary, cumulative, transboundary effects, short, medium and long term, lasting or temporary positive or negative effects of the expected environmental impacts of the project. The Environmental Assessment Act (see chapter 7) describes the content that the environmental assessments must have but does not specify the methods to be used to carry out environmental assessments. Ramboll has therefore developed a method for assessing the environmental impact of a project, which is based on the Environmental Assessment Act and its concepts.

The method is based on a classification that partly describes the general vulnerability of the affected environmental receptor and the nature of the environmental impacts. The aim is to carry out a comparable and transparent assessment of the impact on the individual environmental receptors, so that the assessments appear uniform and as clear as possible, despite the differences in environmental impacts.

The individual environmental impacts caused by the project are systematically assessed based on the following criteria, which form the basis for an overall assessment of the consequences of the environmental impact. Impacts include both direct and indirect impacts. The method cannot stand alone, as it cannot predict the significance of an environmental impact. Therefore, each assessment is also based on professional knowledge and experience from similar projects. The impacts are assessed with a focus on the conditions below, which form the basis for an assessment of the overall consequence of the environmental impact:

- Vulnerability of the environmental receptor
- Geographical extent of the environmental impact
- Intensity of the environmental impact
- Duration of the environmental impact

8.2.1 Vulnerability of the environmental receptor

Initially, the vulnerability of the environmental receptor in question is described. The assessment of "vulnerability" looks at the environmental receptor's sensitivity to a given activity or impact and if the impact is reversible or irreversible, hence able to return to its original state or not. Vulnerability is assessed for the environmental receptor that can potentially be affected. Where relevant, the estimated time for a receptor to return to its original state is mentioned in the assessment of vulnerability.

Very high	An environmental receptor sensitive to a given impact of relatively low intensity which result in irreversible impacts where the receptor cannot be restored to its original state.
High	An environmental receptor which is sensitive to a given impact of relatively low intensity, but which is capable of being restored to its original state and the impact can be reversed.
Medium	An environmental receptor that can withstand a given impact of relatively high intensity without being significantly damaged, or naturally return to its original state over time or can be replaced and/or the impact can be reversed.
Low	An environmental receptor that is resistant to a given impact of relatively high intensity or that will naturally and quickly return to its original state when the activities cease and the impact can be reversed.

8.2.2 Geographical extent of the environmental impact

The geographic extent of the impact is understood as the size of the geographical area that an environmental impact is expected to affect. The geographical extent of the impact is assessed based on the following categories:

Global	The impact has a global effect (e.g. climate effect).
National / international	The extent of the impact includes an area corresponding to a larger part of Denmark (both sea and land) covering more than a radius of 50 km, or a correspondingly larger area that also extends beyond Denmark's borders.
Regional	The extent of the impact includes an area within a radius of 10-50 km from the project or its activities.
Local	The extent of the impact includes a local area within a radius of 1-10 km from the project or its activities.
Immediate vicinity	The extent of the impact is limited to a small area within a radius of 0-1 km immediately from a specific activity.

8.2.3 Intensity of the environmental impact

The "intensity" is referring to the force with which an environmental impact affects an environmental receptor. The intensity is assessed based on the following categories:

Very High	The impact is very strong and can, for example, result in very extensive physical or chemical impact, or high mortality.
High	A strong impact that can result, for example, in significant physical or chemical impact, or cause increased mortality.
Medium	Impacts can be foreseen and are above detection limit and may lead to some detectable temporary physical or chemical change to the resource/receptor concerned, but their basic structure/function is retained. Impact does not lead to any permanent physical or chemical change in the structures or functions of the resource/receptor concerned or significantly increased mortality.
Low	The force of the impact is low, e.g. resulting in limited physical or chemical impact on the environment, or at functions of the resource/receptor concerned.
Negligible	The force of the influence is in practice irrelevant to the surroundings.

8.2.4 Duration of the environmental impact

The "duration" of the impact is understood as how long the project's impact on an environmental receptor extends over. E.g. even if construction activities are short in duration, the impact can be long term if the recovery time for the given environmental receptor is long. The duration can also depend on how often there is an impact e.g., the frequency of the impact. Frequency refers to how often an impact occurs. Low frequency refers to an impact that occurs once or very few times. High frequency refers to an impact that occurs many times during the construction and/or operation phase of the project. In the assessments, the number of times an impact is expected to occur, is stated. If an activity cause, a short-term impact, but the activity is carried out frequently over a long period, the total impact could be long-term. The duration of the impact is assessed based on the following categories:

Permanent	The impact has a high frequency and lasts throughout the entire operation phase of the project or more than 5 years.
Long	The impact has a high to medium frequency and will occur for one year up to 5 years.
Medium	The impact has a medium to low frequency and will occur for one month (31 days) to less than one year.
Short	The impact has a low frequency and will only occur in connection with limited and short-term activity for 7 days to several weeks (up to 30 days).
Very short	The impact has a very low frequency and will only occur in connection with limited and short-term activity for hours up to less than one week (6 days).

At this stage it is also assessed, when relevant, whether the impact is reversible or persistent, e.g. if the environmental receptor can reverse to its original state after an impact e.g. sediment spill can impact benthic fauna for a duration, but the animals will dig themselves out, have a temporary loss of fitness or the area is recolonized from neighbouring areas. Persistent impact could be permanent structures or dredging activities that alter bathymetry permanently to an extent where the habitat is changed (loss of light to the bottom or changes in substrate, salinity or oxygen). This is summarized as reversible or persistent in the tables.

8.2.5 Overall consequence of the environmental impact

The consequences of the environmental impact are assessed as the environmental impact's overall effect on the environmental receptor based on the criteria of vulnerability, geographical extent, intensity, and duration. Furthermore, probability is implicitly incorporated in the overall assessment of consequences for receptors (chapters 11 and 12). Impacts that are assessed as significant, are also likely to occur, hence high probability. Probability is further assessed under accidental events in relation to the risk assessment (chapter 13). The assessment of the consequence is an overall professional assessment and thus not a mathematical sum of the receptors mentioned.

When assessing the consequence, the environmental impacts are compared with the Zero-scenario, which is described in relation to existing conditions without an impact. The vulnerability of the existing environment therefore has a major impact on the consequences of the impacts.

An environmental impact can be both positive and negative. Both types of effects are relevant according to the Environmental Assessment Act.

The consequence of a negative environmental impact is assessed as:

Significant	Environmental topics that are affected to a significant extent have high or medium vulnerability. In that case the impact will typically be widespread and/or of a long-term or continuous nature, and which can cause irreversible damage to a significant extent.
Moderate	Environmental topics that are affected to a moderate extent have high or medium vulnerability. Impacts occur which typically have either a relatively large extent or a long-lasting nature and which may cause certain irreversible but not entirely local damage.
Limited	Environmental topics that are affected to a limited extent typically have a low vulnerability. The environmental impacts may have a certain extent or complexity, a certain duration in addition to very short-term effects, but are very likely not to cause irreversible damage. Environmental subjects with medium or high vulnerability may also be affected to a limited extent, provided that the environmental impact is of low intensity, short duration and local distribution.
None / Negligible	There are minor impacts that are locally limited, uncomplicated, short-term or without long-term effects and completely without persistent effects. Or no impact occurs.

Positive impacts that have a beneficial effect on the environmental subject in question are assessed based on a simpler scale with the two steps; insignificant, which includes an insignificant to moderate positive impact or significant, which includes a significant positive impact.

In the summary section after the review in each chapter, the environmental impacts are described in a table that lists the assessments of vulnerability, geographical distribution, intensity, duration and consequence for each of the identified environmental impacts in the construction phase, the operation phase and possibly the dismantling phase. Only the worst cases will be presented in the summary table.

The form describes both positive and negative environmental impacts:

- Positive consequences are always highlighted with the text (+) after the relevant consequence.
- A significant positive consequence is also marked with a green colour.

- Significant negative consequences are marked in red, while a moderately negative consequence is marked in yellow.
- There is no colour marking if the consequence is limited, negligible or if there is no consequence.

The use of the colours provides a visual overview of the significant impacts, and they thereby contribute to creating a focus on the choices that the decision-makers must make. Assessment forms for several alternatives or locations are possibly inserted, if relevant. An example of an assessment form can be found in Table 8-1.

Table 8-1 Example of an impact assessment form, * = mitigation measures suggested.

Impact	Vulnerability	Geographical extend	Intensity	Duration	Consequence
Construction Phase					
Impact 1	Low	Local	Medium	Permanent	Moderate*
Impact 2	Medium	Regional	High	Medium / Long	Significant (+)
Impact 3	High	Regional	High	Low	Significant
Operation Phase					
Impact 4	Medium	Regional	High	Medium / Long	Significant
Impact 5	Low	Local	Medium	Short	Limited / Negligible

It is indicated with * when mitigation measures have been proposed that minimize the assessed consequence by at least one level in the above assessment hierarchy.

In the summary chapter of the environmental impact report, all assessment forms are collected in one form to create a comprehensive overview of the project's overall environmental consequences (see chapter 24).

8.3 Environmental considerations and mitigation measures (Minimization and assessment of environmental impacts)

In the project, two types of averted measures are used to avert environmental impacts:

Environmental considerations that are part of the project

In connection with the project description, the environmental considerations that the client has made throughout the project are described, and which are a prerequisite for the realization of the project. This also include standard procedures and conditions that apply from authorities for the type of project that is assessed, e.g., use of soft start procedures during seismic surveys.

Mitigation measures

For those environmental impacts that are assessed to have a significant impact, mitigation measures should be considered.

Averting the impacts that may occur in the various phases of the project can be done in several different ways and is based on what is called the impact hierarchy. This is illustrated in Figure 8-1.

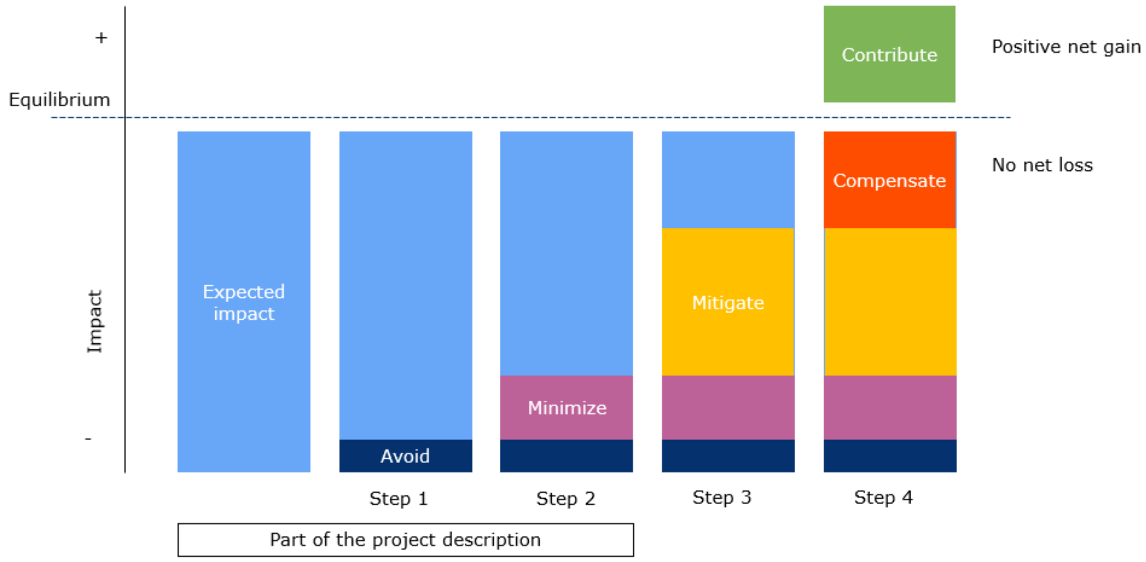


Figure 8-1 Illustration of the mitigation hierarchy and the four steps of measures that can be used in a project to reduce the expected impact. If all impacts can be avoided, there will be no loss in connection with the project and thus equilibrium. It may also be possible to incorporate mitigation measures that contribute positively to a project.

Mitigation measures that are not part of the project description
In connection with the assessment of the individual impacts, the environmental consequence is assessed before and after the relevant mitigation measures have been implemented. Therefore, a section at the end of each chapter describes the mitigation measures that have been implemented with relevance for the individual environmental topic.

Measures that are proposed in the project description to minimize impact
The environmental considerations that have already been incorporated into the project (step 1 and 2 in Figure 8-1) appear in chapter 5. An impact is only assessed where these environmental considerations are already included, as they are a prerequisite for the realization of the project or if they are considered standard procedures that project is obligated to follow.

In connection with the assessment of the individual impacts, the environmental consequence is assessed before and after, if further relevant mitigation measures have been implemented, if these are not already part of the project.

In the overall assessment form, for each receptor, the assessment includes environmental considerations and mitigation measures. The assessment after the implementation of mitigation measures appears in the section on mitigation measures.

9. SCOPE OF IMPACT ASSESSMENT

This chapter describes the receptors, listed in the Environmental Assessment Act (Consolidation Act 4 of 03/01/2023), that can expected to be potentially significantly affected by the project including the population, human health, biodiversity (e.g. fauna and flora), air and climate (e.g. greenhouse gas emissions, impacts relevant to adaptation), material goods, cultural heritage, including the architectural and archaeological aspects, landscape and marine planning (e.g. inclusion of areas). The impact mechanism and relevant receptors are described below for both planned activities and accidental events. Receptors that have been scoped out since impacts will not occur or they are very unlikely are also described. The chapter also describes how cumulative effects from other plans and projects are included in the assessment and which plans and projects that can impact the same receptors as *Project Greensand Future*.

9.1 Impact mechanisms and relevant receptors – Planned activities

9.1.1 Potential impact mechanisms

In the following, the different impact mechanisms associated with activities in this project (chapter 5) are described in relation to which phase they are expected to occur. Decommissioning is described and assessed separately in chapter 18.

Potential impact mechanisms include:

- Underwater noise
- Disturbance from vessels
- Physical footprint
- Physical disturbance of seabed
- Chemical discharges
- Solid waste (only onshore – decommissioning)
- Emissions
- Light
- Resource use
- Restricted zones

Underwater noise

There are several sources of noise emitted from the planned activities and potential impacts can affect the marine fauna. Hearing is the primary sense for many marine mammals for detecting prey, predators, communication, and navigation and underwater noise can therefore cause severe impacts on marine mammals as it potentially inhibits the ability to perform these vital actions. Anthropogenic noise exposure is divided into two specific categories, impulsive or continuous noise (see section 11.8.3). The CO_2 leakage monitoring system (lander) emits noise at a frequency of 500 kHz, which is not detectable by fish or marine mammals, thus it will not be further assessed in this EIA.

<u>Construction phase</u>

It is expected that underwater noise will be generated by vessels, diver- and ROV-operations during installation of the offloading system.

<u>Operation phase</u>

In the operation phase underwater noise is generated from vessels (mainly the CO_2 vessel), ROV operations and seismic monitoring of the reservoirs. ROV operations occur during maintenance of the offloading system, inspection of the subsea structure, maintenance/retrieval of OBSs and validation of the CO_2 leakage monitoring system (lander).

Disturbance from vessels

Construction phase

Vessels required in relation to installation activities in the construction phase are expected to generate disturbance.

Operation phase

In the operation phase, the vessel used for CO_2 transport to the Nini A platform, support vessels for ROV operations and the seismic survey vessel are expected to generate disturbance.

Physical footprint

Construction phase

The physical footprint refers to the area occupied either on the seafloor or throughout the water column by any physical structure needed for realization of the project. Installation of offloading system, anchors, pipeline, pipeline protection as well as the CO_2 leakage monitoring system, connected to an anchor block and a bouy, all result in new structures that occupy space on the seabed.

Operation phase

The offloading system: anchors, pipeline and concrete mattresses for the protection of pipelines, as well as the CO_2 leakage monitoring system connected to an anchor block and a bouy. These all comprise permanent structures on the seafloor, which are present during the entire operation phase. This result in a total footprint area of approx. 850 m^2.

Physical disturbance of seabed

Construction phase

Installation of offloading system can cause physical disturbance of the seabed and consequently lead to sediment resuspension. The resuspension of sediment, as a result of pipelay, placement of concrete mattresses and anchors for the offloading system to cause minor dispersion of the sediment.

Chemical discharges

Construction phase

During the construction phase the offloading system is flooded with seawater and added fluorescent and corrosion inhibitor chemicals, this as part of the hydrostatic testing of the system. Both chemicals are classified as yellow according to the Danish Environmental Protection Agency (DEPA) colour coding and the amount of chemical is in total 11 kg. The yellow chemicals are substances exhibiting some degree of environmental hazard. However, as the discharge volumes are very low, a calculation of an environmental impact factor for each of the chemicals is not relevant.

Operation phase

No activities in the operation phase are expected to cause chemical discharge.

Solid waste (only onshore handling– decommissioning)

Solid waste during construction and operation has been scoped out, see section 9.1.3. Solid waste related decommissioning of the Nini A structures is assessed in chapter 18. Decommissioning of the Nini A platform, the offloading system, pipelines and wells will have limited environmental impact, see chapter 18.

Emissions

Construction phase

Emissions are expected in relation to all activities in the construction phase. Emissions are primarily caused by the use of fossil fuels for transportation of personnel, machinery and material to the Nini

A platform including installation of the offloading system and wireline work in the well. Emissions are not expected from flaring. Other activities requiring the use of fossil fuels include helicopter and boat manning for maintenance and supervision of the construction along with vessels needed for monitoring purposes. Further emissions will be generated by vessel during installation of the CO_2 leakage monitoring system and laydown of OBSs for seismicity baseline.

Operation phase

Fuel consuming activities in the operation phase include helicopter shuttling and boat manning as well as vessels used for transportation of CO_2 to the Nini A platform, seismic surveys, placement of OBSs for seismicity surveys, and maintenance and inspection operations.

Light

Construction phase

Safety lights are present on unmanned platforms such as Nini A to prevent collision with the existing ship and air traffic in the area. Furthermore, vessels needed in the construction activities are equipped with navigational and deck working lights which likewise are sources of artificial light that can potentially impact the environment.

Operation phase

During operation emissions of light will be limited to safety lights on Nini A platform and navigational and deck working lights on vessels needed in the daily operation, mainly the vessel transporting CO_2, but also the vessels carrying out the seismic surveys and maintenance operations.

Resource use

Resource use is described in chapter 5, and is partly scoped out, see section 9.1.3. The only impact assessed from resource use is the derived effect on emissions (see above). The potential impacts to climate gas emissions from the resource usage is assessed in section 11.1.

Restricted zones

Construction phase

A safety exclusion (restriction) zone of 500 m around the Nini A platform exists, where unauthorized vessels are not permitted. There is also a safety zone of 200 m along each side of the pipeline, where no anchoring or trawling is authorized. Besides this, a restriction point will be established around the CO_2 leakage monitoring system marked by one bouy. This is not a restriction zone as such, but a marking to protect the CO_2 leakage monitoring system against activities such as anchoring or trawling.

Operation phase

The vessel for CO_2 transport will operate within the safety exclusion (restriction) zone of 500 m around the Nini A platform. The restriction point of the CO_2 leakage monitoring system remains in the operation phase.

An overview of the planned activities and related potential impact mechanisms is provided in Table 9-1.

Table 9-1 Planned activities and potential impact mechanisms of *Project Greensand Future*. "X" marks the relevance for the impact assessment.

Phase	Potential impact mechanism	Retrofitting of topside equipment	Offloading system	Helicopter shuttling and boat manning	Seismic and seismicity monitoring	CO_2 leakage monitoring	Transportation of CO_2/other vessels	Removal of structures
Construction	**Underwater noise**		X		X		X	
	Disturbance from vessels		X		X		X	
	Physical footprint		X					
	Physical disturbance of seabed		X					
	Chemical discharges		X					
	Solid waste	X	X					
	Emissions	X	X	X	X		X	
	Light	X	X		X		X	
	Resource use	X	X	X	X		X	
	Restricted zones	X	X					
Operation	**Underwater noise**		X		X		X	
	Disturbance from vessels		X		X	X	X	
	Physical footprint		X			X		
	Emissions			X	X		X	
	Light	X	X		X	X	X	
	Resource use			X	X		X	
	Restricted zones	X	X					
Decommissioning	**Underwater noise**						X	X
	Disturbance from vessels						X	X
	Physical disturbance of seabed							X
	Emissions						X	X
	Solid waste							X

9.1.2 Relevant receptors (environmental and social)

The relevant receptors have been assessed based on the project description (chapter 5) and the potential impact mechanisms (Section 9.1). Relevant receptors for the impact assessment are summarized in Table 9-2.

Table 9-2 Potential impact mechanisms and relevant environmental and social receptors and directives of *Project Greensand Future.* "X" marks the relevance for the impact assessment.

	Potential impact on environmental/social receptor	Underwater noise	Disturbance from vessels	Physical footprint	Physical disturbance of seabed	Chemical discharges	Emissions	Light	Resource use	Restricted zones
Environmental Receptors	**Climate and air quality**						X		X	
	Hydrographic condition			X						
	Water quality					X				
	Sediment conditions			X	X					
	Plankton					X				
	Benthic fauna			X	X	X				
	Fish	X		X	X			X		
	Marine mammals	X	X					X		
	Seabirds		X					X		
	Annex IV species	X	X					X		
	Protected areas	X								
Social Recep.	**Material assets**									X
	Cultural heritage			X	X					
	Fisheries									X
Relevant Directives	**Water Framework Directive**					X				
	Marine Strategy Framework Directive	X	X	X	X			X		
	Maritime Spatial Plan									X
	Natura 2000	X	X					X		

9.1.3 Topics that have been scoped out

Some environmental receptors have been scoped out, since no impact is anticipated, or the likelihood of an impact is very low. The following receptors have been scoped out:

- **Geology**: As existing well infrastructure is used, no impact on the geology from this activity is expected. Other impact mechanisms derived from activities in this project are assessed to have no effect on the geology. On these grounds geology is scoped out of this EIA and not treated any further.
- **Land use and surface waters**: The scope of this EIA is transportation of CO_2 from harbour side to the existing offshore oil and gas platform Nini A. Activities occurring on land, which

may potentially impact land use and surface water, are not part of this EIA. These subjects are therefore scoped out of this EIA and not treated any further.

- **Ground water and drinking water**: The scope of this EIA is transportation of CO_2 from harbour side to the existing offshore oil and gas platform Nini A. Activities occurring on land, which may potentially impact ground water and drinking water, are not part of this EIA. Impacts from activities in this project are not expected to have any influence on ground water or drinking water and these subjects are therefore scoped out of this EIA and not treated any further.
- **Landscape**: The scope of this EIA is transportation of CO_2 from harbour side to the existing offshore oil and gas platform Nini A. Activities occurring on land, which may potentially impact landscape values, are therefore not part of this EIA. Impacts from activities in this project are not expected to have any influence on landscape values and the subject is therefore scoped out of this EIA and not treated any further.
- **Resources and solid waste**: The impact related to the extraction of natural resources is not included, however potential impacts to emissions (climate) related to materials usage is assessed. As this project does not involve extraction of natural resources, no impact on resources is expected. Any waste generated in this project will be transported to shore where it is recycled, incinerated, or landfilled in accordance with applicable legislation. Furthermore, as the project plans to use existing oil and gas infrastructure for CO_2 injection, the project is in line with recycling objectives in the EU's Waste Framework Directive (2008/98/EC of 19/11/2008). On these grounds, activities in this project are not expected to have any influence on resources while no impacts from waste are expected. Solid waste generated from decommissioning is however described in chapter 18. These subjects are therefore scoped partly out of this EIA and only treated as part of the potential impacts to climate gas emissions directly from fuels usage and indirectly from materials usage, and waste covered as part of decommissioning activities.
- **Other discharges**: The discharges involve mainly liquid effluents generated by the vessels used during construction and operation. All vessels are expected to comply with the MARPOL regulations; thus no untreated discharges are expected within the jurisdiction borders of the Water Framework Directive. Moreover, as only treated discharge is expected within the 12 nm limit, concentrations of metals and organic contaminants are expected at a level that does not exceed the national quality standards.
- **Human health and recreation**: The scope of this EIA is transportation of CO_2 from harbour side to the existing offshore oil and gas platform Nini A. Although vessels, including the CO_2 vessel, will ship out from Esbjerg harbour, the increased ship traffic, and related emissions relative to the existing traffic in most industrial harbours is not expected to cause an impact to human health. Furthermore, any maritime recreational use of industrial harbours or offshore areas in the North Sea in which the project area is located is very limited. On these grounds, no impact is expected from this project on human health and recreation and the subject is scoped out of this EIA and not treated any further.
- **Physical disturbance of the seabed,** especially related to resuspension of sediments, has been scoped out for water quality and plankton. Resuspension of sediment may lead to mobilization of sediment contaminants that can be released to the water column and thus affect water quality. However, as assessed in following sections, section 11.4.3 and 11.6.3, the potential impacts of physical disturbance are limited, as very little resuspension of sediment is expected from placing structures on the seabed. No trenching or other digging activities will take place, which can lead to greater levels of resuspension and mobilisation of contaminants in the water column. The activities in the construction phase are not expected to lead to resuspended sediment throughout the water column. Furthermore, the baseline survey report found that the upper 30 centimetres of the sediment were well-oxygenated in the project area (DHI and Rambøll, 2023a). As the pipeline will be laid out

on the seabed, no exposure of anoxic sediment is expected, that could lead to mobilization of contaminants from the sediment. Based on this, the impact of remobilization and dispersion of sediment-buried contaminants on water quality or plankton from physical disturbance of the seabed is not assessed further for these receptors.

- **Physical disturbance of the seabed** from deployment of OBSs and optional OBNs by dropping from ship, from retrieval of OBSs (and optional OBNs) with ROV operation and from the secondary bubble detection measure using ROV. These activities are expected to only cause very little potential resuspension of sediment within a few meters of the activity. Since the area is homogenous and vast it is scoped out to assess the minor resuspension of sediment as it will have negligible consequences. Also, the CO_2 leakage monitoring system and related anchor block has been scoped out in relation to physical disturbance of the seabed because this again will only cause minor potential resuspension of sediment. The potential resuspension of sediment from this activity will be very small and definitely smaller than resuspension from the installation of the offloading system.
- **Underwater noise** from the secondary bubble detection measure using ROV. On occasion, and in relation with other ROV activities in the Nini area, an ROV will be deployed to photograph the sea floor near the lander as a means of validation of the lander and as a secondary bubble detection measure. The activity will continue until the lander has proven its durability. This activity will require approx 3 hours annually and will be combines with other ROV activity. Since a slow start will be implemented for any ROV activity, the additional 3 hours are scoped out as a separate activity and covered under ongoing ROV activities.
- **Physical footprint** from OBSs and potentially OBNs. The OBNs may be used in the 2D seismic survey and the optional spot seismic survey. OBNs will be temporarily placed on the seabed during the seismic survey and retrieved after. OBSs are placed for a year during the baseline survey (covered in separate permit) and OBSs will be placed again in the operation phase for continued monitoring of seismicity. The footprint from an OBN is very small (ca. 50 cm diameter) and the OBS takes up approx. 0.5 m^2. Both OBNs and OBSs will be spread over a homogenous and vast area. On these grounds, the physical footprint from OBNs and OBSs have been scoped out of this EIA.

9.2 Impact mechanisms and relevant receptors – Accidental events

9.2.1 Potential impact mechanisms

The scope of potential impact mechanisms from accidental events is based on the risk assessment which was prepared as part of this EIA. Potential impacts from accidental events are only expected in the operation and decommissioning phase and are limited to:

- CO_2 leakage
- CO_2 blowout
- Oil spill blowout
- Leakage from topside and from ships

Leakage of CO_2 from topside and from ships are subject risk assessment and belong to a different legislation regarding work safety conditions, covered by the Danish Working Environment Act (Act no. 2062 of 16/11/2021), and is therefore treated separately from this EIA. For this reason, these topics are not treated in the following. Ships collisions is assessed as a risk to material assets and ship traffic and is described in chapter 12 and 13. An overview of the environmental receptors, that can be affected by the listed accidental events is shown in Table 9-3.

Table 9-3 Relevant environmental receptors for the impact assessment of accidental events for *Project Greensand Future*. "X" marks relevance, while empty fields mark no relevance.

	Potential impact on environmental/social receptor	CO_2 Leakage	CO_2 blowout	Oil spill and blowout
Environmental Receptors	**Climate and air quality**		X	X
	Water quality		X	X
	Sediment conditions	X		X
	Plankton			X
	Benthic fauna	X		X
	Fish			X
	Marine mammals			X
	Seabirds			X
	Annex IV species			X
	Natura 2000-sites			X
	Protected areas			X
	Water Frame Directive			X
	Marine Strategy Framework Directive			X

9.3 Cumulative effects from other projects or plans

Impacts from other projects or plans may cause cumulative effects with impacts from the *Project Greensand Future*. The baseline monitoring of seismicity and CO_2 leakage surveys are conducted prior to first CO_2 injection. These activities are covered by a separate application/permit and will lead to an overlap in activities during the construction phase. As the retrieval of the OBS from the baseline lasts only few days and coincides with the deployment for the continuous monitoring in the operation phase, the overlap is negligible. The impact is limited to vessel activity.

In chapter 21 all existing projects and plans as well as future projects and plans which have either been applied for or given a permit, and which may potentially result in cumulative effects with the current project are described further.

10. EXISTING ENVIRONMENTAL AND SOCIAL STATUS

This chapter provides a description of the current environmental and social status of relevant receptors within the project area (Figure 4-2).

10.1 Climate and air quality

The activities related to the construction, operation and decommissioning phase will result in emissions of gasses and particles to the air, which will potentially lead to a change in the local air quality and affect the greenhouse effect on a global scale.

Air quality

The vast majority of the emissions in the North Sea area are related to cargo ships, and oil & gas facilities. The concentration of anthropogenic emissions decreases with distance from the coast, as illustrated by the NO_2 and SO_2 concentrations in Figure 10-1. The SO_2 concentrations have decreased by 74% between 1990 and 2011 (European Environmental Agency, 2013). A new limit (IMO 2020) on the sulphur content in the fuel oil used on board ships came into force 1st of January 2020. The "IMO 2020" have cut the limit for sulphur content of fuel oil for ships from 3.50 w/w % to 0.50 w/w %, and in the North Sea is within emission control areas (ECAS) with an even stricter limit of 0.10 w/w % (IMO, 2020). Current SO_2 emission is then expected lower than illustrated by Figure 10-1. Particles are also in focus in relation to air quality. Limiting sulphur oxides emissions from ships also reduces emissions of particulate matter, which are tiny harmful particles which forms when fuel is burnt (IMO, 2020).

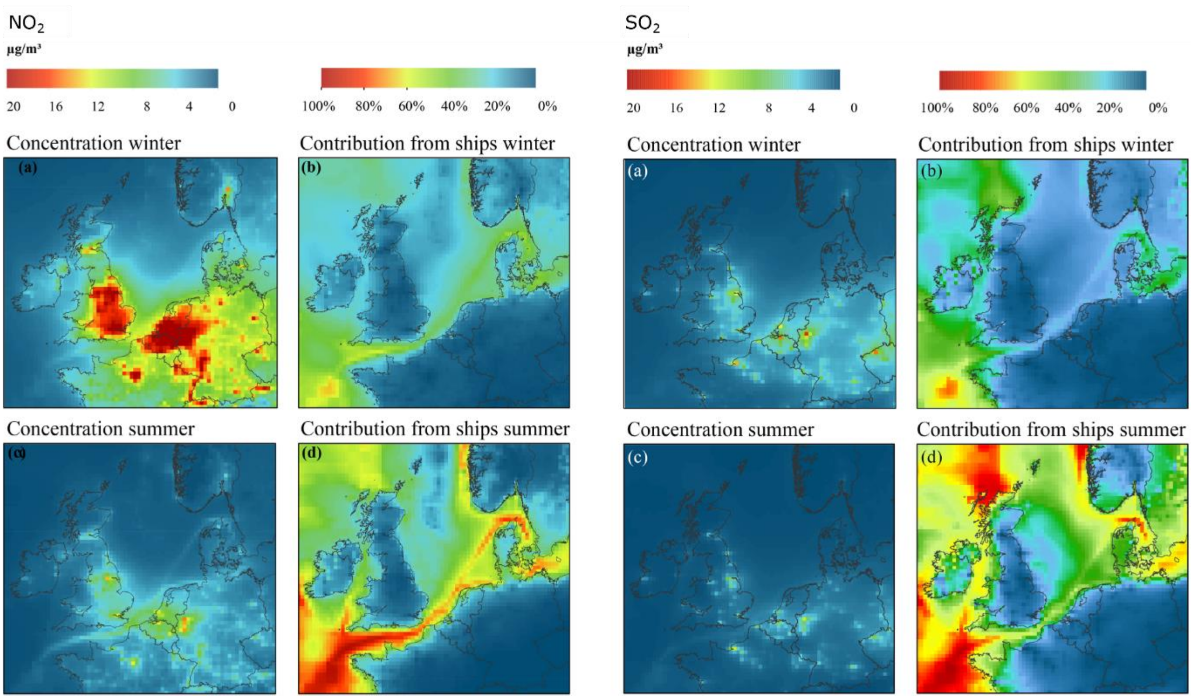


Figure 10-1 NO_2 and SO_2 in summer and winter and the relative contribution of ship emissions (Aulinger et al 2016).

The EU has set limit values for air pollution, which for the Member States are legally binding. The World Health Organization (WHO) has set their own, and in some cases, lower limit values for air pollution, based purely on health professional assessments. The WHO values are only guideline and not legally binding. In Denmark, limit values for the concentration of various substances are specified in the Air Quality Order (BEK no. 1472 of 12/12/2017) (Miljø- og Fødevareministeriet / Miljøstyrelsen, 2017). The Danish air quality limit values are based on the EU Directive (2008/50/EC) "Air quality and cleaner air in Europe", see Table 10-1. These limit values for Nitrogen oxide (NO_2) and particles (PM_{10} and $PM_{2.5}$) will have no direct jurisdiction offshore, however they define levels of concern. As seen from Figure 10-1, the concentration of NO_2 and SO_2 are well below the limit values in the North Sea.

Table 10-1 The three major air pollution parameters – Yearly mean values (Geneva: World Health Organization, 2021; Europa-Parlamentet og Rådet, 2008).

Parameter	WHO limit value (Geneva: World Health Organization, 2021)	EU limit value (Europa-Parlamentet og Rådet, 2008)
NO_2	10 µg/m^3	40 µg/m^3
SO_2	40 µg/m^3	125 µg/m^3 *
$PM_{2.5}$	5 µg/m^3	25 µg/m^3
PM_{10}	15 µg/m^3	40 µg/m^3
*Equal to 1 day value. Cannot be exceeded more than three times per year.		

Climate gasses

The historical and future emissions of greenhouse gases in Denmark and globally are summarized below.

In this report all greenhouse emissions are counted as CO_2 equivalents. The CO_2 equivalents are further referred to as CO_2e, where emissions of other greenhouse gases (including methane and dinitrogen oxide) are converted into their effects in CO_2 equivalents (CO_2e).

CO_2 is the main greenhouse gas, and emissions of CO_2 contributed 67.9% of national total emissions (excluding land use, LULUCF) of greenhouse gases in 2021 Next, methane (CH_4) makes up 19.7%, dinitrogen oxide (N_2O) 11.7% and the remaining greenhouse gases HFCs, PFCs and SF_6 make up 0.7%. Most of global CO_2 emissions are due to the use of fossil fuels (i.e. coal, oil and gas) as fuels in the energy sector, in homes, in industrial plants and in the transport sector (O.-K. Nielsen et al., 2023).

The most important sectors in terms of greenhouse gas emissions in 2021 are estimated to be Energy (61.8%), Industrial Processes and Product Use (4.0%), Agriculture (26.2%), LULUCF (5.3%) and Waste (2.7%), see also Figure 10-2. Emissions from transportation is included in the Energy sector.

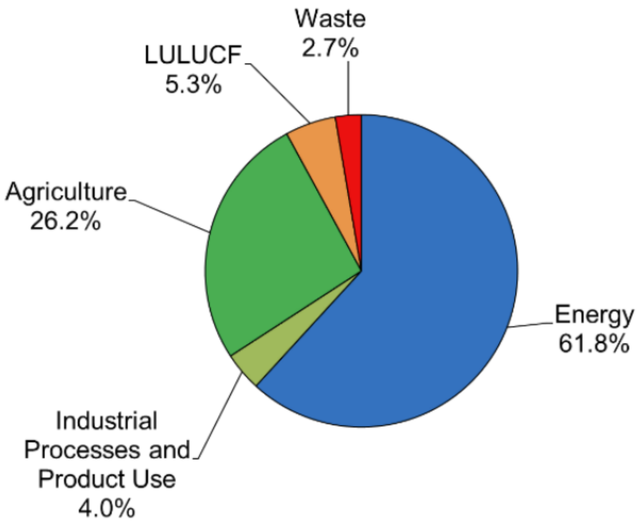


Figure 10-2 Total greenhouse gas emissions (CO_2e) by main sectors for 2021 (O.-K. Nielsen et al., 2023).

The projection of Denmark's greenhouse gas emissions in the Danish Energy Agency's "Climate status and projection 2023" contains estimates for the development up to 2035. This includes estimated effects from the measures implemented or decided until 1 January 2022 (so-called "frozen policy"). According to Danish Energy Agency's "Climate status and projection 2023", Denmark emitted a total of 45.5 million tons of CO_2e in 2021 (Land Use, Land-Use Change and Forestry – LULUCF), and is projected to emit 30.2 million tons of CO_2e by the year 2035 (Energistyrelsen, 2023b). See selected data in Table 10-2.

Table 10-2 Current and future national emissions of CO_2e (million tons), including land use (LULUCF) by "frozen policy".

2020	2025	2030	2035
44.9	41.4	33.6	30.2

Denmark's greenhouse gas emissions can be calculated in several ways. At DS (Statistics Denmark) this is calculated for the Danish economy and includes emissions from international transport. DS has calculated the total emissions to 81 million tons CO_2e in 2022, which is almost double the Danish Energy Agency's estimated emissions within the Danish borders (Danmarks Statistik, 2022).

According to the Danish Energy Agency's "Climate status and projections 2022", the historical and expected development in Danish net greenhouse gas emissions in 2025 and 2030, respectively, are as shown in Figure 10-3. The figure also shows that there is a significant shortfall in achieving the Climate Law's 70% reduction target by 2030 (Consolidation Act no. 2580 of 13/12/2021). This gap between projected and planned greenhouse gas emissions could be lowered by initiatives such as *Project Greensand Future*.

Greenhouse gases affect the greenhouse effect on a global scale and do not directly cause local impacts such as air pollution. Therefore, local levels of CO_2 and other greenhouse gases in the local area offshore are not relevant to describe.

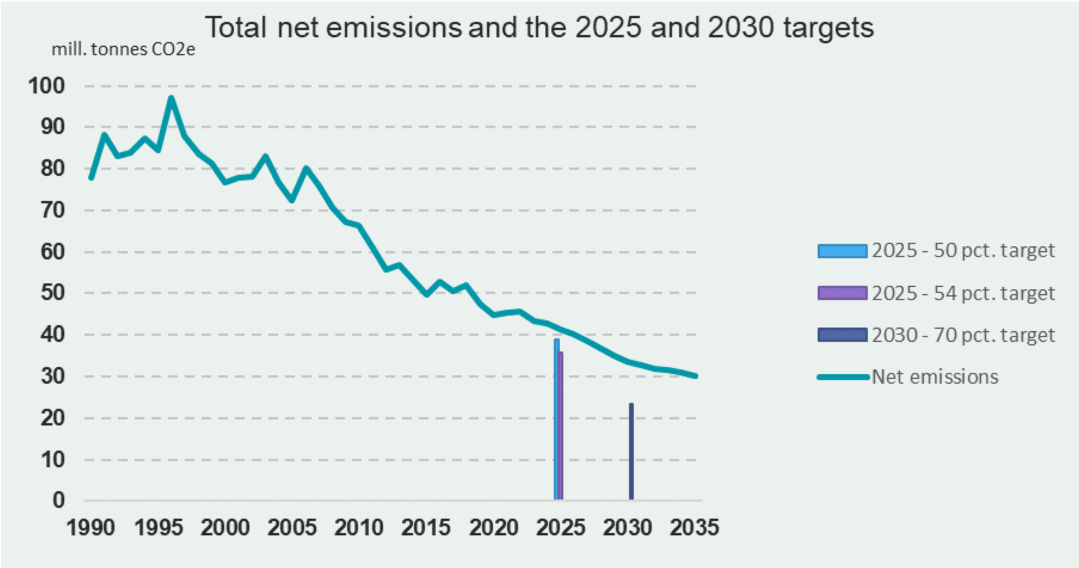


Figure 10-3 The total Danish greenhouse gas emissions (CO_2e) and the reduction targets for 2025 and 2030 according to the 2021 climate law (Energistyrelsen, 2022d).

10.2 Hydrographic conditions

The North Sea is a part of the north-eastern Atlantic Ocean, located between the British Isles and the mainland of north-western Europe. It is relatively shallow with an average water depth of about 90 m. Depths in the Danish part of the North Sea rarely reach below 90 m with the exception of the Northern part (e.g. the Norwegian Trench and the Skagerrak; see Figure 10-4), which is generally deeper (European Commission, 2022).

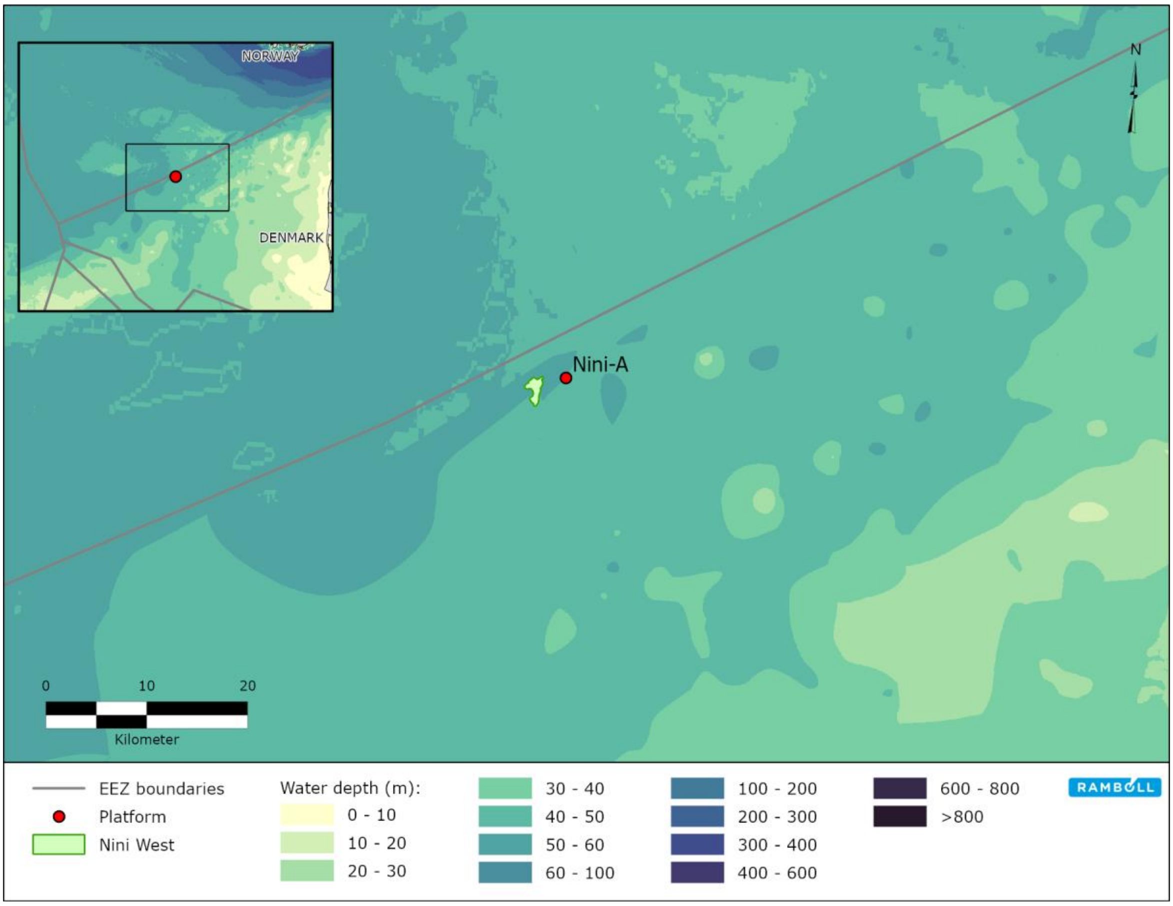


Figure 10-4 Bathymetry of the project area in the North Sea.

The project area is located in the central part of the North Sea with recorded depths ranging between 59 – 61 m. Further east off the project area, depths decrease with decreasing distance to the west coast of Denmark.

The North Sea is a semi-enclosed sea. The water circulation is determined by inflow from the North Atlantic, water through the English Channel, river outflow from the Rhine and Meuse and the outgoing current from the Baltic Sea through Skagerrak (Figure 10-5). These inflows of water, in close interaction with tidal forces and wind and air pressures, create a complicated flow pattern in the North Sea. The project area is located in the central North Sea, where the dominant water circulation is eastward. The natural current influence was estimated from the dynamic forms of the sea floor as observed from the ROV recordings in the baseline survey conducted in July 2022 (Rambøll, 2022). The recordings showed weak to medium current exposure in the project area. Furthermore, the project area is located in a part of the North Sea which is subject to seasonal stratification (Van Leeuwen et al., 2015).

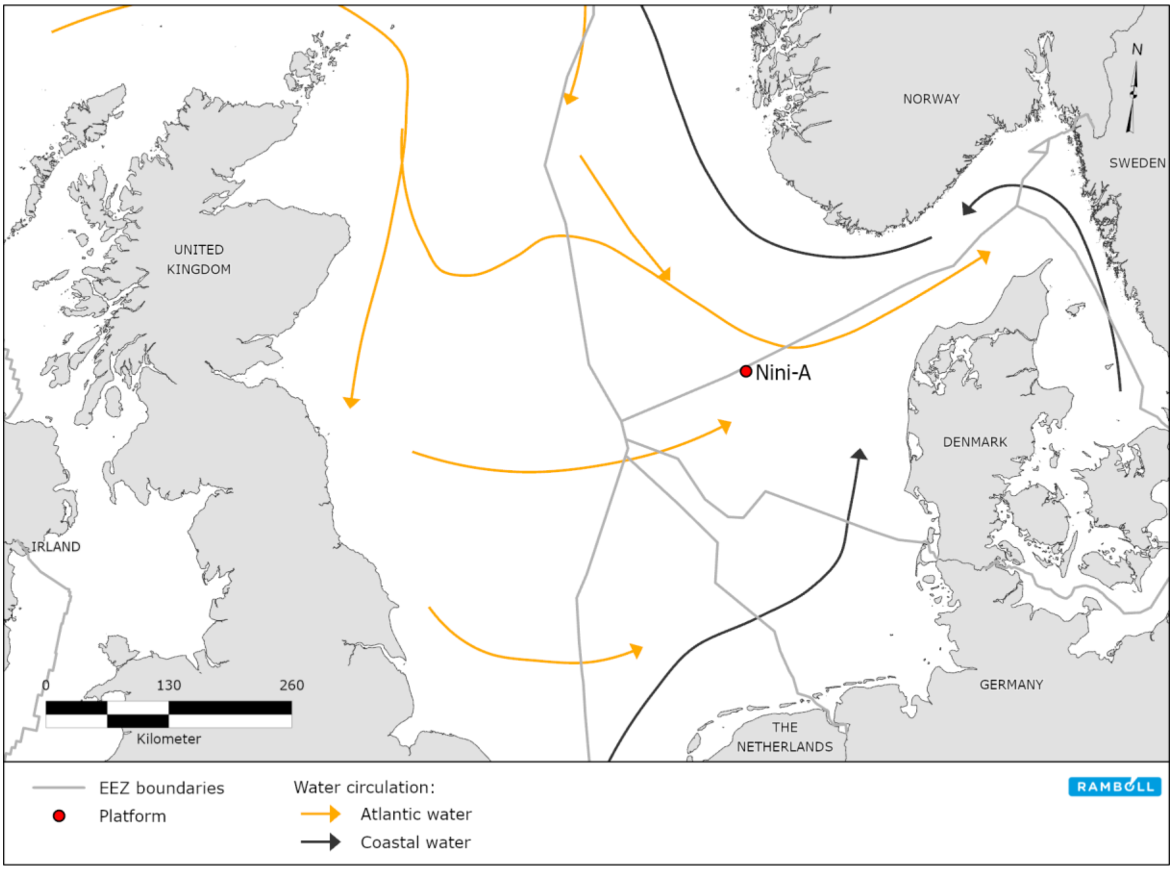


Figure 10-5 General water circulation in the North Sea (*Havforskningsinstituttet*, 2017).

Hydrographic fronts are created where different water masses meet, and include areas of upwelling, tidal fronts, and saline fronts. Hydrographic fronts are considered of great importance to the North Sea ecosystem. No potential for hydrographic fronts has been identified in the project area and the closest proximity to a potential front is more than 20 km from the area of activity (Figure 10-6).

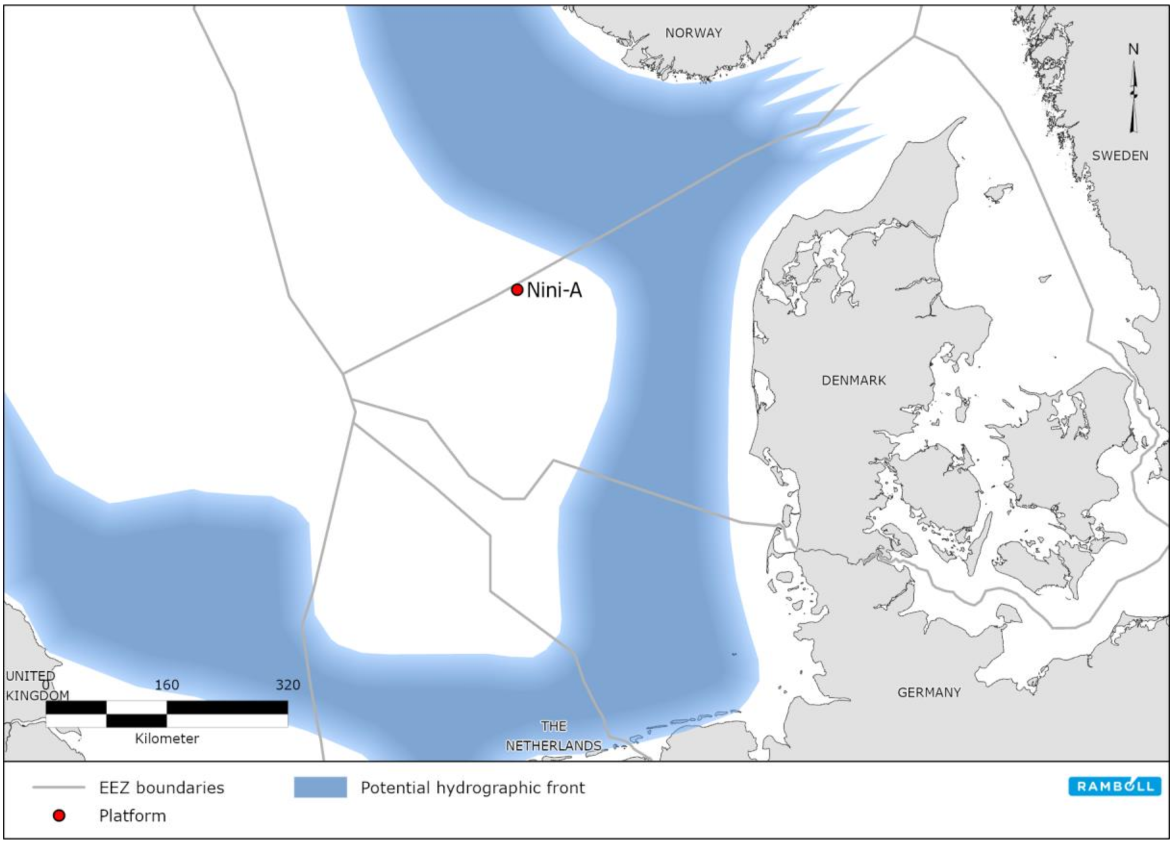


Figure 10-6 Potential for hydrographic fronts in the North Sea (*Havforskningsinstituttet*, 2017).

10.3 Water quality

The salinity in the North Sea varies from the most saline water in the west to more brackish water along the coastal areas in the East. In the project area, bottom salinities are above 35 ‰ (Figure 10-7).

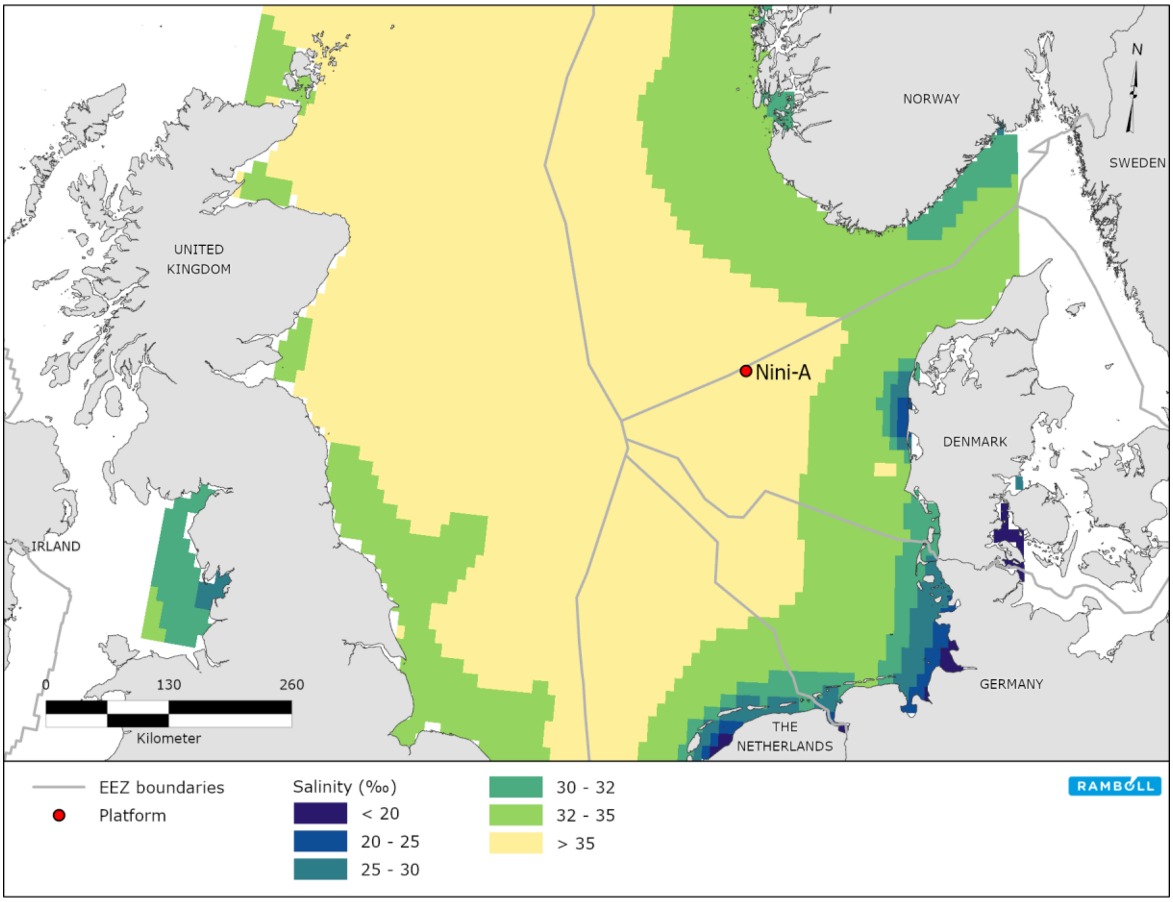


Figure 10-7 Bottom salinities in the North Sea region (EMODnet, 2021a).

The temperature in the North Sea varies seasonally and the lowest temperatures are found in the northernmost part with increasing temperatures further south into the shallower parts of the North Sea. The surface temperature in the project area ranges between 6-8 °C in winter (January) and between 14-16 °C in summer (August), while the bottom temperature only varies slightly seasonally with temperatures between 6-8 °C in winter (January) and 8-10 °C in summer (August) (Rambøll, 2015).

The open North Sea is classified as a "no problem area" in regard to nutrients (OSPAR Commission, 2017). Nutrient concentrations were measured in September 2023 in the surface water at station 91000060 located approx. 15 km from Nini A platform (Danmarks Miljøportal, 2023). The concentration of total-N ranged between 0.010-0.14 mg/l and total-P between 0.01-0.024 mg/l.

The concentration of chlorophyl (uncorrected data) was measured in September 2023 at the same station (91000060) showing an average concentration of 1.25 ug/l chlorophyl close to the project area (Danmarks Miljøportal, 2023). No specific threshold values exist to define good ecological status (c.f. Descriptor 5 (Eutrophication) in the Marine Strategy Framework Directive) regarding chlorophyl. However, according to the Danish Marine Strategy, the environmental status of the open marine waters far offshore is generally assessed as good with regard to eutrophication (Miljø- og Fødevareministeriet, 2019a).

Most parts of the North Sea are classified as 'problem areas' (95%) based on their Chemical Status (European Environment Agency, 2018). Metals, other organohalogens, PCBs and PAHs are the triggering substances. Contaminants in seawater can enter the food web through ingestion by animals and bioaccumulation. The concentration of cadmium, lead, mercury, PCBs, and PAHs has decreased radically since the 1990s. The concentration of PAHs is still above background levels, but below the Environmental Assessment Criteria and thus unlikely to cause any adverse effects (OSPAR, 2017). Seabed monitoring of contaminants has regularly been conducted around the Siri platform located close to the Nini A platform. The results from these surveys are further described in the section below.

10.4 Sediment conditions

The chemical and physical characteristics of the sediment in the project area were examined as part of the baseline survey report – benthic fauna and sediments (DHI and Rambøll, 2023a). The baseline survey was conducted in the period, 12 – 15 July 2022, from the survey vessel Esvagt Server. Sampling of seabed sediments was performed using a HAPS core sampler. 24 stations distributed along two transects stretching between 50 m and 3500 m northeast and southwest of the Nini A platform and above the Nini West gas reservoir were sampled (Figure 10-8). The top 5 cm of surface sediment was sampled for physical and chemical analysis, while the top 0.5 cm of HAPS cores was used for qualitative detritus analyses.

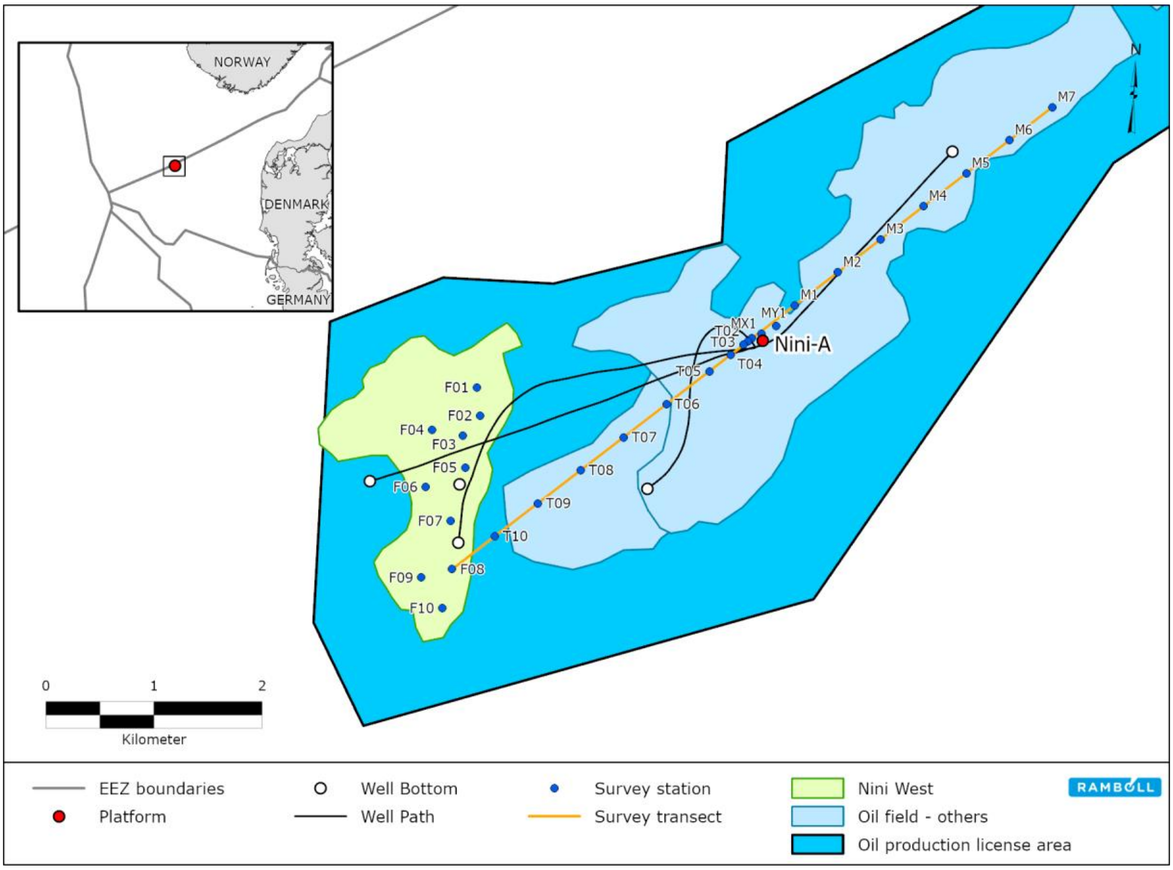


Figure 10-8 Sampling station locations along transects in the project area.

Physical characteristics

Sediment samples from 18 of the 24 stations were analysed for physical characteristics. Most samples were muddy sands or sands with means of fine sands or very fine sands, and with moderate sorting. These findings align with the dominant habitat types found in the western part of the Danish EEZ (Figure 10-9). The D50s (the size under which 50 percentage of the particles are found, also expressed as median) were in the range between 0.12 mm and 0.14 mm.

The results from the baseline sediment survey report indicate that the sediments, found in the project area, are slightly finer in composition compared to sediments found near oil and gas platforms in the vicinity of the project area. Results from baseline surveys and environmental impact assessments from Siri, Solsort and Harald found median grain sizes in the range 0.16 mm to 0.21 mm. Furthermore, comparisons of physical characteristics of sediment samples from Siri between 2002 and 2021 show a high degree of similarity.

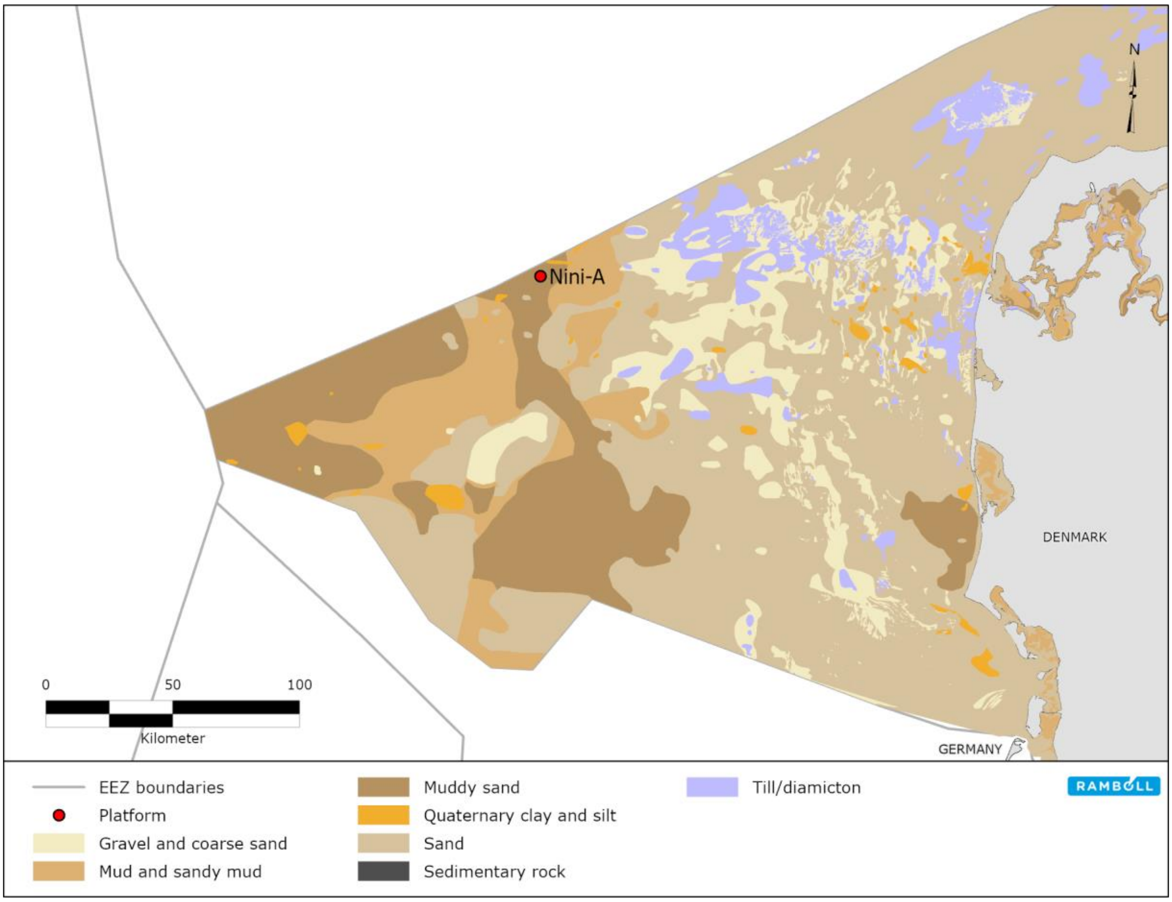


Figure 10-9 Broad sediment types found in the Danish part of the North Sea (EMODnet, 2021a).

Chemical characteristics

Sediment samples from 24 stations were analysed for chemical characteristics. Chemical analyses included assessment of the following indicators:

- Organic content: Total organic carbon (TOC), total nitrogen (TN) and total phosphorus (TP)
- Metals: Silver (Ag), Aluminium (Al), Arsenic (As), Barium (Ba), Beryllium (Be) Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Mercury (Hg), Manganese (Mn),

Molybdenum (Mo), Nickel (Ni), Lead (Pb), Antimony (Sb), Selenium (Se), Tin (Sn), Thallium (Tl), Vanadium (V), and Zinc (Zn)
- BTEX: Benzene, Toluene, Ethylbenzene and Xylenes
- NPD: Naphthalene, C1-Naphtalene, C2-Naphtalene, C3-Naphtalene, C1-Phenantrene, C2-Phenantrene, C3-Phenantrene, Dibenzothiophene, C1-Dibenzotiophene, C2-Dibenzotiophene, C3-Dibenzotiophene
- 16 PAHs (polyaromatic hydrocarbons) (EPA16): Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benz(a)anthracene, Chrysene, Benz(b)fluoranthene, Benz(k)fluoranthene, Benz(a)pyrene, Dibenz(a,h)anthracene, Benzo(ghi)perylene and Indeno(123cd)pyrene
- THC: Total Hydrocarbons (C12 – C35)
- Aliphatic hydrocarbons (C5 – C35)

To assess the environmental status of the sediment in terms of chemical characteristics, Descriptor 8: contaminants of the Marine Strategy Framework Directive (chapter 15) requires that selected indicators are compared to reference conditions. Average historical values from reference stations measured at seabed monitoring campaigns from 1989-2021 were calculated for the northern and the southern North Sea by dividing monitored platforms into the relevant region and averaging values within each group (DHI and Rambøll, 2023a). For the current assessment, the northern reference was the most relevant and was used as a basis for comparison. Background Reference Level (BRL) was obtained from a bootstrap (statistical) analysis conducted (Oil & Gas Denmark, 2017). The OSPAR Effect range low (ERL) values are used for evaluation of the ecotoxicological status, see Table 10-3. The analytical results are scaled against the reference conditions, whereby an index value between 0 and 100 is obtained for those compounds where an index is calculated. Not all metals are calculated. The closer the index value is to 100, the closer the sample is to reference conditions.

Statistical analyses of those variables which is of concern of e.g., OSPAR and HELCOM showed that all PAHs, Lead, and Mercury had an index of 100, whereas Cadmium, Chromium and Cupper had indices between 99 and 100. Lowest score, 95, was found for zinc. Based on the 2021 survey the sediment contamination level can be regarded as low and close to background levels. The index calculation is further elaborated in baseline survey report (DHI and Rambøll, 2023a).

The chemical index values of the top sediments along the transects in the projects area are comparable to or higher than the results of previous chemical analyses of the sediments in the area/Siri Canyon. A 2021 North Sea seabed monitoring at the Siri Platform showed that MSFD contaminants of descriptor 8 index values were on average 97 (with the lowest scores being 78 and 92) (INEOS, 2022). Recent seabed sediment research in the North Sea has shown a general decline over the last 20 years on concentration of pollutants like PAH, PCB and other substances (Logemann et al., 2022) and the low concentrations found in the project area is in line with this study.

Table 10-3 Regional Background Reference Level (BRL) based on reference stations of northern platforms and Effects Range Low (ERL) for MSFD descriptor 8 (Oil & Gas Denmark, 2017).

Indicators	BRL North	ERL
Contaminants – Metals- all mg/kg DW		
Cadmium	0.025	1.2
Chromium	11.0	81
Copper	1.6	34
Lead	11	47
Mercury	0.05	0.15
Zinc	9.5	150
Contaminants – Hydrocarbons – all µg/kg DW		
PAH*	97.6	3340
Naphthalene	3	160
Anthracene	1	85
Phenanthrene	3.1	240
Dibenzothiophene	1	190
Fluoranthene	7.2	600
Benzo(a)anthracene	4.6	261
Chrysene (incl. triphenylene)	6.3	384
Benzo(g,h,i)perylene	23	85
Benzo(a)pyrene	5.9	430
Indeno[1,2,3-cd]pyrene	37	240
Pyrene/ triphenylene	5.5	665
*16 US-EPA PAH		

Investigations of the sediment chemistry showed that although traces were found for several of the analysed variables, all aliphatic groups were under the detection limit and the same was applicable for the BTEX components (Table 10-4).

Generally, the concentrations of both heavy metals and hydrocarbons were similar to the Background Reference Levels (BRL) was found to be lower than GES or TEL. Barium was elevated near the Nini platform. Barium is a constituent of the drilling mud and likely to originate from the past drilling activities.

Table 10-4 Summary of results of the 20 Nini sediment samples (excl. reference sample). Results below the LoQ are not included in the sample average and standard deviation calculations.

Parameters	n*	Average	Min	Max	SD	LoQ**
		mg/kg DM				
Total Nitrogen	24	368	80	590	117	40
Total Phosphorus	24	250	130	430	57	32
Organic matter (%/DM)	1.8	1.8	0.4	2.2	0.4	0.3
TOC (%/DM)	23	0.49	0.03	0.63	0.13	0.1
ΣPAH16	24	0.14	< 0.001	0.51	0.09	0.001
Naphthalene	23	0.0039	< 0.001	0.0120	0.0026	0.001
Anthracene	24	0.0034	0.0001	0.0460	0.0091	0.0001
ΣNPD	24	0.12	0.01	0.30	0.06	0.01
Σmethylnaphthalenes	24	0.01	0.00	0.03	0.01	0.01
THC C12-C35	24	9.5	2.8	38	6.7	1
ΣBTEX	0	<0.01	<0.01	<0.01	-	0.01
Aliphatic hydrocarbons C5-C35	0	<10	<10	<10	-	10
Silver	0	-	< 0.2	<0.2		0.2
Arsenic	24	4.3	2.9	9.0	1.1	0.2
Barium	24	127	6	514	111	0.6
Cadmium	2	0.03	<0.03	0.03	-	0.1
Copper	24	1.2	0.2	2.9	0.5	0.3
Chromium	24	11.2	3.5	13.3	1.9	0.1
Mercury	0	<0.01	<0.01	<0.01	-	0.01
Nickel	24	4.6	1.0	5.9	1.0	0.2
Lead	24	9.4	5.1	10.7	1.3	0.1
Vanadium	24	17.5	13.7	19.8	1.6	0.2
Zinc	24	16.1	5.4	18.8	2.6	2

*Number of positive results
**Limits of Quantification
DM: Dry matter

10.5 Biodiversity

10.5.1 Plankton

The plankton community can generally be divided into a plant component (phytoplankton) and an animal component (zooplankton). Phytoplankton are primary producers constituting the main contributor of organic matter in the North Sea, and thus for the whole marine food web. Other than light, primary production depends on nutrient availability, primarily nitrogen and phosphorous. Nutrients may either be imported from outside to the euphotic zone or derived from local remineralization. Due to grazing by zooplankton and subsequent decomposition of organic matter and release of nutrients into the water column the metabolism of zooplankton and phytoplankton is mutually connected.

In the North Sea, the phytoplankton is mainly light-limited in winter and nutrient-limited in the water above the thermocline in summer (OSPAR Commission, 2000). Data from the ESIA of TYRA platform estimated the average annual phytoplankton colour index (PCI) for the North Sea between

1983-2003 (Rambøll, 2015). PCI is a visual proxy directly related to the biomass and abundance of the phytoplankton close to the surface. The highest biomass and abundance of phytoplankton was found in the Eastern and Southern parts of the North Sea. The project area is located in an area with an average biomass and abundance comparable to the rest of the North Sea (Figure 10-10).

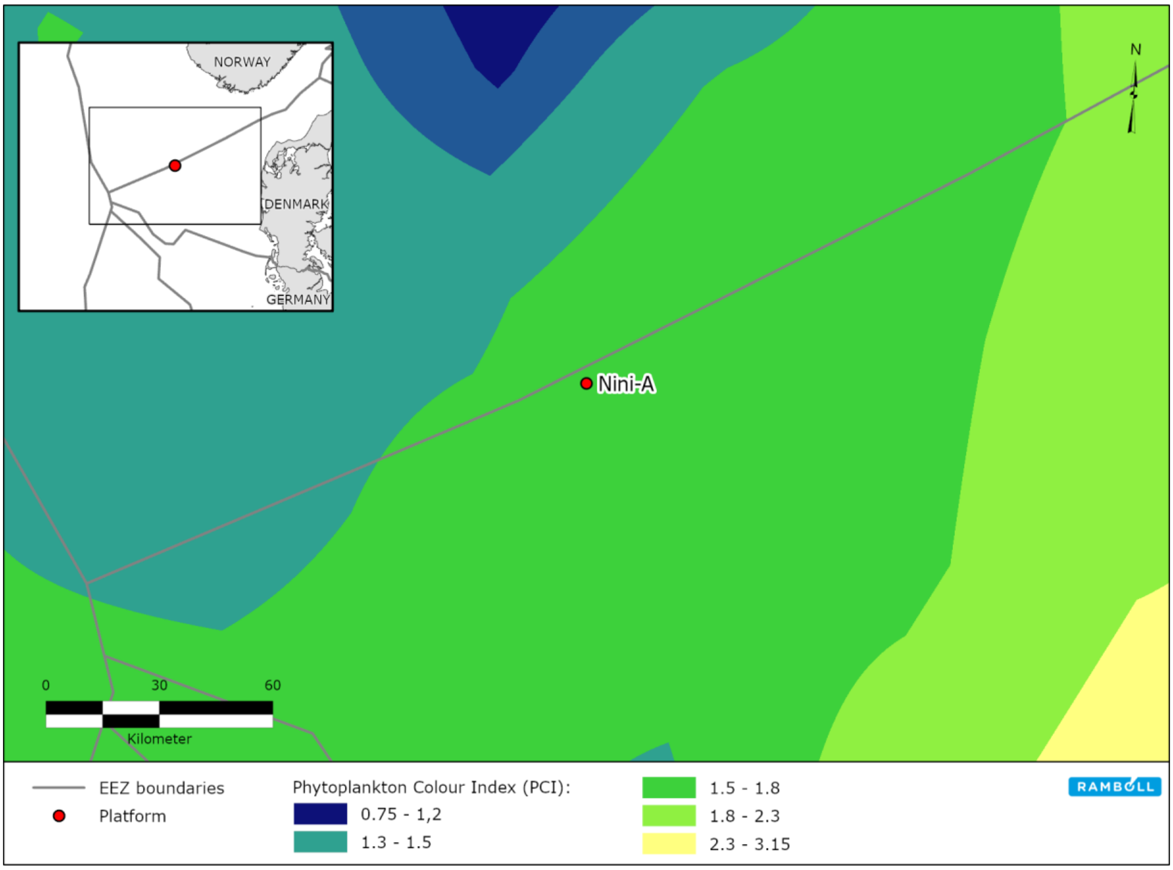


Figure 10-10 Average annual phytoplankton colour index (PCI) for the project area and surrounding areas in the North Sea based on data collected between 1983-2003.

The phytoplankton community is dominated by dinoflagellates and diatoms, while the zooplankton communities in the North Sea are dominated by copepods, particularly Calanus species such as *C. finmarchicus* and *C. helgolandicus* (Rambøll, 2015). Calanoid copepods are large crustaceans (in a planktonic context) which range in size between 0.5 – 6 mm and are an important prey item for many species at higher trophic levels.

10.5.2 Benthic fauna

The benthic fauna in the project area was investigated as part of the baseline survey report – benthic fauna and sediments (DHI and Rambøll, 2023a). The baseline survey was conducted from 12 – 15 July 2022 from survey vessel Esvagt Server, where investigation and sampling of the benthic fauna was performed visually with ROV and based on analysis of 48 Van Veen samples. The Van Veen samples were sifted through a 1 mm mesh. During laboratory analysis, only retained organisms larger than 4 mm were quantified and used in the following description of the benthic fauna. The technical guidelines from the National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environment (NOVANA) instruct the use of a 1 mm sieve, but in this project, focus has been on larger shell bearing invertebrates like mussels, snails and echinoderms which are most likely to be affected by CO_2. Therefore, smaller species has not been analysed. The rest of the samples were stored for later use.

In addition to the analysis of benthic macrofauna, a microbiological baseline study of the sediment samples was conducted (DTI, 2023). This included quantification and characterization (microbial fingerprinting) of bacteria occurring naturally in the seabed sediment. Such bacteria are known to be present in high numbers, typically more than 108 cells per g of sediment, and perform an important ecological function in the environment by degrading organic material deposited on the seabed. A total of 68 samples from 20 stations were retrieved for bacterial eDNA analysis. Further details on methodology of lab work and data analysis can be found in the baseline study report (DTI, 2023).

Prevailing habitat conditions in the project area

Based on the physiochemical conditions in the investigated area (Section 10.4), two benthic habitat types were identified (Table 10-5).

Table 10-5 Characteristics of the benthic habitat type at the Nini field area specified with respect to depth, substrate, current and salinity.

Habitat type	Depth (m)	Substrate	Current exposure	Salinity (‰)	Representative stations
Even aphotic sandy soft bottom	65-70	Fine sand	Slightly variable around weak to medium	33-34, stable	All except M7
Even aphotic sand bottom	60-65	Coarse sand	Varying around medium to strong	33-34, stable	M7

Three decisive selected factors were used as criteria for the division, namely depth (which, among other things, determines the incidence of light at the sea floor), currents and substrate. The salinity in the area was stable at around 34 ‰ in this part of the North Sea and was therefore not considered an independent habitat-defining parameter for the investigated area. In addition, questions on whether the proximity to Nini A platform might have or possibly has had an impact on living conditions in the area were considered.

In the North Sea, depths above 25-30 m will not allow the light to reach down to an extent that enables benthic net primary production.

Based on the grain size, the substrate was divided into three biologically relevant main categories: silty sand (2-120 µm), fine sand (120-240 µm) and coarse sand (240-2000 µm).

The natural current influence was estimated from the dynamic forms of the sea floor as observed from the ROV recordings. Areas characterized by movements at the sediment surface were characterized by a relatively coarse and well sorted substrate texture (particles > 200 µm) and the presence of pronounced wave ridges (dynamic bottom shapes). The degree of influence of currents was divided into three relative categories which can be expected to affect the bottom water in this part of the North Sea (weak, medium, and strong). At those depths and on a topographically plain bottom, the influence of currents will neither be low (non-existent) nor particularly strong (as in tidal zones and straits).

The most distant station (M7) deviated from the pattern by having a coarser substrate type and being more affected by current. Since it was in the extreme eastern part of the studied area, it was not crucial that it was only represented by a single station. Judged from the sediment chemical conditions, there was no detectable effect on the living conditions from the presence of the platform or former oil and gas related activities.

Macrofaunal conditions in the project area

In a recently published overall assessment of the biodiversity in the European sea areas, the Danish part of the North Sea is generally evaluated as being in a not-good status (Vaughan D. et al., 2019). The benthic condition in the open Danish offshore parts of the North Sea is denoted as moderate. The past diversity with a large and varied number of mussels has been replaced by a significantly poor and much more scattered occurrence. Icelandic cyprine (*Arctica islandica*), which previously in terms of biomass dominated the infauna with several individuals per m^2, are today almost rare. Similarly, small opportunistic invertebrate species among echinoderms, bristle worms and crustaceans have taken over larger and more specialized species within these groups.

In this respect, the investigated area around the project area does not differ. The surface of the seabed looks poor in terms of larger motile animals (necto benthos) such as the brittle star *Ophiura albida* and decapods. Instead, small species such as the mud brittle star (*Amphiura filiformes*), small cumaceans and small burrowing sea urchins (*Echinocardium cordatum*) seems to thrive (DHI and Rambøll, 2023a).

The benthic ecosystem is thus greatly impoverished compared to what it was just a few decades ago. The problem is not only about an absence of special species but is due to radical changes in ecological interactions taking place in recent times. The food web structure has apparently changed in favour of small opportunistic species. The reason is as always multifactorial, but the resulting absence of top predators has probably been decisive for the deterioration of the food chain structure. Assuming that the causes of the loss of large organisms within the various marine animal groups are addressed, a recovery of the ecological systems will take decades. This is because the feedback mechanisms in the food chain structure tend to "lock in" and maintain an existing structure. The original physiochemical living conditions, see Section 10.2, 10.3 and 10.4, on the other hand, appear to be reasonably intact and therefore do not pose any immediate obstacle to the re-establishment of the favourable ecological conditions. The qualitative photography using ROV generally showed a relatively varied bottom life (DHI and Rambøll, 2023a). In relation to depth and substrate as well as current exposure (assessed based on sand ridges and substrate structure) a relatively good distribution and appearance of organisms was seen. Lots of signs of activity at the sediment surface of burrowed organism (infauna) was seen. However, the general absence of larger live mussels, as determined from the bottom samples, and compared to the many found shell remains from large mussels, testified to a disturbed seabed. Based on the colour and smell of the sediment, the oxygen conditions seemed good. And since the chemical conditions did not indicate any notable contaminated condition, the probability that it was an ecosystem change or mechanical disturbance is greatest. From the ROV recordings, however, there were no visible signs of a man-made mechanical influence in the form of a bottom trawl or similar. This could indicate that the absence of mussel is caused by a change in the ecosystem. Sampling showed the presence of urchins dominated by the common species; Sea Potato (*Echinocardium cordatum*) which is known for predating on newly settled mussels. A large number of urchins could perhaps decimate the mussel populations. Sea urchins are eaten by sharks and rays, which have declined dramatically in the North Sea due to overfishing and this can in turn lead to an increase in the number of urchins.

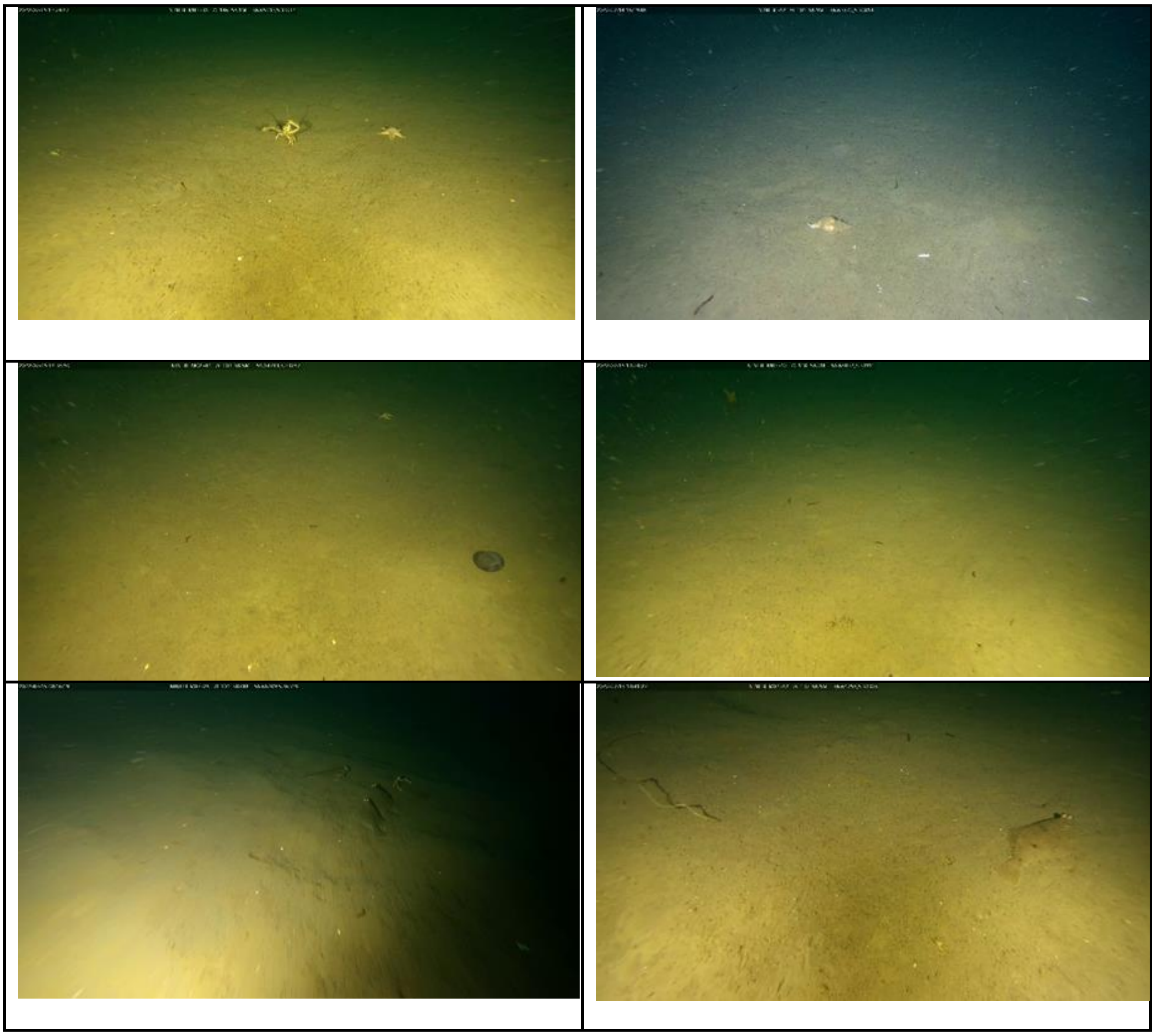


Figure 10-11 Photographs of the macroscopic appearance of the seabed and some of the macroscopic life present in the project area in the North Sea, July 2022.

Upper left: Masked crab (*Corystes caccivelaunus*) and *Luidia* starfish. Also, hubs from Lugworms are seen. Upper right: Red whelk, small holes created by fish seeking food. Middle left: possibly Manganese nodule. Middle right: Dead man's finger seen in the background, the 5-10 cm long shaped checkered forms (which were also recognized on other photos) are probably Ribbon worms. Lower left: three Long rough dab and a Masked crab. Lower right: Plaice and long tube of bristle worm (possibly *Spiochaetopterus typicus*).

In the quantitative inventory of the infauna a total of 90 different benthic invertebrate species were found (Table 10-6).

Table 10-6 Benthic species in the project area, distributed in their respective classes or orders (DHI and Rambøll, 2023b).

Species	Class or Phylum	Species	Class or Phylum
Actiniaria	Anthozoa	*Ophiura sp.*	Ophiuroidea
Cerianthus lloydi	Anthozoa	*Ophiuroidea*	Ophiuroidea
Astropecten irregularis	Asteroidea	not identified to species level	Phoronida
Abra prismatica	Bivalvia	*Tricladida sp*	Platyhelminthes
Acanthocardia echinata	Bivalvia	*Anobothrus gracilis*	Polychaeta
Arctica islandica	Bivalvia	*Aphrodita aculeata*	Polychaeta
Chamelea gallina	Bivalvia	*Diplocirrus glaucus*	Polychaeta
Cochlodesma praetenue	Bivalvia	*Eunereis longissima*	Polychaeta
Dosinia lupinus	Bivalvia	*Galathowenia oculata*	Polychaeta
Gari fervensis	Bivalvia	*Gattyana cirrosa*	Polychaeta
Leda minuta	Bivalvia	*Glycera alba*	Polychaeta
Nucula nitidosa	Bivalvia	*Glycera gigantea*	Polychaeta
Nuculoma tenuis	Bivalvia	*Glycera rouxii*	Polychaeta
Phaxas pellucidus	Bivalvia	*Glycera sp.*	Polychaeta
Spisula subtruncata	Bivalvia	*Glycinde nordmanni*	Polychaeta
Thracia phaseolina	Bivalvia	*Goniada maculata*	Polychaeta
Thyasira flexuosa	Bivalvia	*Harmothoe lunulata*	Polychaeta
Chaetoderma nitidulum	Caudofoveata	*Lumbrineris fragilis*	Polychaeta
Echinocardium cordatum	Echinoidea	*Magelona alleni*	Polychaeta
Echinocardium flavescens	Echinoidea	*Maldane sarsi*	Polychaeta
Echinocyamus pusillus	Echinoidea	*Nephtys assimilis*	Polychaeta
Harrimania kupfferi	Enteropneusta	*Nephtys caeca*	Polychaeta
Buccinum undatum	Gastropoda	*Nephtys hombergi*	Polychaeta
Euspira nitida	Gastropoda	*Nephtys sp.*	Polychaeta
Hydrobia ulvae	Gastropoda	*Notomastus latericeus*	Polychaeta
Mangelia sp.	Gastropoda	*Ophelia borealis*	Polychaeta
Turritella communis	Gastropoda	*Ophelina acuminata*	Polychaeta
Holothuroidea	Holothuroidea	*Owenia fusiformis*	Polychaeta
Leptopentacta elongata	Holothuroidea	*Oxydromus flexuosus*	Polychaeta
Leptosynapta inhaerens	Holothuroidea	*Paramphinome jeffreysii*	Polychaeta
Ampelisca brevicornis	Malacostraca	*Pectinaria auricoma*	Polychaeta
Ampelisca macrocephala	Malacostraca	*Pectinaria koreni*	Polychaeta
Ampelisca tenuicornis	Malacostraca	*Pectinaria sp.*	Polychaeta
Corystes cassivelaunus	Malacostraca	*Pholoe balthica*	Polychaeta
Diastylis bradyi	Malacostraca	*Phyllodoce groenlandica*	Polychaeta
Diastylis lucifera	Malacostraca	*Prionospio sp.*	Polychaeta
Harpinia antennaria	Malacostraca	*Rhodine gracilior*	Polychaeta
Hippomedon denticulatus	Malacostraca	*Scolelepis sp.*	Polychaeta
Pariambus typicus	Malacostraca	*Scoloplos armiger*	Polychaeta
Perioculodes longimanus	Malacostraca	*Spiochaetopterus typicus*	Polychaeta
Phthisica marina	Malacostraca	*Spiophanes kroeyeri*	Polychaeta
Pontocrates altamarinus	Malacostraca	*Sthenelais limicola*	Polychaeta
Westwoodilla caecula	Malacostraca	*Travisia forbesi*	Polychaeta
Nemertea sp	Nemertea	*Trichobranchus roseus*	Polychaeta
Amphiura filiformis	Ophiuroidea	*Antalis entalis*	Scaphopoda

At the sandy current-affected most distant station M7, relatively few species (15 different) were found of which 6 were specific to the respective habitat type. This reduces the number of characteristic species for the main area to 84.

In the project area, the following benthic invertebrates dominated: Bristle worms as the largest group with 39 species, Molluscs with 20 species, Crustaceans with 12 species, Echinoderms with 10 species. The all-dominant species were the small (< 30 mm) tube-dwelling bristle worm *Galathowenia oculata* with > 2,000 individuals per m^2 followed by *Rhodine gracilior* with around 200 individuals per m^2 and *Scoloplos armiger* with approx. 30 individuals per m^2. Among the crustaceans, it was the centimeter long Cumacean *Diastylis lucifera* that dominated with around 30 individuals per m^2. The burrowing brittlestar *Amphiura filiformis* counted over 200 individuals per m^2. Among the molluscs, *Dosinia lupinus* and *Phaxas pellucidus* dominated in number, with a few (< 5) individuals per m^2. In addition, the remarkable outsider *Phoronis muelleri* a marine horseshoe worm was common with around 30 individuals per m^2. No red listed organism for the Norths Sea was found and no invasive species were present. It cannot be excluded that non-indigenous species are present in the area or in the near vicinity due to the highly trafficked area.

In terms of biomass, it was the mussel *Dosinia lupinus* that dominated the benthic animals with approx. 10 g wet weight (WW) per m^2 followed by *Arctica islandica* and the Scaphopoda *Antalis entalis* ("sea tooth") with 3 g WW per m^2 and 2.5 g WW per m^2, respectively. The average biomass for *Arctica islandica*, however, was based on a single found individual (station F10).

The average biomass of dead shells was half as large at the F stations compared to the transect stations (T and M stations), namely around 250 g WW/m^2 versus more than 500 g WW/m^2. This could be a result of an absence of bottom trawling along the transport pipes.

The ecology of the most frequently occurring or abundant macrofauna and their sensitivity to expected impact mechanisms are described in Table 10-7. In general, the most common species are infauna or epifauna, which ingest, burrow in, and construct dwellings from the sediment. These species are characterized by a varying degree of mobility and dispersal capabilities, high vulnerability to seabed loss under a physical footprint, low to high vulnerability to physical disturbances of the seabed, and low to medium vulnerability to sediment spill.

Table 10-7 Ecology and vulnerability of the most common species found in sediment samples in the project area.

Species (references)	**Biology**	**Mobility**	**Dispersal**	**Vulnerability to physical footprint**	**Vulnerability to physical disturbance of the seabed**	**Vulnerability to sediment spill**
Galathowenia oculata (K. Fauchald & Jumars, 1979; Hiscock & Tyler-walters, 2006)	*G. oculate* is an infaunal species which can burrow and inhabit soft sediments.	Low to medium – *G. oculate* builds relatively long tubes in the sediment and is there considered to have low to medium mobility.	High – species-specific data is not available for *G. oculata* but based on dispersal information in species from the *Oweniidae* family, the planktonic larval stage is around 11-30 days with a dispersal potential greater than 10 km.	High – *G. oculate* is an infaunal species and therefore substratum loss would result in mortality. Information from the related species of *Owenia fusiformis* suggests that a high recovery after substrate loss from physical footprint is possible due to high fecundity, large dispersal capabilities and high prevalence of larval supply.	Medium – species-specific data is not available for *G. oculata* but based on vulnerability to physical disturbances from species in the *Oweniidae* family, the species can tolerate physical disturbance with partial removal of its tube as this can be regenerated. However, complete displacement in adult *Owenia fusiformis* can be lethal as new tubes cannot be constructed.	Low – based on the species' biology as an infaunal species which burrows, and information from related species of Oweniidae polychaetes, the species can likely work its way back to the surface after a smothering event.
Rhodine gracilior (Dinesen et al., 2020; Hiscock & Tyler-walters, 2006)	*R. gracilior* is a tube-dwelling polychaete that lives either at or near the sediment surface and requires stable substrata to construct their tubes.	Low – *R. gracilior* is considered a sessile organism and has limited mobility due to its dependency on its tube.	No species-specific information on dispersal was found for *R. gracilior*, but several tube-building species of polychaetes brood their offspring within the tubes and, thus, can be slow to recolonize after disturbance events.	High – *R. gracilior* is a sessile tube-dwelling species, dependent on stable substrata. Loss if substrate would therefore result in mortality.	High – *R. gracilior* is a sessile tube-dwelling species, dependent on stable substrata and is therefore considered to have high vulnerability to the disturbances of the seabed.	N/A
Scoloplos armiger (Hiscock & Tyler-walters, 2006; Kruse et al., 2004)	*S. armiger* is an infaunal species of polychaetes which can burrow and inhabit soft sediments up to a depth of 15 cm.	High – The species is considered mobile in the sediment and acts as biodiffusors, mixing the sediments during movement.	Low – *S. armiger* has low dispersal capabilities as eggs are attached to the seabed. Larvae have a short pelagic phase, but dispersal is limited. Recruitment must therefore occur from local populations or by longer distance dispersal during periods of bedload transport.	High – *S. armiger* is an infaunal species and therefore substratum loss would result in mortality.	Low – Juevenile and adult *S. armiger* stay permanently below the sediment surface and move freely without establishing burrows. Adults may retreat to 10 cm depth or more during disturbances. The eggs, which are laid on the surface, are vulnerable to physical disturbance.	Low – the species' ability to live and burrow down to depths of 15 cm indicates that smothering by sediment of up to 15 cm is unlikely to have detrimental effects.

Species (references)	**Biology**	**Mobility**	**Dispersal**	**Vulnerability to physical footprint**	**Vulnerability to physical disturbance of the seabed**	**Vulnerability to sediment spill**
Diastylis lucifera (Beauchard et al., 2021; Gerken et al., 2022; Hiscock & Tyler-walters, 2006; Tillin, 2016)	*D. lucifera* is a species of hooded shrimp, that burrows into soft sediments to depths between 0 and 5 cm.	Medium – *D. lucifera* is a considered mobile in the sediment and is capable of both crawling and swimming.	Low – No species-specific information on dispersal is available for *D. lucifera*. Cumaceans have, however, direct development and are considered limited in their dispersal.	High – *D. lucifera* is an infaunal species that burrows shallowly into the sediments and substratum loss would therefore result in mortality.	Medium – *D. lucifera* is considered to have medium vulnerability to physical disturbances based on trawling-induced disturbances in the North Sea	Low – the ability of *D. lucifera* to live and burrow down to depths of 5 cm indicates that smothering by sediment of up to 5 cm is unlikely to have detrimental effects.
Amphiura filiformis (Hiscock & Tyler-walters, 2006)	*A. filiformis* is an infaunal species which can burrow and lives up to a depth of 4 cm within the sediment.	Medium – Adults, although mobile, are not highly active. Following displacement individuals could crawl or burrow through sediment.	Dispersal of eggs and larvae is largely determined by water movements and currents, and usually lasts between 1-6 months over distances greater than 10 km. Some immigration of adults from nearby populations may be possible.	High – *A. filiformis* is an infaunal species and substratum loss would therefore result in mortality.	Low – *A. filiformis* can tolerate considerable damage to arms and even the disk without suffering mortality and are capable of arm and even some disk regeneration. The species is furthermore capable of burrowing and crawling and, thus, escaping disturbances.	Low – the species' ability to live and burrow down to depths of 5 cm indicates that smothering by sediment of up to 5 cm is unlikely to have detrimental effects.
Phaxas pellucidus (Fraser et al., 2018; Hiscock & Tyler-walters, 2006)	*P. peelucidus* is a bivalve that burrows into fine and sand sediments	Low – Adults, although mobile, are not highly active. Following displacement individuals can burrow through the sediment within distances of 10-100 meter.	Adults are capable of dispersal within a range of 10-100 meters. *P. pellucidus* can be locally abundant and can dominate disturbed sediments suggesting that it has some opportunistic traits allowing for widespread larval dispersion.	High – *P. pellucidus* is an infaunal species and substratum loss would therefore result in mortality.	Medium – *P. pellucidus* may burrow into the sediment rapidly during disturbances, however, their short siphon indicates shallow burrowing depths and a position near the sediment surface. This position together with a relatively high shell fragility render the species vulnerable to physical disturbances. However, bivalves such as *P. pellucidus*, together with starfish have been reported to be relatively resistant to trawling, indicating that the species can considered to have some protection against surface disturbance.	Low to medium – the species' ability to live and burrow in sediments indicate some tolerance to smothering from sediment spill.

Species (references)	**Biology**	**Mobility**	**Dispersal**	**Vulnerability to physical footprint**	**Vulnerability to physical disturbance of the seabed**	**Vulnerability to sediment spill**
Phoronis muelleri (Hiscock & Tyler-walters, 2006)	*P. muelleri* penetrates vertically into muddy to sandy substrates	N/A	N/A	High – *P. muelleri* is an infaunal species and substratum loss would therefore result in mortality.	N/A	N/A
Arctica islandica (Hiscock & Tyler-walters, 2006)	*A.islandica* lives buried vertically in the top few centimetres of the sediment (soft sands and muddy sands) with is inhalant and exhalent siphons at the surface. Burrows down to depths of 14 cm.	*A. islandica* is a burrowing species, capable of movement in and on the sediment	Medium - Dispersal of eggs and larvae is largely determined by water movements and currents, and usually lasts between 1-2 months over distances greater than 10 km. Some immigration of adults from nearby populations may be possible.	High – *A.islandica* is an infaunal species and substratum loss would therefore result in mortality.	High – *A. islandica* has a high sensitivity to physical disturbances of the seabed as it lives at or near the surface while feeding and only burrows to depth of 14 centimetres. Recovery after small disturbances can happen relatively quickly through recruitment from adult individuals from nearby areas.	Low – the ability of *A. islandica* to live and burrow down to depths of 14 cm indicates that smothering by sediment of up to 14 cm is unlikely to have detrimental effects.

Macrofaunal composition in the project area compared to other stations

The species' composition has been compared to other stations located nearby in the North Sea. A dataset was created, to combine all stations taken at six different locations as shown in Figure 10-12.

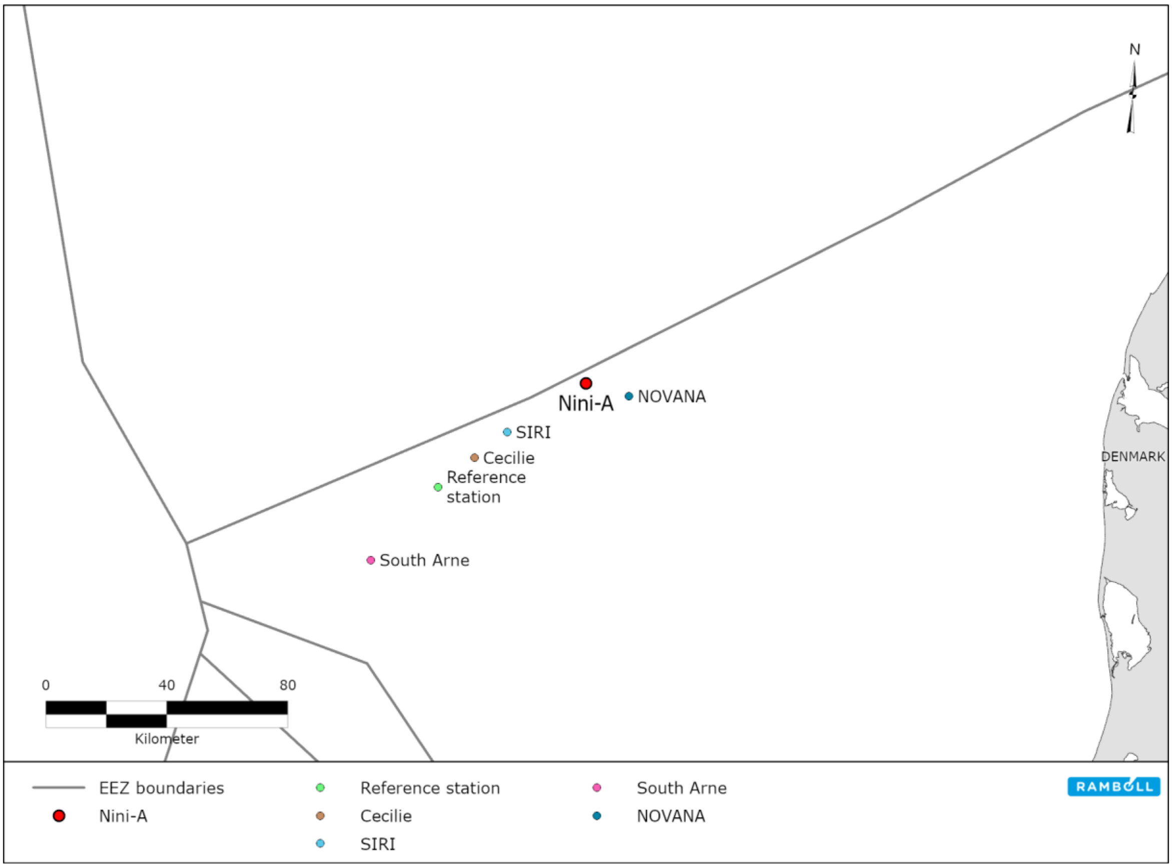


Figure 10-12 Location of stations in the North Sea where species compositions has been compared.

Although distinctly grouped, the similarity among the stations were generally 20 % or higher between the stations at South Arne, SIRI, the reference station, and Cecilie Offshore. The stations within the individual location were typically above 40%. At the Nini field the similarity among the stations were generally more than 40%, but somewhat isolated from the other sampling locations. Lastly, the samples (42 HAPS) under the monitoring and assessment program NOVANA, typically shared more than 40% similarity between each sample taken the same year at the same station (station 91000080 – DMU1027). Analysis showed that the variance between three years at the NOVANA station was larger, the total variance between the Nini stations taken during one week (not including M7), indicating that the benthic community shifts more from year to year at one station, than was observed at different stations several km apart. This has to be taken into consideration in a future monitoring program.

Microbial conditions in the project areas

During the baseline survey samples was taken from all stations at two different depths and analysis for microbial eDNA (K. B. Sørensen & Svenningsen, 2023). The detected microorganisms generally belonged to well-known groups of marine bacteria, that are expected to be widespread in North Sea sediments. The bacterial communities were relatively homogeneous across the 20 stations, and the magnitude of local variation (i.e., the variation among replicates from the same station) was comparable to the magnitude of global variation (i.e., the variation across all 20 stations). Nevertheless, there was a tendency towards slightly decreasing numbers of bacteria with depth, as well as a larger proportion of anaerobic, sulphate-reducing bacteria. Statistical analysis also suggested a statistical difference between upper and lower sediment communities.

These observations indicate that although the samples from 0-3 and 5-8 cm depth were not visually different, there is some degree of biogeochemical stratification in the sediment, probably caused by increased scarcity of oxygen with depth (Lohse et al., 1996). The nevertheless relatively homogeneous microbial fingerprint data is probably caused by bioturbation and other physical disturbances in the upper few cm of sediment.

10.5.3 Fish

More than a 140 fish species are found in the North Sea (Sundby et al., 2017). The diversity in fish species is low in the shallow southern North Sea and English Channel and increases westwards. Species diversity is also generally higher close to shore as habitat diversity increases.

A fish survey at the Halfdan platform located approximately 120 km southwest of the area of activity was conducted in 2002 and 2003 (Mærsk Olie og Gas, 2003). A total of 16 species of fish were registered: eight pelagic or semi-pelagic including Atlantic horse mackerel (*Trachurus trachurus*), Atlantic mackerel (*Scomber scombrus*), cod (*Gadus morhua*), grey gurnard (*Eutrigla gurnardus*), herring (*Clupea harengus*), sand eel (*Ammodytes sp.*), sprat (*Sprattus sprattus*) and whiting (*Merlangius merlangus*) and eight benthic species including American plaice (*Hippoglossoides platessoides*), common dab (*Limanda limanda*), common dragonet (*Callionymus lyra*), European plaice (*Pleuronectes platessa*), haddock (*Melanogrammus aeglefinus*), hooknose (*Agonus cataphractus*), lemon sole (*Microstomus kitt*) and lumpfish (*Cyclopterus lumpus*).

The survey data from the Halfdan platform was supplemented with data from the International Council for the Exploration of the Sea (ICES) trawl surveys. DATRAS (the Database of Trawl Surveys) has been developed to collate and document the survey data, assure data quality, standardise data formats and calculations, and ease data handling and availability. With the possibility for instant remote access, the data from DATRAS are used for stock assessments and fish community studies by the ICES community and public users. For this study, trawl data was collected for the period 2017-2022 for the ICES rectangle 42F5. The maximum distance from the trawl stations analysed to the Nini platform was 35 km, see Figure 10-13.

During the period 2017-2022, 22 different species were registered in the North Sea International Bottom Trawl Survey (NS-IBTS) including herring, European plaice, European sprat, whiting, haddock, lemon sole, grey gurnard, common dab, Norway pout (*Trisopterus esmarkii*), Atlantic cod, Atlantic mackerel, American plaice, witch flounder (*Glyptocephalus cynoglossus*), European pilchard (*Sardina pilchardus*), thorny skate (*Amblyraja radiata*), European anchovy (*Engraulis encrasicolus*), European angler (*Lophius piscatorius*), Blue whiting (*Micromesistius poutassou*), Brill (*Scophthalmus rhombus*), Common dragonet, European hake (*Merluccius merluccius*), Thornback ray (*Raja clavata*). There was variation in the registered abundance by species during the ICES surveys, Figure 10-14, note that the survey targeted benthic species.

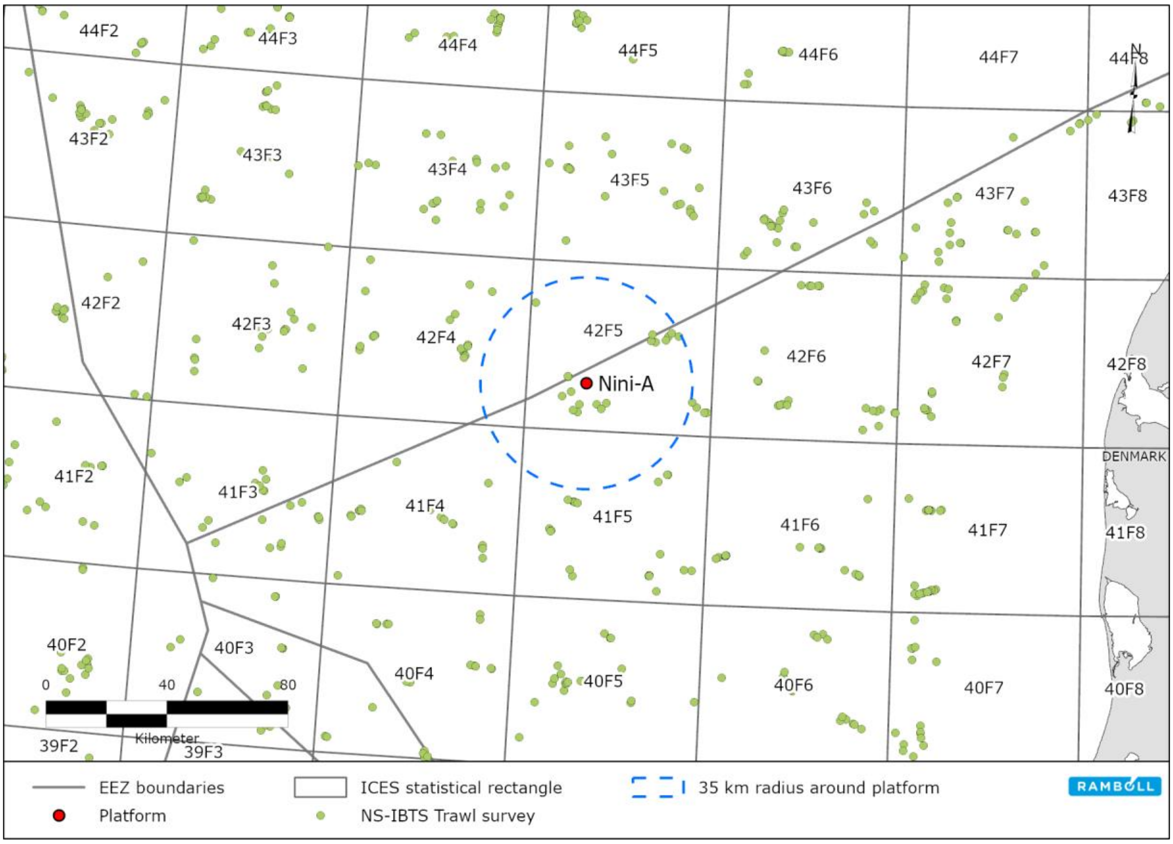


Figure 10-13 North Sea International Bottom Trawl Survey stations in relation to Nini A. Blue circle marks the 35 km radius in which fish trawl stations have been analysed.

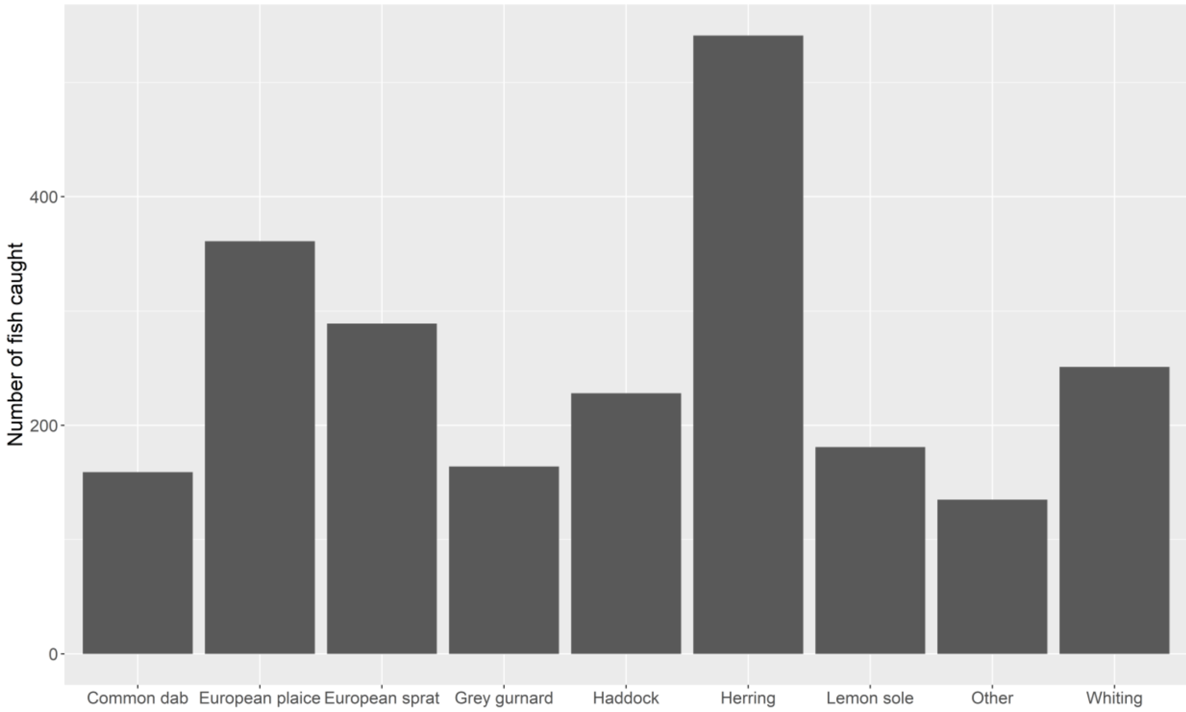


Figure 10-14 Number of fish caught by the NS-IBTS surveys from 2017-2022 in ICES rectangle 42F5. Other = represents species that were caught less than 35 times.

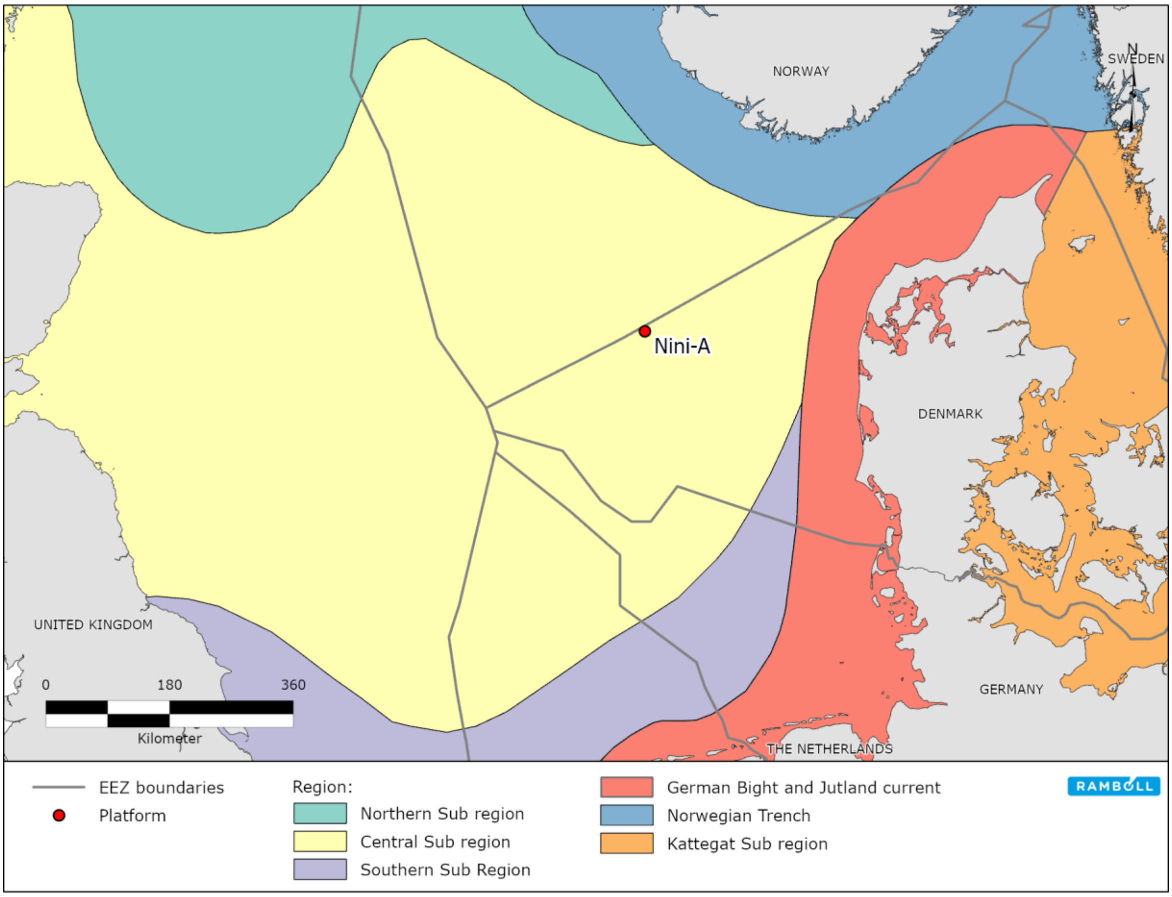


Figure 10-15 Defined ecosystem sub regions. Figure adapted from (Sundby et al., 2017).

The distribution of fish populations, as well as what ecosystem sub region, and the biology of the most common species found in the North Sea are described in Figure 10-15 and Table 10-8. Fish stocks in the North Sea have been assessed by ICES in regard to conservation status and for Atlantic mackerel, sand eel, cod, common dab, European plaice, haddock, grey gurnard, herring, lemon sole, sprat and whiting, no information on stock/species-specific conservation status have been found. ICES advises that activities leading to degradation of sandeel habitat should be avoided (ICES, 2024). American plaice is not assessed by ICES as it is not a commercially exploited species in the North Sea. Carl et al. 2019 indicate that there are no signs that the East Atlantic population of American plaice is threatened (Carl et al., 2019).

Table 10-8 Distribution and biology of the most common species registered in the area as well as spawning grounds and – seasons. Data is from (Carl & Munk, 2019; IMARES, 2005; Sundby et al., 2017).

American plaice *(Hippoglossoides platessoides)*

American plaice is typical for demersal fish assemblages in the northern North Sea and appears to prefer deeper water, occurring regularly below the 50-m line and becoming the dominant flatfish past 100 m depth (Sundby et al., 2017). It is generally absent from shallow (< 5m) waters.

American plaice lives on or near the ocean floor in areas with muddy or finer grained substrate. In the North Sea it primarily feeds on crustaceans as well as polychaetes, fish, molluscs and echinoderms.

Spawning areas are largely confined to the northern part of the North Sea with important spawning areas found around Viking Bank in the Northern sub region (Figure 10-15) and in the area from Ling Bank to the Little and Great Fisher Banks as well as off the coast of Scotland and southward the northern edge of the German Bight. Spawning in the North Sea takes place between February and May peaking in April.

Table 10-9 Spawning period: American plaice (*Hippoglossoides platessoides*).

Spawn	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pelagic												

Atlantic mackerel (*Scomber scombrus*)

Mackerel are widespread throughout the North Sea. It is most abundant in the Northern sub region (Figure 10-15) during winter and spring while it spreads southwards during summer and autumn to the spawning areas in the central North Sea. Mackerel feed on a variety of pelagic crustaceans and small fish.

Three high concentration spawning areas have been identified in the central North Sea. The areas are located east of the southern part of Scotland and northern part of England, as well as along the southern coast of Norway and by the tail end of Dogger bank. Spawning takes place between May and July and peaks in June.

Table 10-10 Spawning period: Atlantic mackerel (*Scomber scombrus*)

Spawn	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pelagic												

Sand eel (*Ammodytes sp.*)

Sand eel is abundant in the North Sea where it constitutes a particularly important species because it is the target for the largest fishery in the North Sea. Moreover, it is a key forage fish in the ecosystem.

There are five species of sand eel in the North Sea, lesser sand eel (*Ammodytes marinus*), small sandeel (*Ammodytes tobianus*), two species of greater sand eel (*Hyperoplus lanceolatus* and *Hyperoplus immaculatus*), and smooth sand eel (*Gymnammodytes semisquamatus*). In offshore waters lesser sand eel dominate. They are generally found in waters ranging between 30-150 m where they spend a large part of their life buried in the sediment and thus show particular preference to sandy sediments to those with more gravel, silt or mud. Important fishing grounds for sand eel include Dogger Bank, banks outside Scotland as well as Great Fisher Bank and Little Fisher Bank. They feed mainly on crustaceans and fish larvae.

Sand eel spawn where they live, thus spawning grounds correspond to fishing grounds. The project area lies at least 10 km from the closest sand eel banks and even further from the closest commercial sand eel fishing grounds mapped in 2018 (Mosegaard et al., 2019). Spawning takes place from December to July.

Table 10-11 Spawning period: Sand eel (*Ammodytes sp.*)

Spawn	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Demersal												

Cod (*Gadus morhua*)

Cod occurs throughout the boreal region of the North Atlantic. In the North Sea cod may be found from shallow coastal waters to the shelf edge (200 m depth) and beyond. Catches have been reported as deep as 500 m in the Norwegian deep.

Spawning grounds appear to be widespread throughout the area with the highest intensities of spawning at; 1) Viking Bank, eastern Shetland banks, and the coastal north-eastern Scotland in the Northern region, 2) Ling Bank – Eigersunds Bank in the eastern part of the Central regions, 3) south of Fisher Banks and 4) Norfolk Bank-Oyster Ground in the Southern region, and 5) the German Bight.

In the North Sea spawning takes place between January and May. Peak spawning differs among the spawning grounds' location in the North Sea. The following peak seasons have been identified for Viking Bank, the north-western North Sea and the southern North Sea; March, February to March and January to February respectively.

Table 10-12 Spawning period: Cod (*Gadus morhua*).

Spawn	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pelagic												

Common dab (*Limanda limanda*)

The common dab is a demersal fish. It lives on sandy bottoms down to depths of about 100 to 150 m. Preferred food items includes sea urchins, brittle stars, polychaetes, crustaceans, mussels and small fish.

Spawning occurs across the entire south-eastern North Sea and high concentration spawning grounds have been identified in the German Bight northwest of Helgoland, along the northern Dutch coast, as an isolated patch off Flamborough and along the southern edge of Dogger Bank.

Spawning takes place from January to August in the southern area, i.e., off Brittany and southern England, and from April to June further north.

Table 10-13 Spawning period: Common dab (*Limanda limanda*)

Spawn	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pelagic												

European plaice (*Pleuronectes platessa*)

European plaice is a demersal species and is found at depths reaching 100-200 m, but adults are often found at depths of 10-50 m. It prefers sandy sediments although older age groups may be found on coarser sand. Plaice is an opportunistic species which primarily forage on molluscs and polychaetes.

In the North Sea, spawning occurs from the English Channel and the Southern Bight in south, north-eastward towards the southern slope of the Skagerrak deeps, and north-westwards to the Orkneys and Shetland. Peak spawning occurs between February and March and January and February for the northern and southern part of the North Sea respectively.

Table 10-14 Spawning period: European plaice (*Pleuronectes platessa*)

Spawn	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pelagic												

Haddock (*Melanogrammus aeglefinus*)

Haddock is a shoal fish that is commonly found near the bottom at depths ranging between 15-200 m. It prefers a variety of substrates from sandy to coarser sediments. Haddock occurs in the entire North Sea but are generally found in the highest concentrations in the Northern and Central sub region, and along the southern slope of the Norwegian Trench in the Skagerrak and along the western slope of the Norwegian Trench off western Norway.

Haddock spawning areas are confined to the northernmost part of the North Sea, particularly from Viking Bank to Shetland. Studies have also shown that spawning occurs east of the Orkneys and east of the Scottish east coast, in addition to a lesser spawning area near the western slope of the Norwegian Trench from Ling Bank to Eigersund Bank. Spawning takes place between February through May peaking in March and April.

Table 10-15 Spawning period: Haddock (*Melanogrammus aeglefinus*)

Spawn	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pelagic		■	■	■	■							

Grey gurnard (*Eutrigla gurnardus*)

Grey gurnard is primarily a demersal species and is most commonly found on sandy sediments but also occurs on mud, shell and rocky bottoms at depths between 10-150 m. Smaller specimens feed on crustaceans and small crabs and larger fish feed on a variety of fish species.

Grey gurnard occurs throughout the North Sea. During winter, grey gurnards are concentrated to the northwest of the Dogger Bank, while densities are low in areas off the Danish coast, and in the German Bight and eastern part of the Southern Bight. During spring densities increase southwards leaving the central subregion less densely populated until next winter.

Spawning areas have been identified in the German Bight but eggs have been found of the English northeast coast as well. Spawning takes place between April and August.

Table 10-16 Spawning period: Grey gurnard (*Eutrigla gurnardus*).

Spawn	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pelagic				■	■	■	■	■				

Herring (*Clupea harengus*)

Herring is a shoal fish and is typically found from the coast and out till depths of 200-250 m. The pelagic larvae feed on copepods and other small planktonic organisms, while juveniles mainly feed on Calanoid copepods but euphausids, hyperiid amphipods, juvenile sand eels and fish eggs are also eaten. Larger herring also feed on copepods, mysids, fish larvae, small fish, amphipods and arrow worms.

It is a migratory species and migration happens throughout the North Sea. During summer, schools of juvenile fish are generally found in shallower waters in the eastern part of the North Sea often close to the western coast of Denmark and into Skagerrak. After spending their first few years in coastal nurseries, two-year-old herring move offshore into deeper waters, eventually joining the adult population in the feeding and spawning migrations to the northern and western areas of the North Sea. From July and until spawning, herring migrate westward to spawning grounds located along the east coast of Great Britain, from the Orkney and Shetland islands in the north and into the eastern English Channel near Buchan, Banks and Downs in the south.

Spawning periods are specific to the spawning grounds and occurs between July and November peaking in August and September for spawning grounds near Orkney-Shetland islands and Buchan and between August and December peaking in September and October at spawning grounds around the Banks. Winter spawning in grounds located near Downs takes place between November to February peaking in December and January.

Table 10-17 Spawning period: Herring (*Clupea harengus*).

Spawn	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Demersal												

Lemon sole (*Microstomus kitt*)

Lemon sole is a demersal fish species, which lives at depths ranging between 10-200 m. It is considered abundant in the central and northern North Sea, where it feeds primarily on small invertebrates such as polychaetes and crustaceans, but their diet includes molluscs, echinoderms and small fish as well.

Spawning occurs across the Central sub region (Figure 10-15) from the English coast to the western slope of the Norwegian Trench with the majority of larvae occurring east of the Moray Firth. Spawning occurs between January and October.

Table 10-18 Spawning period: Lemon sole (*Microstomus kitt*).

Spawn	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Demersal												

Sprat (*Sprattus Sprattus*)

Sprat is a pelagic shoal fish and is found close the coast at depths from 1 m and further offshore to depths down to 150 m. It is found in all subregions of the North Sea (Figure 10-15); however, it is most abundant in the southern part specifically in the English Channel and along the west coast of Denmark and into Skagerrak and Kattegat. Larvae feed on diatoms, copepods and crustacean larvae. After metamorphosis larger planktonic organisms are also eaten.

Spawning occurs primarily in the southern subregion of the North Sea from the German Bight along the Jutland current and into Kattegat. Spawning also occurs further north along the English and Scottish coast. High concentration spawning grounds have been identified in the German Bight, Southern Bight and in the English Channel. Spawning takes place from January to September peaking between May and August.

Table 10-19 Spawning period: Sprat (*Sprattus sprattus*).

Spawn	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pelagic												

Whiting (*Merlangius merlangus*)

Whiting is a pelagic shoal fish often found at depths ranging between 10-150 m. Whiting is distributed throughout all subregions of the North Sea with the highest concentrations near the British coast. Pelagic larvae feed on nauplii and copepodite stages of copepods. Immature whiting feed on crustaceans such as euphausids, mysids and crangonid shrimps whereas mature whitings feed almost entirely on fish.

Spawning grounds for whiting are widely distributed over most of the North Sea from Viking Bank and Shetland in north to the English Channel in the south. However, spawning in the German Bight, Jutland current and in the Norwegian Trench is seemingly absent. Spawning takes place between March and June in the northern part of the North Sea and between January and April in the English Channel in the south. Peak spawning seasons have been reported between April-June and February-March in the north and south respectively.

Table 10-20 Spawning period: Whiting (*Merlangius merlangus*).

Spawn	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pelagic												

There are two main forms of spawning: Demersal and pelagic spawning. The fish species that are found spawning in the project area are characterized by pelagic spawning. Pelagic spawners have free floating eggs that are fertilized in the water column. Spawning grounds for pelagic spawners are often large and less well defined as they can change location from year to year. Hydrographic conditions that are essential for the pelagic spawning have an important role regulating the boundaries of the spawning grounds. Pelagic spawning takes place mostly at depths of 20-100 m. Pelagic eggs and larvae are more or less passively carried around by ocean currents. Some are carried to nursery areas others stay in the water column. Larval growth and transport of larvae and eggs are regulated by a variety of environmental factors e.g., wind, sea temperature and currents affecting larval drift to nursery grounds, as well as density-dependent predation on the eggs and larvae. Most of the natural variability of the fish stocks is due to variation in egg and larval survival. Annual variability in recruitment of juveniles can differ by a factor of 5 for plaice and more than 100 for haddock. Most species show annual or inter-annual movements related to feeding and spawning (OSPAR Commission, 2000). Several species found in the area are benthic spawners however, none of these species are found spawning in the project area. The closest spawning ground for benthic spawners is the Norwegian sand eel fields located approx. 11 km from the project area. During spawning, sand eel produce a large batch of sticky eggs which attach to sand or gravel on the seabed. The larvae hatch a couple of weeks later, after which they float around in the currents for 3-4 months before settling down into the seabed (Hassel et al., 2002; Hvingel et al., 2021). Sandeel are highly substrate-specific with regard to habitats and spawning grounds and thus this area plays a central role for the population dynamics of sand eel in the Norwegian sector of the North Sea (Hvingel et al., 2021).

The project area is situated in an area which constitutes high concentration spawning grounds for lemon sole (Figure 10-16) (Sundby et al., 2017). Furthermore, the project area is part of a larger area which is deemed as important spawning grounds for cod, American plaice, European plaice, whiting, Atlantic mackerel and haddock (ICES, 2023).

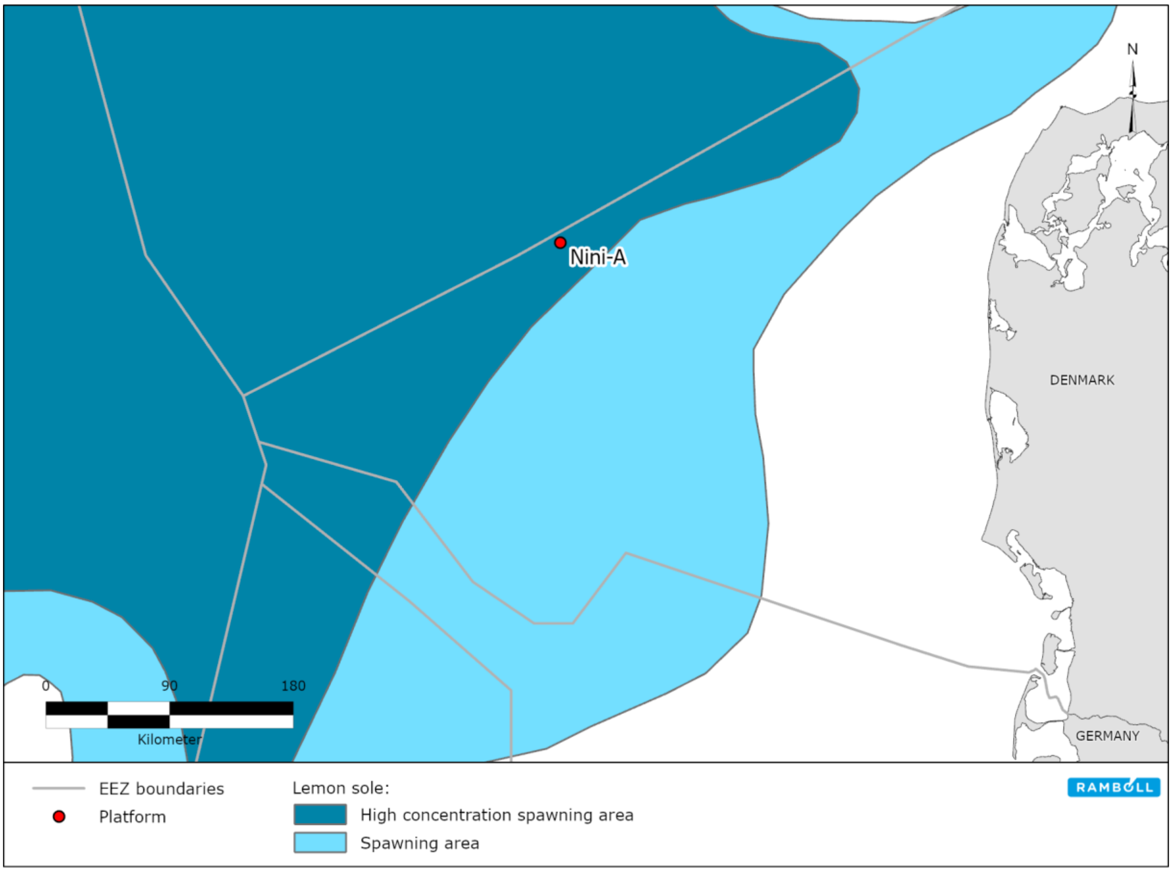


Figure 10-16 The location of the project area with respect to spawning grounds for lemon sole (Sundby et al., 2017).

The Spawning Stock Biomasses (SSBs) of cod, sole and witch are below MSY $B_{trigger}$ (Value of SSB that triggers a specific management action) in2023. Other species are being fished above the maximum sustainable yield (FMSY) i.e., witch, horse mackerel and mackerel in the 2023 assessments (ICES, 2023).

10.5.4 Marine mammals

Harbour seal, grey seal, harbour porpoise, white-beaked dolphin and minke whale are the most common marine mammals in the North Sea (Tougaard et al., 2021a). The biology and distribution of these species as well as their habitat preference is related to the food availability and are described in Table 10-21. The site fidelity varies among species, and the distribution of marine mammals show both intra- and interannual variations.

Table 10-21 Distribution and biology of the most common marine mammals; harbour seal, grey seal, harbour porpoise, white-beaked dolphin and minke whale. Data is from: (De Boer, 2010a; Galatius, 2017a; Hammond et al., 2017; Hansen & Høgslund, 2023; Hansen J.W. & Høgslund, 2021; IUCN, 2022; Miljøstyrelsen, 2020a; Tougaard et al., 2021a)

Species	Distribution and biology
Harbour seals (*Phoca vitulina*)	Harbour seals are one of the most widespread of the pinnipeds. They are found throughout coastal waters of the Northern Hemisphere, from temperate to Polar Regions. Harbour seals are mainly found in the coastal waters of the continental shelf and slope, and are also commonly found in bays, rivers, estuaries and intertidal areas. At sea, they are most often seen alone, but occasionally occur in small groups. Haul-out sites include rocks, sand and shingle beaches, sand bars, mud flats, vegetation and a variety of man-made structures. Harbour seal in Danish waters can be categorized into four genetically distinct population units: the Wadden Sea population, the central Limfjord population, Kattegat population and the western Baltic population. The Wadden Sea population is abundant and individuals from this population occur in waters around the Netherlands and Germany as well. In 2021 the population in the Danish part of the Wadden Sea was estimated at 1700 individuals, which is a decline compared to the survey from 2019. However, population trends in the Dutch and German part of the Wadden Sea are stable. This development points to the carrying capacity of the population to have been met. The species is listed on annex 2 of the Habitats Directive and the population development and status of the species in Danish waters have been assessed in 2019 as favourable according to the EU Habitats Directive. Harbour seals feed primarily on fish such as herring, mackerel, cod, whiting and flatfish, and occasionally upon shrimp, crabs, molluscs and squid.
Grey seals (*Halichoerus grypus*)	Grey seals have a cold temperate to sub-Arctic distribution in North Atlantic waters over the continental shelf. They often haul out on land, especially on outlying islands and remote coastlines exposed to the open sea. Grey seals occurring in Danish waters can be categorized into two distinct populations: the greater North Sea population and the Baltic population. The North Sea population occurs in the Wadden Sea, western Limfjord and Kattegat. The grey seal is less common than the harbour seal but numbers of grey seal have been increasing in the Wadden Sea and in 2021, 331 grey seals were counted during their molting period in the Wadden Sea. The species is listed on annex 2 of the Habitats Directive and the population development and status of the species in Danish waters was assessed in 2019 as unfavourable.

Species	Distribution and biology
	The grey seal feeds on a wide variety of fish including sand eels, cod and other gadoids, flatfish, herring and skates. They may also take octopus and lobster.
Harbour porpoise (*Phocoena phocoena*)	Harbour porpoises are found in cold temperate to sub-polar waters of the Northern Hemisphere. They are usually found in continental shelf waters, and frequent relatively shallow bays, estuaries, and tidal channels. The population in Danish waters is considered to consist of four populations: the North Sea population (inhabiting the North Sea, Skagerrak and the Northern Kattegat), the Belt Sea population (inhabiting the Southern Kattegat, the Belt Seas, the Sound and the western Baltic) and the Baltic population (Baltic Proper). Harbour porpoise is the most common whale species in the North Sea and the highest concentrations are found in the central and southern part and along the west coast of Denmark. The population development and status of the species in the North Sea was assessed as favourable in 2019 (Fredshavn, Nygaard, Ejrnæs, Damgaard, Therkildsen, Elmeros, Wind, Sander, et al., 2019) and in the SCANS-IV aerial survey in 2022 the North Sea population was assessed as stable (Gilles, Authier, Ramirez-Martinez, Araújo, Blanchard, Carlström, Eira, Dorémus, Fernández-Maldonado, et al., 2023). Harbour porpoises feed mainly on fish such as cod, whiting, mackerel, herring and sprat.
White-beaked dolphin *(Lagenorhynchus albirostris)*	White-beaked dolphins have a wide distribution and inhabit cold temperate to subpolar waters of the North Atlantic. White-beaked dolphins inhabit continental shelf and offshore waters of the cold temperate to subpolar zones, although there is evidence suggesting that their primary habitat is in waters less than 200 m deep. The species is found widely over the continental shelf, but especially along the shelf edge. The white-beaked dolphin is commonly encountered in the northern part of the North Sea, and in Skagerrak as well as in Kattegat. They occur year-round and breed in the North Sea, including the Danish part of the North Sea (Tougaard et al., 2021a). The population status has in 2019 been assessed as favourable in the North Sea (Fredshavn, Nygaard, Ejrnæs, Damgaard, Therkildsen, Elmeros, Wind, Sander, et al., 2019). In the North Sea, the population of white-beaked dolphin was estimated at 67,138 individuals during the SCANS-IV aerial surveys in 2022 with densities of 0.06 ind./km2 which is an increase from the SCANS-III survey that estimated 36,287 individuals in the North Sea in 2016 (Gilles et al., 2023; Hammond et al., 2021a). These estimates show no significant change in abundance since 1994. They primarily feed on fish such as herring, cod, haddock, whiting and hake but may also feed on squid, octopus and benthic crustaceans.
Minke whale (*Balaenoptera acutorostrata*)	The minke whale is the smallest species of baleen whales and is a cosmopolitan species found in all oceans and in virtually all latitudes, including the Northeast Atlantic. Minke whales are found in the central and northern part of the North Sea year round and in appreciable numbers. They perform seasonal migrations between high latitude summer feeding grounds and low latitude winter breeding grounds. During spring minke whales seem to be concentrated around the offshore bank slope northeast of Dogger Bank, indicating that this area may be an important spring habitat for the species (De Boer, 2010b). While the distribution and abundance of the species

Species	Distribution and biology
	has been studied across their summer range, their winter distribution and habitats are not well-documented. The population development and status of the species in Denmark was assessed as favorable in 2019 (Fredshavn, Nygaard, Ejrnæs, Damgaard, Therkildsen, Elmeros, Wind, Sander, et al., 2019). The population was estimated at 12,417 individuals during the SCANS-IV aerial survey in 2022 with densities of 0.01 ind./km^2 recorded in the project area (Gilles, Authier, Ramirez-Martinez, Araújo, Blanchard, Carlström, Eira, Dorémus, Fernández-Maldonado, et al., 2023). Minke whale feed primarily on pelagic fish like herring and sprat and on small planktonic crustaceans.

Distribution and breeding areas for Harbour seal and Grey seal

Haul-out sites for pinnipeds such as the harbour seal (*Phoca vitulina*) and grey seal (*Halichoerus grypus*) constitute important areas for resting, molting and breeding and seals are considered most vulnerable around these sites. Haul-out sites for harbour seal and grey seal have been registered along the west coast of Denmark around Limfjorden and Blåvandshuk and southwards from Blåvandshuk to Rømø (Hansen & Høgslund, 2023). In 2002, 10 harbour seals captured in the Danish Wadden sea was GPS tagged and tracked (Tougaard et al., 2008). Their GPS position gives an indication of how far out in the North Sea a harbour seal normally travels.

As seen in Figure 10-17 the 10 tagged seals never travelled as far out as the project area.

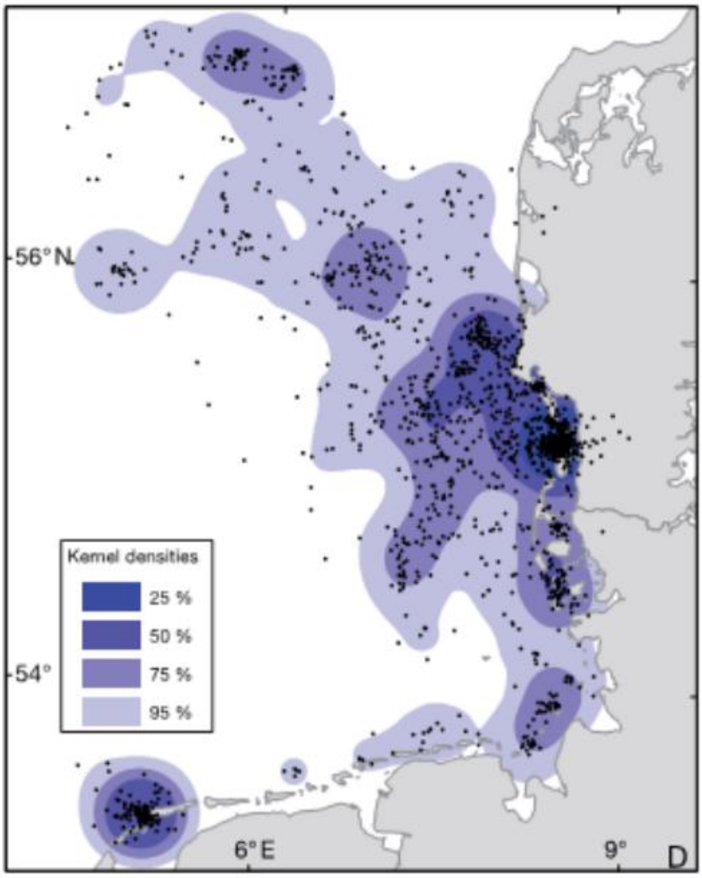


Figure 10-17 Satellite-derived positions of 10 harbour seals tracked in 2002 (indicated by black dots). Fixed kernel probabilities calculated from all positions (Tougaard et al., 2008). Nini A is located further west and not visible on this map.

Harbour seals are mostly stationary around their haul-out sites but have been shown to make multi-day, offshore foraging trips often returning to their original haul-out site or a near-by site (Vance et al., 2021). Mean foraging range was found to 4.3-55 km (P. M. Thompson et al., 1998) however, harbour seals have been found to travel more than 100 km from their haul-out sites (Cunningham et al., 2009). Grey seals generally travel over greater distances between foraging areas and haul-out sites compared to harbour seals, though they will often return to the same haul-out site for breeding (Galatius, 2017b; McConnell et al., 1999). The movements of grey seal can be divided into two geographical scales; long distance travel between haul-out sites (up to 2,100 km) and short distance return trips between haul-out sites and foraging areas (average travel distance 20-60 km) (Mcconnell et al., 1999).

The closest haul-out site for harbour seal and grey seal is located approx. 178 km from the project area and it is therefore likely that grey seals can be encountered foraging within the project area. Periods of breeding, moulting and mating are found in Table 10-22.

Table 10-22 Time of year where seals are breeding (B) or moulting (M) in the North Sea/Danish waters (Miljøstyrelsen, 2020b).

Species	J	F	M	A	M	J	J	A	S	O	N	D
Grey seal			M	M							B	B
Harbour seal						B	M	M				

Seals have amphibious hearing as they can hear both in water and in air. Harbour seals communicate vocally by use of a broad bandwidth of sounds with their auditory bandwidth being between 40 Hz-50 KHz (in water) with the highest sensitivities between 1 kHz and 50 kHz (B. L. Southall et al., 2019; Tougaard et al., 2014a). Data on hearing ranges for grey seal is scarce and it is generally assumed that hearing abilities for both species are similar. Harbour seal and grey seal belong to the hearing group Phocid Carnivores in Water (PCW) and hearing ranges are listed in Table 10-23.

Table 10-23 Practical, indicative frequency ranges for hearing of auditory groups relevant to Danish waters (Energistyrelsen, 2022a). Hearing group abbreviations indicate; LF = Low Frequency, HF = High Frequency, VHF = Very High Frequency, PCW = Phocid Carnivores in Water.

Hearing group	Indicative hearing range
LF (minke whale)	10 – 34,000 Hz
HF (white-beaked dolphin)	1,000 – 120,000 Hz
VHF (harbour porpoise)	1,000 – 150,000 Hz
PCW (seals)	40 – 50,000 Hz

Distribution and breeding areas of Harbour porpoise, white-beaked dolphin and minke whale in the North Sea

The abundance of harbour porpoise, white-beaked dolphins and minke whales in the Danish part of the North Sea is generally higher during spring and summer than during fall and winter (Hammond et al., 2021b; Waggitt et al., 2020a), see Figure 10-18.

Harbour porpoises are known to breed in the North Sea including Danish waters. Specific breeding grounds for harbour porpoises have not been identified but areas with high concentrations of individuals during breeding season are generally considered to be essential for the population and may constitute suitable breeding habitats (Sveegaard et al., 2011). High-density areas of harbour porpoises are commonly known as 'hotspots' and model predictions have shown hotspots located in the southern and south-eastern part of the North Sea in spring, mainly inshore close to the Belgian and Dutch coasts extending toward the German coast off the East Frisian Islands. High densities are also found around the Sylt Outer Reef in the German North Sea as well as of the north coast of Jutland and at Dogger Bank during spring. In summer harbour porpoise hotspots shift toward offshore and western areas, where large hotspots are present off the German and Danish west coast and extends toward the Dogger Bank indicating that these sites may constitute breeding grounds for the species (Figure 10-18).

The modelled summer densities in the project area are considerably lower than the high-density areas concentrated in the western part of the North Sea indicating that the project area may not constitute important breeding area for harbour porpoise.

The newest survey of the North Sea (SCANS-IV) from 2022 show that the population of harbour porpoise is stable. In the North Sea, the estimate for 2022 (339,000, CV = 0.17) is very similar to the estimates for 2016 (345,000, CV = 0.18) and 2005 (355,000, CV = 0.22), compared with a slightly smaller estimate from 1994 (289,000, CV = 0.14). Thus, notwithstanding that the data only have sufficient power to detect a decline of around 1% per year, there is no evidence for a change in harbour porpoise abundance in the North Sea (Gilles, Authier, Ramirez-Martinez, Araújo, Blanchard, Carlström, Eira, Dorémus, Fernández-Maldonado, et al., 2023).Estimated density in the survey block that also covers *Project Greensand Future* is 0.47 ind./km^2 (Gilles et al., 2023).

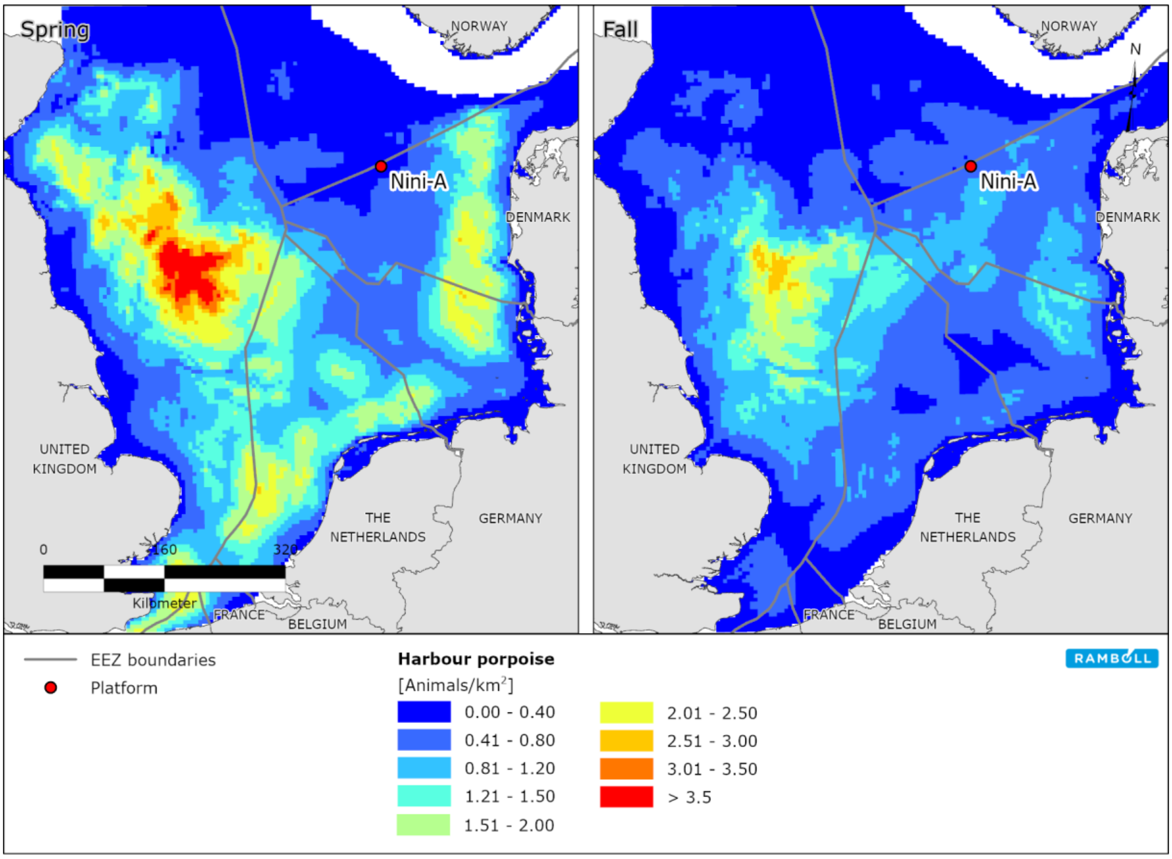


Figure 10-18 Figure from (Gilles et al., 2016). Predicted harbour porpoise densities in the North Sea in spring (March-May.) and fall (Sep.-Nov.).

Densities for white-beaked dolphin area low in the project area, 0.02 ind./km^2 and SCANS-III density data from the 2016 surveys shows that the high-density areas are located along the Scottish coast and the Norwegian shelf (Hammond et al., 2021b), see Figure 10-19. Densities from SCANS IV data is slightly higher 0.06 ind./km^2. The observed distribution of white-beaked dolphins in 2022 is similar to that observed in SCANS-III in 2016, SCANS-II in 2005 and in SCANS in 1994 (Gilles et al., 2023). In 2022, the highest densities were estimated around the Shetland Islands, northern North Sea (NS-E, NS-F) and in northwest Scotland (CS-G and CS-I) and in 17 sightings large groups of >10 individuals were observed. The estimate of abundance in 2022 of 67,138 (CV = 0.33) is higher than all previous estimates from SCANS-III of 36,287 (CV = 0.29), SCANS-II of 37,689 (CV = 0.36) and from SCANS in 1994 of 23,716 (CV = 0.30) (Gilles et al., 2023). The trend analysis of estimates in the North Sea shows no significant change in abundance since 1994 (Gilles et al., 2023).

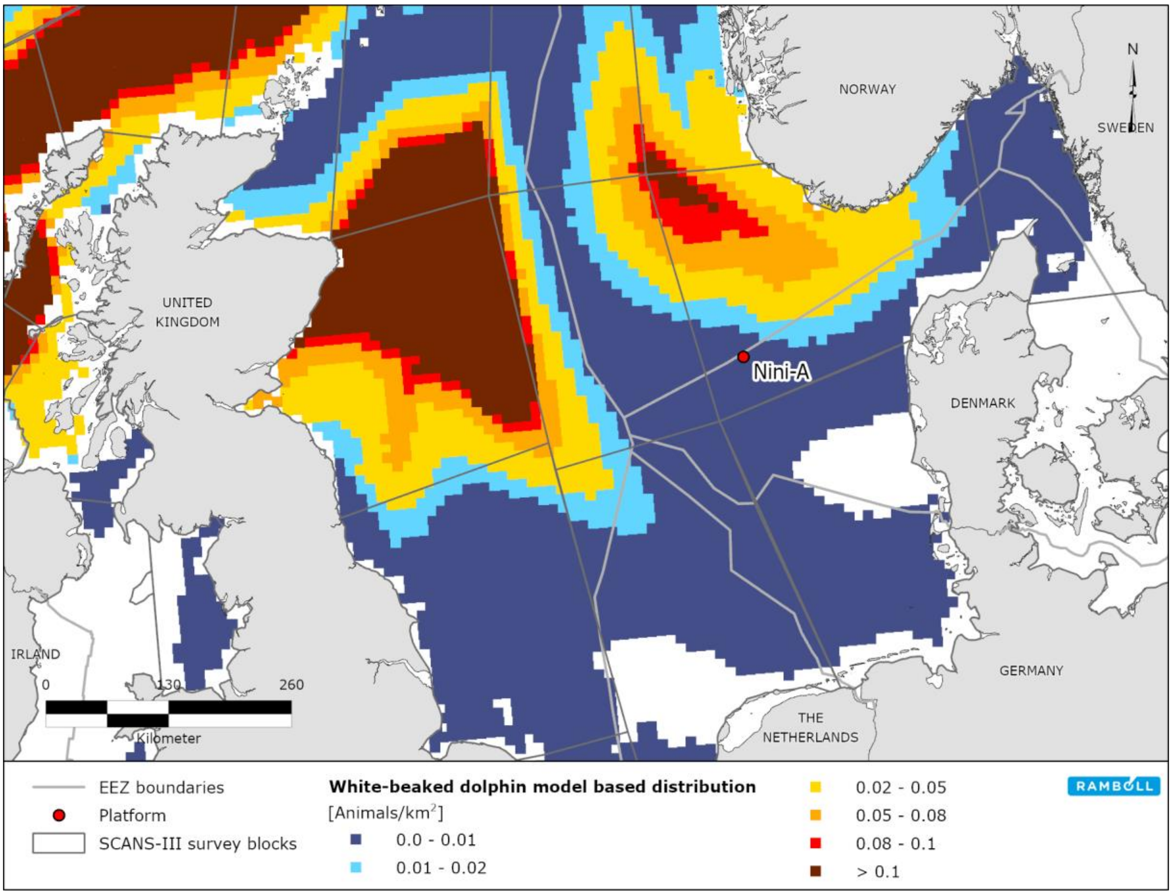


Figure 10-19 Densities of white-beaked dolphin in the North Sea modelled from 2016 survey data (Hammond et al., 2021b).

White-beaked dolphins are also known to breed in the North Sea. Data on breeding grounds for white-beaked dolphin in the North Sea is scarce however, research suggest that the species moves inshore during breeding season (Alstrup et al., 2024; Canning et al., 2008; Evans, 1992; Northridge et al., 1995; Weir et al., 2007).
The project area has not been identified as a potential breeding area for white-beaked dolphin.

SCANS III survey data from 2016 show that densities of minke whale is low in the project area, around 0.02 ind./km^2. Higher densities are found along the Scottish coast and at Dogger Bank, see Figure 10-20. SCANS IV results from 2022 show an even lower density 0.01 ind./km^2 in the project area (Gilles et al., 2023). The population estimate for 2022 in the North Sea was 7,856 (CV = 0.28), which is within the range of previous estimates from SCANS, SCANS-II and SCANS-III but lower than the most recent Norwegian survey (17,792 (CV = 0.24) in 2018; (Solvang, HK et al., 2021). The result of the trend analysis using the available 10 estimates in the North Sea over the period 1989-2022 shows no support for a change in abundance since 1989 (Gilles et al., 2023).

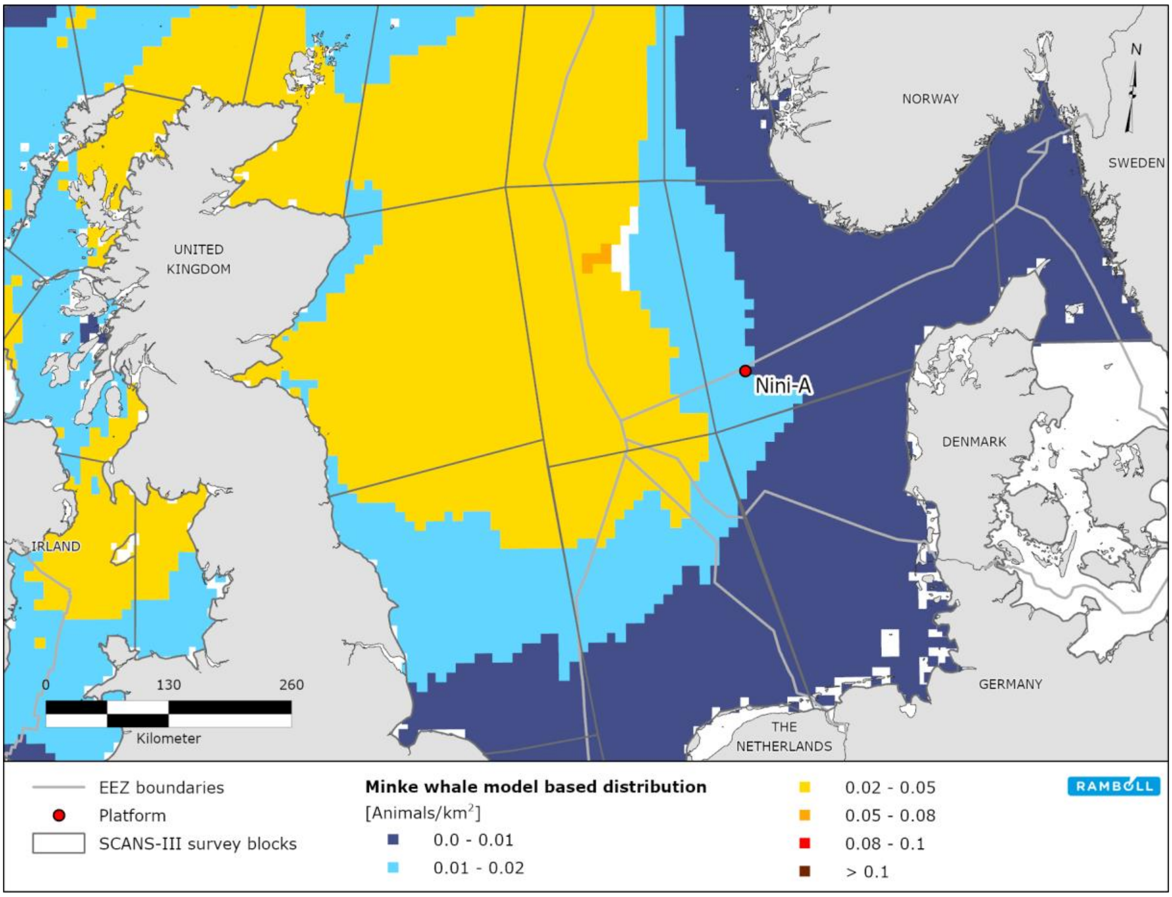


Figure 10-20 Densities of minke whale in the North Sea modelled from 2016 survey data (Hammond et al., 2021b).

The locations of breeding grounds for minke whales are unknown. However, they are believed to be located somewhere close to the equatorial waters of the North Atlantic Ocean (Vikingsson & Heide-Jørgensen, 2005a). As such, the project area has not been identified as a potential breeding area for this species.

All three species are considered most vulnerable within their breeding and mating periods. Periods of breeding are listed in Table 10-24 for the different species of cetaceans relevant to Danish waters.

Table 10-24 Time of year where relevant cetaceans to Danish waters are breeding (B) or mating (A) in the North Sea (Canning et al., 2008b; Galatius et al., 2013; Galatius & Kinze, 2016; Hasselmeier et al., 2004; Lien et al., 2001; Sonntag et al., 1999; T. B. Sørensen & Kinze, 1994). Breeding and mating seasons for minke whale are not well documented and seasons presented in the table are suggestive from the literature (Christiansen et al., 2014; Keen et al., 2021; Lockyer, 1984).

Species	J	F	M	A	M	J	J	A	S	O	N	D
Harbour porpoise				B	B	B	BA	BA	B			
White-beaked dolphin				A	A	A	BA	BA	B			
Minke whale	BA	BA									B	BA

10.5.5 Seabirds

Danish waters generally constitute important areas for seabirds as they provide resting and feeding grounds for migratory birds as well as for a variety of breeding seabird species. Areas of international importance for seabirds (also known as Important Bird Area, IBA) are shown in Figure 10-22 in section 10.6. Seabirds are primarily found in high-productive waters such as coastal areas or tidal mixing fronts where food availability is high. As the project area is located relatively far from the closest IBA (96 km southwest from "Skagerrak – Southwest Norwegian Trench", code DK121) and offshore from the continental shelf, the waters around the platform does not constitute an important area for seabirds. However, several species of seabirds have been found around Solsort and Arne South (COWI, 2022) and it is likely that these species also occur in the waters of the project area. During the NOVANA aerial surveys in spring 2019 the following species were observed near the project area; Northern gannet, black-legged kittiwake, herring gull, great black-backed gull and alcids such as the common gullemot (Teknisk rapport fra DCE, 2019). Furthermore, summer and winter distributions of seabirds in the North Sea was modelled using vessel and aerial data collected between 1980-2018 and showed several species occurring in the project area (Figure 10-21).

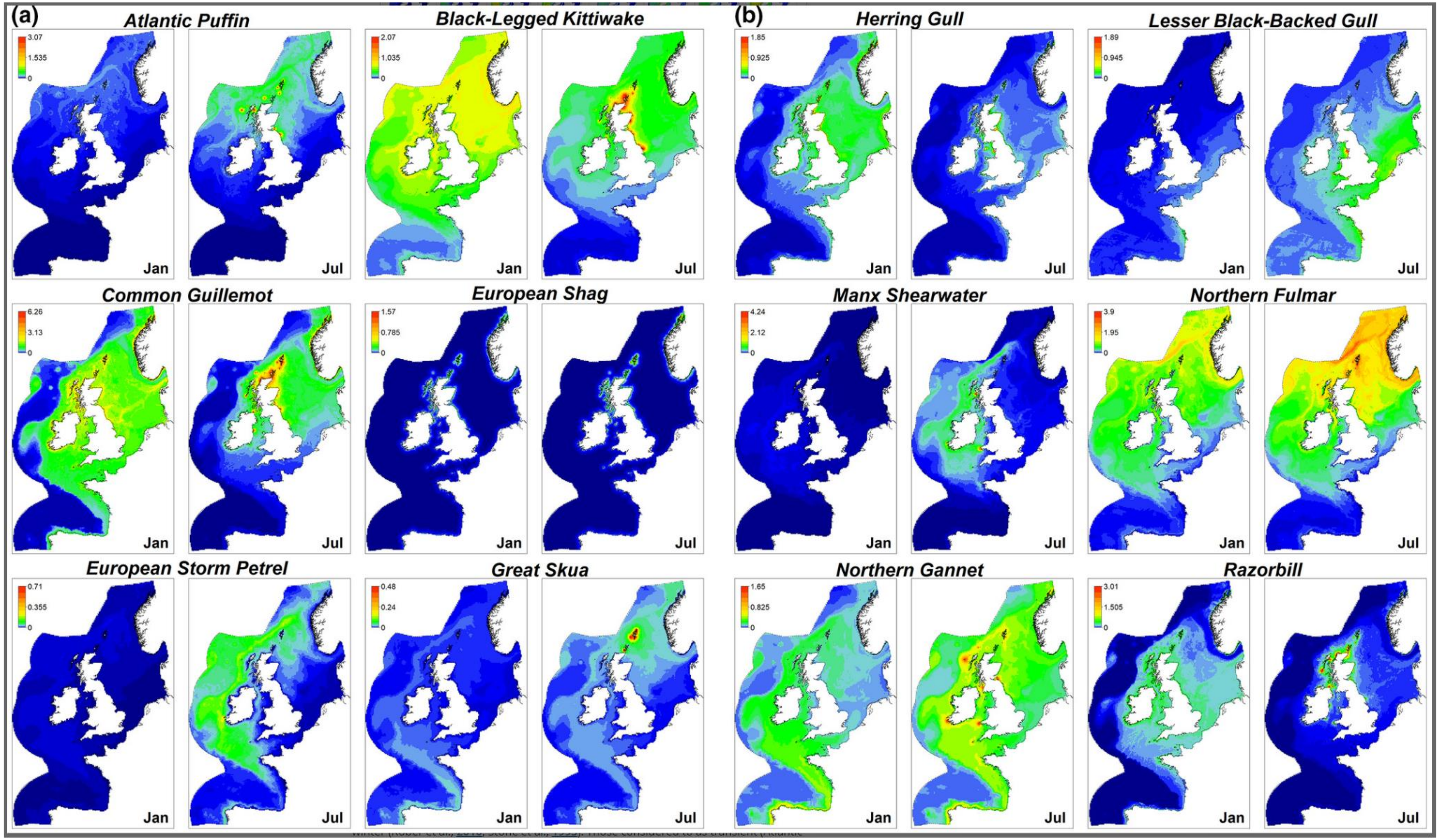
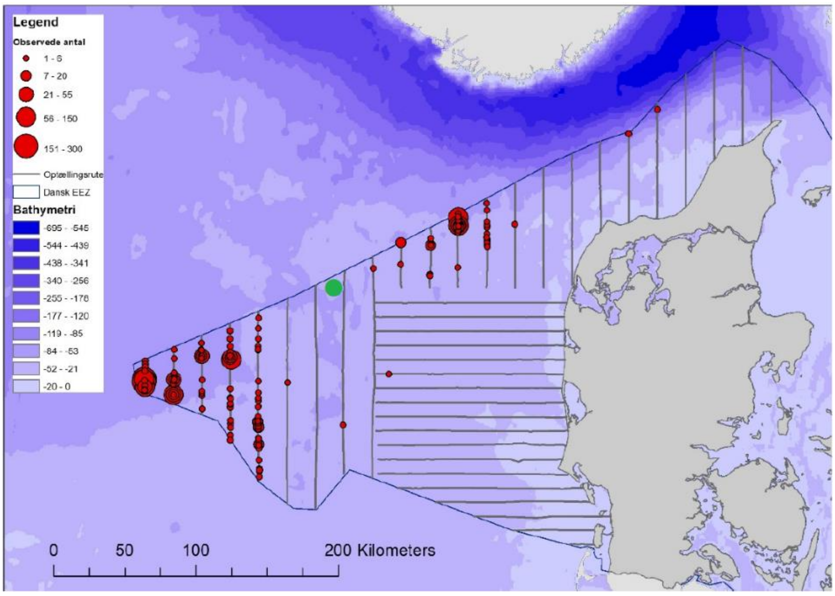


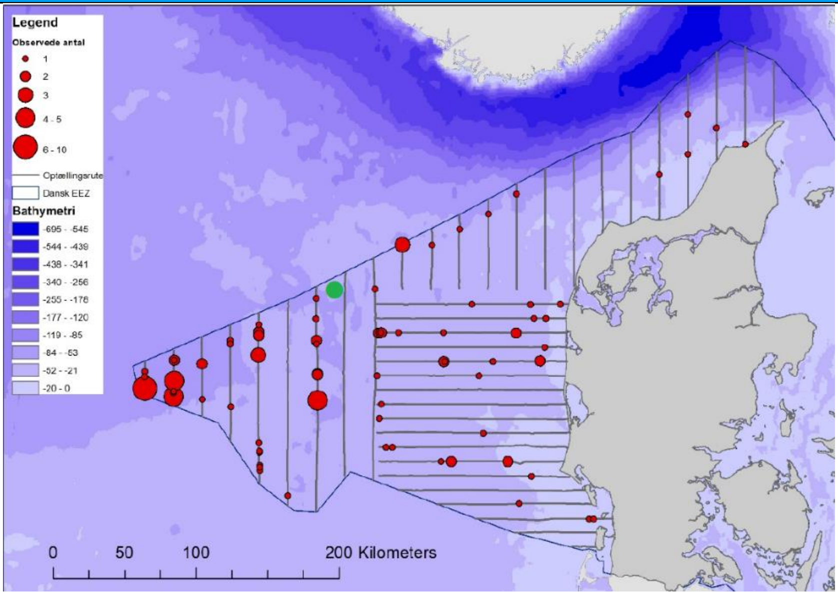
Figure 10-21 Summer and winter distribution of seabirds in the North Sea. Predictions are based on modelled scenarios given in (Waggitt et al., 2020a) which are based on aerial and vessel surveys conducted between 1980 and 2018 in addition to a variety of environmental parameters.

These data are considered the best available source to determine the species distribution of seabirds in the project area. However, it should be noted that these modelled predictions are based on data accumulated over a long period and variations in the species distribution, which may have occurred during this period, may therefore not be accounted for in this data. These predictions may therefore not represent the actual distribution of species found in the project area today.

Based on the NOVANA survey and modelled predictions, the most common species found in the project area are listed in Table 10-25 along with their respective distribution and biology.

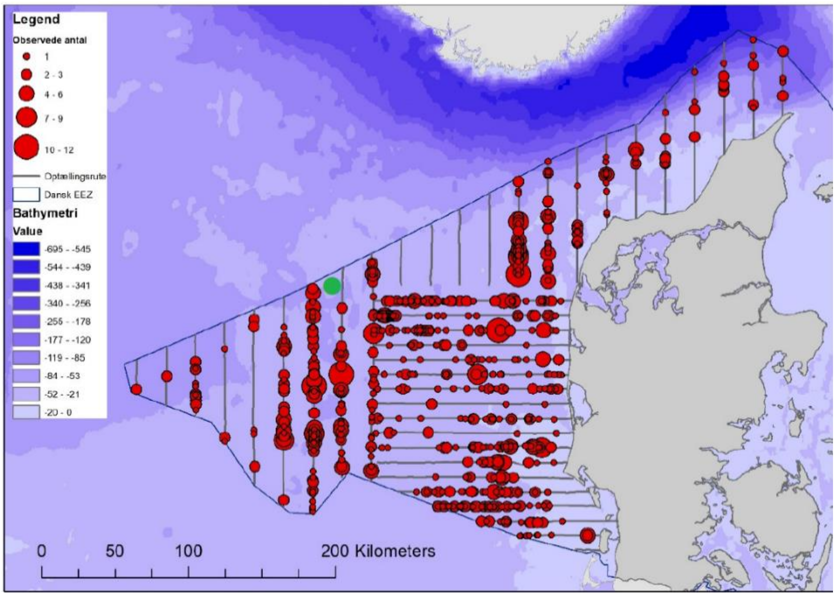
Table 10-25 Distribution and biology of relevant species of seabirds found in the project area. Data is from (Anderson et al., 2014; Birdlife International, 2022; Harris & Wanless, 1989; JNCC, 2021a, 2022b; Waggitt et al., 2020b).

Species	Distribution and biology
Northern Fulmar *(Fulmaris glacialis)*	The Northern Fulmar is a common non-migratory seabird, that breeds on cliffs and steep hills. It feeds on a variety of foods ranging from zooplankton and small fish to offal and discards produced by commercial fishing. In the project area the species is predicted to be found year-round with the highest densities during summer.  Distribution map of 2,455 individuals of Northern Fulmar in 276 observations in the Danish North Sea (April and May 2019) (Teknisk rapport fra DCE, 2019).The green dot marks the approximate project area.
Black-legged Kittiwake *(Rissa tridactyla)*	Black-legged Kittiwake is a common migratory species, that breed on cliffs and its diet consists mainly of small pelagic shoaling fish such as sand eels, sprats and young herring. However, kittiwakes will also scavenge for offal and discards around fishing boats, which can be an important food source in years when their preferred prey species are less abundant. The species is most likely found in highest densities during winter around the project area but occurs year-round in the area.

<table>
<tr><th>Species</th><th>Distribution and biology</th></tr>
<tr><td></td><td>


Distribution map of 115 individuals of black-legged kittiwake in 78 observations in the Danish North Sea (April and May 2019) (Teknisk rapport fra DCE, 2019).The green dot marks the approximate project area.
</td></tr>
<tr><td>Common Guillemot
(Uria aalge)</td><td>
Common guillemot is one of the most abundant seabirds in the temperate and colder parts of the northern hemisphere and is a dispersive rather than migratory species. It breeds on cliffs and rocks along the coast. It primarily feeds on sand eel, sprat and herring.

Common Guillemot is likely found year-round in the project area but in highest densities during winter.



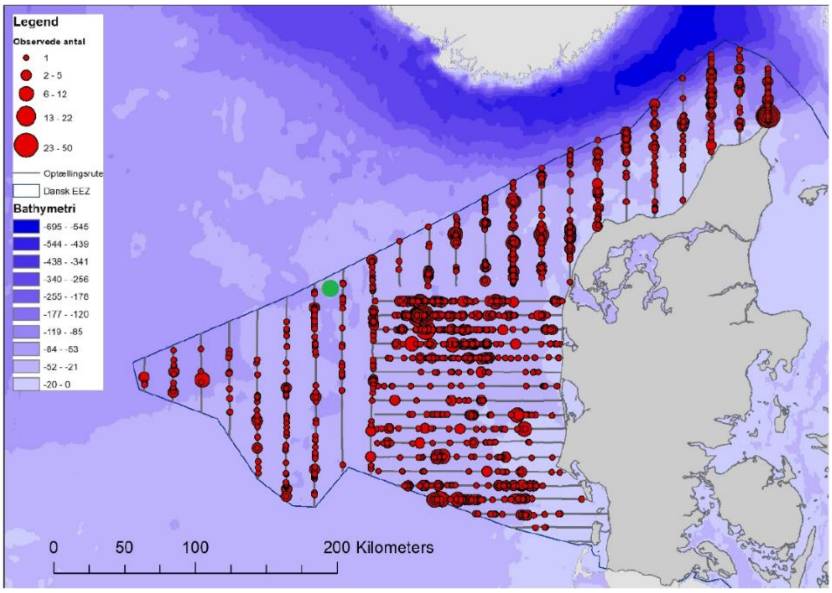
Distribution map of 1,311 individuals of auks in the Danish North Sea (April and May 2019). 1,241 were not identified to species level and 70 were identified as common guillemot (Teknisk rapport fra DCE, 2019). The green dot marks the approximate project area.
</td></tr>
</table>

<table>
<tr><th>Species</th><th>Distribution and biology</th></tr>
<tr><td>Razorbill
(Alca torda)</td><td>The razorbill is a migratory species of the temperate North Atlantic and adjacent parts of the Arctic Ocean. In the east Atlantic they breed as far south as France, north to Svalbard and east to the White Sea in north-west Russia. Razorbills breed mainly on small ledges or in cracks of rocky cliffs and in associated scree, and on boulder-fields. They feed on a variety of fish species such as sand eel, herring and sprat.

Razorbills are primarily found in the project area during winter.

Distribution map: see common guillemot.</td></tr>
<tr><td>Northern Gannet
(Morus bassanus)</td><td>Northern gannet is a migratory species and endemic to the North Atlantic where most breed in Britain and Ireland. Gannets feed on fish from both deep water (20 m) and from the surface, where small shoaling fish like sand eels and discards from fishing vessels make up their diet.

Model predictions show that the species occur in the project area all year-round but in highest numbers during summer.

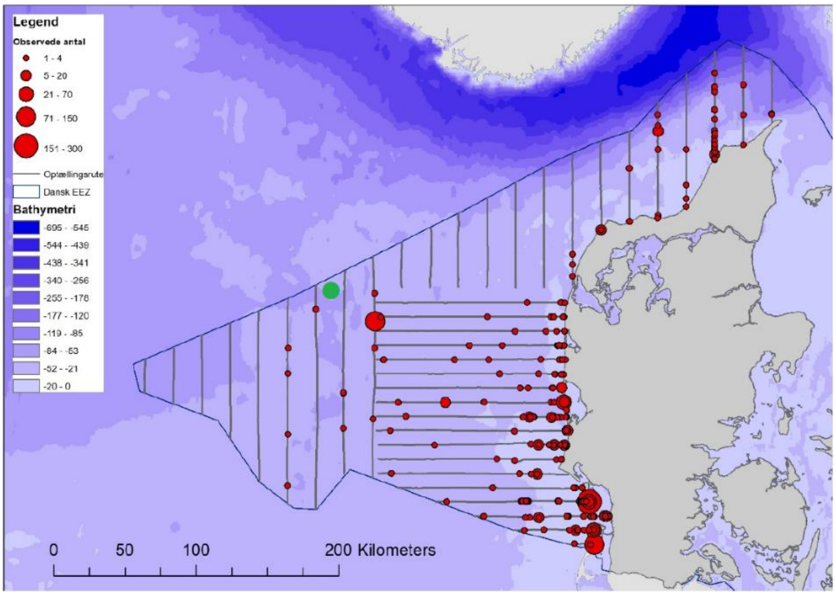


Distribution map of 2,448 individuals of northern gannet in 1,652 observations in the Danish North Sea (April and May 2019) (Teknisk rapport fra DCE, 2019). The green dot marks the approximate project area.</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Lesser black-backed Gull
(Larus fuscus)</td><td>Lesser Black-backed Gull is a common, migratory species in the North Sea. The species nests colonially, often with other gulls, especially the herring gull. Colonies are found on islands offshore and within inland freshwater bodies, coastal cliffs, sand dunes, salt marshes, moorland and on the rooftops of buildings. Lesser Black-backed Gull is an omnivorous, opportunistic feeder and its diet consists of small fish like herring as well as aquatic and terrestrial invertebrates and offal and discards from fishing vessels.

Model predictions show that the species is primarily present in the project area during summer.</td></tr>
</table>

<table>
<tr><th>Species</th><th>Distribution and biology</th></tr>
<tr><td></td><td>There is no distribution map from DCE (Teknisk rapport fra DCE 2019), as there were only 19 individuals of lesser black-backed gull in 17 observations registered.</td></tr>
<tr><td>Herring Gull
(Larus argentatus)</td><td>The Herring gull is a common, migratory species in the North Sea and breeds mainly in north and west Europe. It prefers to nest on rocky coastline, with cliffs, islets and offshore islands, though a range of other habitats are used including sand dunes, shingle banks and, increasingly, rooftops of buildings in urban areas. The Herring gull is an opportunist feeder, being both predator and scavenger. While primarily a coastal feeder, it readily takes advantage of waste from the fishing industry and landfill sites. Outside of the breeding season, herring gulls are common along coastlines and inshore waters but also occur inland.

The presence of Herring Gull is primarily predicted in the project area during winter.



Distribution map of 1,336 individuals of herring gull in 264 observations in the Danish North Sea (April and May 2019) (Teknisk rapport fra DCE, 2019). The green dot marks the approximate project area.</td></tr>
</table>

10.5.6 Annex IV species

It is assessed that whales are the only species group listed in Annex IV in the Habitats Directive that potentially occur in the project area regularly. All whale species are listed as Annex IV species and as such are protected across their entire natural range. Three species of whales is native to the North Sea i.e., harbour porpoise, white-beaked dolphin and minke whale. The population status of all three species have been assessed as favourable in the Danish part of the North Sea in 2019 (Fredshavn, Nygaard, Ejrnæs, Damgaard, Therkildsen, Elmeros, Wind, Sander, et al., 2019). Further detail on distribution and biology for the three species is given in section 10.5.4 – Marine mammals. Other cetacean species are rare and do only occasionally migrate into in the North Sea from the Atlantic (Tougaard et al., 2021b).

As described in section 10.5.4, the project area has not been identified as an important breeding or feeding area for any annex IV species.

10.6 Protected nature

Protected nature include Natura 2000 sites, areas designated under the Marine Strategy Framework Directive, Ramsar sites, Important Bird Areas (IBA's), Valuable and Vulnerable Areas (SVO), and Marine Protected Areas (MPA's). Protected areas in the Central North Sea close to the Project area are shown in Figure 10-22.

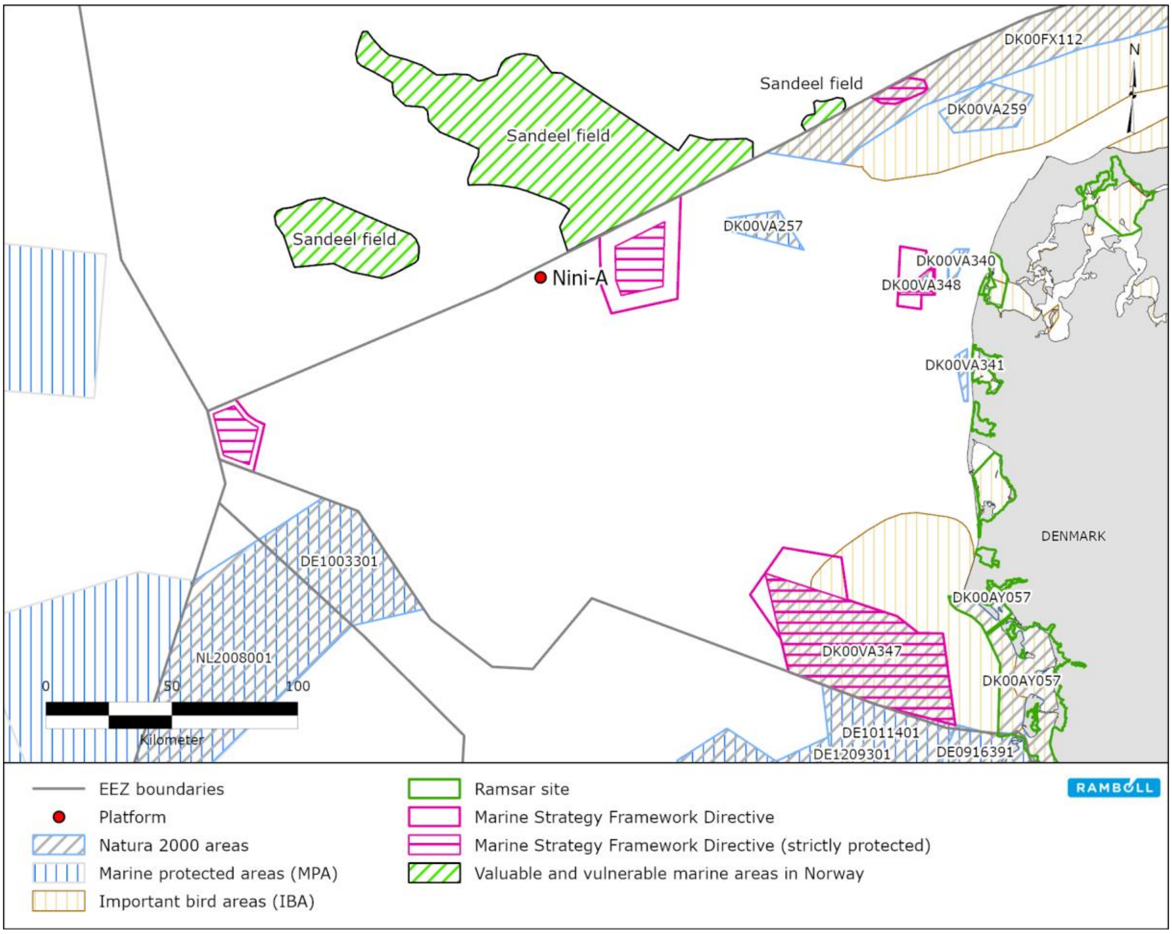


Figure 10-22 Protected areas in the North Sea and the position of the Nini A platform.

10.6.1 Natura 2000 areas

It is mandatory to assess whether the project can significantly affect the conservation objectives of a Natura 2000 area. The nearby Natura 2000 areas is described and assessed in chapter 16.1.

10.6.2 Marine Strategy areas

The Marine Strategy Framework Directive is embodied in the Danish Maritime Strategy Act (Consolidation Act no. 123 af 01/02/2024). State, regional and municipal authorities are bound by the environmental targets and action programs laid down in accordance with this Act. The nearest MSFD area is located approx. 17 km from the project area (Figure 10-22). The projects impact on the Marine Strategy Areas protected under the Marine Strategy Framework Directive as well as the related descriptors are described and assessed in chapter 15.

10.6.3 Ramsar sites

Ramsar sites are wetlands of international importance that have been designated under the criteria of the Ramsar Convention on Wetlands for containing representative, rare or unique wetland types or for their importance in conserving biological diversity. These sites are generally found close to shore and the closest Ramsar site is located approx. 170 km from the project area on the west coast of Jutland (Figure 10-22). In Denmark, all Ramsar sites are coinciding with Special Protection Areas under the Birds Directive (SPAs) and is therefore part of the Natura 2000 network and will be assessed as such in Chapter 16.1.

10.6.4 Important Bird Areas

The Important Bird Areas (IBA) is a program under BirdLife International which aims to protect designated areas that are considered vital for bird populations and biodiversity in general. The closest IBA is "Skagerrak – Southwest Norwegian Trench" – code DK121, which is located 96 km north-east of the project area.

10.6.5 Valuable and vulnerable areas ("Særlig Verdifulle og Sårbare Områder")

Særlig Verdifulle og Sårbare Områder (SVOs) are marine areas of significant importance to biological diversity and production, which have been designated by the Norwegian Government as part of their marine management plan. The purpose of these marine management plans is to achieve good environmental status for all its marine areas.

Project Greensand Future is located in the "North Sea and Skagerrak" management area. According to the latest management plan from 2019-2020, the general objectives for the marine area are:

- Naturally occurring species should be found in viable populations which secure reproduction and long-term survival.
- Species that play a key role in the functioning, structure, productivity and dynamics of the ecosystem should be managed in a way that ensures the species' ability to maintain this this role.
- In marine habitats, which play an important part in the functioning, structure, productivity and dynamics of the ecosystem, all activities should take place in a manner that ensures that all ecological functions are maintained.
- Damage to marine habitats that are considered threatened or vulnerable should be avoided.
- Activities that result in noise pollution to a degree that can affect the behaviour of species should be limited to avoid population displacement or other adverse effects on the marine ecosystem.

Specific objectives concerning SVOs are:

- Human activities within and outside SVOs should exercise particular caution and should take place in a manner that does not threaten the ecological functions or the natural diversity of the SVOs.
- Management plans should show special consideration to the need for protection of vulnerable habitat types and species of SVOs.

Activity inside the SVOs is not restricted, however caution should be exercised within and outside the areas with regard to the objectives in the management plan.

The project area is located approx. 11 km southwest from SVO-area NS2 "The sand eel fields", which have been designated due to its characteristic sediment and physical-chemical qualities making it an ideal habitat and spawning ground for sand eel (Figure 10-22). The area is surveyed annually and in recent years, the area has supported regular recruitment of sand eel (Hvingel et al., 2021). Furthermore, the sand eel fields constitute important feeding grounds for several seabirds including common guillemot (*Uria aalge*), black-legged kittiwake (*Rissa tridactyla*), and northern fulmar (*Fulmaris glacialis*) and to a lesser extent little auk (*Alle alle*) and Atlantic puffin (*Fratercula arctica*) (P. Fauchald et al., 2015; Systad et al., 2019).

10.6.6 Marine Protected Areas

MPAs are geographically distinct zones for which conservation objectives are set. The IUCN defines MPAs as "a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values".
IUCN recognizes six different categories of MPAs, classified according to their objectives:

1. Protected area managed mainly for science or wilderness protection (Strict Nature Reserve/Wilderness Area)
2. Protected area managed mainly for ecosystem protection and recreation (National Park)
3. Protected area managed mainly for conservation of specific natural features (Natural Monument or Feature)
4. Protected area managed mainly for conservation through management intervention (Habitat/Species Management Area)
5. Protected area managed mainly for landscape/seascape conservation and recreation (Protected Landscape/Seascape)
6. Protected area managed mainly for the sustainable use of natural ecosystems (Managed Resource Protection Area).

MPA's are often coinciding with Natura 2000-areas and since the latter offers much more strict protection, only MPA's that are not otherwise protected are considered in the following.

The closest MPA to the *Project Greensand Future* area is Fulmar, a 2,437 km^2 large marine conservation zone located within the United Kingdom's national waters approx. 167 km west of the project area. Fulmar is characterized as "less protected/unknown", which means that the area is somewhat protected but allow for moderate to extensive extraction and associated impacts.

Fulmar has been designated under the Marine and Coastal Access Act (2009) to specifically protect the three habitat types subtidal mixed sediments, subtidal mud, and subtidal sand and the bivalve species Ocean quahog (*Arctica islandica*;(JNCC, 2022a).

10.7 Material assets

Material assets include existing oil and gas infrastructure, offshore wind farms (OWFs), cables and pipelines (collectively addressed as offshore infrastructure in the following) as well as ship traffic. The location of the project area to offshore infrastructure is shown in Figure 10-23.

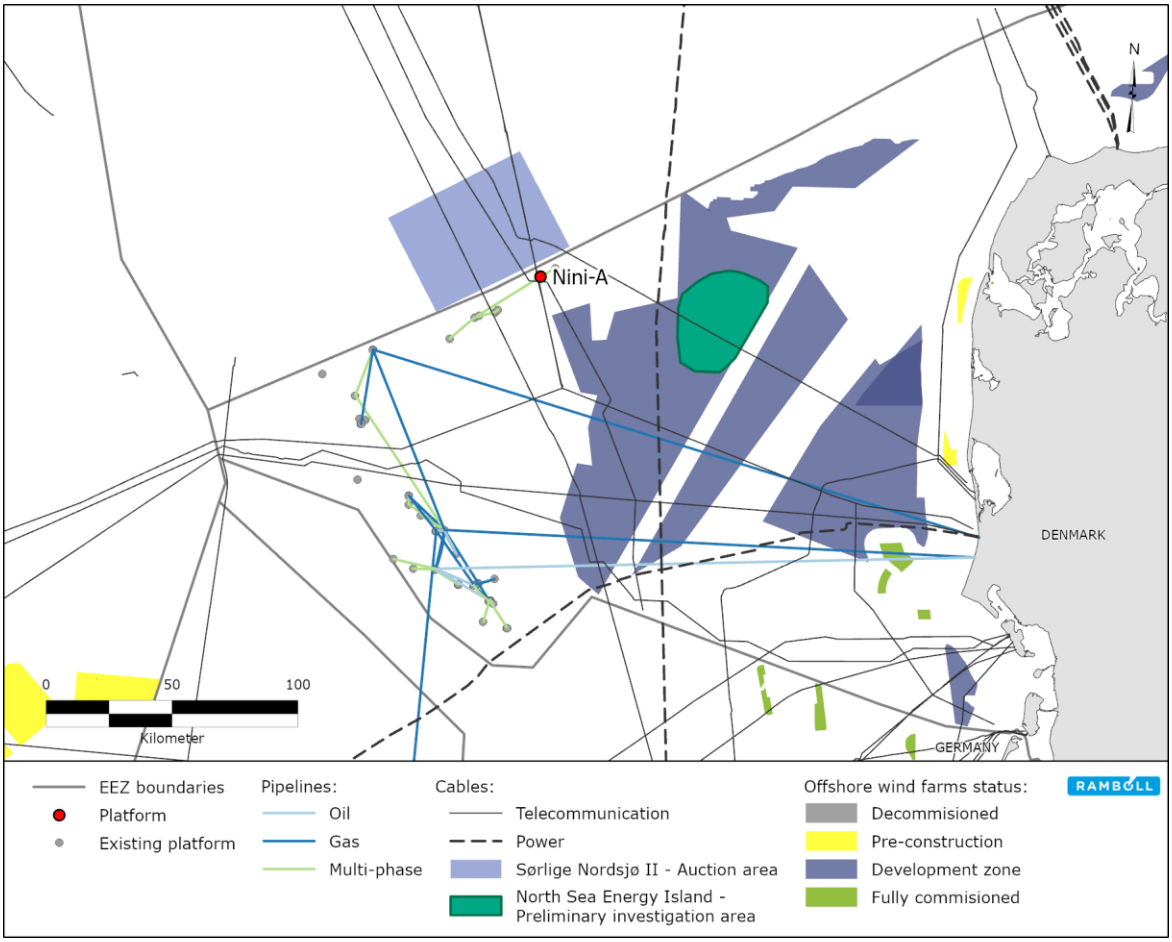


Figure 10-23 Location of project area to existing offshore infrastructure in the North Sea.

Oil and gas extraction

Several oil and gas fields are located in the central North Sea including the project area which is found in the far north-eastern corner of the Danish part of the North Sea oil and gas exploration area. The closest, producing oil and gas fields are Harald and Svend (Figure 10-24), which are both operated by Total Energy and connected to the Tyra field further south. Other fields in the vicinity of the project area include the two fields, Solsort and Hejre, which are both under development and South Arne which is currently in production. All three fields are operated by INEOS E&P A/S.

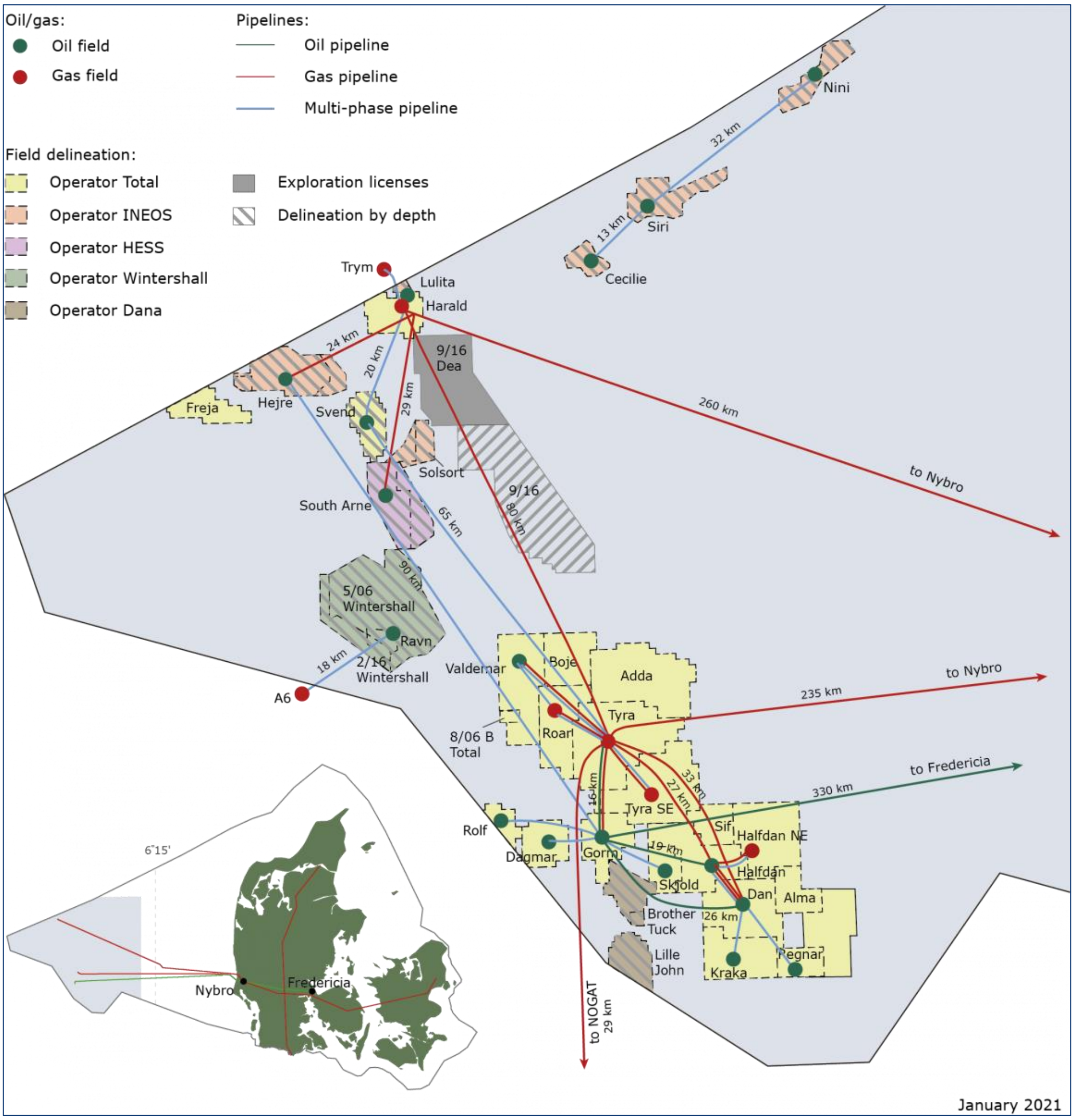


Figure 10-24 Oil and gas fields in the Danish part of the North Sea. Note: figure is from January 2021, where South Arne was still operated by HESS. The field was later acquired by INEOS E&P A/S in 2021 whom is now the operator (Energistyrelsen, 2022e).

Offshore wind energy

The closest operating OWF to the project area is the collection of windfarms near Horns Rev approx. 170 km south-east of the project area, which is comprised of Horns Rev I, Horns Rev II and Horns Rev III with a total of 220 windmills. Furthermore, a broad majority of the Danish Parliament agreed in June 2020 to establish two offshore energy islands, one of which will be placed in the North Sea. The preliminary site investigation area is currently located 53 km east of the project area and the North Sea Energy Island will be placed within this area. Norway has recently proposed a new development zone for OWF, Sørlige Nordsjø II, which will be located on the border of the Exclusive Economic Zone (EEZ) approx. 5 km north of the project area.

Cables and pipelines
The project area is intercepted by two subsea telecommunication cables (see Figure 10-23). Both cables are in use.

Ship traffic
Ship traffic density maps have been created by the European Maritime Safety Agency (EMSA) based on automatic identification system (AIS) data collected in 2021 in a 1x1 km grid covering all European waters including the North Sea. All vessels above 300 gross tonnages are required to have AIS installed (class A transponders). The same is true for passenger ships and all fishing vessels over 15 m in length (EU rules). Smaller vessels with no requirement to carry AIS equipment include pleasure boats and other smaller boats. However, some of these have chosen to have AIS installed (class A or B transponders) to be more visible at sea and will therefore also be represented in the data. Due to the distance from shore, traffic with smaller pleasure boats is assumed to be limited in the project area, and pleasure boat traffic is therefore not addressed further. As seen in Figure 10-25, the project area is located outside shipping routes in an area generally characterized by low density ship traffic (>10-100 ships per km^2 in 2021).

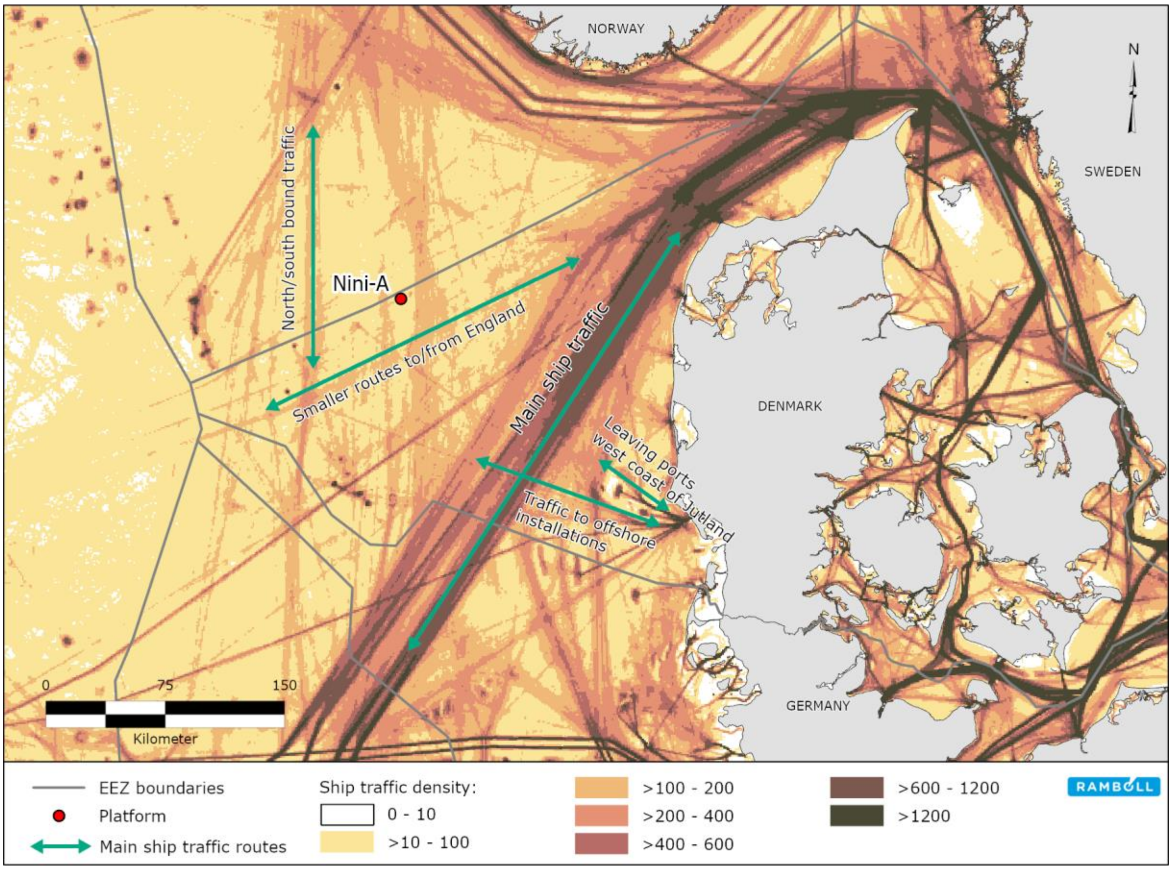


Figure 10-25 Ship traffic in the central North Sea around Nini A. Ship traffic density is shown as routes per square km per year and based on AIS-data collected from all vessels in 2021 (EMODnet, 2021b).

The main ship traffic around the project area consists of transit traffic between the mainland Europe and the entrance to Skagerrak north of the peninsula of Jutland. The traffic density here is more than 1,200 vessels per square kilometre in 2021 corresponding to above 20,000 ship movements per year. The ship traffic mainly consists of merchant vessels, i.e., cargo and tanker vessels. In addition, some ship traffic passes across the North Sea in various directions, e.g., in a direction more east/west between the English coast and the inner Danish Waters, and in a direction north/south towards Norway. Finally, significant ship traffic is also seen entering and leaving ports on the west coast of Jutland, e.g., Esbjerg. Most of this ship traffic is related to traffic to and from offshore installations in the North Sea. This ship traffic crosses the main ship traffic to arrive at the central parts of the North Sea.

There are formal shipping corridors and traffic separation schemes defined in the North Sea north of the coast of Germany, in the English Channel, and in the inner Danish waters. In the central parts of the North Sea and along the Danish west coast, there are no formal IMO regulated shipping routes, and hence navigation is according to the rules of the sea. However, the North Sea is an area for ongoing development, and several areas have been identified as development areas for wind energy. Some areas in-between development areas are defined as areas for shipping corridors in the Maritime Spatial Plan (Søfartsstyrelsen, 2021).

10.8 Cultural heritage

The maritime cultural heritage objects (CHO) in the North Sea primarily consists of two broad categories: submerged paleolithic to neolithic landscapes, settlements and artefacts, and other man-made cultural heritage objects, including ship and plane wrecks from both modern and historical periods.

Ship and plane wrecks are the most likely CHOs present in and near the project area. However, considering the extensive activity around the Nini Complex over the last 20 years, where no wrecks have been identified, the project area is not expected to have any significant importance concerning cultural heritage. The CHO found closest to the project area is an unidentified wreck dated between 1661-2009 AC located approximately 20 km southeast of the project area (Figure 10-26) (Slots- og Kulturstyrelsen, 2022).

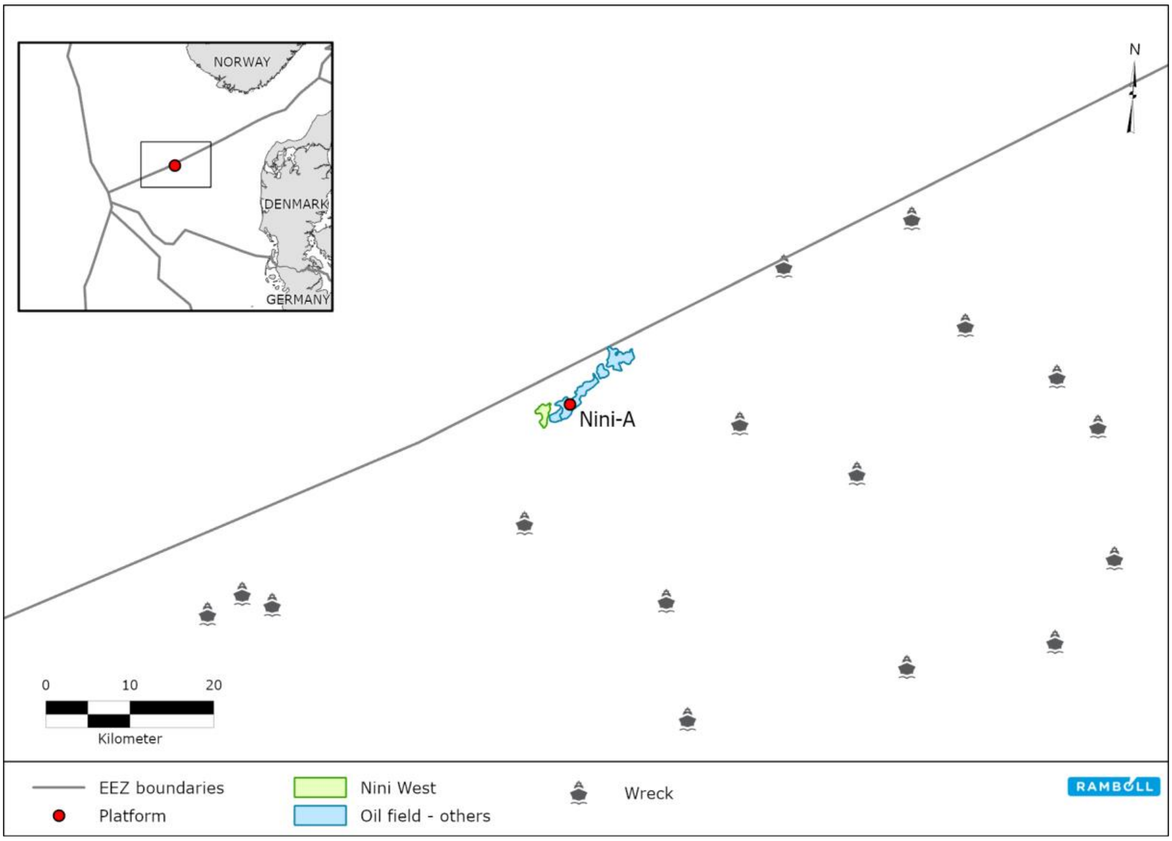


Figure 10-26 Historical artefacts in the Danish part of the North Sea around Nini A. Data is derived from (Slots- og Kulturstyrelsen, 2022).

Shipwrecks reflect a diverse group of vessels that vary in age, size and type. Not all shipwrecks have the same cultural heritage value. Once settled on the seabed, wrecks are prone to physical destruction by natural occurrences, such as storms, or human activities, such as bottom trawling or direct damage from seabed or water column activities. A shipwreck does not necessarily need to be fully intact to be of archaeological interest. Due to physical conditions in the North Sea and the presence of shipworm, the decomposition of wood and other organic materials progresses relatively fast compared to areas such as the Baltic Sea. Even some highly degraded shipwrecks can yield valuable information after thorough investigations of hull remains, equipment, cargo and other artefacts belonging to the wreck. It is therefore important to recognize that the 'ancient monument area' of a wreck site is not only the hull itself but includes the total deposit and distribution area of the remains from a broken wreck, which in many cases is substantially larger than the actual hull.

In a 2005 seabed debris survey from DONG (DONG, 2005) five sonar contacts were observed with side-scan sonar within a 500 x 500-meter square around Nini A. DONG interpreted these as debris and two of the largest contacts were found within spud can depressions. None of the five contacts have been visually confirmed from an archaeological point of view. No archaeological surveys of the project area exist and, thus, the presence of CHOs in the project area cannot be ruled out completely.

10.9 Fisheries

The North Sea is an important area for commercial fisheries. Around 6600 fishing vessels are active in the Greater North Sea, which encompasses the North Sea, English Channel, Skagerrak, and Kattegat. Here, the landings peaked in the 1970s with 4 million tons, and it has since declined to about 2 million tons today. The total fishing effort has declined greatly since 2003. Landings of pelagic fish species (e.g., herring and mackerel) are greater than demersal fish (e.g., sand eel and haddock). The catches stem from more than 100 fish stocks. The level of discarding is highest among demersal and benthic fisheries. The spatial distribution or preference of fishing gear varies in the North Sea. The fish stocks harvested in the North Sea are being fished consistent with achieving good environmental status, under the EU's Marine Strategy Framework Directive, but the reproductive capacity of the stocks has not reached this level. The greatest physical disturbance of the seabed is caused by mobile bottom-contacting gear.

To get a geospatial understanding of the fisheries operating near the project area, a logbook dataset from the Danish Fisheries Agency has been analysed. The logbook contains data entries of landings by species, weight, ICES rectangle, year, and used gear type. The project area is located in the ICES rectangle 42F5, but data was also obtained for 42F4, 42F6, 41F4, 41F5, and 41F6 for the period 2013 to 2022 (see location of ICES rectangles in Figure 10-29). In the period 62 species of fish, crustaceans, and molluscs were registered. Among the registered species 44 were also found in 42F5. The landings in 42F5 mainly consisted of sand eels (54.3%), European plaice (36.9%), lemon sole (2.4%), Atlantic cod (1.8%) and turbot (1.1%). The catch compositions are mainly of demersal species in 42F5. In general, it has been fisheries for sand eels (61.9%), European sprat (24.3%), European plaice (8.4%) and Atlantic herring (1.7%) that has been targeted in the investigated ICES rectangles, see Table 10-26.

Table 10-26 Total landings (tons) by ICES rectangle and species in the period 2013 to 2022. Project area is located in 42F5.

Species	41F4	41F5	41F6	42F4	42F5	42F6	Total
Sand eels	42,446	53,674	10,096	200	6,447	540,12	166,875
European sprat	41	35,580	25,383	0	0	4446	65,451
European plaice	250	4,165	6,070	2,727	4,381	4,925	22,519
Atlantic herring	9	2,710	1,270	0	6	453	4,448
Norway lobster	0	2,012	272	0	81	11	2,375
Atlantic cod	13	124	227	40	210	794	1,408
Lemon sole	22	98	45	205	282	533	1,185
Turbot	13	129	402	17	128	273	963
Common dab	2	75	142	28	75	257	579
Angler	3	38	33	13	64	426	577
Other	3	40	86	22	89	190	431
Grey gurnard	18	200	65	0	1	123	407
European hake	0	82	90	1	12	208	394
Atlantic mackerel	8	149	72	0	6	140	376
Whiting	27	234	46	0	2	64	372
Haddock	14	62	15	3	8	123	225
Brill	0	20	109	1	18	58	207
Witch flounder	5	47	15	41	53	28	188
Edible crab	1	18	98	0	5	46	168
Marine fishes nei	0	14	35	2	13	72	136
Common sole	0	9	92	0	0	12	114
Total	**42,876**	**99,471**	**44,572**	**3,301**	**11,880**	**67,184**	**269,285**

The landings have generally decreased or been relatively stable in the ICES rectangles in the analysis. There is however, some interannual variability, especially driven by the sand eel fisheries, see Figure 10-27.

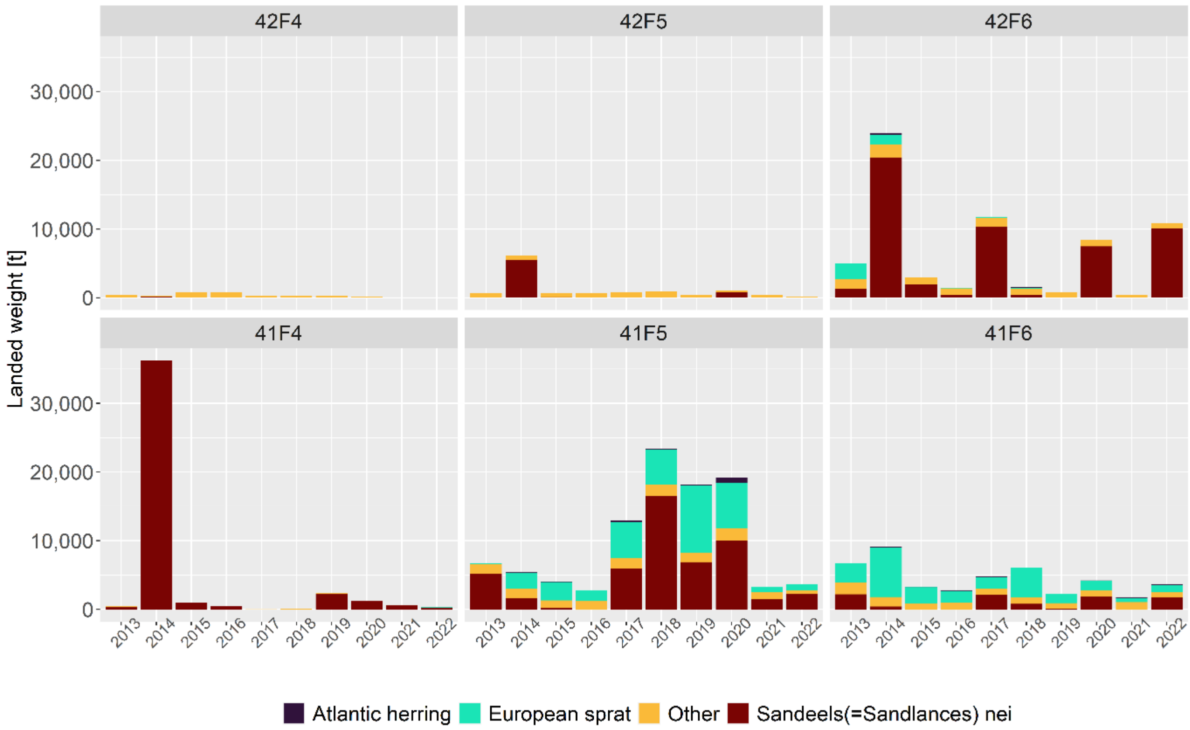


Figure 10-27 Landed weight (t) by ICES rectangle, year, and species. The group *Other* is accumulated, and it consists of species where individual landing (t) registrations by year were less than 15.5 (t).

The landed value (mil DKK) in 42F5 mainly consisted of European plaice (75.3%), lemon sole (15.3%), turbot (2.5%), Atlantic cod (2.1%) and witch flounder (1.4%). In general, it has been fisheries for European plaice (29.4%), sand eels (24.2%), Norway lobster (12.4%), European sprat (10.5%) and turbot (7%) that has generated the biggest profits in the investigated ICES rectangles, see table Table 10-27.

Table 10-27 Landed value (mil DKK) by ICES rectangle and species in the period 2013 to 2022.

Species	41F4	41F5	41F6	42F4	42F5	42F6	Total
European plaice	3.411	61.235	93.905	37.743	65.182	70.481	331.957
Sand eels	63.706	96.809	17.982	0.283	9.712	85.550	274.041
Norway lobster	0.000	118.507	16.038	0.002	4.805	0.642	139.995
European sprat	0.115	66.311	44.750	0.000	0.000	7.206	118.383
Turbot	1.020	10.355	33.399	1.292	10.387	22.670	79.123
Lemon sole	0.787	3.782	1.699	7.693	10.678	20.086	44.725
Atlantic cod	0.353	3.460	6.363	1.054	5.762	22.158	39.150
Angler	0.103	1.474	1.286	0.518	2.446	16.445	22.273
Atlantic herring	0.041	11.112	5.190	0.000	0.027	1.659	18.029
Brill	0.024	1.103	6.294	0.045	1.044	3.307	11.816
Common sole	0.009	0.635	8.274	0.022	0.054	1.018	10.011
European hake	0.004	1.624	1.540	0.030	0.281	3.906	7.385

Species	41F4	41F5	41F6	42F4	42F5	42F6	Total
Edible crab	0.018	0.658	3.822	0.003	0.159	2.025	6.684
Other	0.067	0.945	1.419	0.180	0.579	2.614	5.805
Common dab	0.019	0.687	1.249	0.257	0.722	2.381	5.316
Atlantic mackerel	0.080	1.418	0.644	0.002	0.053	1.301	3.498
Witch flounder	0.081	0.816	0.283	0.717	0.941	0.487	3.326
Wolffishes	0.011	0.091	0.122	0.149	0.985	0.912	2.270
Haddock	0.088	0.465	0.121	0.040	0.089	1.427	2.230
Atlantic halibut	0.017	0.358	0.279	0.085	0.320	0.831	1.890
Whiting	0.108	0.868	0.220	0.000	0.006	0.267	1.470
Marine fishes nei	0.004	0.055	0.382	0.025	0.123	0.682	1.272
Total	**70.064**	**382.770**	**245.263**	**50.142**	**114.354**	**268.054**	**1,130.647**

The landed value (mil DKK) has generally been stable in the ICES rectangles in the analysis. There is however, some interannual variability, see Figure 10-28. The landed value was greatest in 41F5, whereas 42F5 had the fourth highest revenue when compared to the other ICES rectangles in the analysis.

Figure 10-28 Landed value (mil DKK) by ICES rectangle, year, and species. The group *Other* is accumulated, and it consists of species where individual landed value (mil DKK) registrations by year were less than 0.35 (mil DKK).

Fishing types

In the following section different gear types are described, all of which are used in ICES rectangle 42F5, where the survey area is located.

Beam trawl

A beam trawl is kept open horizontally by a steel beam going across the opening of the net and is supported by two heavy beam heads on either side. The beam heads are mounted on "shoes" acting as guides for the trawl. Beam trawls are designed to target species that stay on the bottom or are partly buried in the sediment, but it is not a well targeted fishery and it has poor selectivity and potential to catch non target bycatch. By using a tickler chain mounted between the two beam heads, the seabed in front of the net is penetrated in the upper centimetres and disturbed sufficiently to agitate potential target species enough to be caught in the trawl net itself. Beam trawls can be towed and configured in several ways, and vessels often operate two beam trawls at a time. While the beam heads and beam shoes create furrows in the seabed, the overall effect of a beam trawl is a flattening of the seabed because of the ground gear and the tickle chains. As the chain is stretched out between the beam heads, the disturbance happens along the entire width of the beam trawl itself and thus it effects a relatively large area during the tow.

Bottom otter trawl

Bottom otter trawls are conical nets that are dragged along the seabed catching demersal fish species. Bottom otter trawls can either be operated as single or twin trawls, where two single trawls are attached and adjacent to each other by the use of a clump weight. The otter boards and the clump weight are the main parts of an otter trawl that is rigged to penetrate the sediment. The trawl doors are connected to the vessel by warps and to the trawl net by sweeps, with ground gear mounted beneath the trawl net to prevent wear from abrasion and target species from escaping beneath the trawl. Otter boards, sweeps and ground gear are all in contact with the seabed during trawling. Sweeps and ground gear both flatten seabed features, such as ripples or irregular topography, while the otter boards and the clump weight create furrows and berms to various depth.

Bottom seines

Bottom seines consist of a two long weighted seine ropes and a seine net. During the fishing, the ropes and net are deployed in a specific pattern on the seabed and then towed until the ropes come together, whereafter the net is winched back onto the vessel. During the tow, the agitation of the seabed sediments disturbs bottom dwelling target species, which are then funnelled into the open seine net. Since demersal seining depends on the ropes not getting caught on obstacles during the towing phase, there are clear limitations on the sediment types where it can be used.

Pelagic trawl and seines

Pelagic trawl is spread horizontally by a set of pelagic trawl doors. Like demersal trawl, the opening is dictated by a clump weight. Altering the vessel speed can change the position of the net in the water column to suit the depth where the shoal of fish is swimming at. Pelagic trawls are towed in mid-water with no intentional contact with the seabed. Pelagic trawls are good at being species specific when compared to other gear types. Targeted species are typically caught during their annual migration routes. In the North Sea the gear is used to catch species like herring, sprat, and mackerel.

A pelagic seine is a large net used to surround a shoal of pelagic fish. The bottom of the net is drawn together by hauling in a long wire to form a huge cup shape of netting just below the surface of the water with the targeting fish inside. A purse seine does not meet the seabed and has little seabed impact. The pelagic seine is very species selective, and it can usually only be used on a seasonal basis on particular areas when the target species is known to shoal up in that area.

Fishing distribution

The distribution of the activity from the different commercial fisheries, that are active near and around the survey area, has been presented in Figure 10-29 as average fishing hours or fishing intensity in the period 2015 to 2018. The dataset on fishing intensity in the EU waters was created in 2020 by COGEA for the European Marine Observation and Data Network (EMODnet). It is the result of the elaboration of the ICES data on spatial distribution of average annual fishing effort (mW fishing hours) in the Greater North Sea Ecoregion during 2015–2018. Fishing effort data are only shown for vessels >12 m having vessel monitoring systems (VMS). Due to data confidentiality issues, VMS/logbook data are anonymized and aggregated in a 0.05×0.05-degree grid prior to submission to ICES, using the C-square geocode system. As seen in Figure 10-29, there is overlap with the survey area and activity from beam trawlers and bottom otter trawlers, but the fishing intensity is much higher in both 41F5 and 42F6 in comparison to ICES rectangle 42F5 where the survey area is located. This tendency is also observed in the logbook data. There is also some intensity in the vicinity of the survey area from pelagic trawlers and both bottom and pelagic seines, generally in ICES rectangle 41F5. Fisheries with seines and pelagic trawlers are used less in the area in comparison to mobile bottom contacting fishing gear (Figure 10-29).

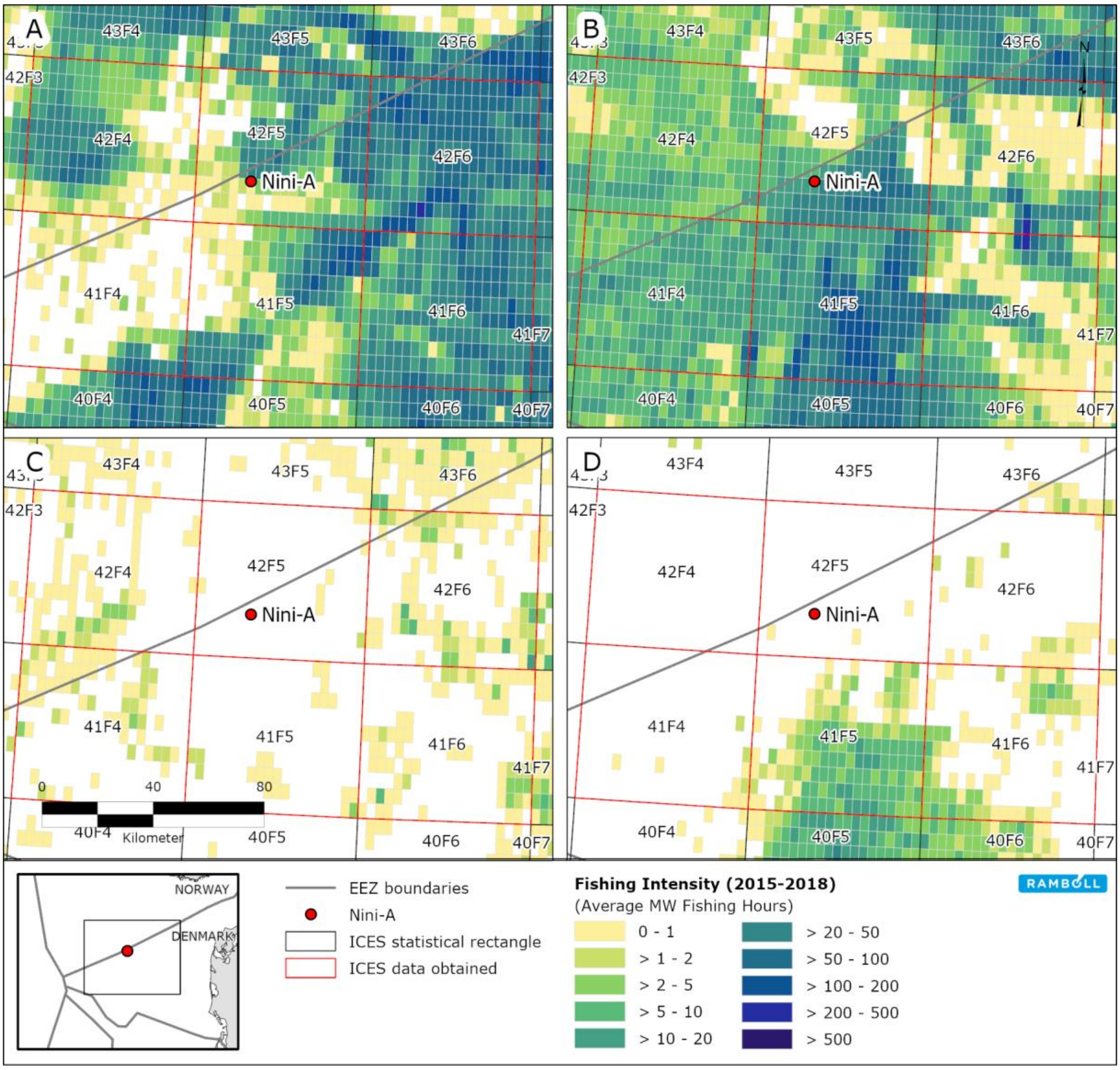


Figure 10-29 Average fishing intensity (mW fishing hours). A) Beam trawl, B) Bottom otter trawl, C) Bottom seines and D) Pelagic trawl and seines (EMODnet, 2021d).

Mobile bottom contacting fishing gear (i.e., bottom otter trawls, beam trawls, bottom seines and dredges) provides a major source of physical disturbance to the seabed. The physical disturbance from fishing has two components: Subsurface and surface disturbance. Here, the average annual surface (Figure 10-30) and subsurface (Figure 10-31) mobile bottom contacting fishing gear abrasion in the Greater North Sea, is expressed as average swept-area ratios (SAR i.e., the average number of times a unit area is swept per year). Abrasion is defined as the process of scraping of the substrate (e.g., by a trawl door or an anchor). Surface abrasion is defined as the pressure to seabed surface features. Subsurface abrasion concerns the penetration or disturbance of the substrate beneath the seabed surface as the various gear types penetrate the seabed in different ways. The presented SAR values indicate the theoretical number of times the entire grid cell area would have been swept if effort were evenly distributed within each cell. The swept-area ratio is calculated separately for surface and subsurface contact.

The North Sea is trawled intensively, especially around the sandbanks. The project area is in an area with a SAR of less or equal to two. Southeast of the project area (distance > 4.5 km) the fishing intensity is higher indicating that this area may constitute an important area for commercial fisheries.

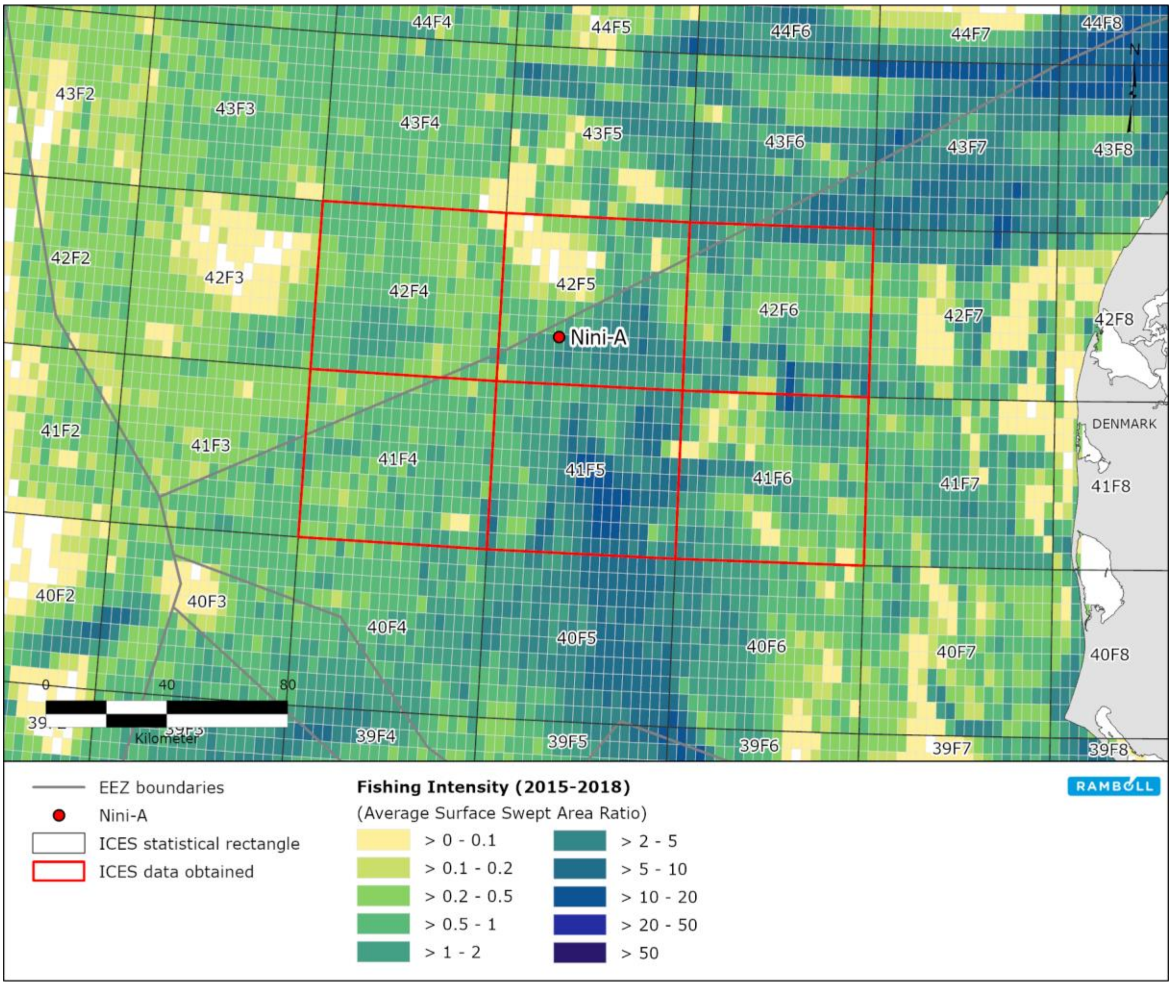


Figure 10-30 Fishing intensity by average surface swept area ratio in the North Sea around Nini A (EMODnet, 2021d).

Fishing intensity using subsurface gear types in the project area showed an equally low intensity-level with SAR of less than one (Figure 10-31).

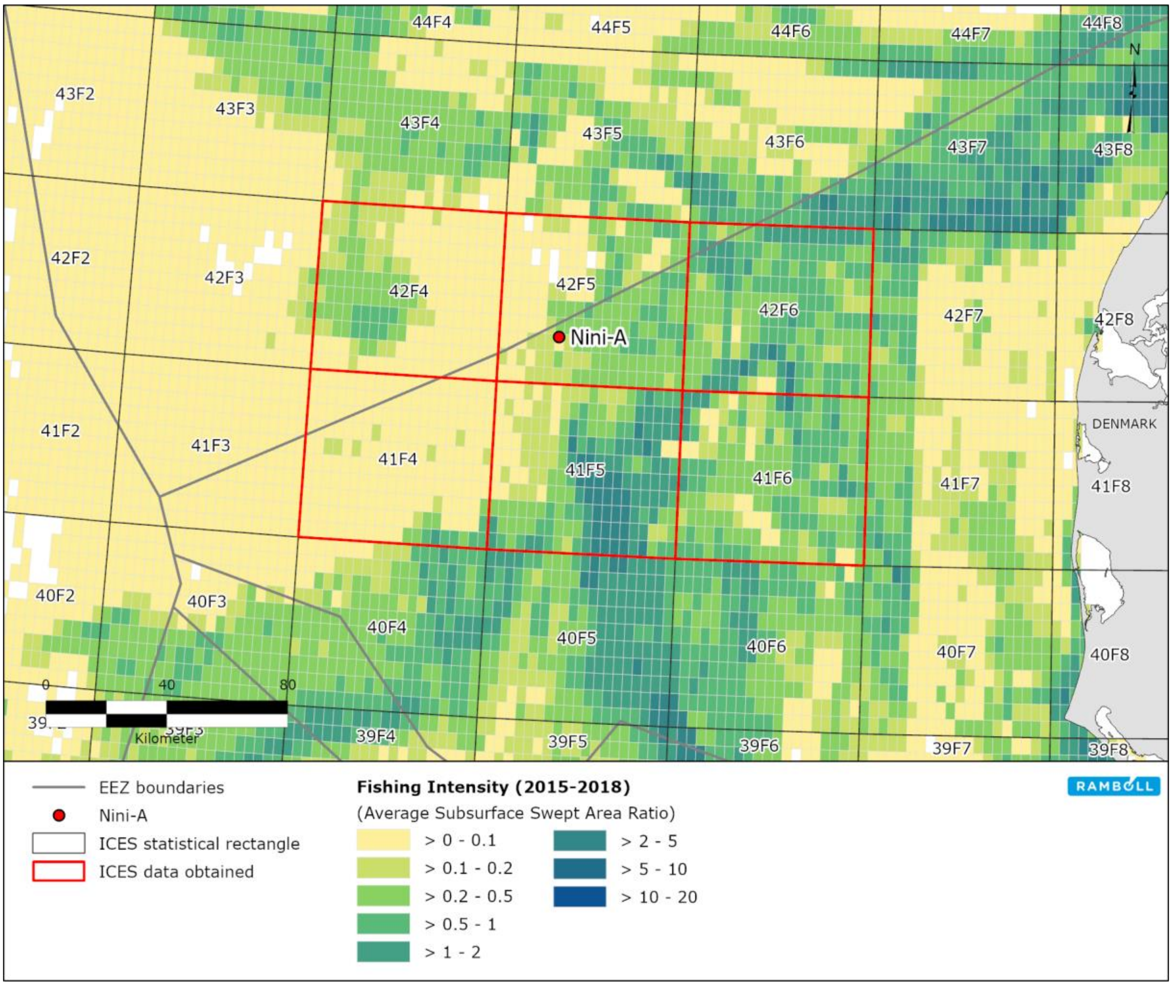


Figure 10-31 Fishing intensity by average subsurface swept area ratio in the North Sea around Nini A (EMODnet, 2021d).

11. ASSESMENT OF ENVIRONMENTAL IMPACTS – PLANNED ACTIVITIES

11.1 Climate and air quality

11.1.1 Potential impacts

The activities and materials (resources) used in relation to the construction and operation phase results in potential impacts to climate and air quality in regard to:

- Emissions – climate: Emissions of gasses will potentially affect the greenhouse effect on a global scale.
- Emissions – air quality: Emissions of gasses and particles to the air, will potentially lead to a change in the local air quality.

Construction phase

Emissions are expected in relation to all construction activities, primarily caused by the use of fossil fuels for vessels, machinery and indirectly by material usage.

During the construction phase various materials will be used as part of:

- The offloading system:
  - Subsea pipeline (fixed) sections
  - Concrete mattresses for pipeline protection
  - Anchor blocks (fixation of pipeline end)
  - Flexible riser (for connection to vessel)
  - Hose End Valve
  - Replaced flowline at Nini A

The major fuel consuming activities in the construction phase are:

- 1 support vessel + 1 standby vessel for 7 + 1.5 days during installation of the offloading system
- 1 standby vessel for 32 days during replacement of flowline
- 1 standby vessel for 30 days during well intervention
- 1 seismic survey vessel for 5-10 days for baseline 2D seismic acquisition
- 1 support vessel for 2 days during installation of the CO_2 leakage monitoring system (lander)
- 1 support vessel for 2 days for placement of OBSs for seismicity monitoring
- And helicopters operation supporting the above

Operation phase

The major fuel consuming activities in the operation phase includes:

- <u>CO_2 vessel:</u> The CO_2 will be transported on a PSV that is modified for this specific purpose and have equipment for pumping CO_2 on and off the vessel. The CO_2 will be transported from Esbjerg to the Nini A platform. The distance is assumed to be approximately 127 nm (235 km) and a maximum of 130 injection cycles is expected per year.
- Seismic <u>survey vessel</u>: A seismic reservoir monitoring program is designed, see section 5.5.4. The program involves fuel consumption during the campaigns from the seismic survey vessel and compressor driven the airgun.
- <u>Maintenance operations with support vessel</u>: every 2 months for seismicity, every 6 months for CO_2 leakage monitoring system, annually for offloading system and biannually for the subsea structure of Nini A.

11.1.2 Methods and data

The following impact assessment of the present project on climate impact and air quality is based on the calculated emissions primarily using the following references:

- European Environment Agency (EEA) EMEP/EEA air pollutant emission inventory guidebook 2023, Technical guidance to prepare national emission inventories, EEA Report, No 13/2019:
    - Ships (European Environment Agency, 2023b)
    - Helicopters (European Environment Agency, 2023a)
- Other conversion factors and materials:
    - Greenhouse gas reporting: conversion factors 2022, version 2.0 (UK Government, 2022)

11.1.3 Assessment of impacts

Emissions – Climate

Vulnerability

The activities related to the construction and operation phase will result in emissions of greenhouse gasses to the atmosphere. The climate system is vulnerable, as the system is out of natural balance. The global surface temperature was 1.09°C higher in 2011–2020 than 1850–1900, and human-caused emissions contributes to 1.07°C of this increase. Climate change has already caused substantial damages, and increasingly irreversible losses, in terrestrial, freshwater, cryospheric and coastal and open ocean ecosystems. The climate system is highly vulnerable against any additional emissions of greenhouse gasses, and as stated by IPCC substantial emissions reduction is required to limit the increasing negative consequences of climate changes (IPCC, 2023). The impact from emissions of greenhouse gasses is then assessed irreversible as the dominant greenhouse gas, CO_2, has a long lifetime in the atmosphere. The lifetime cannot be represented with a single value because the gas is not decomposed over time, but instead moves among different parts of the ocean–atmosphere–land system (Buis, 2019).

The vulnerability of the climate system to any additional greenhouse gasses added is therefore assessed as **high**.

Geographical extent

The emission of greenhouse gasses will affect the climate on a **global** scale, as the greenhouse gasses will interact with the global climate system.

Intensity

The emission of gasses during the construction and operation phase is estimated based on the materials and activities described at a high-level in the sections above and in chapter 5 in more details. The emissions are estimated on a conservative basis regarding durations of the expected activities and is based on INEOS's experiences from similar operations in the North Sea.

The indirect greenhouse gas emissions related to the material usage are listed in Table 11-1, which comprises all known elements of the offloading system, from the hose end valve to the new flowline at Nini A.

The combined list of major construction materials includes steel, concrete and polymers. To make the climate impact estimation of the material manageable, relevant emission factors are applied.

These emission factors are based on average values from databases and do not necessarily reflect the exact composition of the materials used in this project. However, the assessment covers the major impacts and the primary sources to emissions.

As shown in Table 11-1, the climate footprint of the materials used is relatively low. The total climate footprint of the construction materials is ~200 tons CO_2e.

Table 11-1 Greenhouse gas (GHG) emissions related to construction materials.

Materials*	Quantity (tons)	Emission factor (kg CO_2e per unit)	GHG emission (tons CO_2e)	Assumptions
Subsea pipeline	30	4,018 /1/	121	300 meter 6" steel pipe
Concrete mattress	135	131.75 /1/	17.8	100% concrete
Anchor blocks	50	131.75 /1/	6.6	100% concrete and 25 tons each
Flexible riser	6	3,116.29 /1/	18.7	120 meter, 50 kg/m, average polymer
Hose End Valve	1	4,018 /1/	4.0	100% steel
Flowline	4	4,018 /1/	16.1	100% steel
Total emission			**184**	

*The list of materials is based on the information available in this project phase. It does not cover materials used by third parties.
/1/: Average non high-grade steel, average polymer and concrete from: Greenhouse gas reporting: conversion factors 2022, version 2.0 (UK Government, 2022)

Emissions related to fuel consumption in the construction phase are summarised in Table 11-2. The installation of the offloading system results in the largest climate footprint, as well as contributing to the largest emission of NO_x and SO_2.

Table 11-2 Greenhouse gas and air pollutant emissions related fuel consumption during construction

Vessel	CO_2e [tons]	Nox [tons]	SO_2 [tons]	nmVOC [tons]	Comments
Offloading system					
Support vessel	472	10	0.26	0.25	8.5 days
Standby vessel	71	1.6	0.04	0.04	8.5 days
Helicopters	22	0.03	0.01	0.13	8.5 days
Sum offloading sys.	564	12	0.31	0.42	
Replacement flowline					
Standby vessel	266	5.9	0.15	0.14	32 days
Helicopters	81	0.10	0.03	0.49	32 days
Sum flowline	348	6.0	0.17	0.63	
Well intervention					
Standby vessel	250	5.5	0.14	0.13	30 days
Helicopters	76	0.10	0.02	0.46	30 days
Sum well intervention	326	5.6	0.16	0.59	
Baseline 2D seismic acquisition					
Seismic survey vessel	278	6.1	0.15	0.15	5-10 days

Vessel	CO_2e [tons]	Nox [tons]	SO_2 [tons]	nmVOC [tons]	Comments
Installation of CO_2 leakage monitoring system					
Supply vessel	67	1.5	0.04	0.04	2 days
Placement of OBSs for seismicity baseline					
Supply vessel	67	1.5	0.04	0.04	2 days
Total	**1,833**	**33**	**0.9**	**1.9**	

During the operation phase the CO_2 vessel is the largest climate footprint contributor, see Table 11-3. As a conservative estimate, 130 injection cycles per year and a transport distance of 127 nm (235 km) each way is assumed. The fuel consumption for each cycle of the transport vessel has been estimated to be approximately 25 tons of fuel, based on ship fuel consumption derived from prior experiences.

Staff commuting to Nini A is included in the estimations and is mainly expected to be transported by a maintenance helicopter, and to lesser extent by boat. The frequency of these helicopter missions is estimated to 20 cycles a year.

The activities related to seismic surveys varies in frequency as described in detail in section5.5.4, and as seen by the estimated emissions in Table 11-3.

Table 11-3 Greenhouse gas and air pollutant emissions related fuel consumption during operation (one year, see comments related to seismic).

Vessel	CO_2e [tons]	Nox [tons]	SO_2 [tons]	nmVOC [tons]	Comments
PSV for CO_2 transport (CO_2 vessel)	10,562	235	5.9	5.7	Max. 130 cycles a year
Vessel for inspection of offloading system	33	0.7	0.05	0.04	1 inspection per year
Vessel for exchange of CO_2 leakage monitoring system (lander)	67	1.5	0.04	0.04	2 inspection per year
Validation of the CO_2 leakage monitoring system and secondary bubble detection measure with ROV.	8.3	0.18	0.00	0.00	Annually (3 hours)
Vessel for inspection of Nini A subsea structure work	33	0.7	0.02	0.02	2 days bianually (jun-sep)
Vessel for maintenance of OBSs for seismicity	400	8.8	0.22	0.21	2 days (every 2 months)
Seismic survey vessel (2D)	125	2.7	0.07	0.07	
Total	**11,229**	**249**	**6.3**	**6.0**	-> ~31 tons CO_2e/day

As *Project Greensand Future* is part of a carbon storage project, the total system will result in a positive effect on the amount of greenhouse gasses in the global climate system. In the initial operation phase at Nini A, an injection of around 0.3 MT of CO_2 a year is planned. The carbon footprint of the construction phase is estimated to be 1,833 tons CO_2e, and the carbon footprint of the operation is estimated to be ~31 tons CO_2e per day.

The DEA prognosis for CO_2e emissions from the Danish oil and gas extraction are on average ~1.2 MT of CO_2e per year in the period 2020-2035, see also Figure 11-1. The *Project Greensand Future* storage per year is significant compared to this greenhouse gas emissions.

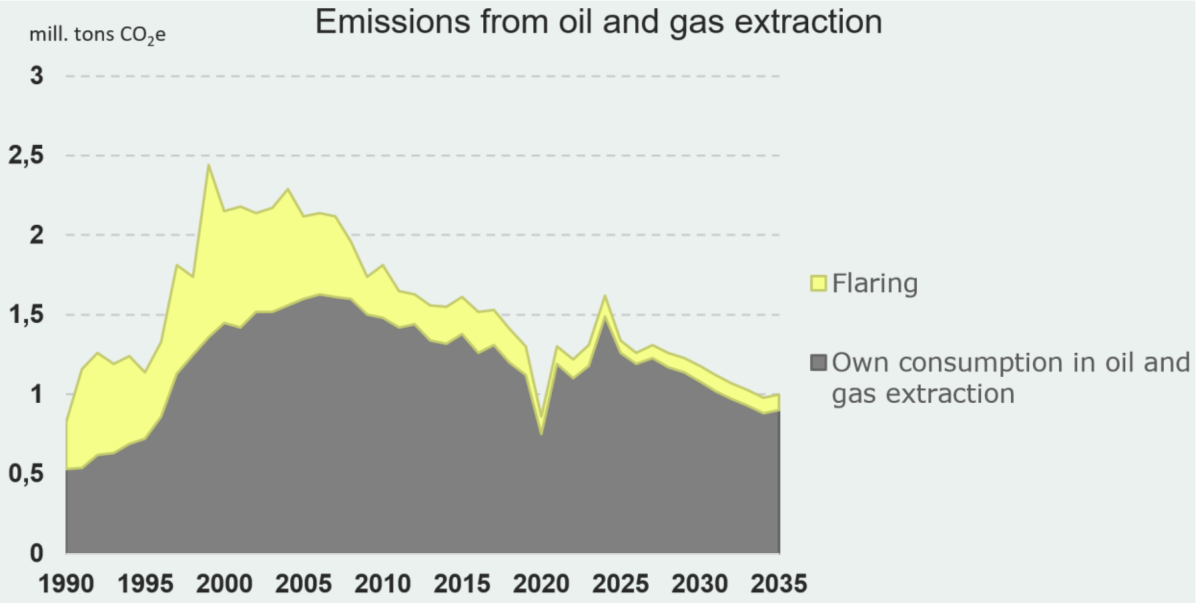


Figure 11-1 Emissions (CO_2e) from oil and gas extraction in Denmark (Energistyrelsen, 2022d).

The intensity of greenhouse gas emissions on the climate during construction and operation are assessed as **medium**. As the project stores large amount of CO_2e the combined intensity is **high** with a positive impact on the climate system.

The intensity of emissions on air quality is summarised under the "Emissions – Air quality" section below.

Duration

In the construction phase, installation of the offloading system and supporting activities at Nini A will generate emissions. The period of construction activities is combined lasting 2-2.5 months, thus assessed as **medium-term** duration. Deployment of lander and OBS will require 2 days of vessel activities done after the installation's activities at Nini A.

In the operation phase, emissions are generated primarily by the CO_2 vessel and to a lesser extent from vessel applied for maintenance and surveys. The location of the activity is irrelevant for the receptor, the climate system. The duration of the impact from emissions generated by the CO_2 vessel are assessed as **permanent**, as the CO_2 vessel will be in operations several times every week during the lifetime of the project.

Consequence

Emissions of greenhouse gasses are assessed as having long lasting impacts on the climate system. The impact from the construction and operation phase is expected to have **moderate** consequences. The impact from the entire CCS loop is however assessed to have **significant positive** consequences on the climate system, as 0.3 MT CO_2e is planned to be stored annually.

Mitigation measures

As there is a significant positive impact on climate from the combined project, mitigation measures are not considered necessary.

Emissions – Air quality

Vulnerability

The activities related to the construction and operation phase will result in emissions of gasses and particles to the air. In relation to air quality, the vast majority of the emissions in the North Sea is related to ships, with concentration of anthropogenic emissions decreasing with distance from the coast. The air quality vulnerability to emissions of gasses and particles in the project area and along the transition routes is assessed as **low**, and **medium** for the periods the CO_2 vessel operates near the shore and in harbours. The emission of gasses and particles to the air will cause reversible impacts, as they will disperse in the atmosphere or deposit on surfaces and be incorporated in natural chemical cycles (Ibanez et al., 2007).

Geographical extent

The geographical extent of the impact on air quality during the construction phase is **immediate vicinity** to **local**, as the majority of the activities will be within the project area and in lesser extent outside.

During the operation phase, emissions are mainly related to the CO_2 vessel, resulting in impact on air quality in a **national** to **international** geographical extent.

Intensity

Emissions are described in detail under intensity in the "Emissions – Climate" section above. Relative to total national annual emissions, emissions of NO_X, SO_X and nmVOCs during construction accounts for 0.044 %, 0.011 % and 0.002 %, respectively, compared to emissions from the total energy supply chain for Denmark in 2020. During one year of operation the emission account to 0.28 %, 0.07 % and 0.006 %, respectively (European Environmental Agency, 2021). Further, the project will cause only a minimal increase in offshore traffic in the area, which will lead to a small increase in emissions of air pollutants only.

The intensity of impact on air quality during construction and operation are assessed as **low**.

Duration

The period of construction activities is combined lasting 2-2.5 months, thus assessed as **medium-term** duration.

In the operation phase, emissions are generated primarily by the CO_2 vessel and to a lesser extent from vessel applied for maintenance and surveys. The duration of the impact from emissions generated by the CO_2 vessel are assessed as **very short** at Nini A and near shore/in harbours, as the PSV will stay <1 day at these locations, but at several times every week during the lifetime of the project.

Consequence

The intensity of emissions on air quality during the construction phase are low and of medium duration. Impacts on air quality is expected to cease once the work is completed, as gasses and particles disperse quickly in the open surroundings of the project area. The impact is expected to have **negligible** or **limited** consequences on air quality.

During the operation phase the impact of emissions on air quality are mainly related to the CO_2 vessel. The emission from the vessel is of low intensity and has a national to international extent. Overall, the impact is assessed as having **negligible** consequences on air quality offshore and in the very short periods operating near shore and in harbours, the consequences is assessed as **limited.**

Mitigation measures

As there is limited/negligible impact on air quality, mitigation measures are not considered necessary.

Overall assessment

The climate system's vulnerability towards any additional greenhouse gasses added is assessed as high. The duration of the impact is medium-term in the construction phase and permanent in the operation phase and impacts are irreversible. The overall impact is assessed to have moderate consequences in both the construction and operation phase. The impact from the entire CCS loop is however assessed having significant positive consequences on the climate system.

The air quality vulnerability in the project area and along the transport route to emissions of gasses and particles is assessed as low to medium. The duration of the impact is medium-term in the construction phase and permanent near Nini A and very short near shore/harbours in the operation phase and impacts are reversible. The overall impact is assessed to have limited to negligible consequences in the construction and operation phase.

Table 11-4 overall assessment of impacts on climate and air quality

Impact	Vulnerability	Geographical extend	Intensity	Duration	Consequence
Construction Phase					
Emissions – Climate gasses	High	Global	Medium	Medium	Moderate
Emissions – Air quality	Low	Immediate vicinity / local	Low	Medium	Limited / negligible
Operation phase					
Emissions – Climate gasses	High	Global	Medium	Permanent	Moderate
Emissions – Air quality *Offshore*	Low	National / international	Low	Very Short	Negligible
Emissions – Air quality *Near shore*	Medium	Regional	Low	Very Short	Limited
The entire CCS loop - Combined impact on climate					
Emissions – Climate gasses	High	Global	High	Permanent	Significant (+)

As *Project Greensand Future* is a carbon storage project, the entire CCS loop will result in an overall positive effect on the amount of greenhouse gasses in the climate system. In the initial operation phase at Nini A, it is planned to inject around 0.3 million tons of CO_2 a year or an average of 892 tons of CO_2 per day. However, the project also results in a carbon footprint. In the construction phase it is estimated to be ~2,000 tons CO_2e, and the daily emission from operation, including the CO_2 vessel and helicopter services, is estimated to ~31 tons CO_2e. This is not including the capture process, onshore processing, other transport and handling. The upstream carbon footprint is currently unknown, however for the entire CCS loop, Concito suggest a possible energy usage of

750 kWh/tons CO_2 (CONCITO, 2023). This corresponds to a carbon footprint of approximately 33 kg and 12 kg CO_2e pr. CO_2 tons stored in 2026 and 2030, respectively. This estimate is based on the Danish prognosis for the carbon footprint of the combined heat and power system and thereby relevant for CCS in Denmark (Energistyrelsen, 2023a). The total daily emission from operation of the entire CCS loop is estimated to 42-59 tons CO_2e. Based on these assumptions on carbon footprint during construction and operation, the *Project Greensand Future* will have a climate positive effect after ~3 days of operation running at full storing capacity.

The impact from an accidental release from the reservoir is described in section 13.2.

Transboundary impacts

No significant transboundary impacts have been identified.

Gaps in knowledge and limitations

The estimation of emissions of gasses and particles and the assessment of the impact on the climate and the air quality includes several limitations as described below:

- Emission factors: The emission factors used in the calculations of the material and machinery usage are from the latest revision of the references available. Overall, the references included represent the best available scientific literature.
- Construction materials: The list of construction materials is based on the current project information. The final project could very well change in some extent, mainly on the details regarding the composition of material used. Well chemicals are not included in the calculations, however check-calculation on various chemicals indicates a greenhouse gas footprint of around ~1% of the combined construction phase footprint.
- Construction activities: The activities described are based on INEOS's experiences from similar operations. The durations of the activities will depend on several unknown factors, such as weather conditions. The emission estimates are assessed on a conservative basis and includes contingency for down days etc.
- Operation activities: The CO_2 vessel is the greatest contributor to emissions during operation. This activity is relative well known. Weather conditions and technical challenges can change this assumption, however the overall impact for these unknowns is assessed as having a relatively low impact on the estimates.

The overall assessment is considered to be sound as is it based on the best available knowledge and include the primary sources off emissions.

11.2 Hydrographic conditions

11.2.1 Potential impacts

Impacts on hydrography relate to:

- The physical footprint i.e., the presence of physical structures on the seabed or throughout the water column: In the construction phase, a physical footprint is expected from the offloading system (subsea pipeline, anchors and concrete mattresses) and the CO_2 leakage monitoring system (lander with monitoring system connected to an anchor block and a bouy). The pipeline and concrete mattresses are laid directly on the seabed, not trenched, thus occupying the space approximately 50 cm above the seabed for 300 meters. These structures are expected to result in a physical footprint in the construction phase when they are installed, and they will remain throughout the operation phase.

11.2.2 Methods and data

The following impact assessment of the present project on hydrographic conditions is based on existing data such as empirical studies, best available scientific literature along with previous environmental impact assessments of similar projects.

The hydrographic conditions of the central North Sea are relatively well known, and projects entailing the presence of physical structures in the marine environment and their impact on hydrography is well documented in the literature. The data basis of this assessment is therefore considered to be sufficient.

11.2.3 Assessment of impacts

Physical footprint

Vulnerability

The presence of physical structures that leave a footprint on the seafloor and occupy space in the water column may result in minor hydrographic changes that could affect prevailing currents, inhibiting flow and potentially causing changes to salinity and temperature regimes at/near the seabed. As the hydrographic conditions are controlled by forces working on a large-scale basis, the vulnerability of the hydrographic conditions to the physical structures is assessed as **low** and once the structures are removed, the hydrographic conditions are expected to be naturally reversed to its original state. The structures will remain in the operation phase.

Geographical extent

In the construction phase, a footprint of approximately 850 m^2 in total is expected. Due to the relatively small dimensions of this physical footprint on the seafloor and in the water column during the construction and operation phase in an area with homogenous physico-chemical characteristics, the impact from the structures on the hydrography is assessed to be in the **immediate vicinity** around the structures. Hydrographic conditions work at a large-scale and the new structures installed in the construction phase are unlikely to have a high impact on this receptor.

Intensity

The installation and presence of the structures have **negligible** intensity because of the small dimensions of the structures in a vast area where the hydrographic forces work at a much larger scale.

Duration

The structures are installed during the construction phase over an estimated 7 days and will remain throughout the operation phase and thereby impose a **permanent** impact on hydrographic conditions. Deployment of the lander will require 1-day onsite vessel activity done after the installation's activities at Nini A.

Consequences

The physical footprint from the structures placed in the construction phase and remaining in the operation phase is permanent. However, as the project area is located outside major hydrographical pathways and considering the limited extent of impact to overall existing hydrodynamic forces in the region, the impact is expected to have **negligible** consequences for the hydrography in either phase of the project.

Mitigation measures

As no significant impact from physical footprint in the current project is expected, mitigation measures are not considered necessary.

Overall assessment

The vulnerability of hydrography to physical footprint is assessed as low. Considering the relatively small dimensions of the structures in the construction and operation phase, impacts are expected to only occur in the immediate vicinity around the structures. The intensity of the impact is assessed as negligible in the construction phase and operation phase. The duration of the impact is permanent in the construction and operation phase. The overall impact of hydrography from physical footprint is assessed to have negligible consequences in both the construction and operation phase.

Table 11-5 overall assessment of impacts on hydrographic conditions.

Impact	Vulnerability	Geographical extend	Intensity	Duration	Consequence
Construction Phase					
Physical footprint	Low	Immediate vicinity	Negligible	Permanent	Negligible
Operation Phase					
Physical footprint	Low	Immediate vicinity	Negligible	Permanent	Negligible

Cumulative impacts

No other projects, planned or in operation, is assessed to have cumulative impacts with the current project. It is therefore assessed that cumulative impacts are irrelevant.

Transboundary impacts

No significant transboundary impacts have been identified.

Gaps in knowledge and limitations

The hydrographic conditions of the central North Sea are relatively well known and well-described through several environmental impact assessment and the baseline survey report. The data basis of this assessment is therefore considered to be sufficient.

11.3 Water quality

11.3.1 Potential impacts

Potential impacts on water quality (turbidity, chemical composition etc.) relate to:

- Chemical discharges i.e., from leak testing of the offloading system (assessed in section 11.5 and 11.6).

11.3.2 Methods and data

The impact assessment on water quality is based on existing data such as empirical studies, best available scientific literature along with previous environmental impact assessments from similar projects.

Several physio-chemical parameters are monitored annually in the central North Sea by the Danish Environmental Protection Agency (DEPA) and the water quality is therefore relatively well known with the exception of concentration of dissolved metals in the water column. Furthermore, several impact assessments of similar project activities and their effect on the water quality has been published and data is readily available. The data basis of this assessment is therefore considered to be sufficient.

11.3.3 Assessment of impacts

Potential impacts to water quality from the project include chemical discharges which are assessed in sections 11.5 and 11.6.

Table 11-6 Overall assessment of impacts on water quality.

Impact	Vulnerability	Geographical extend	Intensity	Duration	Consequence
Construction Phase					
Chemical discharges	Low	Immediate vicinity	Low	Very short	Negligible

11.4 Sediment conditions

11.4.1 Potential impacts

Potential impacts on sediment conditions are related to the following impact mechanisms:

- Physical footprint i.e., the area occupied by any physical structure. In the construction phase, a physical footprint is expected from the offloading system (subsea pipeline, anchors and concrete mattresses) and the CO_2 leakage monitoring system (lander with monitoring system connected to an anchor block and a bouy). These structures are expected to result in a physical footprint in the construction phase when they are installed and persisting throughout the operation phase and thereby constituting a permanent loss of substrate.
- Physical disturbance of the seabed i.e., installation and construction of structures affecting the seabed. In the construction phase, physical disturbance is expected from the placement of the subsea pipeline and concrete mattresses on the seabed which can cause resuspension of sediment.

11.4.2 Methods and data

The following impact assessment of the current project on the sediment conditions is based on existing data such as empirical studies, the baseline survey report on sediment conditions from 2022 (DHI and Rambøll, 2023a), best available scientific literature along with previous environmental impact assessments from similar projects (Energinet, 2019). The seabed of the central North Sea is relatively well known and documented in the literature, therefore the data basis for this assessment is considered to be sufficient.

11.4.3 Assessment of impacts

Physical footprint

The installation of structures that leave a physical footprint on the seafloor result in loss of substrate under the structure, potential change the physical and chemical compositions of the sediment through redistribution of sediments, and affect sediment conditions surrounding the structure following changes in hydrographic conditions. However, changes in hydrographic conditions around the structures have been assessed as negligible (chapter 11.2), and changes in sediment composition in the surrounding area due to altered hydrographic conditions are therefore not assessed in this chapter.

Vulnerability
The baseline survey report on sediment conditions found no signs of past seabed activities in the physical or chemical characteristics, indicating either no impact from past activities or that any impacts on the sediments have reverted to conditions similar to those generally found in the project area and surrounding sediments (DHI and Rambøll, 2023a). The physical and chemical composition of the sediments in the project area are characterized by a very high degree of homogeneity and this type and habitat is not protected. It is a very common habitat in the North Sea. Due to the permanent placement of the structures, the sediment conditions are not expected to be able to revert to pre-construction conditions until after the operation phase when they will be removed. Based on these arguments, the vulnerability of the sediment conditions to physical footprint in both the construction and operation phase from the abovementioned activities are therefore assessed as **low**.

Geographical extent
In the construction phase, a footprint of approx. 850 m^2 is expected from the installation of the offloading system and CO_2 leakage monitoring system. Considering the relatively small dimensions of the physical footprint in the homogenous physical and chemical characteristics of the sediment in the project area (as described in section 10.4), the extent of the physical footprint is therefore considered to have an impact in the **immediate vicinity** only.

Intensity
The introduction of hard surfaces to the soft-bottom habitat creates a new substrate type, thus changing the physical composition of the seabed. However, due to the small area of substrate loss beneath the structures and in a vast homogenous area, the basic structure and function of the seabed is retained. The intensity of the impact from the physical footprint in the construction and operation phase is therefore assessed as **high**. The introduction of hard-bottom substrate may have a positive impact on the benthic community and diversity. These impacts are assessed in following sections 11.6 and 11.7 for benthic fauna and fish, respectively.

Duration
The structures are installed during the construction phase and will remain throughout the operation phase thereby imposing a **permanent** impact. The impact from placement of permanent structures happens once during the construction phase and, thus, has low frequency.

Consequence
The vulnerability of the sediment conditions to physical footprint from loss of substrate under the installed structures is assessed to be low. The footprint is permanent and the sediment conditions are not able to revert to pre-construction phase state during the lifetime of the project. However, the characteristics of the sediment conditions are vast and homogenous. The impact occurs in the immediate vicinity of the structures due to their relatively small dimensions and the impact is of high intensity due to the loss of substrate and introduction of hard surfaces. This introduction of hard-substrate habitats in a predominantly soft-bottom may change the physical characteristics of the seabed in the project area. However, due to the vast area of homogenous sediment, the loss of approx. 850 m^2 does not impact the overall function or structure of the sediment conditions. Based on these arguments, the consequence from physical footprint to sediment conditions are assessed as **negligible**. Despite the permanent impact, the overall assessment of physical footprint is still assessed to have negligible impact on sediment conditions due to the very small dimensions of the placed structures in comparison to the vast and homogenous area of similar sediment conditions.

Mitigation measures

No significant impacts are expected, therefore no mitigation measures are planned.

Physical disturbance of the seabed

Activities near or on the seabed can result in physical disturbances that impact the sediment conditions. The baseline survey report found that the upper 30 centimetres of the sediment were well-oxygenated in the project area (DHI and Rambøll, 2023a). Since no trenching will be carried out, because the pipeline will be laid directly onto the seabed, no exposition of anoxic sediment is expected, that could lead to mobilization of contaminants from the sediment. As only the upper 5 cm of the sediment has been analyzed for contaminants, no knowledge of the contaminant levels in the deeper sediment has been obtained.

The natural sedimentation rates in the North Sea has been measured to be in the range of 5 to 35 cm per 100 years, meaning between 0.5 and 3.5 mm per year. Furthermore, the degree of surface sediment contamination has decreased in the North Sea in the last 20 years (DHI and Rambøll, 2023a). The baseline survey results on sediment contamination were below detection limit and below GES or TEL limits for most contaminants except for slightly elevated levels of Arsenic in one station (station M7) and Barium in a few stations near the Nini A platform (stations T03, T04, M1, Mx1, My1) (DHI and Rambøll, 2023a). It is unlikely that there will be an impact related to resuspension of contaminants. The planned activities will not cause an increase in Arsenic or Barium concentration in the sediment.
Based on this, the impact of remobilization and dispersion of sediment-buried contaminants on sediment conditions from disturbance of the seabed is not assessed further in this chapter.

Vulnerability

- The physical disturbance of the seabed is related to potential resuspension of sediments from installation of the offloading system during the construction phase. Potential resuspension of sediment will not change the physical aspects of the sediment due to the homogeneity of the sediment conditions in the area and minor physical or chemical changes are expected to quickly return to its original state once the activity cease. The vulnerability of the seabed to physical disturbance from these activities are therefore assessed as **low**.

Geographical extent

Around 850 m^2 of seabed will be impacted from the physical footprint and a relatively small area around the permanent structures may be impacted by resuspension of sediment in the construction phase, and as such, the physical disturbance is therefore considered to have an impact in the **immediate vicinity** only.

Intensity

The potential resuspension of sediment will only occur during installation and not along the whole length of the subsea pipeline at once, rather shortly after placement of each pipeline section or individual concrete mattress. The intensity of physical disturbance to the sediment conditions in the construction phase is thus assessed as **low**.

Duration

The physical disturbance of the seabed may occur during the installation of structures in the construction phase. The installation is expected to take 7 + 1.5 days in which sediment conditions could be impacted by physical disturbance and the duration of the impact is therefore assessed as **short-term**. Deployment of the lander will require 1-day onsite vessel activity done after the installation's activities at Nini A.

Consequence

The sediment conditions in the project area are considered to have low vulnerability to physical disturbance of the seabed. The sediment conditions are expected to return to its original state and keep their basic structure and function. With low intensity, short duration and the potential for the impact to only occur in the immediate vicinity, the overall consequence from physical disturbance to sediment conditions is assessed as **negligible**.

Mitigation measures

No significant impact is expected, therefore no mitigation measures are planned.

Overall assessment

The assessment of the vulnerability of the sediment conditions to impacts in the construction and operation phase is low considering the homogenous and vast habitat. All impacts occur in the immediate vicinity of the activity due to the small dimensions of the installed structures. While a permanent impact from the physical footprint is expected due to the loss of substrate, the sediment conditions are expected to recover after decommissioning. The overall structure and function of the sediment in the project area is not impacted and the consequence of physical footprint and physical disturbance of the seabed is assessed as negligible.

Table 11-7 Overall assessment of impacts on sediment conditions.

Impact	Vulnerability	Geographical extend	Intensity	Duration	Consequence
Construction Phase					
Physical footprint	Low	Immediate vicinity	High	Permanent	Negligible
Physical disturbance of the seabed	Low	Immediate vicinity	Low	Short	Negligible
Operation Phase					
Physical footprint	Low	Immediate vicinity	High	Permanent	Negligible

Cumulative impacts

No other projects, planned or in operation, is assessed to have cumulative impacts with the current project. It is therefore assessed that cumulative impacts are irrelevant.

Transboundary impacts

No significant transboundary impacts have been identified.

Gaps in knowledge and limitations

The sediment conditions around and in the project area are relatively well-known and well-described through several environmental impact assessment and the baseline survey report. The data basis of this assessment is therefore considered to be sufficient.

11.5 Biodiversity – plankton

11.5.1 Potential impacts

- Potential impacts on plankton (phyto- and zooplankton) relate to:
  - Chemical discharges i.e., discharge of hydrotest water from leak testing of the offloading system.

-

11.5.2 Methods and data

The following impact assessment of the current project on plankton is based on existing data such as empirical studies, best available scientific literature along with previous environmental impact assessments from similar projects.

Phytoplankton abundance has been monitored as part of other oil and gas activities in the central North Sea and the status and development in plankton biomass is therefore relatively well known. Furthermore, several impact assessments of similar project activities and their effect on plankton has been published and data is readily available. The data basis of this assessment is therefore considered to be sufficient.

11.5.3 Assessment of impacts

Chemical discharges

The chemical discharges from preparation of the offloading system, described in section 9.1, have the potential to affect water quality and marine organisms such as plankton in the water column and in the sediment.
The total discharged volume is assessed to be around 13 m^3. The chemicals used for the hydrotest are approved by the DEPA and categorized as yellow.

The fluorescent tracer chemical will have a maximum concentration of 50 ppm. The minimum No Effect Concentration (NOEC) presented in the Harmonised Offshore Chemical Notification Format (HOCNF) for all trophic levels is 5 ppm indicating that a dilution of 10 related to the discharge of hydrotest water will ensure that a toxic effect is unlikely.

Corrosion inhibitor may be added if the hydrotest water is present in the pipeline for a longer period before actual testing is commenced. The initial concentration of the added corrosion inhibiter will be maximum 500 ppm. The minimum No Effect Concentration (NOEC) presented in the Harmonised Offshore Chemical Notification Format (HOCNF) for all trophic levels is 9 ppm indicating that a discharge dilution of approximately 50 times will ensure that a toxic effect is unlikely. This is a conservative assumption as the components of the corrosion inhibitor will have reacted before testing discharge.

<u>Vulnerability</u>

Some plankton may show a quick response to a toxic effect, however, as mentioned in previous sections, plankton has a short turnover time (Gasol et al., 1997b), which enables it to recover rapidly to its pre-impact status once an environmental impact cease. Thus, the impact is reversible. The vulnerability of plankton towards a toxic effect is assessed as **low**.

<u>Geographical extent</u>

The hydrotest discharge water will have a lower oxygen content than the receiving water body. The immediate dilution at the discharge point, and the low discharge volume, will ensure that a potential effect is limited to a few meters from the discharge point. A conservative assessment indicates that a dilution of 50 times would be achieved within a minimum distance of 10 meters from the discharge. Initial dilution of the hydrotest discharge water will be more than 500 times in the immediate vicinity (a few meters from the discharge) point depending on current speed. A potential toxic or anoxic impact will therefore be restricted to this area impact (Botes, 1994). The geographical extent of the impact is therefore assessed to be within the **immediate vicinity**.

Intensity

The total discharge volume is approximately 13 m^2 and the concentration of the added chemicals result in a total discharge of 11 kg. The chemicals are approved by the DEA for discharge. The plankton concentration close to the seabed is low and the intensity of the impact from discharge of hydrotesting chemicals is assessed as **low**.

Duration

The chemicals are discharged over a period of one day. The potential impact period is expected to be contained to this period and therefore of **very short** duration. The discharges will only occur once during the lifetime of the project.

Consequence

Chemical discharges are only associated with the leak testing of the offloading system and discharge of the hydrotest water. The discharge plume that could affect plankton is restricted to a local area with a maximum impact range of a few meters. Some plankton are sensitive to toxic effects, however, most plankton have a fast turn-over rate and the concentration of plankton close to the seabed is low. The effect would be reversible within a short timeframe and the consequence of chemical discharge on plankton is therefore assessed as **negligible**.

Mitigations measures

No significant impacts on plankton from chemical discharges have been identified and mitigation measures are therefore not considered necessary.

Overall assessment

The vulnerability of plankton is low due to a fast turn-over time and its ability to recover rapidly to pre-impact levels. Chemical discharges are only expected in the construction phase causing short term, reversible effects. Impacts are of low intensity impacting only the near vicinity around the discharge point. The overall assessment of the impact from chemical discharge on plankton is assessed to have negligible consequences.

Table 11-8 Overall assessment of impacts on plankton.

Impact	Vulnerability	Geographical extend	Intensity	Duration	Consequence
Construction Phase					
Chemical discharges	Low	Immediate vicinity	Low	Very short	Negligible

Cumulative impacts

No other projects, planned or in operation, is assessed to have cumulative impacts with the current project. It is therefore assessed that cumulative impacts are irrelevant.

Transboundary impacts

No significant transboundary impacts have been identified.

Gaps in knowledge and limitations

Reporting on the impact from chemical discharges are rather limited. However, plankton has been monitored for decades as part of existing oil and gas installations in the central North Sea, and as no significant impacts have been detected, the overall conclusion of this assessment is considered sound.

11.6 Biodiversity – Benthic fauna

In this section potential impacts on the benthic fauna are assessed. Descriptions of the benthic fauna and the most commonly found species are found in section 10.5.2.

11.6.1 Potential impacts

Potential impacts on benthic fauna are related to three impact mechanisms (see 9.1):

- Physical footprint i.e., in the construction phase, a physical footprint is expected from the offloading system (subsea pipeline, anchors and concrete mattresses) and the CO_2 leakage monitoring system (lander with monitoring system connected to an anchor block and a bouy). These structures are expected to result in a physical footprint in the construction phase when they are installed, persisting throughout the operation phase. The total physical footprint in the construction and operation phase is approx. 850 m^2.
- Physical disturbance of seabed i.e., the disturbance of the sediment, such as resuspension, following installation of structures on the seabed. In the construction phase, physical disturbance is expected from installation of the abovementioned structures.
- Chemical discharges i.e., discharge of hydrotest water from leak testing of the offloading system.

11.6.2 Methods and data

The following impact assessment of the current project on benthic fauna is based on existing data such as empirical studies, best available scientific literature along with previous environmental impact assessments from similar projects, including:

- Baseline survey report - Benthic fauna and sediments (DHI and Rambøll, 2023a)
- North Sea Seabed Monitoring 2021 Siri Platform Macrofauna and Sediment Chemistry (INEOS, 2022)
- Descriptor-based review of 25 years of seabed monitoring data collected around Danish offshore oil and gas platforms (Oil & Gas Denmark, 2017)

The benthic fauna of the project area is relatively well known, and scientific research as well as previous impact assessments of similar project activities on benthic fauna is well documented in the literature. The data basis of this assessment is therefore considered to be sufficient.

11.6.3 Assessment of impacts

Physical footprint

The installation of structures that leave a physical footprint on the seafloor may result in loss of substrate under the structures and impact the benthic fauna living on the affected substrate.

During the construction phase, activities leading to an impact on benthic fauna from a physical footprint include placement structures for the offloading system and CO_2 leakage monitoring system that persist throughout the operation phase and thus constitute a permanent physical footprint impact.

Vulnerability

The project area is characterized by homogenous soft-bottom seabed with very little variation in physical and chemical conditions, and benthic faunal composition.

The offloading system and CO_2 leakage monitoring system result in permanent loss of substrate thereby impacting the benthic fauna under the structures. The benthic fauna in the space under the structures is therefore not expected to return to its original state until after decommissioning when the structures are removed. The benthic fauna around the structures is not impacted and no red listed species were found during the baseline survey (see section 10.5.2). The vast and homogenous characteristics of the habitat allow the species that may be excluded form living under the structures to live right nearby. The vulnerability of the benthic fauna to the physical footprint from permanent structures is assessed as **low**.

Geographical extent

The total physical footprint from structures is approx. 850 m^2. Considering the relatively small dimensions of the physical footprint and that the loss of substrate only occurs under the structures, the impact is to have an impact in the **immediate vicinity** only.

Intensity

Due to the permanent loss of substrate under the structures, the habitat below the structures is unable to be recolonised until the structures are removed during the decommissioning phase. The introduction of hard surfaces may create habitat for some benthic organisms that might otherwise not successfully inhabit the area, thus altering the conditions and potentially the benthic community to an extent. The intensity of the impact from the physical footprint in both the construction and operation phase is therefore assessed as **high**.

Duration

The structures are installed during the construction phase and will remain throughout the operation phase thereby imposing a **permanent** impact. The impact from placement of permanent structures happens once during the construction phase and, thus, has low frequency. The sediment conditions are not expected to be able to revert to pre-construction conditions until after decommissioning phase.

Consequence

Since the installed structures remain during the operation phase, the benthic faunal community will not be able to recolonize the areas lost under the permanent structures. The impact is restricted to approx. 850 m^2 which is relatively small in comparison to the overall homogenous habitat and large extent of near-identical benthic community. Therefore, there will be no de-facto negative change of the benthic fauna in the immediate vicinity of the placed structures, yet permanent and high intensity impact from physical footprint. Overall, the consequence on the benthic fauna from the physical footprint is considered **negligible**. Despite the permanent impact, the overall assessment of physical footprint is still assessed to have negligible impact on benthic fauna due to the very small dimensions of the placed structures in comparison to the vast and homogenous area in which benthic fauna will continue to exist.

Mitigation measures

No significant impacts are expected on the benthic fauna from physical footprints and no mitigation measures are therefore needed.

Physical disturbance of the seabed

Activities near or on the seabed can result in physical disturbances that impact the benthic fauna through direct disturbance or indirectly through changes in chemical and physical conditions of the sediment. As described in section 5.4.1, disturbance of the seabed will occur during placement of the subsea pipeline and concrete mattresses which can cause resuspension of sediment near the activity.

<u>Vulnerability</u>

Installation of the subsea pipeline and concrete mattresses may lead to an impact on the benthic fauna if surrounding top sediments are disturbed or organisms are displaced or experience increased mortality. However, the physical and chemical characteristics of the sediments have been found to be very homogenous in the project area(DHI and Rambøll, 2023a). The community is expected to recover, and as such, the impact of physical disturbance is reversible (DHI and Rambøll, 2023a). The analysis of monitoring around of offshore platforms in the Danish North Sea has shown that impacts on the fauna composition typically have been eradicated within 1-5 years after cessation of discharges depending on the volume and the location of the discharges. Interannual natural changes in species composition can however be significant (Bach & Robson, 2008). Monitoring conducted around the Nina A platform in 2022 confirmed that changes in species composition could not be related to historical drilling discharges and that benthic fauna composition was homogenous and in a good state. It is therefore assessed that potential impacts on the benthic fauna, resulting from the activities, are reversible. However, as the North Sea is significantly exposed to bottom trawling and fisheries in general it may be difficult to clearly establish the natural state of the area. Affected organisms are expected to be able to find suitable habitat in nearby sediments during the duration of the impact, and the existence of similar benthic communities in the surrounding seabed will allow for recolonization of the disturbed sediments faster. The colonization capabilities of the benthic community vary between species, ranging from low with limited mobility and slow dispersal to high with high mobility and fast dispersal. A complete recovery of the benthic community after impact may therefore last from months to years depending on the impacted species, with opportunistic mobile species recovering faster than long-lived sessile species with low dispersal capabilities. Based on these arguments, the vulnerability of the benthic fauna to the impact from physical disturbance of the seabed is therefore assessed as being **low** as recovery can be expected.

<u>Geographical extent</u>

Physical disturbance of the seabed is related resuspension of sediment from placement of abovementioned structures. The potential resuspension of sediment is expected to be much smaller than for other installation methods of subsea pipelines such as trenching. Thus, the total area impacted is assessed to be small compared to the vast extent of similar soft-bottom sediments and homogenous benthic faunal communities. Based on these arguments, the geographical extent of the impact is considered to affect the **immediate vicinity**.

<u>Intensity</u>

Physical disturbances of the seabed from installation of the offloading system may lead to resuspension of sediment which can impact the benthic fauna through direct physical disturbance from resuspension of sediment potentially burying benthic animals. The structures installed are relatively small and little resuspension is therefore expected. The impact is expected to occur immediately during placement of the structures and potential resuspension is expected to quickly settle within hours to few days. Placement only occurs once during the construction phase, thus the intensity of physical disturbance to benthic fauna is assessed as **low**.

Duration

- Installation of the structures are carried out in the construction phase over 7 + 1.5 days and the impact is not expected to exceed this timeframe. Therefore, the duration is assessed as **short-term**. Deployment of the lander will require 1-day onsite vessel activity done after the installation's activities at Nini A.

Consequence

The project area is characterized by a homogenous soft-bottom seabed with very little variation in physical and chemical conditions, and benthic faunal composition, indicating that previous activities near the Nini A platform have not affected the benthic in any significant way. The short-term duration, low intensity and extent in the immediate vicinity of the construction activities may lead to burial or displacements of organisms in the impacted area. Nearby individuals are, however, able to recolonize disturbed communities relatively shortly after the activities have ceased in the construction phase, and no permanent change in ecological functioning of the benthic faunal community is expected. The consequence of the physical disturbance to the benthic fauna community is considered as **negligible**. Despite the permanent impact, the overall assessment of physical footprint is still assessed to have negligible impact on benthic fauna, due to the very small dimensions of the placed structures in comparison to the vast and homogenous area in which benthic fauna will continue to exist.

Mitigation measures

No significant impacts are expected on the benthic fauna from disturbance of the seabed and therefore no mitigation measures are needed.

Chemical discharges

The chemical discharges related to the leak testing of the offloading system could result in a toxic effect on benthic fauna. However, as described in section 5.7.1 the chemical discharge volumes are small (13 m^3 of hydrotest water) and dilution of the chemical discharge will result in non-detectable levels within a few meters from the discharge point. The chemicals have been approved for discharged by the DEPA and are not considered to pose a long-term effect on marine organisms. The chemicals are not expected to accumulate in the sediment and the effects will be reversible.
The total discharged volume is assessed to be around 13 m^3. The chemicals used for the hydrotest are approved by the DEPA and categorized as yellow.

The fluorescent tracer chemical will have a maximum concentration of 50 ppm. The minimum No Effect Concentration (NOEC) presented in the Harmonised Offshore Chemical Notification Format (HOCNF) for all trophic levels is 5 ppm indicating that a dilution of 10 related to the discharge of hydrotest water will ensure that a toxic effect is unlikely.

Corrosion inhibitor may be added if the hydrotest water is present in the pipeline for a longer period before actual testing is commenced. The initial concentration of the added corrosion inhibiter will be maximum 500 ppm. The minimum No Effect Concentration (NOEC) presented in the Harmonised Offshore Chemical Notification Format (HOCNF) for all trophic levels is 9 ppm indicating that a discharge dilution of approximately 50 times will ensure that a toxic effect is unlikely. This is a conservative assumption as the components of the corrosion inhibitor will have reacted before testing discharge.

Vulnerability

Field and laboratory studies have shown that benthic fauna communities affected by chemical discharges are re-established relatively quick (Neff, 2010; Trannum et al., 2010b). This is in line with a 2017 review of benthic impacts from oil and gas production activities in the North Sea, where it was confirmed that the benthic environment has the ability to recover from chemical discharges (Oil & Gas Denmark, 2017).

Overall, the results from previous studies and the benthic baseline survey report indicate that discharges have a limited impact on the benthic community and that the associated fauna recovers after the discharges have stopped. The vulnerability of the benthic fauna to the impact from discharge of approved chemicals is therefore assessed as being **low**.

Geographical extent

The hydrotest discharge water will have a lower oxygen content than the receiving water body. The immediate dilution at the discharge point, and the low discharge volume, will ensure that a potential effect is limited to a few meters from the discharge point.
A conservative assessment indicates that a dilution of 50 times would be achieved within a minimum distance of 10 meters from the discharge.
Initial dilution of the hydrotest discharge water will be more than 500 times in the immediate vicinity (a few meters from the discharge) point depending on current speed. A potential toxic or anoxic impact will therefore be restricted to this area impact (Botes, 1994).
The geographical extent of the impact is therefore assessed to be within the **immediate vicinity**.

Intensity

The potential toxic effect from the discharge of chemicals will be short in a localized area. The intensity of the impact from discharge to benthic fauna is assessed as **low**.

Duration

The potential impact period is expected to be contained to the discharge period. The discharges will only occur one time over a few hours, thus the duration is **very short**.

Consequence

The impacts are expected to be contained to an area within a few meters from the discharge point. The consequence of chemical discharges and the effect on benthic fauna is therefore assessed as **negligible**.

Mitigations measures

No significant impacts on benthic fauna have been assessed and mitigation measures are there not considered necessary.

Overall assessment

The overall assessment of the impacts on the benthic fauna from physical footprint, physical disturbance of the seabed and chemical discharges are negligible in both the construction and operation phase. Overall, the impacts on the benthic community are not expected to affect the benthic species at a population level nor lead to functional changes in the ecology of the benthic community.

Table 11-9 Overall assessment of impacts on benthic fauna.

Impact	Vulnerability	Geographical extend	Intensity	Duration	Consequence
Construction Phase					
Physical footprint	Low	Immediate vicinity	High	Permanent	Negligible
Physical disturbance of the seabed	Low	Immediate vicinity	Low	Short	Negligible
Chemical discharges	Low	Immediate vicinity	Low	Very short	Negligible
Operation Phase					
Physical footprint	Low	Immediate vicinity	High	Permanent	Negligible

Cumulative impacts

No other projects, planned or in operation, is assessed to have cumulative impacts with the current project. It is therefore assessed that cumulative impacts are irrelevant.

Transboundary impacts

No significant transboundary impacts have been identified.

Gaps in knowledge and limitations

The following impact assessment of the current project on benthic fauna is based on existing data such as empirical studies, best available scientific literature along with previous environmental impact assessments from similar projects.

The distribution and biology of benthic fauna of the central North Sea is relatively well known, and scientific research as well as previous impact assessments of similar project activities on benthic fauna are well documented in the literature. The data basis of this assessment is therefore considered to be sufficient.

11.7 Biodiversity – Fish

11.7.1 Potential impacts

Potential impacts to fish are related to:

- Underwater noise i.e., in the construction phase, underwater noise is expected from vessels, ROV operations using HiPAP USBL system and the seismic baseline survey. In the operation phase, underwater noise is expected from seismic surveys, the seismic monitoring vessel, the CO_2 vessel and from support vessels used for maintenance operations using ROV.
- Physical footprint i.e., the area occupied by the physical structures (offloading system and CO_2 leakage monitoring system) placed in the construction phase and persisting throughout the operation phase. The total physical footprint is approx. 850 m^2.
- Physical disturbance of seabed i.e., in the construction phase, the disturbance of the sediment (resuspension) may cause impacts following installation of structures on the seabed.
- Light i.e., in the construction phase and operation phase, light emissions are expected from vessels and the Nini A platform.

Noise from equipment related to ROV operations (HiPAP) occur at frequencies above 20 kHz. The hearing ability of fish is generally confined to low frequencies, often to no more than 800–1,000 Hz, but this is very species dependent (A. N. Popper & Hawkins, 2019). Noise from equipment related to ROV operations (HiPAP) occur at frequencies above 20 kHz, i.e., at frequencies higher than what is believed to be detectable by most fish species. However, some clupeid fish species may be able to detect sound in frequency ranges above 20 kHz (Mann et al., 1997) while others do not (Mann et al., 2005). It has been speculated that some herring species are able to show avoidance behavior towards echolocation equipment and thereby questioning the use of this type of equipment for stock assessment for these types of species (Mann et al., 2001). Impact thresholds for high frequency noise have not been specified for the Atlantic herring (*Clupea harengus*) in the North Sea, however, earlier studies indicate that hearing threshold increases significantly around 5 kHz making them less likely to detect noise above 20 kHz (Enger, 1967).

Chemical discharges i.e., leak testing of the offloading system will not be further assessed for fish as this impact was found to have negligible impacts on plankton and benthic fauna (see sections 11.5 and 11.6). The toxicity test of the chemicals used for the leak testing show that the No Effect Concentration for Fish are much higher than for plankton and benthic fauna i.e. fish are unlikely to be exposed to a toxic effect.

11.7.2 Methods and data

The assessment is supported by existing data and available scientific literature as well as previous environmental impact assessments of similar projects. Underwater noise modelling was performed to assess impacts from seismic surveys and ships.

The distribution and biology of fish in the central North Sea is relatively well known, and scientific research as well as previous impact assessments of similar activities causing physical footprint, physical disturbance of the seabed (sediment resuspension), and derived effects on fish are well documented in the literature. The data basis for the assessment of impacts derived from these impact mechanisms are considered to be sufficient for this assessment. However, research on impacts to fish from underwater noise is relatively scarce and has only been carried out for a few of fish species. The modelling is based on the best available data and includes two species (herring and cod) and two life stages of fish (juvenile and adult cod) found in the project area that represent different sensitivities to noise, some of which is considered to exhibit the highest sensitivities. However, the temporary threshold shift (TTS) value for fish has been based on freshwater species and some uncertainty exists for the applicability of these threshold values to saltwater species (A. N. Popper & Hawkins, 2019). As the modelling is based on the most sensitive species and life stages, the data basis of this assessment is considered to be sufficient to assess the impacts on fish from underwater noise as it is based on a worst-case approach dealing with the response from the most sensitive species and life stages of fish found in the project area.

Furthermore, only a few studies have focused on the impacts from light emissions on fish. The assessment of light emissions on fish is based on the best available data. However, as effects from artificial light are not well documented, the data basis is partly insufficient.

Underwater noise modelling

For a detailed method description of the underwater noise modelling, it is referred to the *Technical Note: Project Greensand Future EIA – Underwater noise modelling*, which is found in the Appendix to this EIA. The modelling and background information is shortly described below.

The underwater sound propagation model that has been applied for this EIA calculates the sound field generated from underwater sound sources. The modelling results are used to determine the potential impacts distances from the identified significant underwater noise sources for the various identified marine life for the area. Based on source location and underwater source sound level, the acoustic field at any range from the source is estimated using dBSEA's acoustic propagation model (Parabolic equation method (≤1000 Hz), methodologies described in (Jensen et al., 2011) and ray tracing (> 1000 Hz)). The sound propagation modelling uses acoustic parameters appropriate for the specific geographic region of interest, including the expected water column sound speed profile, the bathymetry, and the bottom geo-acoustic properties, to produce site-specific estimates of the radiated noise field as a function of range and depth. The acoustic model is used to predict the directional transmission loss from source locations corresponding to receiver locations. The received level at any 3-dimensional location away from the source is calculated by combining the source level and transmission loss, both of which are direction dependent.

Underwater acoustic transmission loss and received underwater sound levels are a function of depth, range, bearing, and environmental properties. The output values can be used to compute or estimate specific noise metrics relevant to safety criteria filtering for frequency-dependent marine mammal hearing capabilities. Underwater sound source levels are used as input for the underwater sound propagation program, which computes the sound field as a function of range, depth, and bearing relative to the source
location.

Bathymetry data is provided from EMODNET (The European Marine Observation and Data Network). Water column data (Salinity, Temperature, Speed of underwater sound/depth) is provided from ICES (International Council for the Exploration of the Sea) HELCOM specific measurement stations positioned close to the selected modelling positions. Seabed Conditions (Sand, Clay /depth) are provided from Geological survey data for areas close to the modelling position.

11.7.3 Assessment of impacts

Underwater noise

<u>Vulnerability</u>
The extent to which underwater noise may impact fish depends upon a number of factors including the level of noise produced at the source, the frequencies at which the sound is emitted, the rate at which sound attenuates (which will vary for different frequencies and environmental conditions) along with the sensitivities of different fish species and individuals to different sound exposure levels and frequencies of noise. The hearing ranges of fish differ between species, but most fish show best hearing at frequencies ranging between <100-1,000 Hz while other species respond to higher frequencies i.e., 200-3,000 Hz (Ladich & Fay, 2013).

Noise can impact fish in several ways, including:

- *Mortality and mortal injury:* Immediate or delayed death.
- *Recoverable injury*: Injuries, including hair cell damage, minor internal or external hematoma, etc. None of these injuries are likely to result in mortality.
- *Temporary Threshold Shift (TTS):* Short- or long-term changes in hearing sensitivity that may or may not reduce fitness.
- *Behavioural effects:* Change in behaviour i.e., feeding, mating, etc., or by means of avoidance.
- *Masking:* Refers to the interference of anthropogenic noise with the fish ability to hear a sound that is of biological importance to them

Mortality and mortal injury is caused by rapid pressure changes generated from high intensity sound exposure resulting in damage to internal organs including the swim bladder, liver, kidney and gonads (Halvorsen, Casper, Matthews, et al., 2012; Halvorsen, Casper, Woodley, et al., 2012). In terms of sensitivity, fish can roughly be divided by anatomy. Fish without swimming bladders have low sensitivity (e.g. adult flatfish, where the swim bladder degenerates). Fish that have swim bladders that are not connected to the inner ear have a higher sensitivity (e.g., cod or sand eel). Fish that have a coupling between the swim bladder and the inner ear have high sensitivity (e.g., herring and sprat (A. N. Popper et al., 2014). As the impact on fish from underwater noise depends on a series of factors, a certain level of uncertainty remains as to when exposure to high intensity sound leads to mortality or mortal injury. While mortality was found close to a piledriving source in a pile installation demonstration project for the San Francisco-Oakland Bay Bridge (California Department of Transportation, 2001) exposure to very high intensity, low-frequency sonars resulted in no mortality in fish (Halvorsen et al., 2013; A. N. Popper et al., 2007) nor did exposure to seismic airguns (A. N. Popper et al., 2005, 2016).

Impacts in the form of recoverable injury and TTS are caused by exposure to high-energy sound sources or long-term noise exposure and are reversible over time. Studies have shown that fish can regenerate the hair cells in the ear and thus hearing can be restored (Popper A.N. and Hastings M.C., 2009). However, the period in which hearing is restored could be relatively long (up to 58 days) after airgun exposure implicating consequences to their fitness and survival (McCauley et al., 2003). While experiencing TTS, fish may experience a decrease in fitness in terms of communication, detecting predators or prey, and/or assessing their environment (Carroll et al., 2017). After termination of the noise exposure, normal hearing ability returns over a period extending from minutes to days, depending on many factors, including the intensity and duration of exposure (Amoser et al., 2004; Smith et al., 2006; Smith & Monroe, 2016).

Fish exhibit behavioural responses to noise, however, the underlying mechanisms are not well understood. Sound pressure levels that may deter some species, may attract others. Fish may also freeze and stay in place, leaving it exposed to potential impact. If the fish swims away, it could minimize the potential impact. Conversely, this behavioural response of swimming away from the source of noise may lead to other negative effects such as fish avoiding important feeding grounds, mating or spawning areas. Long-term impacts with underwater noise could therefore potentially lead to failure of reproduction and stock recruitment (Bakke et al., 2013).

Masking can negatively impact reproductive and foraging behaviours and impair predator detection, use of sound cues for orientation and navigation, as well as intraspecific communication (Slabbekoorn et al., 2010)(Erbe & McPherson, 2017). The significance of the masking effect is influenced by the duration and level of noise exposure. The level of noise exposure limits the lowest sound level that a fish can detect. Chapman and Hawkins (1973) found that increasing the level of ambient noise led to an increase in the auditory threshold in Atlantic cod thereby resulting in a decline in the fish’s ability to detect, locate and recognize particular sounds (Chapman & Hawkins, 1973).

Most studies on the effect of human-induced noise on fish have examined effects on individuals rather than at the population level. In a recent study, population-level effects of acoustic disturbance on Atlantic cod were modelled with respect to four possible effect pathways and their individual effect on cod population growth rate: 1) increased energy expenditure, 2) reduced food intake, 3) increased mortality, and 4) reduced reproductive output. Results showed that higher energy expenditure and decreased food intake had the strongest effect on the population growth rate as they indirectly affected the age of sexual maturity, survival and fecundity. However, growth rates were only strongly affected when at least 50 % of the population was affected by noise (Soudijn et al., 2020).

Anthropogenic noise exposure is divided into two specific categories, impulsive or continuous noise. Impulsive noise refers to a discontinuous sound source comprising one or more instantaneous sounds such as an airgun. Continuous noise refers to a continuous sound source, like a vessel engine humming. The impact on fish from these different sound sources and the associated threshold levels are presented in Table 11-10. Very few investigations on the responses of eggs and larvae to anthropogenic noise have been performed but research indicates that the hearing range of fish larvae is similar to that of adults (Malishov, 1992; A. N. Popper et al., 2014). No threshold limits for behavioural response have been reported in the literature and are therefore not presented in Table 11-10. As the level of masking is related to the level of ambient sea noise, no specific threshold value for this impact type exists (Chapman & Hawkins, 1973).

Table 11-10 Underwater noise threshold limits for fish according to type of noise (A. N. Popper et al., 2014).

* SELcum = Cumulative Sound Exposure, which is the time integral of the squared pressures over the duration of a sound or series of sounds.

Species	Impact type	Fleeing speed [m/s]	Impulsive noise criteria [dB] Peak	Impulsiv noise criteria [dB] SELcum	Continuous noise criteria [dB] SELcum
Fish	Mortal injury	1.04 Herring 0.38 Cod (juvenile) 0.9 Cod (adult)	207	207 (SELcum)	-
Fish	Recoverable injury	1.04 Herring 0.38 Cod (juvenile) 0.9 Cod (adult)	207	203 (SELcum)	222 (SELcum) 48 hours, 170 RMS
Fish	TTS	1.04 Herring 0.38 Cod (juvenile) 0.9 Cod (adult)	-	186 (SELcum)	204 (SELcum) 12 hours, 158 RMS
Larvae	Mortal injury	N/A	207	210 (SELcum)	-
For continuous noise criteria a value with designation rms is used. RMS stands for Root Mean Square and is a type of average sound for a given sound source. Exposure distances for herring and cod are shown including escape rates. For herring this study will use 1.04 m/s and for cod this study has used 0.38 m/s (juvenile) and 0.9 m/s (adult).					

The ways in which fish can be impacted by underwater noise of a relatively high intensity are largely reversible over time or cease as the noise exposure is terminated, thereby attributing fish low sensitivity to underwater noise. Fish that have evolved a swim bladder, like herring have better hearing and is therefore more sensitive to noise that for example flatfish that does not have a swim bladder. The overall vulnerability of fish to underwater noise is assessed as low, as the threshold levels for physical injuries are high. Noise threshold for behavioural response have not been specified and will be highly species-dependent, as mentioned above. Fish are however, expected to return to areas from where they have been displaced as a result of noise from the mentioned activities. The potential behavioural impact is therefore considered reversible.

<u>Geographical extent</u>

In the construction phase, underwater noise is expected from vessels and the seismic baseline survey (see Table 11-11 and Table 11-12). Underwater noise from vessels is not expected to impact fish, but it may induce behavioural effects in fish which may in turn affect reproductive success and stock biomass. Ivanova et al. (2020) found displacement of Arctic cod (*Boreogadus saida*) at a distance of up to 350 m from vessels (Ivanova et al., 2020). However, the impact from vessels depends on a variety of factors including the species of fish, type of vessel, vessel speed and the environment in which the noise propagates. Consequently, the extent of the impact from vessels causing behavioural effects in fish in the current project cannot be deduced from the literature. It is however expected that the impact will occur in the **immediate vicinity** to the vessels.

Noise emitted from vessels in the construction phase can also impact fish through masking of biologically important sounds affecting foraging and reproductive behaviours, while impairing predator detection and use of sound cues for orientation and navigation which ultimately may lead to a decline in general fitness as well as reproductive failure. Masking effects caused by vessel traffic was shown by (Stanley et al., 2017), where the effective vocalization radius for Atlantic cod was significantly lower in areas impacted by vessel traffic. It is therefore expected that masking effects may arise likely impacting close to the vessels.

In the operation phase, underwater noise from seismic, the monitoring vessel and the CO_2 vessel is expected. As no impact from vessels resulting in mortal injury, recoverable injury or TTS was assessed in the underwater noise modelling, only impacts resulting in these impact pathways are assessed for seismic. Table 11-11 shows the impact distances for fish using 1760 cu. in. airgun (3D) with 35 min soft start positioned 5 m beneath the sea surface with a maximum survey line length of 5 km and animal fleeing and ship movement 9 knots. The calculated prolonged soft start period to prevent any risk of TTS or PTS for fish is due to the slow fleeing speed of juvenile fish (cod). The results in Table 11-11 show the impact distances for fish using 2500 cu. in. airgun (2D) positioned 5 m beneath the sea surface with a maximum survey line length of 5 km and animal fleeing and ship movement 9 knots.

Table 11-11 Results of impact distances for fish from 1750 cu. in. seismic airgun (with 35 minute soft-start). *Includes animal fleeing and ship movement 9 knots (maximum survey line length of 5 km)

Receptor	Impact type (Popper et al. 2014)	Fleeing speed [m/s]	Radial distance to threshold limits
Fish	Mortal injury	Herring 1.04 Cod(j) 0.38 Cod 0.9	*0 m** *0 m** *0 m**
Fish	Recoverable injury	Herring 1.04 Cod(j) 0.38 Cod 0.9	*0 m** *0 m** *0 m**
Fish	TTS	Herring 1.04 Cod(j) 0.38 Cod 0.9	1 km* 1.5 km* 1 km*
Larvae	Mortal injury	0	1.5 km (SPLpeak)/ 0.8 km (SELcum)

Table 11-12 Results of impact distance for fish from 2500 cu. in. seismic airgun (with 40 minute soft-start). *Includes animal fleeing and ship movement 9 knots (maximum survey line length of 5 km)

Receptor	Impact type (Popper et al. 2014)	Fleeing speed [m/s]	Radial distance to threshold limits
Fish	Mortal injury	Herring 1.04 Cod(j) 0.38 Cod 0.9	*0 m** *0 m** *0 m**
Fish	Recoverable injury	Herring 1.04 Cod(j) 0.38 Cod 0.9	*0 m** *0 m** *0 m**
Fish	TTS	Herring 1.04 Cod(j) 0.38 Cod 0.9	1.5 km* 2.0 km* 1.5 km*
Larvae	Mortal injury	0	2 km (SPLpeak) / 0.9 km (SELcum)

Soft start procedure is a part of the standard conditions set forth by the authorities and the operator is required to comply with the Danish guidelines for exploration at sea (Standardvilkår for undersøgelser til havs, 2018) combined with Joint Nature Conservation Committee guidelines (Energistyrelsen, 2018; Joint Nature Conservation Committee, 2017) see section 5.5. Implementing soft start procedure as described by the DEA effectively means that no fish are impacted by mortal injury from seismic monitoring campaigns.

However, applying soft start procedure to seismic monitoring does not remove the risk of mortal injury to larvae. 2D/3D seismic with soft start may potentially lead to mortal injury in larvae at a range of 800-900 m from the source. The maximum impact range was recorded for juvenile cod, indicating that juvenile cod are most susceptible to underwater noise compared to adult cod and adult herring (see Table 11-12,). This area of impact would mean that a substantial number of fish potentially could be impacted by an inability to communicate, detect prey or predators and/or assessing their environment (Carroll et al., 2017) which in turn could have implications for breeding and feeding behaviours as well as for their energy budgets and general survival. However, as indicated by (Soudijn et al., 2020), population growth rates of cod were only affected strongly when noise exposure resulted in a persistent decrease to net-energy availability impacting at least 50 % of the total population. As 2D/3D seismic is only carried out once every other year lasting approx. 5 days per campaign (baseline period will occur at 6 month intervals) and normal hearing ability generally returns over a relatively short period of time (minutes to days or as a worst case up to a few weeks (Amoser et al., 2004; Smith et al., 2006; Smith & Monroe, 2016)) the impact will be very short-termed and will therefore not result in a persistent decrease in net-energy availability. As indicated by Amoser et al., 2004; Smith et al., 2006 and Smith & Monroe, 2016 potential TTS recovery period will have taken place mostly within minutes or days. It is therefore highly likely that potentially impacted fish have recovered before the next campaign.

Consequently, the impact from 2D/3D seismic is unlikely to have repercussions for reproduction and stock recruitment. Furthermore, a degree of uncertainty exists on the applied TTS threshold for fish used in the underwater noise modelling as the applied threshold is derived from freshwater fish species as opposed to saltwater species relevant to the project area. The impact distance may therefore be overestimated. TTS in fish from seismic monitoring is therefore not expected to affect the population metrics. The extent of the impact from 2D/3D seismic is therefore assessed to be **local**.

Underwater noise from 2D/3D seismic, the monitoring vessel and the CO_2 vessel may also induce behavioural effects. However, the literature reports different responses from fish to high-energy sound exposure. Where behavioural reaction distances of 5-10 km for cod have been suggested (Hovem et al., 2012), herring schools being exposed to spot seismic showed no changes in swimming speed, swimming direction, or school size that could be attributed to the transmitting seismic vessel (Peña et al., 2013). The response to high-energy sounds such as spot seismic depends on the character of the sound exposure (frequency, sound pressure level, duration) and local sound propagation, which in turn is affected by the physical environment, bottom topography, and bottom substrate (Hovem et al., 2012). Whether a behavioural response is induced is likely also dependent on the internal state and the behavioural context of the fish and there is not necessarily a direct link between sound exposure and fish reaction. Consequently, behavioural effects in fish caused by spot seismic in the current project can be expected, but the geographical extent of the impact cannot be precisely estimated based on the literature.

Behavioural effects generated by vessels may also impact fish in the operation phase, similar to what is expected in the construction phase. It is expected that the impact will occur close to the vessels and the impact is therefore **immediate vicinity**.

Masking effects caused by vessel traffic affects the effective vocalization radius of Atlantic cod. The impact from vessels depends on a variety of factors including the type of vessel, vessel speed and the environment in which the noise propagates. Consequently, the geographical extent of masking effects in fish generated from the monitoring vessel in the operation phase cannot be precisely deduced from the literature.

Intensity

In the construction phase, underwater noise from vessels and the seismic baseline survey is expected. Impacts from vessels are related to behavioural and masking effects which are expected to cease once the impact ceases. The intensity of the impact from vessels the seismic baseline survey in the construction phase is assessed as **low**. The intensity of underwater noise from 2D/3D seismic is assessed as **medium** (see operation phase).

In the operation phase, seismic monitoring of the reservoirs is carried out using 2D/3D seismic . 2D/3D seismic emits high energy sounds which may potentially lead to mortality or mortal injury in fish. As soft start procedure is required by the authorities, the risk of non-reversible effects in fish (mortality and mortal injury) is prevented. The intensity of underwater noise from 2D/3D seismic is therefore assessed as **medium.**

In the operation phase, underwater noise from the monitoring vessel and CO_2 vessel is expected. Impacts from vessels are related to behavioural and masking effects which are expected to cease once the impact ceases. The intensity of the impact from vessels in the operation phase is assessed as **low**.

Duration

In the construction phase, vessels are expected to be present for approx. 2 months. The duration of the impact from underwater noise from vessels is therefore expected to be **medium-termed**. 2D/3D seismic is carried out for approx. 5-10 days per campaign, therefore the impact from 2D/3D seismic in the construction phase is assessed as **short-term**.

In the operation phase, 2D/3D seismic is carried out for approx. 5-10 days per campaign with the first monitoring campaign carried out just before the first CO_2 injection cycle. The duration of the impact from 2D/3D seismic in the operation phase is therefore assessed as **short-term**. There is a risk of TTS for juvenile cod within a distance of 2 km from the 2D seismic location. TTS impact is of short-term duration (minutes to days (Amoser et al., 2004; Smith et al., 2006; Smith & Monroe, 2016)). The potential impact is therefore limited to the survey duration.

Impacts from underwater noise from the CO_2 vessel are considered **very short-term**, despite the high frequency of the impact, the impact with cease immediately once the vessel is no longer present.

Consequence

The vulnerability of fish to underwater noise is assessed as low, as underwater noise largely results in impacts that are reversible over time, only causing mortality when fish are exposed to high energy sounds within a relatively close range to the source without implications at the population level.

Behavioural or masking effects in fish derived from underwater noise generated by vessels in the construction phase may lead to changes in important biological behaviours. Long-term impacts with underwater noise could therefore potentially lead to failure of reproduction and stock recruitment (Bakke et al., 2013). The duration of the impact is conservatively assessed as medium lasting the entire construction period as it is not possible to conclude on details regarding vessel traffic at this point. Impacts are however expected to occur close to the vessels, but behavioural changes or masking effects, cease once the activity stops. As a result, it is assessed that behavioural changes or masking effects, are unable to lead to reproduction failure or have negative implications on a stock biomass level. The consequence of noise generated by vessels in the construction phase is assessed as **negligible** with no impact at the population level.

Underwater noise in the operation phase is expected from 2D/3D seismic and the vessel carrying out the seismic surveys as well as from the CO_2 vessel. 2D/3D seismic is carried out in the operation phase causing impacts of medium intensity as soft start procedure is applied resulting only in reversible effects on fish locally around the source of noise. However, a substantial number of fish may potentially be impacted with TTS which may have implications for the population dynamics. As the monitoring campaigns are carried out every other year over the course of 5 days, any impacts on fish are expected to be very short-termed and will not lead to long term changes to the size of fish stocks in the North Sea in general. Furthermore, as a degree of uncertainty exists on the applied TTS threshold for fish, the impact distance may be overestimated. Behavioural or masking effects in fish derived from exposure to 2D/3D seismic may lead to changes in important biological behaviours. Long-term impacts with underwater noise could therefore potentially lead to failure of reproduction and stock recruitment (Bakke et al., 2013). As the exposure to 2D/3D seismic is only very short-term lasting 5 days every other year and impacts on fish behaviour or masking effects are expected to cease once the impact ceases, any behavioural or masking effects from seismic surveys carried out in the current project is not expected to lead to reproduction failure neither to have implications for the stock biomass. The consequence from noise generated by 2D/3D seismic in the operation phase is assessed as **limited** with no impact on fish at the population level.

In the operation phase, underwater noise is expected from the monitoring vessel carrying out the seismic survey and from the CO_2 vessel. No effects on fish from vessels were found with regard to mortal injury, recoverable injury or TTS. Underwater noise generated by vessels in the operation phase are expected to only cause behavioural or masking effects and the intensity of this impact is assessed as low as these effects are expected to cease once the impact ceases. The duration of the impact from the monitoring vessel is very short-term as monitoring campaigns are carried out every other year lasting 5 days per campaign. The duration of the impact from the CO_2 vessel is assessed as very short. However, it should be noted that the CO_2 vessel is not expected to cause a continuous impact throughout the operation period as it will operate travelling back and forth. Although the extent of the impact from vessels causing behavioural of masking effects cannot be estimated precisely in this EIA, impacts are expected to occur close to the sources. The consequence of noise generated by vessels in the operation phase is assessed as **negligible** with no impact on fish at the population level.

Mitigation measures

With the application of soft start procedure, the impact from underwater noise is of negligible significance and no further mitigation measures are required.

Physical footprint

Vulnerability

The new solid structures introduced, mainly by the concrete mattresses, may provide new places for fish to find hiding places (Hixon & Beets, 1989; Moreau et al., 2008). Some fish are attracted to the solid structures with their somewhat heterogeneous characteristics which creates cavities where small fish and fry can hide from predators. Also, bentho-pelagic fish as cod and whiting are attracted to the larger food supply and sheltering offered by protective materials surrounding the pipelines as well as the pipelines themselves (Redford et al., 2021). However, an artificial reef is not expected to be created within the lifetime of the project. Due to the small dimensions of the physical footprint in a vast and homogenous area, there will not be an impact on fish populations. The vulnerability of fish to physical footprint related to the presence of physical structures, is therefore assessed as **low**(Bohnsack, 1989). The impact is not reversible until the decommissioning phase as the structures persist throughout the operation phase.

Geographical extent

The physical footprint from the structures installed in the construction phase will occupy approx. 850 m^2 in total and persist throughout the operation phase. The dimensions of the structures are small and the physical footprint from these individual structures are assessed to impact fish in the **immediate vicinity** only.

Intensity

The structures installed in the construction phase will persist throughout the operation phase resulting in a permanent loss of habitat. However, the loss of habitat is relatively small as the dimensions of the structures only occupy approx. 850 m^2 of the vast homogenous habitat of the seabed. The intensity of the impact from the physical footprint on the fish community in the construction and operation phase is therefore assessed as **low**.

Duration

The structures installed in the construction phase impose a **permanent** impact as they remain throughout the entire operation phase. The impact only happens once as the structures are placed and remains throughout the period in which the structures are present, thus low frequency of the impact.

Consequence

In the construction and operation phase, permanent structures may provide new shelter and hiding places for some fish despite the loss of substrate. The intensity of the impact is consequently assessed as low as it results in a relatively small loss of habitat. The extent of the collective footprint from these structures is assessed as having an impact in the immediate vicinity. The vulnerability of fish to physical structures resulting in a physical footprint is assessed as low. The consequence of physical footprint in the construction and operation phase is assessed as **negligible** for fish. Despite the permanent impact, the overall assessment of physical footprint is still assessed to have negligible impact on fish due to the very small dimensions of the placed structures in comparison to the vast and homogenous area in which fish will continue to exist.

Mitigation measures

No significant impact from physical footprint on fish has been assessed and no mitigation measures are therefore required.

Physical disturbance of seabed

Vulnerability

Potential impacts to fish caused by physical disturbance of the seabed, such as resuspension of sediment, can impact demersal fish species or species that rely on the seabed for spawning. No impacts are anticipated on pelagic spawners. Adult demersal fish species are resilient to physical disturbance of the seabed due to their lifestyle of being submerged in the sediment (Humborstad et al., 2006; Wenger et al., 2017). Furthermore, their ability to escape an area of disturbance makes them more resilient compared to immobile demersal eggs and larvae. The amount of resuspended sediment from placing structures, mainly the concrete mattresses, on the seabed is expected to be very small and temporary and the impact is reversible. Therefore, vulnerability of demersal fish towards physical disturbance on the seabed is considered to be **low**.

Geographical extent

Due to the relatively small dimensions of the structures and the fact that no trenching will take place, very little resuspension with limited dispersal is expected, thus the extent of the impact is assessed to affect the **immediate vicinity** only.

Intensity

Impacts from physical disturbance of the seabed are primarily linked to demersal species and the extent of impact is limited to the footprint of the physical disturbance in very near vicinity of the 850 m^2 of structures placed on the seabed. This area is negligible compared to the surrounding habitats that are physically uniform and support similar fish communities. Although some individuals may exhibit avoidance behaviour and/or demersal larvae or eggs may be killed, physical disturbance of the seabed in the construction phase will not impact fish at the population level. As the impact only occur once within a short timeframe, the intensity of physical disturbance to fish is assessed as **low**.

Duration

Placement of structures on the seabed is carried out in the construction phase and is expected to last for 7 +1.5 days. The placement of structures on the seabed will result in very little resuspension of sediment and the sediment conditions around the structures are expected to revert quickly to pre-placement conditions. The impact from physical disturbance of the seabed is therefore assessed as **short-term**. The impact is carried out once, hence low frequency.

Consequence

The vulnerability of fish to physical disturbance of the seabed is assessed as low as only demersal eggs and larvae may be mortally impacted and only adult demersal fish may display avoidance behaviour. No impacts are expected on pelagic fish. The extent of the impact occur in the immediate vicinity of the approx. 850 m^2 of structures placed on the seabed resulting in a limited degree of resuspension of sediments. The disturbed area is expected to quickly regain its characteristics, thereby only impacting fish short-termed in the construction phase. The potential loss of eggs and larvae and temporary loss of habitat is assessed as being of negligible effect to fish at the population level due to its relatively limited extent, low intensity and short-term duration and since both the project area and adjacent areas generally constitute similar, suitable spawning areas and habitats for fish. The consequence on fish from physical disturbance of the seabed is assessed as **negligible**.

Mitigation measures

No significant impact is expected from physical disturbance of the seabed and mitigation measures are therefore not considered necessary.

Light

Vulnerability

Illuminated structures may provide an enhanced foraging environment for larval, juvenile and adult fish by providing sufficient light to locate and capture prey, as well as by concentrating positively phototaxic prey taxa. For juvenile fish, there may be a trade-off between living and foraging in an artificially illuminated nocturnal environment. The increased illumination likely allows them to feed on zooplankton that is concentrated within the light field near the surface; however, the same light may make them more vulnerable to predators (Keenan et al., 2007). As light can both have a positive and negative effect on fish, the vulnerability of fish to light emissions is generally assessed as being **low**. Impacts from safety lights on Nini A platform and vessels in both the construction and operation phase are assessed as reversible as fish are mobile and the impact is expected to cease once they are out of range of the impact.

Geographical extent

In the construction phase, vessels used for installation of structures are illuminated. The potential disturbance to fish from light emissions from the vessels is expected to occur in the **immediate vicinity**, extending 90-100 m from the source (Keenan et al., 2007; Woodside, 2010).

Safety lights are always present at all platforms and vessels throughout the construction and operation phase. Not much is known about the extent of impact on fish from light emissions from safety lights on platforms and vessels. However, as safety lights are generally low-intensity light sources, the impact from safety lights is expected to have a smaller extent than the illuminated vessels. The extent of the impact is therefore assessed as in the **immediate vicinity**.

Intensity

The impact on fish from light emissions can potentially cause both negative and positive effects. As the impact is expected to occur in the immediate vicinity mainly around the vessels and not continuously, only a limited number of fish are potentially impacted negatively. Any impacts from light emissions on fish are not expected to be significant at the population level. The intensity of the impact is therefore assessed as **low**.

Duration

Safety lights are always present at Nini A. Vessels are present for approx. 2 months during the construction phase thus assessed as **medium-termed**. In the operation phase vessels are present throughout the entire lifetime of the project at a high frequency and is therefore assessed as **permanent**. Light emissions from vessels are not expected continuously throughout the operation period but at a certain frequency as vessels move in and out of the project area, thereby only impacting fish while vessels are present.

Consequence

- Safety lights are present at the platform and vessels during the construction and operation phase and will therefore constitute a permanent impact. As the vulnerability of fish is generally assessed as low to light emissions and the impact is only expected to occur in the immediate vicinity, any impacts on fish arising from light emissions are considered to be of low intensity without significance at the population level for fish. The consequence of light emissions from the platform and vessels to fish is assessed as **negligible**.

Mitigation measures

No significant impact is expected from light emissions on fish and mitigation measures are therefore not considered necessary.

Overall assessment

The vulnerability of fish to the potential impacts from the project is for most impact mechanisms assessed to be low, since fish are highly mobile, and the area does not constitute important spawning grounds for fish. All impacts on fish will happen in the immediate vicinity (< 1km) to locally (<10 km) around the source and impacts are of very short-, short-, medium-term or permanent duration. Impacts of permanent duration are expected from light in the operation phase and physical footprint. The presence of physical structures in a vast and homogenous area is assessed to have negligible impacts on fish. Overall, all impacts to fish from activities in this project are assessed to have negligible to limited consequences for fish in both the construction and operation phase.

Table 11-13 overall assessment of impacts on fish.

Impact	Vulnerability	Geographical extend	Intensity	Duration	Consequence
Construction Phase					
Underwater noise	Low	Immediate vicinity	Medium	Medium	LimitedN
Physical footprint	Low	Immediate vicinity	Low	Permanent	Negligible
Physical disturbance of the seabed	Low	Immediate vicinity	Low	Short	Negligible
Light	Low	Immediate vicinity	Low	Medium	Negligible
Operation Phase					
Underwater noise	Low	Local	Medium	Short	Limited
Physical footprint	Low	Immediate vicinity	Low	Permanent	Negligible
Light	Low	Immediate vicinity	Low	Permanent	Negligible

Cumulative impacts

No other projects, planned or in operation, is assessed to have cumulative impacts with the current project. Light emissions from existing platforms in the North Sea may potentially result in cumulative effects with light emissions from the current project. However, as the nearest platform is located > 30 km from the project area, no cumulative effects from light emissions are therefore expected. It is therefore assessed that cumulative impacts are irrelevant.

Transboundary impacts

The Norwegian SVO-area "the sand eel fields" is located relatively near the Danish-Norwegian EEZ border approx. 11 km from the project area and 4.6 km to the monitoring OBS (seismicity). There will be no seismic source involved in this monitoring, as only measurements of the vibrations from the earth itself will be taken.

Underwater noise (2D-seismic) is the only impact mechanism which could potentially cause transboundary impacts. However, as soft start is applied to 2D-seismic, the expected impact ranges of non-reversible (PTS) and reversible (TTS) impacts are effectively reduced to 0 m and 2 km respectively and is not expected to result in a transboundary impact. Mortal injury in larvae might occur up to 2 km (SEL peak), thus is not expected to impact the SVO-area.

Gaps in knowledge and limitations

The fish distribution and biology of the central North Sea is relatively well known, and the effect of underwater noise on fish is relatively well understood. Although the TTS threshold for fish is based on freshwater species, the knowledge drawn from other species applies to some extent, and considering the temporary nature of the impact, the conclusion of this assessment is regarded as sound. However, the effect of light emissions on fish in pelagic zones, namely safety lights from platforms and vessels,
is not well understood. The effect of artificial light on fish in coastal urban developments has been studied broadly and may act as a proxy for assessing the effects of safety lights on fish. Overall, the conclusion of this assessment is considered to be sound.

11.8 Biodiversity – Marine mammals

In this section impacts on marine mammals is assessed. Section 10.5.4. gives a description of species found regularly in the project area.

11.8.1 Potential impacts

Potential impacts on marine mammals relate to:

- Underwater noise i.e., in the construction phase, underwater noise is expected from vessels, ROV operations and the seismic baseline survey. In the operation phase, underwater noise is expected from seismic surveys, the seismic monitoring vessel, the CO_2 vessel and from support vessels used for maintenance operations using ROV.
- Disturbance from vessels i.e., both in the construction and operation phase.
- Light i.e., in the construction phase and operation phase, light emissions are expected from vessels and the Nini A platform.

Chemical discharges i.e., discharge of hydrotest water from leak testing of the offloading system are assessed under sections 11.5 and 11.6. As impacts from chemical discharge on plankton and benthic fauna was assessed as negligible, it will not be further assessed for marine mammals.

11.8.2 Methods and data

The following impact assessment of the current project on marine mammals is based on underwater noise modelling supported by existing data and best available scientific literature as well as previous environmental impact assessments of similar projects. The method for noise modelling is the same as used for assessing impacts on fish and is described in section 11.7.2 For a detailed method description of the underwater noise modelling, it is referred to the *Technical Note: Project Greensand Future EIA – Underwater noise modelling*, which is found in the Appendix to this EIA. The modelling and background information is shortly described below.

The distribution and biology of marine mammals in the central North Sea is relatively well known, and scientific research as well as previous impact assessments of similar activities on marine mammals is well documented in the literature. The data basis of this assessment is therefore considered to be sufficient.

11.8.3 Assessment of impacts

Underwater noise

There are several sources of noise emitted from the planned activities. In construction phase this includes underwater noise from vessels, ROV and diver equipment as well as the seismic baseline survey. In the operation phase underwater noise can derive from ROV equipment, the CO_2 vessel and survey vessel (continuous noise) but also from the use of airguns during seismic monitoring of the reservoir (section 5.5.4). The use of sonar systems to detect bubbles (section 5.5.5) operates at very high frequencies, outside the hearing range of marine mammals and is therefore not assessed further.

Vulnerability

Hearing is the primary sense for many marine mammals for detecting prey, predators, communication, and navigation. Underwater noise can therefore cause severe impacts on marine mammals as it potentially inhibits the ability to perform these vital actions. The effect of underwater noise on marine mammals can be divided into four broad categories that largely depend on the individual's proximity to the sound source (B. L. Southall et al., 2007, 2019):

- Physical damage to marine mammals relates to damage to the hearing apparatus, which may lead to permanent changes in the animals' detection threshold (permanent threshold shift, PTS). This can be caused by the destruction of sensory cells in the inner ear, or by metabolic exhaustion of sensory cells, support cells or even auditory nerve cells. Hearing loss can also be temporary (temporary threshold shift, TTS) where the animal will regain its original detection abilities after a recovery period. For PTS and TTS, the sound intensity and profile are important factors for the degree of hearing loss, as is the frequency, the exposure duration, and the length of the recovery time.

- Behavioural changes can range from very strong reactions, such as avoidance, to more moderate negative reactions where the animal may orient itself towards the sound or move slowly away.

- Masking is where the noise conceals other sounds, e.g., communication between individuals. The impact to e.g., communication is not well understood.

- Detection is where the animals can hear the noise. Detection ranges depend on background noise levels as well as species specific audible threshold profiles.

Mortal injury resulting from underwater noise is highly unlikely and therefore not considered as one of the broad categories after Southall (B. L. Southall et al., 2007, 2019).

Harbour porpoise is categorized as being in the Very High Frequency (VHF) hearing group. Harbour porpoises use echolocation to communicate, orientate themselves in the water, search for prey and detect obstacles and barriers with sound frequencies ranging from a few hundreds of Hz to tens of kHz. The signals made for prey detection and navigation is above 100 kHz. The auditory bandwidth for porpoises is between 200 and 180 kHz (B. L. Southall et al., 2007; Tougaard et al., 2014b). In Figure 11-2 an audiogram for harbour porpoise, is presented.

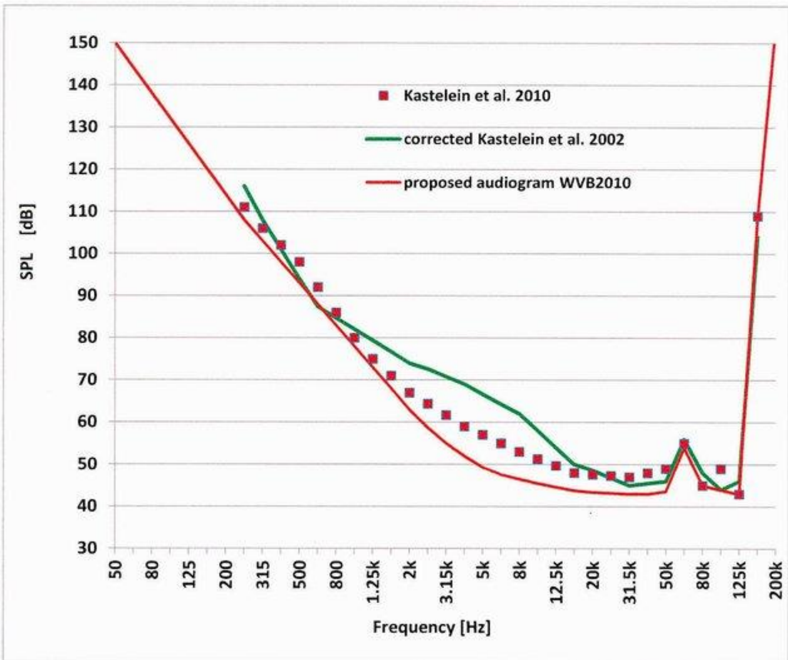


Figure 11-2. Audiogram of harbour porpoise (Verboom, 2012). The audiogram shows the hearing threshold. Thus, the best ability to detect sound is at frequencies with the lowest threshold (the best sensitivity). The frequency range of harbour porpoise vocalization lies around 100-110 kHz.

White-beaked dolphin is categorized as being in the high frequency (HF) hearing group. Hearing sensitivity has been measured for several species within this group using behavioural or Auditory Evoked Potentials (AEP) measurements (NOAA, 2018). High-frequency cetaceans generally possess a higher upper-frequency limit and better sensitivity at high frequencies compared to the mid-frequency cetacean species. Individuals of the HF hearing group are most sensitive around 90-105 kHz (NOAA, 2018) (Figure 11-3).

Minke whale is categorized as being in the low frequency (LF) hearing group (Figure 11-3). This group of whales primarily hear and communicate with potential mates and conspecifics within the low frequency (LF) range of ~10 Hz-30 kHz which can propagate many kilometres underwater (Boisseau et al., 2017). The information from which audiogram data are derived for the hearing group 'LF cetaceans' (i.e. minke whale) is limited, with no direct measures for auditory thresholds made for any species within the LF cetacean group (Boisseau et al., 2017). A range of audibility for LF cetaceans has therefore been established from observed vocalisation frequencies and reactions to playbacks of sound and from anatomical measurements of the auditory system. The upper and lower limits of the most sensitive hearing range (range over which animals are likely to be most sensitive to sounds) for LF cetaceans is given as 0.2-19 kHz in the latest guidelines from NOAA (NOAA, 2018).

Seals are categorized as being in the Phocid water (PW) hearing group (Figure 11-3). Seals have amphibious hearing as they can hear both in water and in air. The general assumption is that the hearing abilities in both species are very similar. Seals communicate vocally by use of a broad bandwidth of sounds with an auditory bandwidth from 75 Hz-75 kHz (in water), having the highest sensitivities between 1 kHz and 50 kHz (NOAA, 2018; B. L. Southall et al., 2007; Tougaard et al., 2014b).

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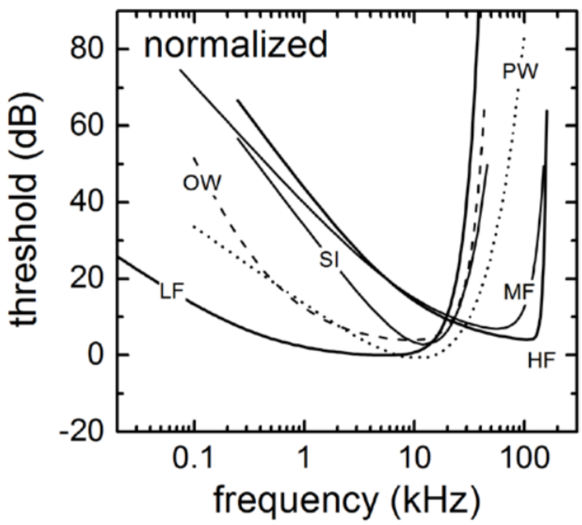

Figure 11-3 Normalized audiogram of different hearing groups of marine mammals (except VHF) (NOAA, 2018). The audiogram shows the hearing threshold. Thus, the best ability to detect sound is at frequencies with the lowest threshold (the best sensitivity). HF=High-frequency cetaceans (Harbour porpoise), MF= Mid-frequency cetaceans (White-beaked dolphin), LF= Low-frequency cetaceans (Minke whale), Si=Sirenians, OW=Otariids, PW=Phocids (true seals)

Anthropogenic noise exposure is divided into two specific categories, impulsive or continuous noise (see section 11.7.3). The impact on marine mammals from these different sound sources and the associated hearing threshold levels are presented in Table 11-14. Thresholds for damage to hearing and behavioural responses used in the assessment is based on frequency weighted thresholds from the Danish Energy Agency's 2022 guidelines (Energistyrelsen, 2022b). The thresholds are based on the work done by (E. B. L. Southall et al., 2019) and the compiled newest knowledge on impacts from pile driving (B. L. Southall et al., 2019; Tougaard, 2021c, 2021a). No threshold limits for behavioural response have been reported in the literature for minke whale and white-beaked dolphin. The value provided by (Tougaard, 2016) (145 dB re1UPa) is largely accepted by the DEA to be applied to all marine mammals, that inhabits the Danish North Sea, thus this value is used in Table 11-14. Behavioural responses from seals caused by underwater noise are not covered in the new guidelines, here experience from piledriving at wind farms has been used (Russell et al., 2016).

Table 11-14 Noise threshold limits for different marine mammal hearing groups (impulsive/non-impulsive)

Marine mammal hearing group	**TTS SELcum** (weighted) [1] dB re1 µPa2s SELcum	**TTS Peak** (unweighted) [1] dB re1 µPa	**PTS SELcum** (weighted) [1] dB re1 µPa2s SELcum	**PTS Peak** (un-weighted) [1] dB re1 µPa	**Behavior single pulse**
Low Frequency Minke whale	168 dB / 179 dB	213 dB	183 dB / 199 dB	219 dB	145 dB re1 µPa2s SELss (unweighted) [2]
High Frequency White-beaked dolphin	170 dB / 178 dB	224 dB	185 dB / 198 dB	230 dB	145 dB re1 µPa2s SELss (unweighted) [2]
Very High Frequency Harbour Porpoise	140 dB / 153 dB	196 dB	155 dB / 173 dB	202 dB	103 dB (VHF weighted) [3] rms 125 ms dB re1 µPa
Phocidae carnivores in water (PCW) seals	170 dB / 181 dB	212 dB	185 dB / 201 dB	218 dB	151 dB (unweighted) [4] dB re1 µPa2s SELss (impulsive)

[1] (E. B. L. Southall et al., 2019) *Marine Mammal Noise Exposure Criteria*
[2] (Tougaard, 2016) – *(based on harbor porpoise limits as instructed by DEA)*
[3] (Energistyrelsen, 2022c).
[4] (Russell, 2016)

SEL (Sound Exposure Level)*: this is a decibel measure for describing how much sound energy a receptor (e.g. a marine mammal) has received from an event and is normalized to an interval of one second (quoted in dB re 1 µPa^{2}s). It can be thought of as a logarithmic measure of Sound Exposure and hence a 3 dB increase in SEL equates to a doubling of sound energy.*

SEL (cum)*: this is the time integral of the squared pressures over the duration of a sound or series of sounds. It enables sounds of differing duration and level to be characterized in terms of total sound energy (quoted in Pa^{2}s).*

Behavioural, changes are difficult to evaluate. They range from very strong reactions, such as avoidance, to more moderate negative reactions where the animal may orient itself towards the sound or move slowly away. However, the animals' reaction may vary greatly depending on season, behavioural state, age, sex, as well as the intensity, frequency and time structure of the sound causing behavioural changes (B. L. Southall et al., 2007, 2019). Harbour porpoises move around 20-40 km a day when foraging and minke whales around 50-80 km a day (Nielsen et al., 2013; Read & Westgate, 1997; Vikingsson & Heide-Jørgensen, 2005). Minke whales will therefore be able to forage in neighbouring areas. Like whales, seals also travel long distances (section 10.5.4) while foraging and are highly mobile. Marine mammals are therefore not considered sensitive to displacement areas that are comparatively small to their large daily foraging range.

Studies carried out in connection with marine activities, e.g. ploughing of pipelines into the seabed, piledriving and seismic surveys shows that underwater noise can cause avoidance behaviour in marine mammals and fish, but that the animals most often return to the area when the construction is completed (Tougaard, 2014a). There are no studies that suggests that marine mammals are permanently displaced from an area after activities are stopped. Research on seismic surveys shows that all species show some kind off avoidance behaviour e.g. altering swimming speed, diving or swimming away from the survey vessel (Pirotta et al., 2014; Stone & Tasker, 2006; Weilgart, 2013). It is however assessed that marine mammals return to the area after activities have stopped as has been shown for other loud noise sources e.g. pile driving. Studies have indicated that there were no long tern effects on seals at haul out sites during construction and operation of a nearby windfarm despite short term displacement of seals on land (Edrén et al., 2010). Studies of harbour porpoise activity in relation to the construction of windfarms have shown that the impact of ramming activity had a substantial but short-lived effect (Carstensen et al., 2006).

Noise impacts causing TTS is also considered reversible as the animals will regain their ability to hear. Although PTS is an irreversible damage to the hearing of the affected animal, the impact, it in itself is considered reversible on population level as the population is not expected to be affected.

Although underwater noise in some cases can cause irreversible damage to the hearing, the marine mammals are expected to avoid the area and they are assessed to be insensitive to small displacement impacts. The vulnerability of marine mammals to underwater noise is therefore assessed as **medium**.

<u>Geographical extent</u>

Underwater noise in the construction phase is expected from vessels, ROV equipment and the seismic baseline survey. impact thresholds are presented in Table 11-14. Impact distances have been modelled (section 11.7.3) and include the fleeing speed for harbour porpoise swimming at 1.5 m/s. Impact distances for the ROV with transceiver system are shown in Table 11-15.

Table 11-15 Impact distances for ROV surveys for marine mammals with and without slow start.

Modelling results are shown in the table. The results show the impact distances for marine mammals using 1 vessel transponder and 1 ROV transponder. Impact distances by implementing a slow start procedure are also indicated. Impact threshold limits for marine mammals and associated impact distances for impulsive noise (cumulative noise (SELcum, weighted) and peak noise exposure (unweighted)). LF = Low Frequency, HF = High Frequency, VHF = Very High Frequency, PCW = Phocid Carnivores in Water.

Marine Mammal group	**TTS SELcum** (weighted) [2,3] dB re1 µPa2s SELcum	**TTS Peak** (unweighted) [2,3] dB re1 µPa	**PTS SELcum** (weighted) [2,3] dB re. Pa2s	**PTS Peak** (un-weighted) [2,3] dB re1 µPa	**Behavior single pulse**
LF distances Minke Whales	0 meter	0 meters	0 meters	0 meters	60 meters [4]
HF distances White-beaked Dolphin	0 meters	0 meters	0 meters	0 meters	60 meters [4]
VHF distance Harbour Porpoise	550 meters 0 meters [6]	0 meters	35 meters 0 meters [6]	0 meters	4,200 meters [1]
PCW distances Seals	0 meters	0 meters	0 meters	0 meters	0 meters [5]

[1] (DEA, 2022).
[2] (E. B. L. Southall et al., 2019) *Marine Mammal Noise Exposure Criteria*
[3] *Includes animal fleeing at 1.5 m/s*
[4] (Tougaard, 2016)
[5] (Russell, 2016)
[6] *with 5-minute slow start and vessel disturbance of 100 m*

The modelled impacts distances for the activities in the construction phase that may cause underwater noise are 35 m for PTS and 550 m for TTS for Harbour porpoise (without slow start), while all other marine mammal species show impact distances of 0 m as described in Table 11-15. The main impact source is the HiPAP and transponder USBL system used by the vessel to locate and position the ROV during the construction of the pipeline. The systems operate at frequencies between 21 – 32 kHz and therefore the potential impact will mainly be restricted to Harbour porpoises as they are more sensitive to disturbance within this frequency range. However, HF and PCV marine mammals (white-beaked dolphins and seals) overlap with this frequency as well. The

HiPAP USBL system will operate in minimum power mode and further reduction in noise levels is not possible. However, as marine mammals are unlikely to come this close to vessels, it assessed that there is limited risk of PTS or TTS in the construction phase. Behavioural changes a result of vessel and ROV operations may occur up to 4.2 km from the sound source. Impacts from underwater noise in the construction phase are therefore assessed be **local**.

Slow start is used for ROV, diving activity and the seismic baseline survey to minimize underwater noise impacts on marine mammals and fish. A 5 minute and 15-minute slow start was modelled, where one single individual vessel transponder signal (ping) is emitted every 20 seconds for 5 or 15 minutes respectively. The ping is released at a low power setting. The 5-minute slow start applies for ROV activities using a USBL transmitter and one transponder placed on the ROV whereas the 15-minute slow start is used for diving operations i.e. scenarios with multiple transponders on divers, ROV and supporting equipment (see Appendix). The calculated slow start periods are taking into account that the presence of the vessel will deter the animals to be at least 100 meters away from the sound source. The results for the diving operations are shown in Table 11-16.

Table 11-16 Impact distances for diving operations for marine mammals with and without slow start.

Modelling results are shown in the table. The results show the impact distances for marine mammals using 1 Vessel Transponder, 3 Diver Transponders, 1 ROV Transponder, 1 Dive Bell transponder, 1 DP Beacon transponder). Impact threshold limits for marine mammals and associated impact distances with regard to impulsive noise (cumulative noise (SELcum, weighted) and peak noise exposure (unweighted)). LF = Low Frequency, HF = High Frequency, VHF = Very High Frequency, PCW = Phocid Carnivores in Water.

Marine Mammal group	**TTS SELcum** (weighted) [2,3] dB re1 µPa2s SELcum	**TTS Peak** (unweighted) [2,3] dB re1 µPa	**PTS SELcum** (weighted) [2,3] dB re. Pa2s	**PTS Peak** (un-weighted) [2,3] dB re1 µPa	**Behavior single pulse** (RMS 125 ms, VHF weighted) (SELss for Seals, unweighted)
LF distances Minke Whales	0 m	0 m	0 m	0 m	60 m [4]
HF distances White-beaked Dolphin	0 m	0 m	0 m	0 m	60 m [4]
VHF distance Harbour Porpoise	1,200 m 0 m [6]	0 m	80 m 0 m [6]	0 m	4,850 m [1]
PCW distances Seals	0 m	0 m	0 m	0 m	60 m [5]

[1] (Energistyrelsen, 2022c).
[2] (E. B. L. Southall et al., 2019) *Marine Mammal Noise Exposure Criteria*
[3] *Includes animal fleeing at 1.5 m/s*
[4] (Tougaard, 2016) – *(based on harbor porpoise limits as instructed by DEA)*
[5] (Russell, 2016)
[6] *With 15-minute slow start and vessel disturbance of 100 m*

Underwater noise from seismic monitoring is expected during the construction (baseline) and operation phase to map the CO_2 migration in the reservoir. Results from the modelling of underwater noise related to seismic surveys are presented in Table 11-17 (3D) and Table 11-18 (2D). Impact distances include the fleeing speed for harbour porpoise swimming at 1.5 m/s and the movement of the ship at 9 knots (maximum survey line length of 5 km). Impact distances also include that the soft start procedure described in section 5.5.4 is used, so that animals have time to leave the area before the airgun shoot at full power.

Table 11-17 Results of impact distances for marine mammals from 3D 1760 cu. in. seismic airgun (with 35 minute soft-start, values in parenthesis indicate distances without soft-start).

Marine Mammal group	**TTS SELcum** (weighted) dB re. Pa²s	**TTS Peak** (un-weighted) dB re 1 µPa	**PTS SELcum** (weighted) dB re. Pa²s	**PTS Peak** (un-weighted) dB re 1 µPa	**Behavior single pulse average/maximum** (RMS 125 ms, VHF weighted) (SELss for LF, HF, PCW, un-weighted)
LF distances Minke Whales	*0 m** *(10,000 m*)*	*0 m* (260 m)	*0 m** (7,000 m*)	*0 m* (120 m)	27.4 / 33.2 km
HF distances White-beaked Dolphin	*0 m** (10 m*)	*0 m* (60 m)	*0 m** (0 m*)	*0 m* (30 m)	27.4 / 33.2 km
VHF distance Harbour Porpiose	*0 m** (60 m*)	*0 m* (2,300 m)	*0 m** (5 m*)	*0 m* (1,150 m)	*4.9 / 5.3 km*
PCW distances Seals	*0 m** (6,000 m*)	*0 m* (300 m)	*0 m** (600 m*)	*0 m* *(140 m)*	*18.0 / 20.3 km*

* Includes animal fleeing at 1.5 m/s and ship movement 9 knots (maximum survey line length of 5 km)
With regard to impulsive noise (cumulative noise (SELcum, weighted) and peak noise exposure (unweighted)). TTS = temporary threshold shift, PTS = permanent threshold shift, LF = Low Frequency, HF = High Frequency, VHF = Very High Frequency, PCW = Phocid Carnivores in Water

Table 11-18 Results of impact distances for marine mammals from 2D 2500 cu. in. seismic airgun (with 40 minute soft-start, values in parenthesis indicate distances without soft-start).

Marine Mammal group	**TTS SELcum** (weighted) dB re. Pa²s	**TTS Peak** (un-weighted) dB re 1 µPa	**PTS SELcum** (weighted) dB re. Pa²s	**PTS Peak** (un-weighted) dB re 1 µPa	**Behavior single pulse average/maximum** (RMS 125 ms, VHF weighted) (SELss for Seals, un-weighted)
LF distances Minke Whales	*0 m** *(13.000 m*)*	*0 m* *(320 m)*	*0 m** *(10.000 m*)*	*0 m* *(150 m)*	30.1 / 36.8 km
HF distances White-beaked Dolphin	*0 m** *(13 m*)*	*0 m* *(90 m)*	*0 m** *(10 m*)*	*0 m* *(45 m)*	30.1 / 36.8 km
VHF distance Harbour Porpiose	*0 m** *(80 m*)*	*0 m* *(3.000 m)*	*0 m** *(8 m*)*	*0 m* *(1.400 m)*	*5.7 / 6.1 km*
PCW distances Seals	*0 m** *(9.000 m*)*	*0 m* *(400 m)*	*0 m** *(800 m*)*	*0 m* *(185 m)*	*23.2 / 28.9 km*

* Includes animal fleeing at 1.5 m/s and ship movement 9 knots (maximum survey line length of 5 km)
With regard to impulsive noise (cumulative noise (SELcum, weighted) and peak noise exposure (unweighted)). TTS = temporary threshold shift, PTS = permanent threshold shift, LF = Low Frequency, HF = High Frequency, VHF = Very High Frequency, PCW = Phocid Carnivores in Water

As shown in Table 11-17 no TTS or PTS for any of the marine mammal species will be caused by the impact. Since marine mammals avoid vessels at a distance of 200-400 m (see disturbance from vessels), it is assessed that there is no risk of PTS or TTS during the seismic monitoring in the operation phase.

Avoidance behaviour for Harbour porpoise is modelled to be up to 6.1 km and for seals the avoidance distance is up to 36.8 km (Table 11-18). Both minke whales and white-beaked dolphin are expected to avoid an area up to 36.8 km away. In one study the closest distance the minke whale was observed to shooting airguns was 1 km (Stone & Tasker, 2006). White-beaked dolphin is expected to show avoidance distances similar to harbour porpoise as their hearing threshold is similar. The impact extent is therefore assessed to be **local** for harbour porpoise, minke whale and white-beaked dolphin and **regional** for seals.

Intensity

Since underwater noise is highest near the source e.g., a vessel or an airgun and attenuates with increasing distance from the source, the intensity of the impact will also vary depending on how close a marine mammal is to the sound sources (activities). The intensity for sound levels, that can cause PTS is assessed to be high, as it can lead to permanent injury to the hearing of marine mammals. Sound levels, that can cause TTS is assessed as medium intensity impacts, as the hearing threshold is only temporally decreased. Modelling of impacts distances related to the use of ROV in the construction phase shows that the distances where permanent hearing loss (PTS) or temporary hearing loss (TTS) can be expected are short and only occur within a 35 m and 550 m radius, respectively. In the construction and operation phase the impact distances has been minimized due to the use of soft start procedures for the seismic survey. It is assessed that PTS and TTS will not occur, since marine mammals will not come this close to the activities or vessels.

Noise levels that cause avoidance behaviour is assessed to cause a low intensity impact as no loss of function will occur and since the impacted areas are small compared to their daily foraging areas for these highly mobile species.

Based on the arguments above it assessed that the intensity of the underwater noise impact in both the construction and operation phase is **medium**.

Duration

In the construction phase, vessels are expected to be present around 2 months as a worst-case scenario. The use of the ROV is expected to be limited to a few days. The seimic suvey will take approx. 5-10 days. The duration of the impact from underwater noise and ROV is therefore expected to be **medium termed** at a low frequency.

In the operation phase, reservoir monitoring is carried out every other year lasting approx. 5-10 days per campaign. The maintenance operations during the operation phase will each last between 1 to 2 days. The impact from the vessels carrying out monitoring and maintenance activities is assessed as **short-termed**. This is due to the fact that marine mammals are expected to return to the survey area in less than a day after the survey vessel has moved from the area (Dyndo et al., 2015) (Wisniewska et al., 2018).

Consequence

With the application of soft start procedure, there will be a very limited risk of injury (PTS or TTS) either in the construction phase or the operation phase from underwater noise.

In the construction phase the noise levels can cause avoidance in a local area around vessels and ROV operations with HiPAP system up to 4,200 m away for harbour porpoises. All impacts in the construction phase are reversible and short to medium-term. The consequence is assessed to be **limited** as the marine mammals are displaced, but the impacted area is too small to have any effect on the fitness of the animals, since they are highly mobile when foraging. The project area is also not an important breeding area for either of the marine mammal species.

In the construction and operation phase the seismic monitoring can cause avoidance behaviour of minke whales and white-beaked dolphins up to 36.8 km away from the source and the impact is therefore regional. For harbour porpoises, avoidance behaviour is expected up to 6.1 km away and the impact area is therefore local. Monitoring is mainly carried out during October to March outside the period, where Harbour porpoise is the most vulnerable (calving and breeding). The project area is also not an important breeding area for either the three whale species. Densities of all three whale species are relatively low in the project area compared to other parts of the North Sea (Harbour porpoise 0.47-0.61 ind./km^2, White beaked dolphin 0.06 ind./km^2, minke whale 0.01 ind./km^2), see also section 10.5.4. An avoidance radius of 6.1 km would displace approximately 70 Harbour porpoises on average out of a population of around 345,000 animals, which is less than 0.02% of the population in the North Sea. With the same avoidance distance for minke whale and White beaked dolphin, the displacement would affect less than 0.01% of the total North Sea populations. The impact is reversible and very short-termed, since the survey period is only 5 days every other year. Again, the area that is impacted is relatively small compared to the daily foraging habitat. Based on the arguments above, the consequence of impacts from underwater noise in the operation phase is assessed to be **limited**.

In the operation phase the seismic monitoring can cause avoidance of seals up to 28.9 km away from the source and the impact is therefore regional. The closest haul-out site for harbour seal and grey seal is located approx. 178 km from the project area and it is therefore likely that grey seals can be encountered foraging within the project area, as they can swim long distances from their haul-out. Density of seals is expected to be low and no resting or breeding areas occur in the project are. The impact is reversible and very short-termed, since the survey period is only 5 days every other year. The area that is impacted is relatively small compared to the daily foraging habitat and will only affect a very limited number of seals. Based on the arguments above, the consequence of impacts from underwater noise on seals in the operation phase is assessed to be **negligible**.

Mitigation measures

With the application of soft start procedure (ROV (5 min) and diving operations (15 min) and seismic monitoring (35-40 min)) in the project description, the impact from underwater noise is expected to cause avoidance from the areas closest to the source, but there will be no risk of injury (PTS or TTS). Therefore, no further mitigation measures are required.

Disturbance from vessels

Marine mammals can be temporarily disturbed by vessels due to the presence of the vessel, although it is still uncertain whether it is a visual response or in combination with underwater noise.

Vulnerability

A study in the Black Sea has shown that harbour porpoises avoid vessels at a distance of 200-400 m (Bas et al., 2017), other whales and seals are estimated to have approximately the same avoidance distance from vessels (Skjellerup et al., 2015). A recent study from the Dan-F platform show high activity of harbour porpoise around the platform despite elevated under water noise levels (Clausen et al., 2021). This indicates that avoidance of structures and vessels depends on other factors as well. This is possibly due to increased prey availability created by the combined effect of the artificial reef formed by the underwater structure and the local protected area around all platforms where fishery is banned (Clausen et al., 2021). As described for underwater noise, marine mammals are not considered sensitive to displacement from relatively small areas and the impact is reversible as the disturbance from vessels cease once the vessels leave the area. Recent studies indicated that harbour porpoises demonstrated foraging disruption when exposed to high rates of vessel noise, however, long term effects were not specified (Dyndo et al., 2015). Studies have indicated that behavioral responses of harbor porpoises to vessel activity are short-lived (Wisniewska et al., 2018). The vulnerability for disturbance from vessels is therefore assessed to be **medium**.

Geographical extent

Impact from disturbance is assessed to be in in the **immediate vicinity** since marine mammals are expected to avoid vessels at a distance of 200-400 m.

Intensity

Since the disturbance only occur in the immediate vicinity of vessels and only causes avoidance from a small area compared to the total marine mammal foraging habitat in the North Sea the intensity of the impact is assessed as **low**.

Duration

Generally, the disturbance is expected to cease immediately once the vessels have left the area. In the construction phase, vessels are expected to be present for approx. 2 months. The duration of the impact from disturbance from vessels is therefore expected to be **medium-termed**.

In the operation phase, one CO_2 vessel is expected to carry out a maximum of 130 injection cycles per year. Despite the high frequency of this impact, the impact cease immediately when the boat is not present, therefore the impact of the disturbance from vessels is assessed to be **very short-termed**.

In the construction and operation phase, reservoir monitoring is carried out by a single vessel every other year lasting approx. 5-10 days per campaign every other year. The maintenance operations during the operation phase will each last between 1 to 2 days. The impact from the disturbance of these vessels is assessed as **short-term**, as each operation lasts less than one week.

Consequence

Marine mammals are expected to avoid areas in the immediate vicinity of vessels. The impact is medium-term in the construction phase and very short-termed in the operation phase. The impact is reversible and only occur while vessels are present. Intensity is assessed to low as impacts on marine mammals will cause avoidance of a relatively small area and since all species are highly mobile, they will be able to forage in nearby areas. The overall consequence is assessed to be **negligible**.

Mitigation measures

Since disturbance only occur in the immediate vicinity of the vessels and marine mammals are expected to just avoid the area, it is assessed that mitigation measures are not necessary.

Light

Safety lights will present at Nini A and vessels will be illuminated in the construction phase. In the operation phase the platform is unmanned, but safety light will be present and the CO_2 vessel will also be illuminated. Navigational and deck working lights used to illuminate working areas, are sources of artificial light into the environment. Light may locally attract fish (section 11.7.3), serving as prey for marine mammals.

A study at the Dan platform showed that harbour porpoises near the platform had variable diurnal acoustic activity, but a general trend showed higher acoustic activity during the night close to the platform (Balle et al., 2014). At further distance from the platform this pattern was not observed. The presence of marine mammals at Maersk Oil platforms indicates that marine mammals do not avoid light and may be following attracted prey (Keenan et al., 2007). A recent study shows similar results, with high activity of harbour porpoise around the Dan-F platform even during active drilling operations (Clausen et al., 2021).

Vulnerability

The vulnerability of marine mammals to light is assessed to be **low**, since it has no direct impact on the animals, but an indirect (potentially positive) impact since light attract prey items as described above. The impact is reversible as it will only occur while the platform or vessels are illuminated.

Geographical extent

Impact from light is assessed to be in in the **immediate vicinity** since lights from vessels and the platform is expected to only illuminate the sea in the nearest 100-200 m.

Intensity
Since the illumination only occur in the immediate vicinity of the platform and vessels and it is an indirect impact on prey availability in a small area compared to the total marine mammal foraging habitat in the North Sea, the intensity of the impact is assessed as **low**.

Duration
In the construction phase, lights will be present on the Nini A platform and vessels during the whole phase which is expected to last around 2 months. The impact is therefore assessed to be **medium-term**.

In the operation phase, the platform will have safety lights and the CO_2 vessel will also be illuminated. The impact duration is therefore assessed to be **permanent**, since lights will be present during the whole operation phase.

Consequence
Marine mammals will not be impacted directly, but potentially attracted to an increase in food availability. The impact is medium-term in the construction phase and permanent in the operation phase. The impact is reversible and only occur while the platform or vessels are illuminated. The intensity is assessed as low because impacts on marine mammals may cause a local attraction due to an increase in food availability. The overall consequence is assessed to be **negligible**.

Mitigation measures
Since impacts from light only occur in the immediate vicinity of the source and marine mammals will not be impacted directly but drawn to an increase in food availability it is assessed that mitigation measures are not necessary.

Overall assessment
The vulnerability of marine mammals to the potential impacts from the project is assessed to be low or medium, since marine mammals are highly mobile, and the area is not found to be an important breeding area. In the construction phase, the impacts on marine mammals occur in the immediate vicinity or locally. In the construction and operation phase underwater noise can cause local avoidance of whales and regional avoidance of seals. The intensity off impacts is assessed to be low to medium, as there is little risk of injury, increase in mortality or loss of fitness. Duration is medium termed in the construction phase while it is very short to permanent in the operation phase. The seismic monitoring is assessed to have a very short-term impact. All impacts are reversible. The overall consequence is thereby assessed to be negligible or limited for both the construction and operation phase.

Table 11-19 overall assessment of impacts on marine mammals.

Impact	Vulnerability	Geographical extend	Intensity	Duration	Consequence
Construction Phase					
Underwater noise	Medium	Local	Medium	Medium	Limited
Disturbance from vessels	Medium	Immediate vicinity	Low	Medium	Negligible
Light	Low	Immediate vicinity	Low	Medium	Negligible

Impact	Vulnerability	Geographical extend	Intensity	Duration	Consequence
Operation Phase					
Underwater noise	Medium	Local/regional	Medium	Short	Limited
Disturbance from vessels	Medium	Immediate vicinity	Low	Short	Negligible
Light	Low	Immediate vicinity	Low	Permanent	Negligible

Cumulative impacts

There are no approved plans or projects that overlap in time or impacts with the impacts from *Project Greensand Future* and therefore no cumulative impacts on marine mammals are anticipated.

Baseline monitoring activities (seismicity and CO2 leakage) will be carried out in Q1-Q4 2025 and completed before the first CO_2 injection. These activities are covered by a separate application/permit. The baseline activity ends in Q4 2025 and the construction phase begins in Q3 2025, leading to a temporal overlap. In Q1 2025, seabed stations (OBS) will be deployed for baseline seismicity data acquisition and the CO2 leakage monitoring system (lander) for baseline monitoring. OBSs and the lander will be retrieved in Q4 2025. Recovery of baseline OBSs will require an ROV operation in which all 8 OBSs will be retrieved within 3 days. The retrieval of the baseline OBSs coincides with the deployment of OBSs for the continuous monitoring in the operational phase.Seismic survey and recovery of baseline OBSs (seismicity) are not planned to take place at the same time and in close proximity to each other. The impacts of the baseline monitoring activities are local, short-term, and temporary, and it is assessed that the risk of impact on Annex IV species and the integrity of Natura 2000 sites are not significant. Furthermore, the period where the baseline activities potentially coincide with other activities are very short (a few hours at the nearest station) and the impact is assessed negligible. Based on the above, it is concluded that there is no risk of cumulative effects from the activities.

Transboundary impacts

Impacts in the construction phase are local and mainly related to the use of ROV equipment using high frequency sound. Behavioural effects may occur up to 4.2 km from the Nini A platform and there could be a displacement of animals in Norwegian waters since the distance to the EEZ is approx. 4 km. However, since the impact is short-termed (less than 30 days), reversible and only affect a very limited number of animals, it is assessed to have negligible transboundary impacts.

In the operation phase the reservoir monitoring takes place in a survey area where the closest distance is approx. 1 km from the Norwegian EEZ. Since the airguns used during the survey can cause avoidance behaviour for harbour porpoise in a distance of up to 6.1 km, displacement of animals about 5.1 km into Norwegian waters could occur. Since the impact is short-termed (5 days), reversible and only affect a very limited number of animals, it is assessed to have negligible transboundary impacts.

Seismic monitoring can displace seals in a 28.9 km radius, but since the distance to the Norwegian coast where haul-outs could occur is more than 100 km and generally few seals use the project area, it is assessed to not impact Norwegian seal populations.

Gaps in knowledge and limitations

Knowledge on impacts on marine mammals is well understood as they have been monitored near oil and gas installations for decades and guidelines for noise impacts are updated regularly, most recently in 2022 (Energistyrelsen, 2022b). There are no guidelines for avoidance from underwater noise for minke whale and white-beaked dolphin, but the value provided by (Tougaard, 2016) (145 dB re1UPa) is largely accepted by DEA to be applied to all marine mammals, that inhabits the Danish North Sea.

11.9 Biodiversity – Seabirds

11.9.1 Potential impacts

Impacts on seabirds relate to:

- Disturbance from vessels i.e., in the construction phase vessels are required for transport, installation and seismic survey activities. In the operation phase, disturbance from vessels is expected from the CO_2 vessel vessels, the seismic monitoring vessel and from support vessels used for maintenance operations.
- Light i.e., in the construction phase and operation phase, light emissions are expected from vessels and the Nini A platform.

11.9.2 Methods and data

The following impact assessment of the project on seabirds is based on existing data such as empirical studies, best available scientific literature along with previous environmental impact assessments from similar projects.

The distribution and biology of seabirds associated with the North Sea is relatively well known. However, considerable uncertainties are associated with the effect of artificial light on seabirds. Estimates of mortality of seabirds indirectly due to light emissions are often imprecise and difficult to translate into significance at the population level. Furthermore, knowledge on nocturnal migratory behaviour is generally lacking as well as an understanding of the underlying factors controlling annual varia
ions in volumes of migrating birds. However, this assessment has been conservatively based on worst-case assumptions and the most recent data specific to the North Sea. The data basis of this assessment is therefore considered to be sufficient.

11.9.3 Assessment of impacts

Disturbance from vessels

<u>Vulnerability</u>

Disturbance from vessels may cause a risk-avoidance response in seabirds which in turn may affect the time available for resting or foraging (Frid & Dill, 2002) thereby impacting survival and reproductive success, potentially affecting population dynamics (Carney & Sydeman, 1999).

The vulnerability of seabirds to disturbance from vessels is however species-specific and birds are likely impacted more severely when alone than when impacted as part of a flock. Redfern et al. (2019) developed a vulnerability index for ship traffic assessing the vulnerability of 26 species of characteristic seabirds in the German North Sea and Baltic Sea (Redfern et al., 2019). Black guillemot (*Cepphus grylle*), which is found in the project area, is among the most sensitive species showing a flush distance of up to 417 m from an approaching vessel with an average speed of approx. 10 knots (18.5 km/h). Flush distances likely increase with increasing speed (R. Ronconi & St. Clair, 2002) while prolonging resettlement of impacted birds (Burger et al., 2019). However, the impact is assessed as reversible as impacted birds are expected to resettle again relatively quickly after the impact ceases or further away from the impact point. The vulnerability of seabirds to disturbance from vessels is assessed as **low**.

<u>Geographical extent</u>

In the construction phase, vessels are required for installation activities. As mentioned above, the most sensitive species found in the project area is the black guillemot showing a maximum flush distance of up to 417 m. The extent of the impact from vessels in the construction phase is therefore assessed to only occur in the **immediate vicinity** of the vessels.

In the operation phase, the CO_2 vessel and vessel for seismic monitoring of the reservoirs are expected to cause a disturbance to seabirds. The extent of the impact is similarly expected to occur in the **immediate vicinity** of the vessels.

<u>Intensity</u>

It is expected that seabirds will be impacted by disturbance from vessels in the construction phase. However, as relatively few vessels are required over a relatively short period of time (around 2 months) and the impact only occur in the immediate vicinity of the vessels, the impact is not expected to result in significant impacts on the population dynamics of any species found in or around the project area. Furthermore, the North Sea is generally a busy area in relation to ship traffic and seabirds living in these waters are likely accustomed to the high level of disturbance. The intensity of the impact is therefore assessed as **low**.

In the operation phase, the frequent presence of the CO_2 vessel and annual presence of the seismic survey vessel result in a low force of impact. It will not result in physical impacts or changed function of the population of seabirds in the area. The intensity of the impact from disturbance from vessels in the operation phase is therefore also assessed as **low**.

<u>Duration</u>

Disturbance from vessels is expected throughout the entire construction period lasting in total around 2 months. Vessels will generate disturbance which ceases once the vessel is outside flush-distance for birds. Intermissions in vessel activity is expected during the construction phase where no impact on birds is expected. The duration of impact from disturbance from vessels is therefore conservatively assessed as **medium-term**.

In the operation phase, one CO_2 vessel is expected to carry out a maximum of 130 injection cycles per year. Despite the high frequency of this impact, the impact cease immediately when the boat is not present, therefore the impact of the disturbance from vessels is assessed to be **very short-term**.

In the operation phase, reservoir monitoring is carried out by a single vessel every other year lasting approx. 5-10 days per campaign. The maintenance operations during the operation phase will each last between 1 to 2 days. The impact from the disturbance of these vessels is assessed as **short-term**, as each operation lasts less than one week.

<u>Consequence</u>

The vulnerability of seabirds to disturbance from vessels is assessed as low. The duration of impacts associated with disturbance from vessels is generally very short to medium-termed. Impacts on seabirds are expected to occur in the immediate vicinity of all vessels and be of low intensity in both the construction and operation phase. The consequence of the impact of disturbance from vessels to seabirds is assessed as **negligible**.

Mitigation measures

No significant impact is assessed for disturbance of vessels on seabirds and mitigation measures are therefore not considered necessary.

Light

Vulnerability

A significant number of birds migrate across the Greater North Sea at least twice a year and/or use the Greater North Sea as a feeding and resting area. This includes the project area, which constitutes a resting place for breeding populations of guillemot and razor bills from both Norway and Scotland during winter (Buckingham et al., 2022; Hestem, 2019; Thaxter et al., 2012).

The migratory behaviour is an essential part of the natural lifecycle of seabirds, and its disruption may have severe consequences for the impacted species. Some species migrating across or otherwise using the area may become attracted to offshore light sources, particularly during nocturnal migration or in deteriorating weather conditions where visibility is limited (R. A. Ronconi et al., 2015). However, the influence of light from offshore installations on seabirds is not well understood and the evidence is not sufficient to conclude if there is an impact at the population level (Marappan et al., 2022). The vulnerability of birds to light emissions is therefore conservatively assessed as **medium**. Impacts from safety lights on the Nini A platform and vessels in both phases are assessed as reversible as seabirds are highly mobile and the impact is expected to cease once seabirds are out of range of the impact.

Geographical extent

In the construction phase, light emissions from the vessels and the platform may potentially impact seabirds (Gjerdrum et al., 2021). These sources of light are expected to only impact seabirds in the **local**.

Safety lights are present at Nini A and vessels throughout the construction and operation phase. Not much is known about the extent of impact on birds from these types of light emissions. However, as safety lights are generally a low-intensity light sources, the impact from safety lights is expected to have a smaller extent. The extent of the impact is therefore assessed as in the **local** in both the construction and operation phase.

Intensity

Light emissions from safety lights on the Nini A platform and vessels are only expected to impact locally of the source. Although some individuals may be impacted by these light sources, impacts are not expected to cause adverse effects at the population level. The intensity of the impact from light on seabirds is therefore assessed as **low**.

Duration

The impact from light on seabirds is assessed as **medium-termed** in the construction phase as vessels will be illuminated during the approx. 2 months of construction activities.

Safety lights are present at Nini A and all vessels throughout the construction and operation phase and the impact is therefore assessed as **permanent**. Light emissions from vessels are not expected continuously throughout the construction or operation phase but at a certain frequency as vessels move in and out of the project area, thereby only impacting seabirds while vessels are present.

Consequence

The response of seabirds to light emissions from offshore installations, and vessels is not well documented in the literature. However, as artificial light may pose a risk to migratory behaviour thereby potentially leading to reproductive failure, the vulnerability to light emissions have been conservatively assessed as medium. In the construction phase, the potential attraction of birds and disruption of migratory behaviour is assessed to occur locally around the light sources and the impacts are assessed

- to be of low intensity and of medium-term duration.

In the operation phase, safety lights at the Nini A platform and on vessels constitute a permanent impact. However, impacts are expected to occur locally to the source and any impacts on seabirds arising from these light emissions are expected to be of low intensity without implications at the population level.

Impacts from light in both phases of the project are assessed as reversible as seabirds are expected to move around and the impact is expected to cease once they are out of impact range. Based on this, the consequence is assessed to be **negligible** with no impact at the population level for seabirds.

Mitigation measures

No significant impacts are expected from light emissions on seabirds and mitigation measures are therefore considered unnecessary.

Overall assessment

The vulnerability of seabirds to disturbance from vessels and light emissions is assessed as low to medium and impacts are expected to be of low intensity and occur in the immediate vicinity or locally around the sources. Impacts are medium-termed in the construction phase and very short-term to permanent in the operation phase resulting only in reversible impacts. No significant implications for the population dynamics of seabirds were found in the project area. The overall assessment is that impacts to seabirds are negligible in both the construction and operation phase.

Table 11-20 Overall assessment of impacts on seabirds.

Impact	Vulnerability	Geographical extend	Intensity	Duration	Consequence
Construction Phase					
Disturbance from vessels	Low	Immediate vicinity	Low	Medium	Negligible
Light	Medium	Local	Low	Medium	Negligible
Operation Phase					
Disturbance from vessels	Low	Immediate vicinity	Low	Short	Negligible
Light	Medium	Local	Low	Permanent	Negligible

Cumulative impacts

No other projects, planned or in operation, are assessed to have cumulative impacts with the current project. It is therefore assessed that cumulative impacts are irrelevant.

Transboundary impacts
No significant transboundary impacts have been identified.

Gaps in knowledge and limitations
The distribution and biology of seabirds associated with the North Sea is relatively well known. However, considerable uncertainties are associated with the effect of artificial light on seabirds. Estimates of mortality of seabirds due to light emissions are often imprecise and difficult to translate into significance at the population level. Furthermore, knowledge on nocturnal migratory behaviour is generally lacking as well as an understanding of the underlying factors controlling annual variations in vo
umes of migrating birds.

11.10 Annex IV species

All species of whales are listed in the Habitats Directive Annex IV, and special protective measures apply. All EU member states must prohibit among others:

- all forms of deliberate capture or killing of individuals of these species in the wild
- deliberate disturbance of individuals of these species, e.g. during breeding, rearing, hibernation and migration
- deterioration or destruction of breeding sites or resting places of these species
- the use of all indiscriminate means of capture or killing capable of causing local disappearance and serious disturbance to populations of such species

The project area is not a known breeding site for cetaceans, and no deliberate capture or killing is foreseen.

11.10.1 Potential impacts

The potential impacts on Annex IV whales are described in section 11.8.1.

11.10.2 Methods and data

The methods and data used for the assessment of impacts is described in section 11.8.2.

11.10.3 Assessment of impacts

The project area is not a known breeding site for minke whale or white-beaked dolphin (section 10.5.4). As described in section 10.5.4, harbour porpoises are known to breed in the North Sea including Danish waters. Specific breeding grounds for harbour porpoises have not been identified but areas with high concentrations of individuals during breeding season are generally considered to be essential for the population and may constitute suitable breeding habitats (Sveegaard et al., 2011). The project area is not considered a high-density area and it is therefore assessed to be of no special importance as a breeding area for harbour porpoises.

The project does not include deliberate capture or killing of Annex IV species.

Modelled underwater noise of activities in the construction and operation phase, show that there is a small risk of physical of injury (PTS or TTS) for harbour porpoises. This is related to the use of the ROV equipment (HiPAP USBL system) emitting high frequency noise. The risk is restricted to the immediate vicinity of the Nini A platform and the presence of the vessel will most likely result in displacement of marine mammals in the immediate vicinity, thereby reducing the risk of physical injury to near zero. This assessment is described in further detail in section 11.8.3 for underwater noise. The model results show that there is a risk of displacing a low number of animals from the project area, since noise levels are high enough to cause avoidance behaviour.

In the operation phase, seismic surveys will occur every other year starting in March 2026, meaning that the following campaign will be in March 2028. All 5-10 day seismic monitoring campaigns will be carried out in March, when the most abundant whale species; harbour porpoise, is the least vulnerable. By using a soft start procedure (section 5.5.4) which is standard in Danish waters, it is assessed that there is no risk of PTS or TTS for any of the three species. Avoidance behaviour for harbour porpoises is assessed to occur in a distance of up to 6.1 km from the survey vessel. As described in section 11.8.3, the number of animals that are expected to be displaced constitute less than 0.02% of the population in the North Sea. With the same avoidance distance for minke whales and white-beaked dolphin, the displacement would affect 0.01% of both total North Sea populations. The impact is reversible.
In the construction phase, the duration of the impact is **medium-termed**. In the operation phase, duration **short-termed**. The area that is impacted is relatively small compared to the daily foraging habitat and will only affect a very limited number of whales.

Impacts caused by disturbance from vessels and lights are assessed in section 11.8.3 and it is concluded that the impacts are short-termed and happens in the immediate vicinity of the activities and therefore the impact is **negligible**.

<u>Mitigation measures</u>

It is assessed that no mitigation measures are needed as impacts are negligible or limited and seismic monitoring with the largest impacts on marine mammals follow standard soft start procedures for minimizing impacts.

Overall assessment

Based on the above, it is concluded that the project does not cause impacts that may affect Annex IV species' chances of survival, breeding success or reproductive ability. The ecological functionality of breeding and/or resting sites is maintained.

Cumulative impacts

There are no approved plans or projects that overlap in time or impacts with the impacts from *Project Greensand Future* (section 9.3) and therefore no cumulative impacts on marine mammals are anticipated.

In the construction phase, baseline monitoring of seismicity with ocean botton stations (OBSs) and CO_2 leakage with a lander will be conducted in Q1-Q4 2025 and completed prior to first CO_2 injection. These activities are covered by separate application/permit. OBSs and lander will be deployed in Q1 2025 and recovered in Q4 2025. Only recovery of OBSs will include ROV operation. In the construction phase, the impact distance for avoidance is up to 4.2 km for harbour porpoises.

Transboundary impacts

Impacts in the construction phase are very local and only impacts marine mammals in the immediate vicinity of the Nini A platform in the project area. In the construction phase it is therefore assessed that there are no transboundary impacts.

In the operation phase the reservoir monitoring takes place in a survey area where the closest distance is around 1,200 m from the Norwegian EEZ. Since the airguns used during the survey can cause avoidance behaviour for marine mammals in a distance of up to 6.1 km there could be a displacement of animals in Norwegian waters. Since the impact is short-termed (5 days) and reversible and only affect a very limited number of animals it is assessed to have negligible transboundary impacts on Annex IV species.

Gaps in knowledge and limitations

Knowledge on impacts on marine mammals is well understood as they have been monitored from oil and gas installations for decades and guidelines for noise impacts are updated regularly, most recently in 2022 (Energistyrelsen, 2022b). There are no guidelines for avoidance from underwater noise for minke whale and white-beaked dolphin, but the value provided by (Tougaard, 2016) (145 dB re1UPa) is largely accepted by DEA to be applied to all marine mammals, that inhabits the Danish North Sea.

11.11 Protected nature

11.11.1 Potential impacts

Protected nature refers to Ramsar sites, Important Bird Areas (IBA's), Valuable and Vulnerable Areas (SVO), and Marine Protected Areas (MPA's) (Figure 10-22). As Ramsar and IBA areas are coinciding with Natura 2000 SPA areas, these are collectively described in section 10.6 and assessed in chapter 16.1. Potential impacts on MPA and SVO areas can derive from physical disturbance (sediment resuspension) and underwater noise. The nearest MPA and SVO-areas are located > 75 km and approx. 11 km, respectively, from the project area and 4.6 km to the monitoring OBS (seismicity), therefore no impact is expected from sediment resuspension as it is expected that sediments settle within the immediate vicinity of the source. Only the Norwegian SVO-areas are assessed in the following in relation to impacts from underwater noise due to their proximity to the project area.

Potential impacts to SVO-areas relate to:

- Underwater noise i.e., in the construction phase, underwater noise is expected from vessels, ROV operations and the seismic surveys. In the operation phase, underwater noise is expected from seismic surveys, the seismic monitoring vessel, the CO_2 vessel and from support vessels used for maintenance operations using ROV.

11.11.2 Methods and data

An underwater noise model has been developed and assessed for fish as part of this EIA (see section 11.7.2). Aside from the underwater noise modelling, this assessment is supported by existing data and best available scientific literature as well as previous environmental impact assessments of similar projects.

The SVO area is the NS2 "the sand eel fields". Sand eel are the target species of the protected area and the following assessment. Research on impacts on fish from underwater noise is relatively scarce and has only been carried out for a few fish species. The modelling is based on the newest and most comprehensive data and includes the two species herring and cod and two life stages of cod (juvenile and adult) found in the project area that represent different sensitivities to noise, some of which is consi

ered to exhibit the highest sensitivities. However, the threshold value for TTS in fish has been based on freshwater species and some uncertainty exist for the applicability of this threshold value to saltwater species. As the modelling is based on a worst-case approach dealing with the response from the most sensitive species and life stages, the data basis of this assessment is considered to be sufficient to assess the impacts to sand eel or fish in the sand eel fields from underwater noise.

11.11.3 *Assessment of impacts*

In the construction and operation phase, underwater noise only causes an impact in the immediate vicinity of the vessel. With 11 km from the project area and 4.6 km from the monitoring OBS to the SVO-area, no impact is expected in this protected area.

In the operation phase, underwater noise from seismic with application of soft start procedure reduces TTS distance to 0 m. However, applying soft start procedure to seismic monitoring does not remove the risk of mortal injury to larvae. seismic with soft start may potentially lead to mortal injury in larvae at a range of 100 m from the source. As seismic is carried out at least 4.6 km from the Norwegian EEZ border, the impact will not reach into the SVO-area. Therefore, underwater noise will not be assessed further as no impacts can be expected in the SVO-area.

12. ASSESSMENT OF SOCIAL IMPACTS - PLANNED ACTIVITIES

12.1 Material assets

In this section impacts on material assets are assessed. Material assets include existing oil and gas infrastructure, offshore wind farms (OWFs), cables and pipelines (termed offshore infrastructure in the following) and ship traffic. Potential impacts to ship traffic are assessed in section 13.3 and is therefore not part of this chapter. Descriptions of offshore infrastructure in the North Sea are found in section 10.7.

12.1.1 Potential impacts

Potential impacts to material assets relate to:

- Restriction zones i.e., in the construction phase, a CO_2 leakage monitoring system will be deployed on the seabed near the legacy well (Nini 4). This system will be protected by a restriction point to mark and protect against anchoring and trawling.

The offloading system installed in the construction phase is located within the already existing restriction zone of 500 m around the platform and will therefore not be assessed further in this section. Anchoring and trawling is restricted within the entire zone. This safety zone already applies and will remain throughout the entire operation phase.

12.1.2 Methods and data

The following impact assessment of the project on material assets is based on available mapping of the existing offshore infrastructure. Offshore infrastructure is treated collectively in the following.

12.1.3 Assessment of impacts

Restricted zones

Restricted zones i.e., in the construction phase and throughout the operation phase a restricted zone will be imposed by the installation of offloading system and a restriciton point by the CO_2 leakage monitoring system. The project needs to comply with regulation no. 939 of 27/11/1992 on protection of sea cables and submarine pipes. Under the Administrative Order on protection of subsea cables and pipelines, subsea pipe fields are given a 200 m wide restriction zone along and on each side of the pipeline. The subsea pipeline used in the offloading system lies within in the already existing restriction zone of 500 m around the platform and is not assessed further.

In the operation phase, there will be continuous monitoring of potential CO_2 leakage from the legacy well (Nini 4). The CO_2 leakage monitoring system will be placed at the seabed and marked with a navigation buoy.

<u>Vulnerability</u>

There are no additional impacts from the established restriction point to mark the CO_2 leakage monitoring system, as there is no existing offshore infrastructure present in the project area besides subsea cables (telecommunication, Figure 10-23), which are not affected by the restriction point. The impact is irreversible within the operation phase where the restriction point persists, but reversible after the installations are removed. The vulnerability of existing offshore infrastructure to restricted zones is assessed as **low**.

Geographical extent

The restriction point related to the CO_2 leakage monitoring system restricts anchoring and trawling. This point is far from other offshore activities. On these grounds, the geographical extent of the impact is assessed as **immediate vicinity**.

Intensity

Ships may not, without urgent necessity, anchor in the safety zones established for such infrastructure. In the restriction zones, trawling, suction dredging, fishing for stones as well as any use of tools or other gear that is dragged on the seabed is prohibited. The fisheries should be informed to avoid the restriction zones and points during the operational period. The CO_2 leakage monitoring system will be marked with a buoy to show the restriction point to avoid and the intensity of the impact is therefore assessed to be **medium**.

Duration

The restriction point of the CO_2 leakage monitoring system will persist throughout the operation phase and will result in a **permanent** impact.

Consequence

The restriction point of the CO_2 leakage monitoring system where anchoring or trawling is restricted is assessed to be of medium intensity, in the immediate vicinity and of permanent (operation phase) duration. The overall consequence from restricted zones is assessed to be **negligible**.

Mitigation measures

No significant impact is expected from restricted zones and mitigation measures are therefore not considered necessary.

Overall assessment

The vulnerability of existing offshore infrastructure to restricted zones is assessed as low and the geographic extent of the impact is in the immediate vicinity. The intensity of impacts is assessed to be medium during the operation phase. The duration of impact is permanent during operation and the impact is only reversible after end of the project. Overall, the impact on material assets is considered to have negligible consequences as the impact area is very small.

Table 12-1 overall assessment of impacts on existing offshore infrastructure.

Impact	Vulnerability	Geographical extend	Intensity	Duration	Consequence
Operation Phase					
Restricted zones	Low	Immediate vicinity	Medium	Permanent	Negligible

Cumulative impacts

No other projects, planned or in operation, are assessed to have cumulative impacts with the current project. It is therefore assessed that cumulative impacts are irrelevant.

Transboundary impacts

No significant transboundary impacts have been identified.

Gaps in knowledge and limitations

Existing offshore infrastructures are well accounted for in the North Sea and the extent of restricted zones is known to a high degree. As such, no gaps in knowledge or limitations for this assessment have been identified and the conclusion of this assessment is considered sound.

12.2 Cultural heritage

Prior to initiation of project activities, a geophysical site survey will be completed to screen the area for obstacles. The survey will be able to detect potential cultural heritage objects (CHOs). The design and execution of the site survey is coordinated with The Agency for Culture and Palaces. If any potential CHOs are identified in the project area, the necessary protection and handling procedures will be initiated in coordination with The Agency for Culture and Palaces and the responsible museum, Moegaard Museum, before further activity can proceed.

Even the highest standard of geophysical survey may not identify every single CHO of importance. Therefore, a chance finds-procedure will be implemented to manage actions in the event of chance finds of objects that could potentially be a CHO. The chance finds-procedure will prescribe notification instructions to inform the national cultural heritage agencies of the finds, contractor roles, management actions, responsibilities, and lines of communication.

12.2.1 Potential impacts

Potential impacts on cultural heritage are related to two impact mechanisms:

- Physical footprint i.e., the area occupied by any physical structure. In the construction phase, a physical footprint is expected from the offloading system (subsea pipeline, anchors and concrete mattresses) and the CO_2 leakage monitoring system (lander with monitoring system connected to an anchor block and a buoy). These structures are expected to result in a physical footprint in the construction phase when they are installed persisting throughout the operation phase and constitute a permanent loss of substrate.
- Physical disturbance of the seabed i.e., in the construction phase, installation of structures on the seabed that potentially cause resuspension of sediment.

12.2.2 Methods and data

The following impact assessment of the current project on cultural heritage is based on existing data such as public databases (Slots- og Kulturstyrelsen, 2022), empirical studies, best available scientific literature along with previous environmental impact assessments from similar projects.

12.2.3 Assessment of impacts

Physical footprint

Installed structures leave a physical footprint on the seafloor that can cause direct damage to CHOs, for example ship and plane wrecks, which are the most likely CHOs to be found within the project area. Physical footprint on the seabed during the construction and operation phase has the potential to damage cultural heritage sites/objects or render these inaccessible for future research during the lifetime of the project.

The long-term presence of protruding structures on the seabed has the potential to alter sedimentation patterns and/or cause erosion around CHOs due to local changes in currents in the areas where the structures are situated. However, as assessed in section 11.2, the local currents are not expected to change due to presence of structures on the seabed or in the water column. The impact from changed currents on sedimentation and erosion is therefore not expected and not assessed in this section.

<u>Vulnerability</u>

Due to the high importance of CHOs, the protection under the Danish Museum Act (Consolidation Act no. 358 of 08/04/2014 § 29g) as well as the low resilience to potential impacts from construction activities, the vulnerability of CHOs to the physical footprint from structures is assessed as **high** in both the construction and operation phase. Both temporary and permanent structures may lead to irreversible damage to the CHO.

Geographical extent

The relatively small physical footprint on the seabed is assessed to have a potential impact on CHOs in the **immediate vicinity**.

Intensity

The placement of structures on the seabed can result in physical impact and permanent loss and damage of CHOs when placed on the sediment or operated in the water column. CHOs are often fragile and sensitive to physical impacts, and the intensity of the impact from physical footprints is assessed as **very high**.

Duration

The impact from physical footprint of structures is of **permanent** duration as it potentially renders the CHO inaccessible for future research during the lifetime of the project.

Consequence

CHOs are of high cultural and historical importance and have low resilience to direct damage from the physical footprint of structures and are therefore highly vulnerable. The geographical extent of the potential impact on CHOs is assessed as being in the immediate vicinity. The impact is assessed to be of very high intensity due to the fragile nature of CHOs and significant physical impact from installed structures on CHOs. The duration of the impact is assessed as permanent. As described in section 10.8, no CHOs have been found near the project area. The overall impact on cultural heritage physical footprints of construction and operation phase activities is assessed to be **limited**, as no impact is expected to occur since no CHOs have been found in the area.

Mitigation measures

No significant impacts are expected from physical footprint on CHOs, and mitigation measures are therefore considered unnecessary. Furthermore, the geophysical site survey will provide verification on whether protection measures of findings need to be in place. In the case of chance finds, these will be reported to the relevant authorities and further action identified and coordinated, if needed.

Physical disturbance of the seabed

Construction and placement of structures near or on the seabed can lead to physical disturbance of the seabed and damage to any cultural heritage, for example ship and plane wrecks, which are the most likely CHO to be found within the project area. During the construction phase, installation of the offloading system may cause resuspension of sediment.

Vulnerability

Due to the high importance of CHOs, the protection under the Danish Museum Act (Consolidation Act no. 358 of 08/04/2014 § 29g) as well as the low resilience and reversibility to direct damage, the vulnerability of CHOs to physical disturbances from subsea pipelay is assessed as **high**.

Geographical extent

Based on the relatively small extent of the activities, the geographical extent of the potential impact from physical disturbance on CHOs is assessed as being in the **immediate vicinity**.

Intensity

Installation of the subsea pipeline and protective concrete mattresses can result in physical disturbance of the seabed by causing resuspension of sediments. CHOs are often fragile and sensitive to physical disturbance. The potential resuspension of sediment is however small due to the small dimensions of the installed structures and because no trenching is required.
Based on this, the intensity of the impact from physical disturbance of the seabed is assessed as **low**.

Duration

The installation of structures is expected to take 7 + 1.5 days in which physical disturbance of the seabed may occur. The impact is not expected to last beyond this timeframe. The duration of the impact is therefore assessed as **short-term**.

Consequence

CHOs are of high cultural and historical importance and have low resilience and reversibility to direct damage from physical disturbance of the seabed and are therefore highly vulnerable. The impact from physical disturbance of the seabed is assessed to be of low intensity, in the immediate vicinity, and of short duration. Due to the low likelihood of encountering CHOs within the project area, the overall impact on cultural heritage from physical disturbance of the seabed during construction phase activities is therefore assessed to be **limited**.

Mitigation measures

No significant impacts are expected from physical disturbance of the seabed on CHOs, as the likelihood of an impact to occur is low and mitigation measures are therefore considered unnecessary.

Overall assessment

The vulnerability of CHOs to physical footprint and physical disturbance of the seabed is assessed as being high due to the fragile nature, and cultural and historical importance of the objects. The impact of physical footprint and physical disturbance of the seabed on cultural heritage is assessed to be of very low to very high intensity, in the immediate vicinity, and of short to permanent duration. However, the area has been scanned and commercially utilised prior to this project and due to the very low likelihood of encountering cultural heritage within the project area, the overall impact on cultural heritage is assessed as limited.

Table 12-2 overall assessment of impacts on cultural heritage.

* due to very low likelihood of encountering cultural heritage objects within the project area.

Impact	Vulnerability	Geographical extend	Intensity	Duration	Consequence
Construction Phase					
Physical footprint	High	Immediate vicinity	Very high	Permanent	Limited*
Physical disturbance of the seabed	High	Immediate vicinity	Low	Short	Limited*
Operation Phase					
Physical footprint	High	Immediate vicinity	Very high	Permanent	Limited*

Cumulative impacts

No other projects, planned or in operation, are assessed to have cumulative impacts with the current project. It is therefore assessed that cumulative impacts are irrelevant.

Transboundary impacts
No significant transboundary impacts have been identified.

Gaps in knowledge and limitations
The seabed of the project area has been surveyed on multiple occasions during geophysical and debris surveys. An archival control from Moesgaard Museum will be carried out as an initial step to ensure a marine archaeological interpretation of the potential for CHOs in the project area.

12.3 Fisheries

12.3.1 Potential impacts
Impacts on fish (resource) have been evaluated in section 11.7, and as a result, the following impacts have been scoped out from the potential impacts to commercial fisheries:

- Underwater noise may impact fisheries by impacting fish at the population level thereby affecting fish stock. The impact on fish from underwater noise is assessed to have limited consequences without adverse effects on the population metrics (section 11.7) and is therefore not treated further in relation to impacts on fisheries.
- Physical footprint of the area of the seabed that is occupied will be negligible compared to the existing fish habitats. These structures may act as potential habitats and foraging sites for some fish species, thereby resulting in a net-positive effect for the commercial fisheries. The consequence of physical footprint in the operation phase is assessed as negligible for fish species which are associated with sandy substrate (section 11.7) and is therefore not treated further in relation to impacts on fisheries. For fish species living in reef habitats and which may be attracted by artificial reef-like structures, a negligible positive effect is expected due to a local reef effect.
- Physical disturbance of the seabed can disperse the fish from fishing grounds as they may display avoidance behaviour. Due to the short construction phase and relatively small dimensions of the structures, very little resuspension of sediment is expected. The overall impact on fish from physical disturbance of the seabed was assessed to be of negligible consequence (section 11.7) and is therefore not treated further in relation to impacts on fisheries.
- Light emissions can potentially attract or disperse fish, dependent on the species, which in turn can affect the commercial fisheries. The vulnerability of fish is generally assessed as low to light emissions and the impact is only expected to occur in the immediate vicinity, without significance at the population level for fish. The impact of light emissions from the platform and vessels is assessed to have negligible consequences for fish (section 11.7) and is therefore not treated further in relation to impacts on fisheries.

Potential impacts on fisheries assessed in the following relate to:

- Restricted zones i.e., in the operation phase, a new restriction point will be imposed around the CO_2 leakage monitoring system in addition to the already existing safety zone of Nini A. The project needs to comply with Regulation no. 939 of 27/11/1992 on protection of sea cables and submarine pipes. Under the Administrative Order on protection of subsea cables and pipelines, subsea pipe fields are given a 200 m wide restriction zone along and on each side of the pipeline, which lies within in the already existing restriction zone of 500 m around the platform. Further there will be a new restriction point related to the CO_2 leakage monitoring system. Ships may not, without urgent necessity, anchor in the restricted zones or near the points. In the restriction zones, trawling, suction dredging, fishing for stones as well as any use of tools or other gear that is dragged on the seabed are prohibited. The fisheries should be informed to avoid the restriction.

12.3.2 Methods and data

The following assessment is based on existing data from OSPAR on fishing intensity and landing data from the Danish Fisheries Agency in rectangles 42F4, 42F5, 42F6, 41F4, 41F5 and 41F6 over the past 10 years (2012-2022) as described in section 10.9. The distribution of the activity from the different commercial fisheries are presented for the period 2015 to 2018 (Figure 10-29). Together the data basis forms a relatively high resolution of the importance of the area to fisheries. The data basis is considered to be sufficient for this assessment.

12.3.3 Assessment of impacts

Restricted zones

Vulnerability

The North Sea constitute important fishing grounds. No fishing is allowed within the restriction zones. For the subsea pipeline, no additional restriction zone will be applied, since the 200 m zone around the pipeline lies within the already existing restriction zone of 500 m around the platform. Fisheries will be no more impacted from this restriction zone around the platform than they are today. However, a new restriction point will be placed for the CO_2 leakage monitoring system. This is not a restriction zone as such, but a point to avoid in order to protect the CO_2 leakage monitoring system against anchoring and trawling. The vulnerability of fisheries to restricted zones and points is assessed as **low**. Once structures imposing restricted zones or points are decommissioned the fishing ground will return to a pre-impact state.

Geographical extent

The restriction zone around the pipeline lies within the already existing restriction zone of 500 m around the platform (0.8 km^2), where anchoring and trawling is restricted. The restriction point related to the CO_2 leakage monitoring system will have similar restrictions. On these grounds, the geographical extent of the impact is assessed as in the **immediate vicinity**.

Intensity

Important fishing grounds in which trawling intensity is relatively high is located >4.5 km from Nini A (Figure 10-29). The restricted zone and restriction point are therefore not expected to coincide with important fishing grounds, but some alterations of the fisheries pattern in the area can be expected. The intensity of the impact is therefore assessed as **low**.

Duration

The offloading- and CO_2 leakage monitoring systems installed in the construction phase will persist throughout the operation phase. Restriction zone and point will be imposed throughout the operation phase resulting in a **permanent** impact where no anchoring or trawling is authorized.

Consequence

As the project area is located within an area of relatively low-level fishery in comparison to nearby high intensity areas (Figure 10-29), the addition of a restricted point related to the CO_2 leakage monitoring system to the already existing 0.8 km^2 around the Nini A platform, is assessed to have negligible significance to fisheries. The impact is assessed to be of low intensity, immediate vicinity and permanent duration. The overall impact to fisheries from restricted zones is assessed to have **negligible** consequences.

Mitigation measures

No significant impact is expected from restricted zone on fisheries and mitigation measures are therefore not considered necessary.

Overall assessment

The vulnerability of fisheries to expected impacts from activities related to the *Project Greensand Future* is assessed as low and impacts are assessed to be of low intensity, in the immediate vicinity, and of permanent duration. Overall, the impact on fisheries is considered to have negligible consequences.

Table 12-3 overall assessment of impacts on fisheries.

Impact	Vulnerability	Geographical extend	Intensity	Duration	Consequence
Operation Phase					
Restricted zones	Low	Immediate vicinity	Low	Permanent	Negligible

Cumulative impacts

No other projects, planned or in operation, is assessed to have cumulative impacts with the current project. It is therefore assessed that cumulative impacts are irrelevant.

Transboundary impacts

No significant transboundary impacts have been identified.

Gaps in knowledge and limitations

The distribution of the activity from the different commercial fisheries are presented for the period 2015 to 2018. The dataset on fishing intensity in the EU waters was created in 2020 by COGEA for the EMODNET (EMODnet, 2021d). Fishing effort data are only shown for vessels >12 m having a VMS, which is not a limiting factor, because smaller vessels are not expected to commercially fish in the area far offshore. Overall, the data basis for the assessment is considered sufficient.

13. IMPACT ASSESMENT - ACCIDENTAL EVENTS

This chapter describes possible impacts on the environment from unplanned events such as accidents or other uncontrolled events. Potential impacts from accidental events include:

- Oil spill in case of a blowout from injection well (13.1)
- CO_2 release in case of a blowout from injection well and CO_2 leakage from reservoir and from the offloading operation (section 13.2)
- Ship collisions (section 13.3)

As part of a blowout event, other impact parameters, besides oil and CO_2, have been considered. Impact from impurity in the gas's releases and lowering of seawater cause by CO_2 could results in impact from heavy metals, sulphide and ammonia, however there are found no noteworthy impact (DHI, 2023). This is not assessed further in this chapter.

Loss of well control is among the major emergency incidences that would have low probability of occurring but high risk of causing an uncontrolled gas and oil release into the marine environment All wells have a BOP (Blow out Preventer) installed topside to prevent and regulate well pressure. A blowout can result from a range of causes. These include loss of well control because of design, failure of the BOP, equipment and/or human failure.

The SINTEF Offshore Blowout Databases contains data on blowout releases that have occurred worldwide since 1955. Based on data from wells in Europe, an estimation on the frequency of operations that may result in a blowout have been conducted by looking at the respective frequencies per well year and upscaling these by the number of active wells in Europe (OOW, 2013). The probability of blowout during "production" is in the range of 9.7×10^{-6} per well per year (IOGP, 2019). However, the probability is based on an oil well in production the entire year around, whereas the CO_2 injection well will only be in use, when CO_2 is injected. Thus, the probability is expected to be even lower. As a result, the probability of a blowout in the injection phase is therefore assessed to be **low.**

Several mitigating measures are in place to ensure that loss of well control is highly unlikely. Even in the event of a blowout there are installations in place to ensure that the well is shut down and that a spill to the environment is kept to a minimum. A blowout will last until the well is under control again. This may take anywhere from a few hours if control can be regained using the safety systems present, up to several months if an additional well (relief wells) needs to be drilled to regain control over the original well. History shows that most wells can be brought back under control within one to a few days.

As the CO_2 injection well is in a mature oil reservoir there will be a risk of oil reaching the environment during a potential blow out in the operational phase. The following sections describe the potential environmental risk and mitigating measures related to both the potential CO_2 release and the associated oil spill associated to a blow-out.

13.1 Oil spill blowout

13.1.1 Oil spill response strategy

A blowout occurring in *Project Greensand Future* one year after injection start is predicted to result in an oil release rate of less than 100 m^3/d, while a blowout occurring after last injection, which is

8 years after injection start, is expected to result in an oil release rate of approximately 70 m^3/d (INEOS, 2022).

INEOS E&P A/S has developed and implemented an Oil and Chemical Spill Contingency Plan (OSCP) in case of an oil or chemical spill incident. The plan is approved by Authorities. In the event of an uncontrolled blowout, the OSCP will be initiated to mitigate the impact of the spill. The OSCP is established to address a response to a blowout with a daily rate of 4.400 m^3.

The general response techniques considerations and strategy options are summarized in Figure 13-1.

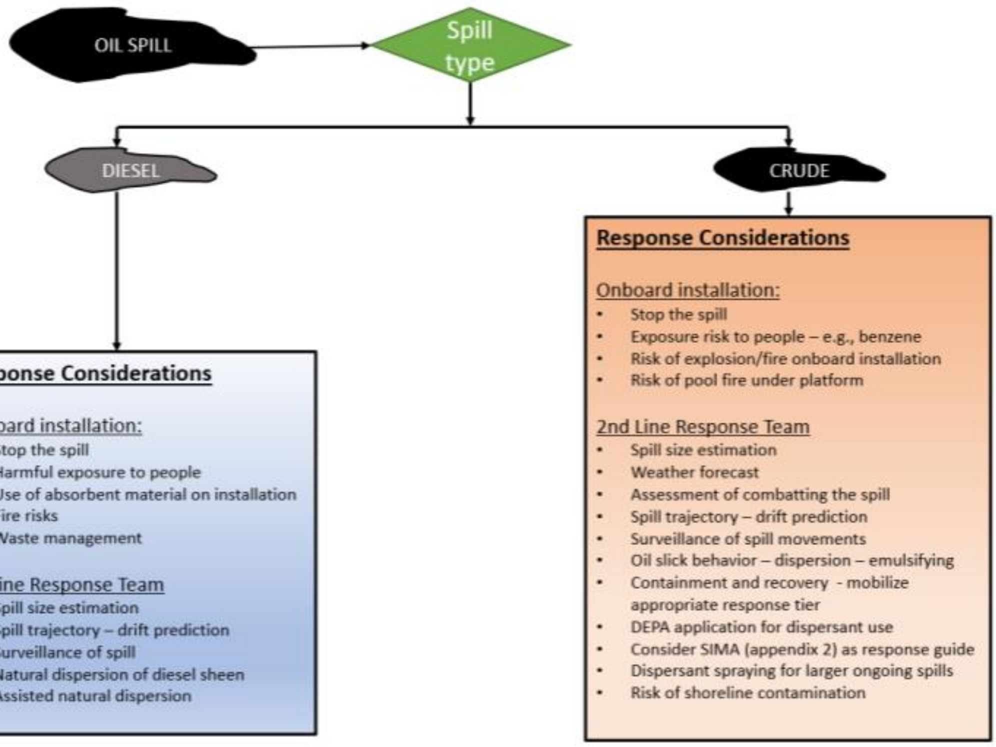

Figure 13-1 General Response Technique Considerations and Strategy Options

The Danish oil and gas producers in the North Sea TotalEnergies EP Denmark (hereafter TOTAL) and INEOS have as basis for this plan, established a legally binding cooperation arrangement for mutual assistance in case of an oil spill incident from one of the operators.

INEOS owns and maintains one containerized DESMI fast sweep oil C&R system permanently located on the Esvagt Innovator support vessel. The vessel is on permanent call and can immediately be mobilized for spill response in case of a spill incident from an INEOS operated field in Danish waters. This response resource is nominated as Tier 1 resource for INEOS.

The agreement between TOTAL and INEOS requesting each party immediately to provide and assist with available response resources in case of a spill incident at any of the parties' installations. For that purpose, TOTAL has two containerized DESMI fast sweep system identical to the INEOS equipment – one C&R system permanently stored on a PSV (Esvagt Dee), and one system stored on the offshore installation Crossway Eagle to be loaded on Havila Fano or a similar vessel suitable for purpose as decided by TOTAL. In case of a blowout further oil spill mitigation resources will be provided by Oil Spill Response Ltd (OSRL).

In Denmark, the preferred response strategy is containment and recovery of spilled oil. Use of dispersant is subject to a case-by-case approval from the DEPA. Details on the specific equipment available for the preferred response strategy (mechanical containment and recovery) for the three tier responses are outlined in Figure 13-2.

TIER 1	TIER 2	TIER 3
Oil spills are likely to be small and effect a localized area. The spill can be managed by using INEOS pre-arranged PSV resources.	A spill incident in which TOTAL response resources and support are required to control the spill	An incident where assistance is required from international (OSRL) and national resource (other operators based on OCES agreement).
Characteristics of a Tier 1 oil spill	**Characteristics of a Tier 2 oil spill**	**Characteristics of a Tier 3 oil spill**
Spill occurs within immediate site proximity and is likely above 5 m3	Spill extends beyond the immediate site proximity	Uncontrolled Well blowout/ loss of control / risk of total GBS inventory loss.
Spill can be easily managed using response resources available on site.	Tier 1 resources are overwhelmed	Spill has crossed international maritime boundaries
The spill source has been secured	Spill source cannot be immediately secured	Tier 1 and Tier 2 resources are overwhelmed

Figure 13-2 The tier response approach (INEOS, 2023b).

An elaboration of the available equipment for the different oil spill response strategies are provided in Table 13-1, and in Table 13-2 is listed the mobilisation time versus Tier 1-3.

Table 13-1 Equipment for the oil spill response strategies at INEOS E&P A/S offshore installations (INEOS, 2023b).

Resources Available		
Tier 1 Resources Local/ INEOS	C &R	One containerized DESMI Speed Sweep 1500 system (swath width 25 m) with an in-built Ro-Skim 1500 skimmer connected to a DOP 250 pump system (nameplate capacity[1]: 100-125 m^3/hour). The sweep system is operated along with a DESMI Ro-Kite 1500 allowing operation of the sweep system by one vessel. Limitations: Wave height: 3.5mtr, Ocean current: 3kts. Operational temp: -35 to 70degC For additional system details, please refer to Appendix 7 section 3.2.1.
Tier 1 Resources Local/ INEOS	C &R	The system is stored permanently on **Esvagt Innovator** - ready for immediate deployment. Esvagt Innovator liquid storage capacity for recovered oil: 1200m^3 The strike team equipment is owned by INEOS.
Tier 1 Resources Local/ INEOS	Surveillance	Aerial Surveillance by crew change helicopter or support vessels INEOS oil spotter and/or OSRL observer. Drift forecast modelling "Seatrack Web". OSRL oil spill modelling and OSRL Satellite imagery
Tier 2 Resources Regional / National TOTAL	C &R	One containerized DESMI Speed Sweep 1500 system with in-built skimmer (same for Tier 1). The system is stored permanently on **Esvagt Dee** – ready for immediate deployment. Esvagt Dee liquid storage capacity: 510m^3
Tier 2 Resources Regional / National TOTAL	C &R	One containerized DESMI Speed Sweep 1500 system with in-built skimmer (as for Tier 1). The system is stored on the TOTAL offshore installation **Crossway Eagle** – in case of mobilization the system it will be loaded on a suitable vessel- preferably Hvila Fanø -with a 1150 m^3 liquid storage capacity should be nominated. The two strike team systems are owned by TOTAL.
Tier 2 Resources Regional / National TOTAL	Surveillance	Aerial Surveillance by crew change helicopter or support vessels + OSRL observer. Drift forecast modelling "Seatrack Web". OSRL oil spill modelling and OSRL Satellite imagery
Tier 3 Resources International OSRL	C&R	OSRL is Tier 3 Provider for INEOS. Appendix 4 and : Readiness Dashboard | Oil Spill Response lists OSRL equipment. OSRL has a variety of booms and skimmer systems including fast sweep systems that can be operated by one vessel. Provision of personnel to operate and manage the incident is a part of the service. 50% shall be made available to INEOS). INEOS will hire suitable vessels of opportunity on the day.
Tier 3 Resources International OSRL	Surveillance	Aerial Surveillance by crew change helicopter or support vessels + OSRL observer. Drift forecast modelling "Seatrack Web". OSRL oil spill modelling and OSRL Satellite imagery
Tier 3 Resources International OSRL	Dispersant	Subject to DEPA approval before use. See relevant dispersant chemicals in Appendix 19 OSRL Spray equipment and dispersant stockpile max. 50% of 750 m^3 stockpile. Suitable vessels will be hired on the spot market by INEOS.

Table 13-2 Estimated Mobilisation Time per response options (INEOS, 2023b).

Response option	Response tier			Estimated mobilisation time (hours or days)	Operational duration (days)
	1	2	3		
Surveillance	✓	✓	✓	>6 hrs for Tier 1, 24 hrs for Tier 2/3	90
Containment and recovery	✓	✓	✓	>4 to 16 hrs for Tier 1, >9 to 24 hrs for Tier 2	90
Surface dispersant			✓	2 days (subject to DEPA permit)	90
Relief well			✓	90 days	NA

13.1.2 Modelled dispersion of oil from an unmitigated blowout

An oil dispersion modelling from an unmitigated blowout has previously been conducted for the NB-01 well on the Nini B platform located 8 km from the Nini A platform. The modelling scenario addressed a total spill of 26,280 m^3 oil over 90 days (292 m^3 d^{-1}) occurring in either summer or winter (Oil Spill Response Ltd, 2018). The modelled scenario is therefore a very conservative estimate of the impact that could occur in case of a blow-out, as the release rate is at least 3 times higher than the worst-case scenario for the CO_2 injection well at the Nini A platform. The model shows that most of the oil (>99.5 %) is expected to stay offshore, with less than 0.5% reaching the shore, however, the likelihood of oil reaching is high on certain locations on the Danish vest coast as indicated in Figure 13-3.

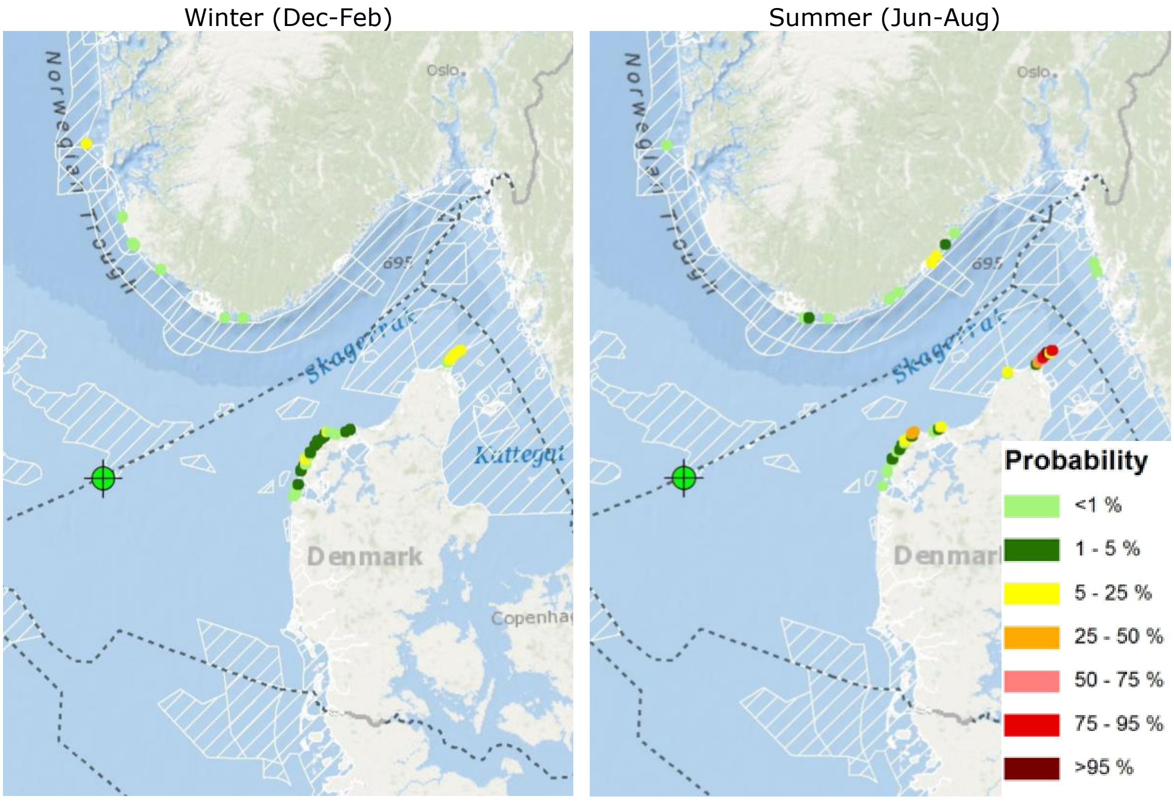

Figure 13-3 90-Day Surface Well Blowout – Shoreline Likelihood of Cell Impact – Winter (left) & Summer (right) (Oil Spill Response Ltd, 2018)

An unmitigated spill has an average 56 % likelihood of making shoreline impact (light oiling or minor occurrence of moderate oiling) if the spill happens in winter, but a 98% chance of shoreline impact if it occurs in summer. Denmark and Norway are the only two countries at risk of shoreline impact from a spill in either season, whilst a spill in summer could also impact the Swedish coastline.

Total concentration at the surface does not exceed 250 ppb during either season except around the release site. At 30 m depth, the water column impact is restricted to Denmark and Norway only and is predominantly less than 50 ppb, except around the release site. At 60 m depth, the water column impact is restricted to an area no more than 30 km from the release site and no greater than 50 ppb (Oil Spill Response Ltd, 2018).

The maximum exposure time at the surface is shown in Figure 13-4. The exposure time is below three days in a relative confined area in the central North Sea covering Danish and Norwegian waters.

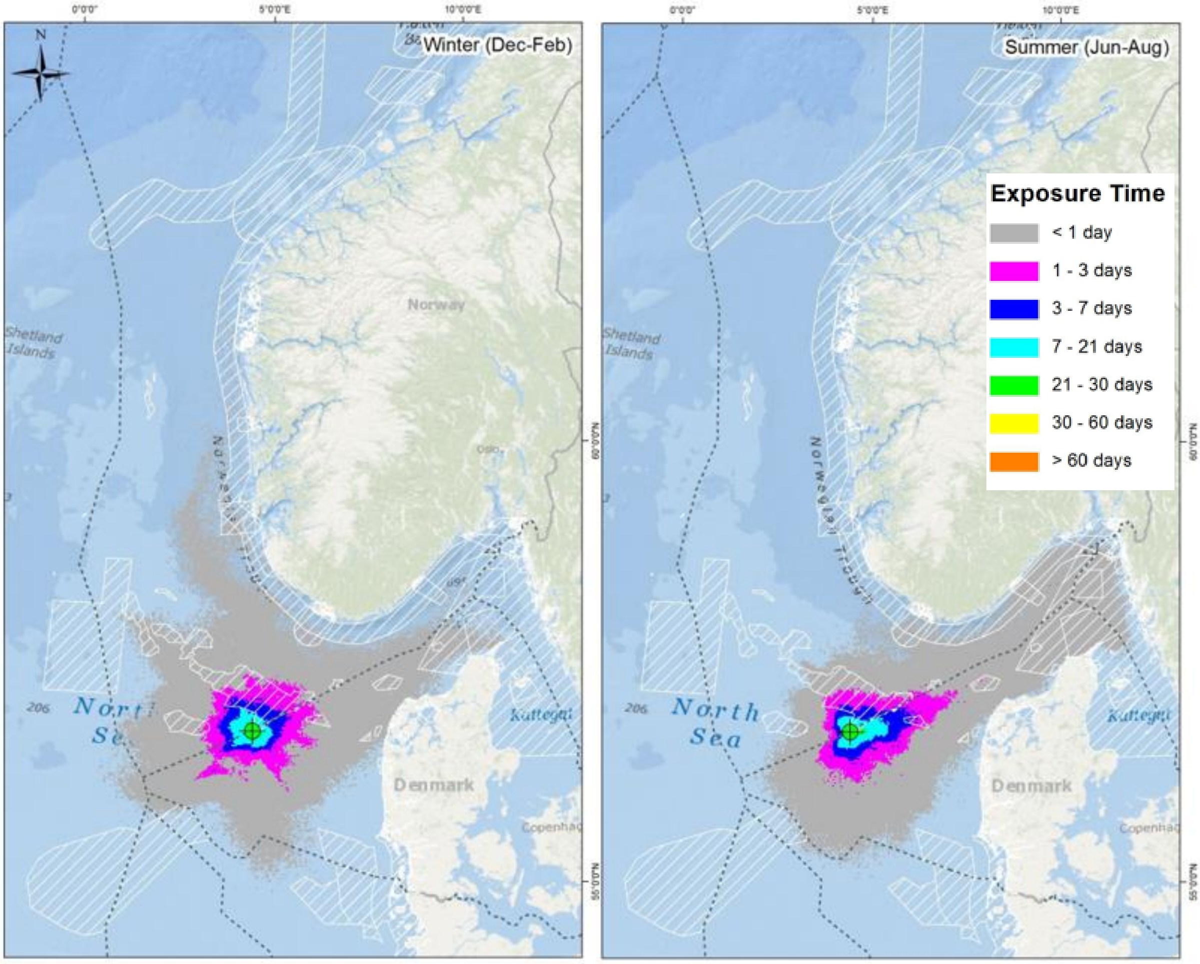

Figure 13-4 90-Day Surface Well Blowout – Water Column – Maximum Exposure Time at 0m depth – Winter (left) & Summer (right) (Oil Spill Response Ltd, 2018)

13.1.3 Oil spill impact assessment

During a blowout the oil is spread with the currents, simultaneous undergoing a wide array of processes including evaporation, dispersion, emulsification, dissolution, oxidation, sedimentation, and biodegradation. Oil components and their breakdown product may affect marine and coastal habitats and species. In general, the most severe impacts of an oil spill will occur if the oil slick passes concentrations of seabirds or if the oil ends up in near coastal waters and on shorelines.

An oil concentration of 25 ppb is generally considered to be a threshold at which the most sensitive marine life will begin to be affected. It is based on guidelines from the Norwegian Oil Industry Association concerning the effects of acute oil pollution on fish eggs and larvae (Norsk Olje og gass, 2003). 500 ppb is a general threshold level at which acute toxicity can be expected among the majority of marine species. In the following, the modelled dispersion of oil from an unmitigated blowout in section 13.1.2 is assessed in relation to potential impacts on relevant receptors.

Air quality

Evaporation of the lighter fractions in the oil spill will result in approximately up to 50% of the oil being emitted to air. This oil evaporation fraction is however highly depended on temperature, weather and emulsion rate. The spill may result in fumes containing oil contaminants that could pose a safety hazard. However, Nini A is located far from coastal areas and manned platforms are more than 10 km away. The wind exposed area will also result in the air quality being less vulnerable to the evaporation of oil components. The area affected is expected to be regional as most of the evaporation will take place immediately after the release of the oil to sea. The exposure period is restricted to the spill duration and the effect on air quality will be reversible. Considering the low probability of the spill to occur the overall consequence is regarded as **moderate**.

Water quality and plankton

The overall impact on water quality is assessed in section 11.3 and in following is further elaborated on impact from oil spill. Based on previous oil spill modelling the total concentration of oil at the surface is not expected to exceed 250 ppb except around the release site. At 30 m depth, the water column impact is restricted to Denmark and Norway only, and is predominantly less than 50 ppb, except around the release site. At 60 m depth, the water column impact is restricted to an area no more than 30 km from the release site and no greater than 50 ppb. The effect on water quality and plankton is therefore assessed to be restricted to a regional to international area. While the intensity of the impact will potentially be high on plankton production the effect is in general limited to the spill period i.e., result in a short to medium impact period. The water column in this part of the North Sea and particularly the Skagerrak area is exposed to strong currents that will result in rapid dilution of the oil and associated contaminants. The effect on the water quality and plankton production is reversible. The overall consequence of the impact is assessed to be **moderate**, however, there is a low probability of occurrence.

Sediments and benthic fauna

As mentioned above most of the oil evaporates, however, sedimentation of oil becomes an important factor particularly after the first 20 days of the spill resulting in increased accumulation of oil on the seabed in the predominant current direction.

Seabed habitats and flora and fauna may be affected depending on the extent of oil sedimentation in the area and the sensitivity of the associated flora and fauna. The vulnerability of submerged sandbanks and the associated fauna is assessed low to medium. Sedimentation will occur in a regional to international area and the intensity of the impact will be **medium**. The biota is adapted to natural re-suspension events and changes to the environment. The oil contaminants will be mixed with the sediment over time and a natural biodegradation process will take place. The reversibility of the impact is uncertain and will be very site specific and highly dependent on the extent of the spill.

The fauna associated with reefs are more vulnerable to sedimentation of oil as it is characterized by epibenthic species i.e. species that inhabit the surface of the sediment and reef structures. Reefs are located in appointed Nature 2000 areas as described in section 13.1.4. The area closest to the spill location is approximately 70 km away and the intensity of the oil sedimentation and impact is assessed to be medium. The impact can in some cases be irreversible, the overall consequence is assessed to be **moderate** for more sensitive habitat types such as reef, however **high** impact may occur locally for some biota and there is a low probability of occurrence.

Sea birds

Seabirds are most often highly vulnerable to oil spills as they are regularly in contact with surface water. Contact with oily water severely affects the buoyancy and the isolating quality of the plumage. Birds smothered in oil will usually die of cold or starvation or drown. Even very small spots of oil may be fatal, especially during winter. Mainly seabirds that stay on the sea surface for longer periods are at risk, but all types of seabirds may be affected (Troisi et al., 2016). The threshold for emulsion thickness considered as harmful for birds is 1 µm (French-McCay, 2009). Exposure above this threshold will lead to effects such as transferring oil to eggs reducing hatching success. Emulsion thickness of more than 10 µm may lead to immediate mortality.

In the event of a blowout incident at Nini A, the oil will most likely be transported towards northeast with the prevailing currents and pass the internationally important bird areas in the north-eastern part of the North Sea.

The affected area is important for gulls and auks (i.e., mainly little auk, but also guillemot and razorbill (Skov et al., 1995, 2007). The auks are particularly vulnerable to oil spills as they spend most of their time on the sea surface. The birds are particularly vulnerable during winter where most species are clustering. It is estimated that around 1 million birds are present in the North Sea during winter (Skov et al., 2007). The northern part of the Danish EEZ in the North Sea is considered an intermediate important conservation area for seabirds (Skov et al., 2007).

The emulsion thickness at the surface is expected to be less than 5 µm in most of the potentially impacted area while emulsion thickness above 5 µm will be restricted to areas closer to the blow-out location. The expected exposure time in areas with expected emulsion thickness above 5 µm will predominantly be limited to less than three weeks except areas close to the blowout location (Figure 13-4). Important bird areas in and immediately off the Wadden Sea will not be affected.

In summary seabirds are highly vulnerable to a major oil spill resulting in high intensity impact. The impact will be mainly local but may have a regional to international effect depending on weather and current direction. The duration of the impact is short to medium. The probability of such a blowout event is low and the overall consequence of the impact is assessed to be **high**.

Marine mammals

Oil from a blowout may affect areas where harbour porpoise, minke whale, white-beaked dolphin, grey seals or harbour seal, see section 10.5.4, may be encountered. Whales and seals are generally less vulnerable to oil spill than birds (i.e., threshold for seals is estimated to an oil emulsion thickness of 10 µm while the threshold for cetaceans is 100 µm, (French-McCay, 2009).

<u>Whales</u>

Comparative little is known about the effects of oil on cetaceans (whales, dolphins and porpoises) compared to e.g. waterfowl, but based on scant records of cetacean mortality associated with oil spills, it has been suggested that an oil spill may only affect small numbers of cetaceans. The threat of most immediate concern is inhalation of evaporated volatile toxic components from the oil slick on the sea surface if they emerge at the surface to breathe in the middle of an oil slick. This risk is greatest near the source of a fresh spill because volatile toxic vapours evaporate and disperse relatively quickly. When concentrated vapours are inhaled, mucus membranes may become inflamed, lungs can become congested, and pneumonia may ensue. Inhaled fumes from oil may accumulate in blood and other tissues, leading to possible liver damage and neurological disorders. As porpoises rely on blubber for insulation, their thermoregulatory ability does not seem seriously hampered by contact with oil (Helm et al., 2015).

Whales in the Central North Sea, may be affected in the unlikely incidence of a blowout at Nini A. However, the oil slick during a blowout is transported in a relatively narrow band in the direction of the currents and the density of whales is relatively low, see section 10.5.4.

Emulsion thickness above 100 µm is only expected within the immediate proximity of the blowout location. The overall consequence of the impact is assessed to be **moderate**.

Seals

Seals may be affected by direct contact with oil in a variety of ways. Oil can coat all or portions of their body surface and they may inhale toxic fumes of hydrocarbons, which affects their lungs. In addition, they may ingest oil directly or ingest oil-contaminated prey. As seals rely on blubber for insulation, their thermoregulatory ability does not generally seem seriously to be hampered by contact with oil. However, observations suggest that some individuals have become so encased in oil that they were not able to swim and subsequently drowned. In addition, observations also suggest that eyes, oral cavity, respiratory surfaces and urogenital surfaces are particularly sensitive to contact with oil (Helm et al., 2015).

It cannot be excluded that seals in the Central North Sea may be affected. However, as mentioned above, the area affected with emulsion thickness above 10 µm is limited to the area in the vicinity of the blowout and exposure time of such concentration will generally be less than three weeks. Seals are relatively rare in the Central North Sea and as the main concentration of seals are found in coastal areas that are less likely to be affected by high concentrations of oil. It is therefore not likely that a potential oil contamination of the modelled blowout will significantly directly affect the population of the seals in the North Sea.

In summary seals are less vulnerable to a major oil spill resulting in medium intensity impact. It is expected that marine mammals will leave areas that exposed to the oil spill. The impact will be mainly local but may have a regional to international effect depending on weather and current direction. The duration of the impact is short to medium. The probability of a blowout event is low, and the overall consequence of the impact is assessed to be **moderate**.

Fish

Fish eggs and larvae are considered the most sensitive life stages of fish in terms of acute impacts of spilled oil. The Norwegian Oil Industry Association use 25 ppb as the concentration at which fish eggs- and larvae and other sensitive marine life begin to be affected by oil components (Norsk Olje og gass, 2003).

The risk of encountering surface oil concentrations above 25 ppb that may affect fish eggs and larvae would be present found in the surface water within most of the Danish North Sea and along the southern coast of Norway. Eggs and/or larvae of cod, mackerel, plaice, herring and sand eels that may be encountered in this area may therefore be affected. However, the exposure is limited to a few days except in the vicinity of the blowout location.

Consequently, there is a little risk that larvae in the important nursery areas for larvae of cod, whiting, Norway pout, and haddock at the productive hydrographical front in the north-eastern part of the North Sea will be significantly affected by an oil blowout.

Important sand eel spawning grounds are found in Norway at the designated SVO area Vikingebanken located 11 km from the Nini A platform. It is almost certain that the area will be affected in the event of the modelled blowout scenario. The sheen could have a thickness of 5 – 50 µm and a total maximum concentration of 250 ppb. At the seabed, the maximum oil concentration is expected to be 25-50 ppb in this area.

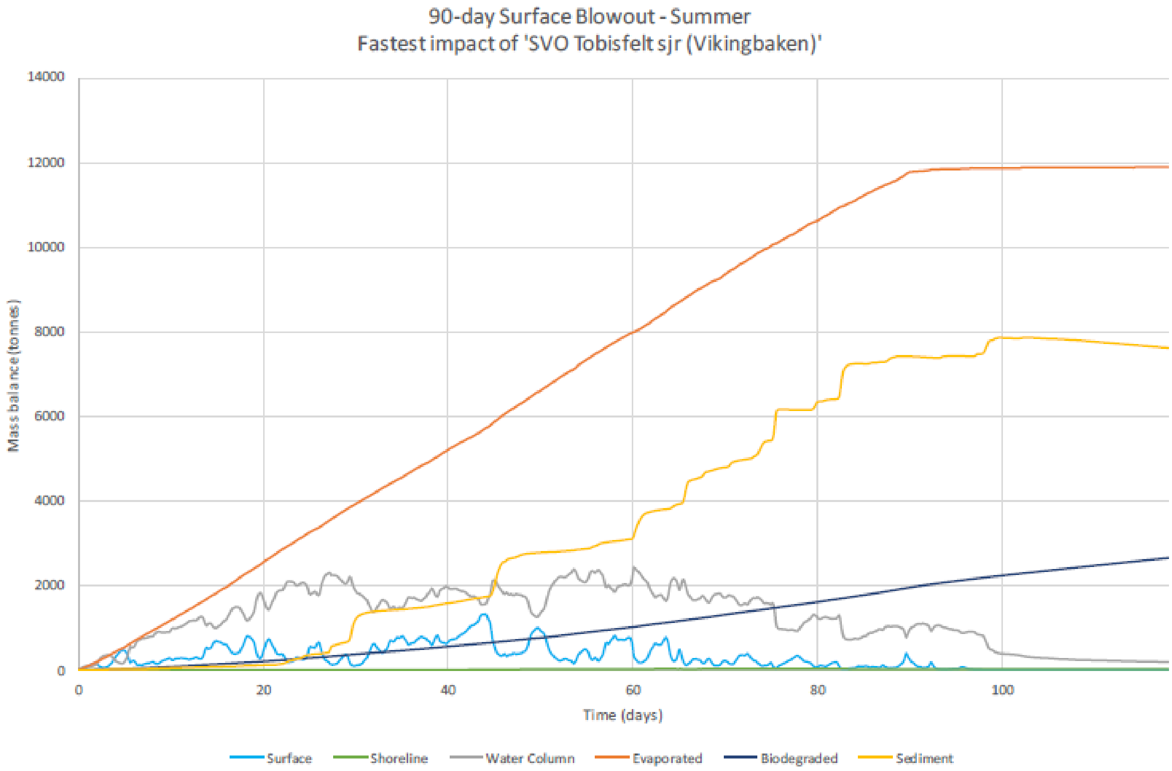

Figure 13-5 Mass balance plot for a worst-case surface blowout during summer (Oil Spill Response Ltd, 2018).

Both herring and sand eels are demersal spawners, and the eggs will be attached to the sediment. The eggs could therefore be affected in the vicinity of the blow-out location incl. the sand eel spawning grounds at Vikingebanken in Norway during the spawning season. Figure 13-5 indicates that the majority of the oil evaporates, however, sedimentation of oil becomes an important factor particularly after the first 20 days of the spill resulting increased with increased accumulation of oil on the seabed in the predominant current direction.

Once the eggs hatch, the larvae will predominantly be present where the concentration of zooplankton is highest which is expected to be in the mid-water column or closer to the seabed. At 30 m depth, localized maximum oil concentration is expected to be more than 100 ppm in the Vikingebanken area with most of the area will be exposed to oil concentrations of 25-70 ppm. There is therefore potential risk of acute toxic effect during the blowout period.

Based on the modelled oil spill, it can therefore not be excluded that the blowout could affect fish stocks of spawning fish species in the vicinity of the blowout (up to approximately 20 km away) as a consequence of increased mortality of fish eggs and larvae.

In summary fish eggs and spawning sites are highly vulnerable to a major oil spill resulting in high intensity impact. The impact will be mainly local but may have a regional to international effect depending on weather and current direction. While the duration of the impact is short to medium there could be an overall long-term effect on the stock recruitment of sand eel in the area. The probability of such a blowout event is low and the overall consequence of the impact is assessed to be **high**.

Impacts of oil stranded on shorelines

Shorelines are exposed to the effects of floating oil. Oil stranded on beaches often gives rise to concern because it may affect sensitive coastal habitats and important socioeconomic conditions. Further, the cleaning of oiled beaches may be costly. The vulnerability of shorelines to oil spills differs considerably depending on the type of habitat and with respect to how easy they are to clean up after an oil spill.

The modelling showed, that in case of a blowout with surface release during summer, oil may strand on beaches along the west coast of Vendsyssel and Thy (likelihood 1-25%) (Figure 13-3). Oil may also strand on the south coast of Norway (likelihood 1-50%) and in a very small area in the northern part of the Swedish Skagerrak coast (likelihood less than 1%). The oiling on the Norwegian south coast and the Swedish coast will mostly be light indicating oil concentration of 0.1-1 litres/ m^{-2} and thickness of 0.1-1 mm.

The highest likelihood of oil stranding is 5-95% around the northern tip of Denmark at the Skagen area. Along the affected Danish coast, the degree of oiling will only be light to moderate indicating oil concentration of 1-10 litres/ m^{-2} and thickness of 1-10 mm.

The Danish coastlines at risk of oil stranding include both exposed, gentle sandy beaches, which typically have lower ecological productivity and are not highly vulnerable to oil, as well as areas within the Natura 2000 network, which are ecologically rich and sensitive. Therefore, the potential impact of oil stranding varies greatly, with some regions being less affected and others requiring careful consideration due to their ecological importance.In addition, the oil does not penetrate the sand readily, facilitating mechanical removal. As the drift time from Nini A to the shoreline will be more than 20 days, the stranded oil will mostly be in the form of tar balls. The most volatile components have evaporated, and emulsification and dispersion have almost terminated after approximately a week, leaving only hard degradable oil components that can form tar balls by wave impacts. Tar balls are even easier to remove on sandy beaches compared to less weathered oil. The effect on coastal biota is therefore also limited. However, the stranded oil in the summer period may be a nuisance to beach guest and tourists.

The biologically highly productive tidal flats and saltmarshes in the Wadden Sea in the southern part of the Danish coast will not be affected.

The Norwegian and Swedish coastlines that may be hit by oil are rocky shores that are more sensitive to oil spills compared to the Danish sandy shores. However, with a drift time of 30 days to more than 60 days most of the oil will be in the form of tar balls, which are considerably less damaging as they are no longer sticky or toxic.

The overall likelihood of shoreline impact of an unmitigated blow-out ranges between 80-98% for winter and summer releases, respectively. Shoreline oiling is likely to range between very light and moderate, as defined by ITOPF's recognition of shoreline oiling guidelines (ITOPF, 2002, 2019).

Under the worst-case metocean conditions, the quickest impact on the shoreline in Denmark will be two to three weeks. Shoreline impact may also happen in Norway (after three weeks) and Sweden (after 4 weeks). There will be no shoreline impact in UK, Germany or the Netherlands.

Overall assessment

Based on the impact assessment of the modelled unmitigated blowout scenario an overview of possible impact is given, see Table 13-3. The impact is regional to international as the oil can spread to Norwegian, Swedish and Danish coasts. The impact intensity and probability are very conservative as the modelled scenario uses a daily spill rate of 292 m^3 over 90 days and the expected worst case from *Project Greensand Future* is less than 100 m^3 per day and an estimated mobilisation time within 24 hours. The likelihood of occurrence is low.

Table 13-3 Summary of impact assessment from oil blowout incident from the Nini A platform

Receptor	Vulnerability	Geographical extend	Intensity	Duration	Consequence
Air quality	Low	Regional	Medium	Short	Moderate
Water Quality	Medium	International	High	Short	Moderate
Sediment conditions	Medium	International	High	Medium	High
Plankton	Low	International	High	Medium	Moderate
Benthic fauna	Medium	International	High	Medium	High
Fish	Medium	International	High	Medium	High
Marine mammals	Low	International	High	Medium	Moderate
Seabirds	High	International	High	Medium	High

13.1.4 Impacts on Natura 2000 and protected areas

Table 13-4 provides an overview of the nearby Natura 2000-sites and other protected areas that may be at risk of impacts by an unmitigated oil spill (Oil Spill Response Ltd, 2018). The risk and arrival times are based on an unmitigated spill scenario lasting 90 days with a volume three times higher than a worst-case spill from the *Project Greensand Future*. Consequently, the impact assessments presented in the table are to be regarded as conservative and the risk of impact is considerably lower.

Table 13-4 Summary of impact assessment on Natura 2000 areas related to potential blow-out incident from the Nini A platform

Natura 2000 Site code/name	Designated marine species and natural habitats	Assessment of impacts resulting from a blow-out at Nini A	Likelihood of Impact (top), Minimum Arrival Time (P100) (middle) and the 95th Percentile (P95) Arrival Time (bottom)		Distance to project area
			Winter (Dec-Feb)	Summer (Jun-Aug)	
• **Denmark**					
DK00VA257 Jyske Rev, Lille-fiskerbanke	1170 Reef 1351 Harbour porpoise	Some risk of impacts on reef Negligible risk of harmful effects on Harbour porpoise	100% 2 days, 0 hrs 2 days, 11 hrs	100% 2 days, 6 hrs 2 days, 18 hrs	71 km
DK00VA258 Store rev	1170 Reef 1351 Harbour porpoise	Some risk of impacts on reef Negligible risk of harmful effects on Harbour porpoise	100% 5 days, 12 hrs 9 days, 18 hrs	100% 7 days, 15 hrs 10 days, 9 hrs	259 km
DK00VA259 Gule rev	1170 Reef 1351 Harbour porpoise	Some risk of impacts on reef Negligible risk of harmful effects on Harbour porpoise	100% 3 days, 12 hrs 5 days, 12 hrs	100% 5 days, 0 hrs 6 days, 6 hrs	171 km
DK00FX112 Skagens Gren og Skagerrak	1110 Sandbanks which are slightly covered by sea water all the time 1180 Submarine structures made by leaking gases 1351 Harbour porpoise 1365 Harbour seal	Some risk of impacts on sand-banks and submarine structures Negligible risk of harmful effects on Harbour porpoise and Harbour seal	100% 7 days, 3 hrs 11 days, 23 hrs	100% 9 days, 9 hrs 12 days, 6 hrs	270 km
DK00VA301 Lønstrup Rødgrund	1170 Reef 1351 Harbour porpoise	Minor risk of impacts on reef Negligible risk of harmful effects on Harbour porpoise	51% 13 days, 6 hrs 37 days, 9 hrs	97% 12 days, 21 hrs 16 days, 23 hrs	270 km
DK00VA348 Thyborøn Stenvolde	1170 Reef 1351 Harbour porpoise	Minor risk of impacts on reef Negligible risk of harmful effects on Harbour porpoise	82% 10 days, 12 hrs 19 days, 15 hrs	100% 6 days, 18 hrs 11 days, 2 hrs	142 km
DK00EX023 Agger Tange	19 different species of sea birds including species of terns, ducks and wading birds.	Negligible risk of harmful effects on birds	15% 18 days, 18 hrs 48 days, 5 hrs	3% 13 days, 15 hrs n/a	178 km
DK00VA340 Sandbanker ud for Thyborøn	1110 Sandbanks which are slightly covered by sea water all the time	Negligible risk of harmful effects on sandbanks	75% 13 days, 0 hrs 22 days, 0 hrs	95% 8 days, 12 hrs 14 days, 12 hrs	162 km

Natura 2000 Site code/name	Designated marine species and natural habitats	Assessment of impacts resulting from a blow-out at Nini A	Likelihood of Impact (top), Minimum Arrival Time (P100) (middle) and the 95th Percentile (P95) Arrival Time (bottom)		Distance to project area
			Winter (Dec-Feb)	Summer (Jun-Aug)	
	1351 Harbour porpoise	Negligible risk of harmful effects on Harbour porpoise			
DK00VA347 Sydlige Nordsø	1110 Sandbanks which are slightly covered by sea water all the time 1351 Harbour porpoise 1364 Grey seal 1365 Harbour seal *Gavia stellata, Gavia arctica, Hydrocoloeus minutus*	Negligible risk of harmful effects on sandbanks Negligible risk of harmful effects on Harbour porpoise, Harbour seal and Grey seal Negligible risk of harmful effects on birds	41% 29 days, 6 hrs 36 days, 17 hrs	13% 14 days, 0 hrs 32 days, 0 hrs	147 km
• **Germany and Netherlands**					
DE1003301 Dogger Bank	1110 Sandbanks which are slightly covered by seawater all the time 1351 Harbour porpoise 1365 Harbour seal Fulmar Lesser black-backed gull Northern gannet Kittiwake Common guillemot	Negligible risk of harmful effects on sandbanks Negligible risk of harmful effects on Harbour porpoise, Harbour seal and Grey seal Negligible risk of harmful effects on birds	56 % 36 days, 18 hrs 45 days, 9 hrs	22 % 13 days, 6 hrs 21 days, 0 hrs	121 km
NL2008001 Dogger Bank	1110 Sandbanks which are slightly covered by sea water all the time 1351 Harbour porpoise 1364 Grey seal 1365 Harbour seal	Negligible risk of harmful effects on sandbanks Negligible risk of harmful effects on harbour porpoise, harbour seal and grey seal Negligible risk of harmful effects on birds	9 % 43 days, 12 hrs 104 days, 6 hrs	5 % 18 days, 18 hrs n/a	156 km

Impacts on Danish Natura 2000-sites

In case of a blowout, 5 Danish Natura 2000-sites are at risk of oil contamination dependent on distance from the blow-out and the position in relation to the axis of the prevailing direction of the oil slick drift. The different sites can be grouped in terms of likelihood of being affected, concentration of oil and exposure time. The basis of the designation of these Natura 2000-site are listed in Table 13-4. The table also provides an overview of the assessments of impacts on the Habitat types and Habitat species in the areas.

DK00VA257, Lille Fiskebanke, DK00VA258, Store rev, DK00VA259, Gule Rev, and DK00FX112, Skagens Gren and Skagerrak, are the closest Danish Natura 2000 sites in the prevailing direction of the oil slick drift. There is a relatively high likelihood that these sites will be affected by a blowout spill.

The exposure time will predominantly be limited to less than one day and up to three days at surface (Figure 13-4). While there is some risk of oil sedimentation and consequently impact on seabed habitats and associated flora and fauna there is negligible risk of harmful effects on Harbour porpoise and seal population in these areas as described in section 13.1.3.

DK00VA301, Lønstrup Rødgrund, and DK00VA348, Thyborøn stenvolde, are located outside the axis of the prevailing drift direction at a quite large distance from Nini A. The risk that the area is affected by oil is therefore less than the above-mentioned protected areas. Consequently, it assessed that there will a minor risk of impacts on reefs and negligible risk of harmful impacts on Harbour porpoise.

DK00VA340, Sandbanker ud for Thyborøn, is also located outside the axis of the prevailing drift direction at a quite large distance from Nini A. The risk that the area is hit by oil is therefore less than the above-mentioned protected areas and drift time ranges from 8 days to more than 22 days. It assessed that there will a negligible risk of impacts on sandbanks and negligible risk of harmful effects on Harbour porpoises.

DK00VA347, Sydlige Nordsø, is located outside of the prevailing direction of the oil slick drift. Designation habitats and species include 1110 Sandbanks which are slightly covered by sea water all the time, 1351 Harbour porpoise,1364 Grey seal, 1365 Harbour seal and seabirds (*Gavia stellata, Gavia arctica, Hydrocoloeus minutus*). The risk that the area is affected by oil is therefore small and the drift time ranges from 14 days to more than 36 days. It assessed that there will a negligible risk of impacts on sandbanks and negligible risk of harmful effects on Harbour porpoises and seals. There would be a negligible risk of oiling and killing of birds in these areas based on the assessment described in section 13.1.3.

Impacts on German and Dutch Natura 2000-sites south-southeast of Nini A

In the event of a blowout, the German and Dutch Natura 2000-sites south-south-west of Nini A are less likely to be affected by the spill (1-5 %). The German DE 1003301, Doggerbank, would have an exposure time of less than one day while maximum oil concentrations at the surface would reach 25-50 ppm. The Dutch NL2008-001, Doggerbank, is also less likely to be affected. The basis for the designation of the area is the habitat type 1110 Sandbanks and the habitat species 1351 Harbour porpoise, 1365 Harbour seal and 1364 Grey seal. Potential impacts related Impacts on marine mammals are described in section 13.1.3.

There may be a negligible risk of sedimentation of oil on the habitat type 1110 Sandbanks, thereby affecting the benthic infauna community that has been characterized as a *Bathyporeia-Fabulina*

(Amphipod-Tellina) community, with the crustacean *Bathyporeia elegans* and the bristle worms *Spiophanes bombyx* and *Spio decorata* as characterising species.

Impacts on Norwegian SVOs

Table 13-5 shows that it is very likely (75-95 %) that Norwegian SVOs to the north of the Nini A platform may be affected by an unmitigated spill from a blowout (Oil Spill Response Ltd, 2018). The SVOs "*Vikingbanken*", and "Tobisfelt" are spawning areas for mackerel and sand eel from May to July. The potential effect on fish has been described in section 13.1.3 the concentration of oil in these areas above 25 ppb, which is above the concentrations that are harmful to fish eggs and larvae. Spawning in this area is therefore at risk.

Table 13-5 Summary of impact assessment on nearby protected areas related to potential blowout incident from the Nini A platform.

Protected area	Species	Assessment of impacts resulting from a blow-out at Nini A	Likelihood of Impact (top), Minimum Arrival Time (P100) (middle) and the 95th Percentile (P95) Arrival Time (bottom)		Distance to project area
SVO Tobisfelt(Vikingebank)	Spawning area for mackerel and sand eel Vulnerable area for Common guillemot (*Uria aalge*) and Northern fulmar (*Fulmarus glacialis*)	Significant risk of harmful effects on sand eel spawning ground	100% 0 days, 3 hrs 0 days, 5 hrs	100% 0 days, 3 hrs 0 days, 3 hrs	11 km

Furthermore, the Sand eel field is a valuable habitat for common guillemot (*Uria aalge*) and northern fulmar (*Fulmarus glacialis*) from April to December. There would be a risk of oiling and killing of birds in these areas as described in section 13.1.3.

13.2 CO_2 Releases

CO_2 could accidental be released as part of the *Project Greensand Future*. These 3 scenarios are assessed in the following:

- **Blowout** - High rate and short duration: In the unlikely event of a blowout from a well during or after the injection phase, it would result in a release of a part of the injected CO_2 along with oil and water from the reservoir.
- **Leakage from reservoir** - Low rate and long duration: The probability of CO_2 leakage from the reservoir is expected to be low and the main impacts are expected at the sea bottom as the release of small CO_2 gas bubbles quickly dissolute.
- **Leakage from offloading system** - High rate and short duration: The probability of CO_2 leakage from an accidental rupture of hose during offloading is low.

When CO_2 gas is released to the water, either as a consequence of a blowout from the injection well or from a leak, the chemical and physical conditions change quickly. The chemistry is complicated in seawater and involves a variety of different acid-base species. The underlying system is the CO_2/carbonic acid system. Firstly, as CO_2 gas enters the water, the $CO_2(g)$ gas dissolves in water:

$$CO_2(g) \rightarrow CO_2(aq) \quad (1)$$

The CO_2(aq) is hydrated to carbonic acid (H_2CO_3), this reaction is slower than the ionisation into carbonate and bicarbonate ions:

$$CO_2(aq) + H_2O \rightarrow H^+ + HCO_3^- \quad (2)$$
$$HCO_3^- \rightarrow H^+ + CO_3^{2-} \quad (3)$$

After the new equilibrium state in the seawater is reached, the CO_2 exists in different forms of dissolved inorganic carbon (DIC) as: dissolved carbon dioxide, bicarbonate ion, and carbonate ion. In the general presumption, approximately <1 % is present as dissolved unionized carbon dioxide (CO_2), about 90 % as bicarbonate (HCO_3^-) and around 10 % is present as carbonate (CO_3^{2-}) in the ocean. The relative distribution depends on the pH of the seawater, the partial pressure and salinity, and inorganic content in general (Dickson, 2010). The CO_2/carbonic acid system in seawater is illustrated by Figure 13-6. As shown by the figure the carbonic acid will release H^+ and form bicarbonate (HCO_3^-). Buffer reactions in seawater play an important role in maintaining the pH of the seawater, this is mainly controlled by the above-described carbonate buffer system and minor CO_2 leakage are then only expected having a local impact of the pH in the water.

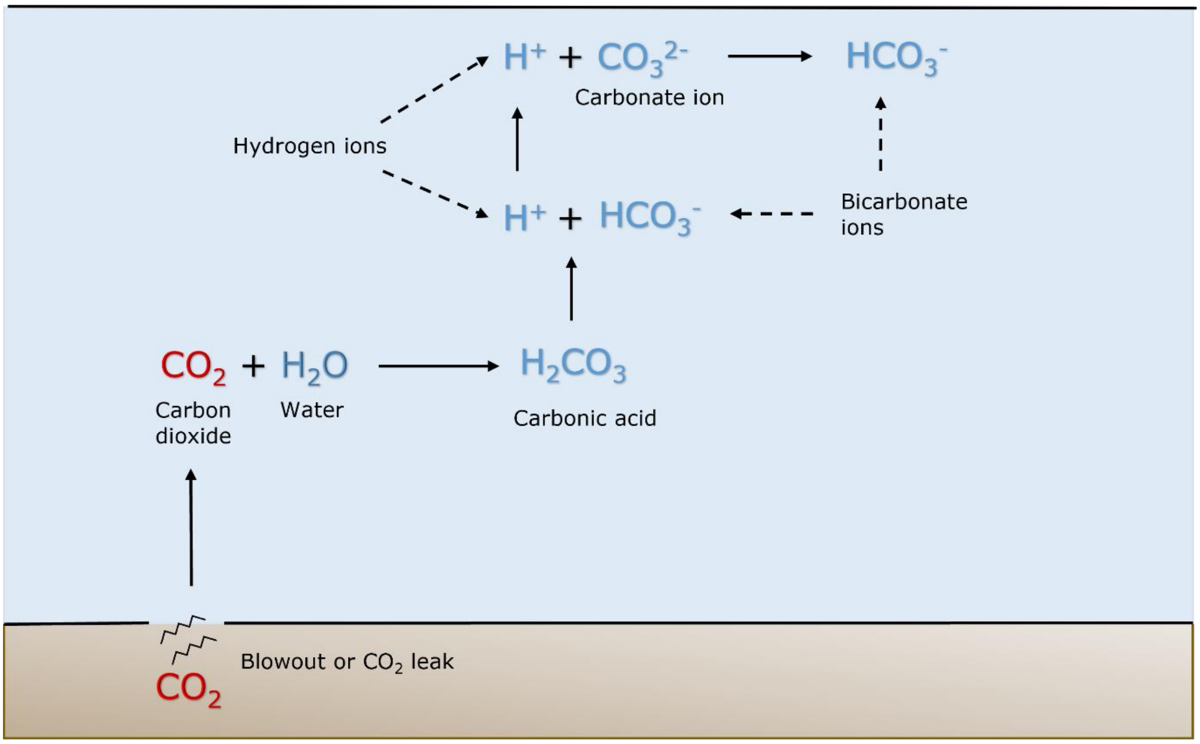

Figure 13-6 Illustration of the chemical reactions resulting from a CO_2 leakage from the reservoir. The relative distribution of the inorganic carbon species depends on the pH of the seawater. Figure is modified from (Center for Environmental Visualizations, 2014)

13.2.1 Blowout

If a blowout would occur during or after the injection phase, this would result in a release of the injected CO_2 along with oil (discussed in section 13.1) and water from the reservoir. A CO_2 blowout can occur either at the wellhead at the topside of the platform or at the seabed. A blowout at the wellhead is considered a work safety and climate risk, while a blowout at the seabed is treated as an environmental and climate risk. Thus, the following description of environmental risks associated with a blowout is related to a blowout at the seabed.

To evaluate the potential effects of a CO_2 blowout, a worst-case scenario has been defined (Table 13-6). The scenario is based on blowout from the Nini West reservoir (DHI, 2023), assuming a total storage capacity of 10 million tons (MT) CO_2. The *Project Greensand Future* however only compromises of a 2.4 MT total capacity, and therefore accidental CO_2 release rates at this project is presumable some lower than presented in the following.

From the long-term reservoir modelling is found that free phase CO_2 represent the largest fraction of CO_2 after 8 years of full-scale injection, and a smaller fraction is dissolved in the brine, however in +10 years after completion of injection, the fraction of the free phase CO_2 is expected declining, and at that point the major fraction of CO_2 will be trapped either dissolved in the brine or finally also mineralised as e.g., carbonates. The intensity of impact from a blow-out will then decline in the period after completion of injection, and the scenarios presented here will only be valid as worst-case scenario for a defined timeframe.

Table 13-6 Worst case blowout rates at wellhead and temperature & pressure in reservoir (DHI, 2023).

CO_2 flow rates				Water flow rate	Oil flow rate	Reservoir Temp	Near wellbore reservoir pressure
supercritical	supercritical or gas		gas				
$Sm^3\ d^{-1}$	$Kg\ s^{-1}$	$Tons\ d^{-1}$	$m\ Sm^3\ d^{-1}$	$Sm^3\ d^{-1}$	$Sm^3\ d^{-1}$	ºC	Bar
~30,000	200	17,280	9.45	2,200	100	55	100

When CO_2 is held above its critical temperature (31.1 ºC) and critical pressure (73.8 bar), it will be in a supercritical fluid state (Budisa & Schulze-Makuch, 2014). Thus, the injected CO_2 will, due to the present pressure and temperature, be stored as a supercritical fluid in the reservoir and the compressibility of the CO_2 is maximized. The CO_2 is stored in the reservoir along with oil residues and water. If a blowout were to occur at the seabed, the CO_2 would go undergo a phase transition from supercritical to gas and will approximately follow the changes as depicted by the arrow in the phase diagram, see Figure 13-7. This transition is driven by the large pressure- and temperature drop occurring as the supercritical fluid enters the water at the seabed. At worst case 30,000 m^3/d supercritical CO_2 enters the water phase, and this transforms at a high rate to gas: 1.7 million m^3/d at seabed pressure, corresponding to 10 million m^3/d at sea surface. Thus, the CO_2 volume is expanding during this phase transition and further due to the upwards decreasing pressure, resulting in an expansion of volume by around x50 at the seabed and around x330 at sea surface. These physical processes, together with turbulence, buoyancy forces and dispersion of gas bubbles, will result in formation of cone-shaped zone with rising gas through the water column. The CO_2 blow-out will generate an enormous force, assumable resulting in a visual impact at the sea surface similar to first days of leakage of gas from the North Stream gas pipelines in the Baltic Sea (Jia, 2022).

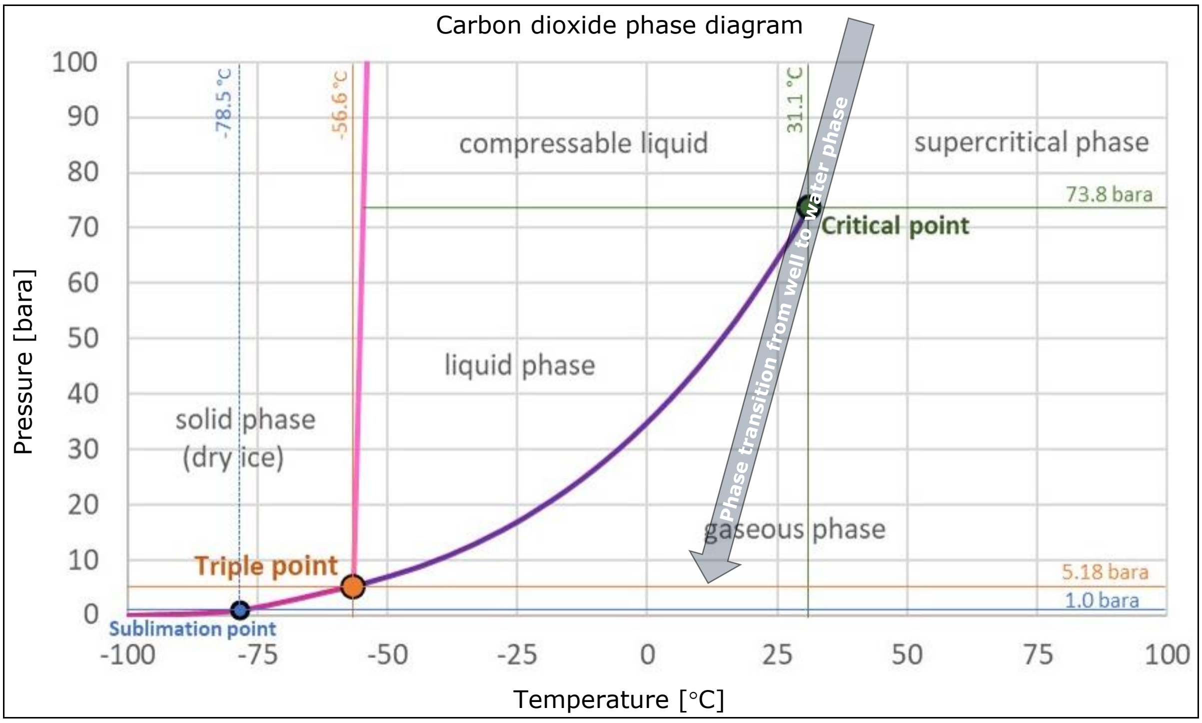

Figure 13-7 Carbon dioxide (CO_2) phase diagram – Arrow indicates the phase transition from well to sea. Figure is modified from (Engineering ToolBox, n.d.).

A simulation of the first scenario where a blowout occurs one year after initial injection was conducted to assess the physical and chemical impacts. Model setup and methods is further described in the DHI-report (DHI, 2023). Due to the rapid ascend of CO_2 gas from well to sea surface, it is assessed by DHI that only a few % of the CO_2 gas will dissolve in seawater (DHI, 2023). The blow-out will result in formation of large gas bubbles resulting in the largest impact on pH in the upper section of water column and thereby not impacting benthic fauna, but most likely only plankton, as more mobile fauna (fish, birds and marine mammals), are expected to flee the area.

In this section is presented various model outputs from the simulation of blow-out. It is important to emphasise that conditions highly vary over time and pH-values will vary highly over time. This is reflected in Figure 13-8, showing timeseries of the simulated pH at the sea surface, both at the centre of release and 40-50 m away.

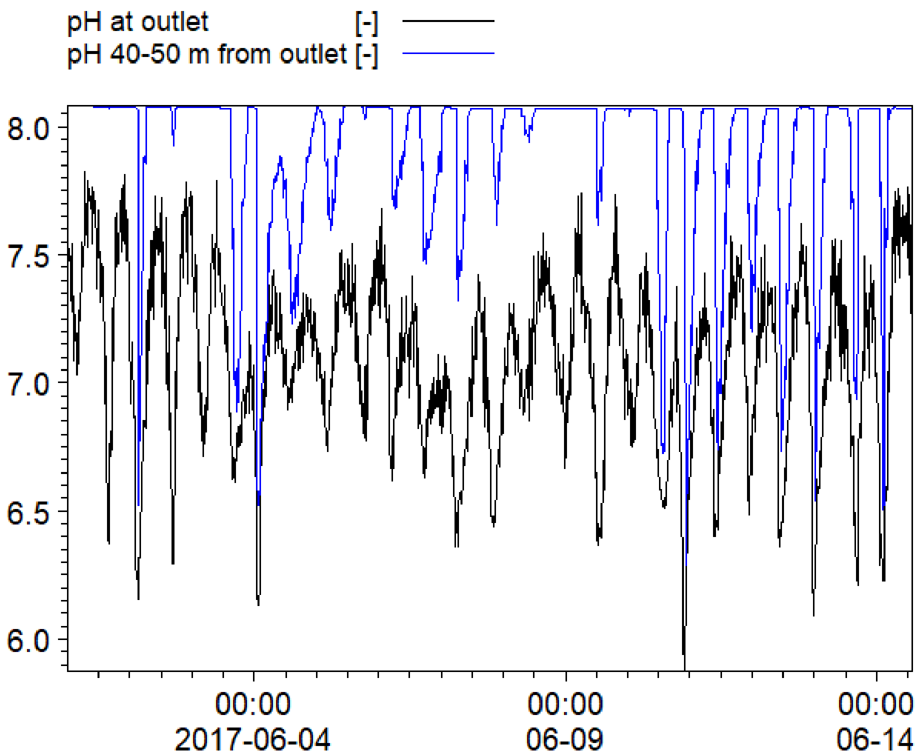

Figure 13-8 Timeseries of simulated pH close to the sea surface in June.

Figure 13-9 shows the statistical minimum pH-values near sea surface across the simulation period of 14 days. In general, the simulation showed that the pH rarely drops more than 1 pH unit, and that these conditions are very short-term (minutes to a few hours) and only occurs in a smaller area near the blowout, as visualized in Figure 13-9. In Figure 13-10 is found a vertical profile of minimum pH-values, and the simulations indicates the impact is isolated to the surface zone. Under in-situ conditions the physics near the outlet may be more complex than predicted by the modelling, and some minor impact on pH-values in the lower part of water column would then also be expected.

The relative low impact is further clearly illustrated by Figure 13-11 showing the statistical mean values across the simulation period of 14 days. Around the blow-out centre is found an area of approximately 40 meter in diameter having a mean pH value below 7.5. Seawater pH is typically ranging between 7.5 and 8.6. In the surface water in the North Sea pH values ranging between 7.7 and 8.6, with a typical value of 8.1 (Bolding et al. 2016). Similar data are seen at DEPA stations (91300001 and 92300002) 10 km west of the coast of Jutland, with median pH values of ~8.1 and range between 7.7 and 8.5 (Danmarks Miljøportal 2023) and as the pH rarely drops below 7.5 and only for a short time in a limited geographical area, the CO_2 blowout and related pH changes are not expected to have any significant impact on plankton and the surrounding marine environment.

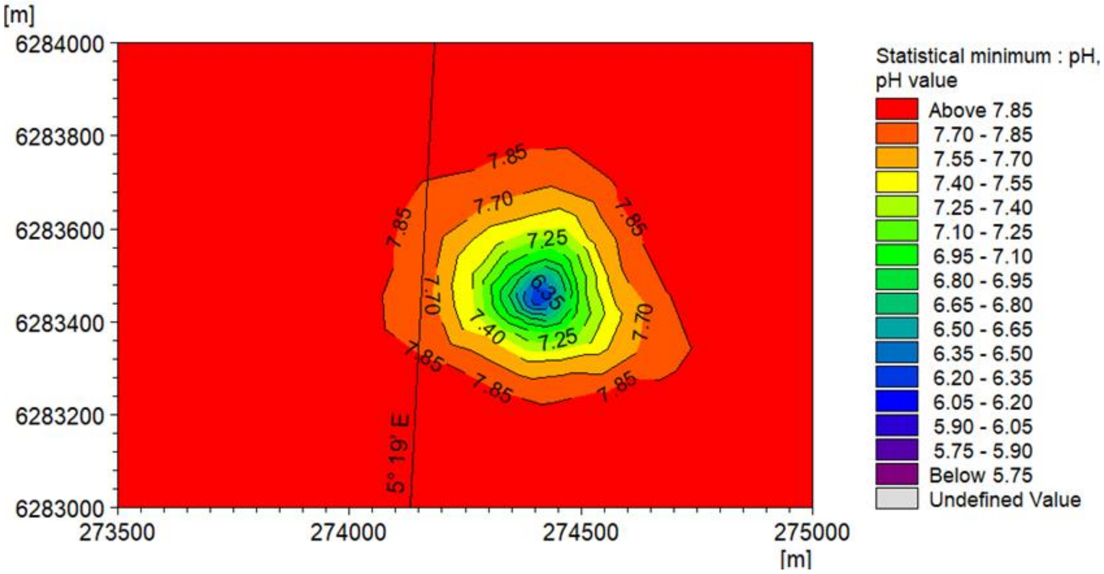

Figure 13-9 Sea surface pH values. Statistical minimums data across the simulation period of 14 days.

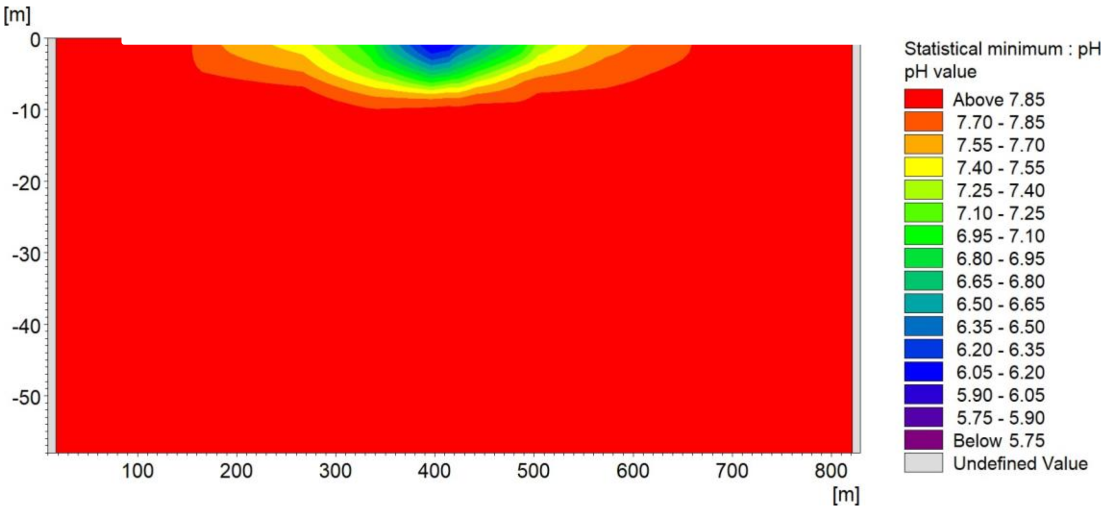

Figure 13-10 Vertical profile of pH. Statical minimum data across the simulation period of 14 days.

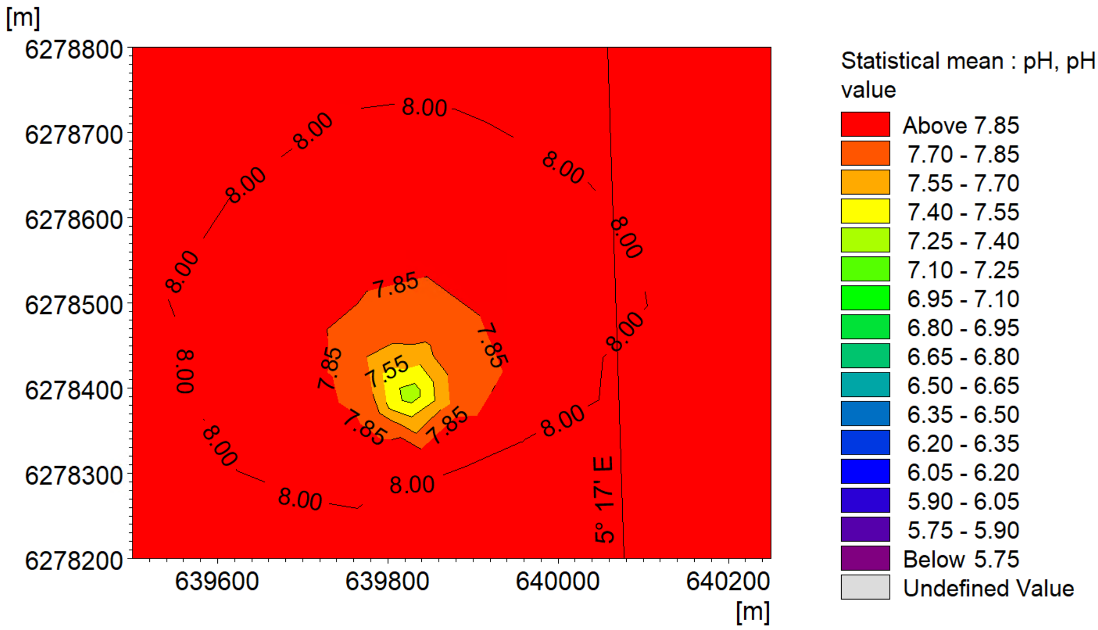

Figure 13-11 Sea surface pH values. Statistical mean data across the simulation period of 14 days.

The temperature of the released components will vary depending on when the blowout occurs after initial injection, and it is expected that the water will have low oxygen concentrations. The in-sea phase transition of CO_2 from supercritical to gas is an endothermic process and this will lower the impact from the energy added to the system from the reservoir fluids. An increased temperature is assumed being a local phenomenon only close to the outlet point.

Additionally, based on previous sodium and chloride measurements from the reservoir, it is estimated that the salinity of the water in the reservoir will be between 78-80 ‰, thus approximately 2.2 times higher than the seawater. However, due to the blowout release force of CO_2 and the accompanied water, it is expected that the water from the reservoir will be mixed rapidly with seawater and therefore only cause a local impact.

Further H_2S (hydrogen sulphide) at maximum 5 ppm follows the released CO_2 gas and at worst-case results in concentrations of >1.0 µg/l in a zone of around 20 metre in diameter near the sea surface (DHI, 2023). Free molecular hydrogen sulphide (H_2S) has been found to be the major toxic form of sulphide, because H_2S can pass through the cell membrane in the microorganism (Okabe et al., 1995). Due to the dissociation of hydrogen sulphide in water, the pH value is important for evaluation of the toxicity of sulphide. As seen from the modelling, pH rapidly returns to normal sea water conditions, and at pH 8 is only ~5% of the sulphide found as hydrogen sulphide (H_2S). Further, the modelling doesn't include the degradation mechanism, the half-life of sulphide in the aerobic surface water will be in the range of hours. Summaries the impact from the released concentrations will be low and occur within the immediate vicinity of the well.

The probability of a blowout (described in section 13.1) is based on an oil well in production the entire year around, whereas the CO_2 injection well will only be in use, when CO_2 is injected. Thus, the probability is expected to be even lower. As a result, the probability of a blowout is therefore assessed to be **low**. The geographical extent of impact is assessed within the **immediate vicinity**. The duration of impact is **short/medium** (a matter of weeks, maximum time it takes to close a blowout (90 days)), and due rapid mixing the period with reduction in pH is **short**. The pH reduction during a blowout occurs close to the sea surface and is therefore not critical for the benthic community. And further the intensity of impact on temperature, salinity, oxygen and sulphide concentrations will be **low** and occur within the **immediate vicinity** of the well. The overall consequence of the impact is assessed to be **limited**. The major biological risks associated with a blowout is not related to the CO_2 blowout, but to the oil spill (assessed in section 13.1).

Furthermore, as the CO_2 is released at the surface, this will also have a climate impact, which is assessed in the next section.

Climate impact

As the majority of the CO_2 from a well blowout presumably will be released into the atmosphere, it will result in large emissions of CO_2. The duration of blow-outs is most likely short-term (~15 days) but may last up to 90 days. A blow-out occurring 1 year after start of injection will as worst-case result in a release of all the injected CO_2 (around 0.3 MT CO_2). However, a blow-out occurring at the end of the operation phase, 8 years after injection start, is estimated resulting in a worst-case release of 1.1 MT CO_2 (1.3 MT CO_2 remaining in the reservoir). The reservoir will retain part of the CO_2 injected as it is dissolved or mineralized, again depending on how long injection has lasted. 0-1.3 million tons CO_2 are assessed remaining in the reservoir depending on the scenario. After 8 years the remaining quantity of CO_2 in the reservoir are far larger than the greenhouse gas emission related to construction of *Project Greensand Future* and 8 years of operation (~0.089 million tons).

As the climate system is vulnerable towards any additional climate gasses added, the emission of CO_2 will affect the climate as a **global** impact. The intensity of the blowout events is **high**. The durations of the impact are **permanent** and the effect from emissions of greenhouse gasses is assessed irreversible as the CO_2, are having long lifetimes in the atmosphere. The probability of the worst-case event is assessed to be low. The impact from a blow out on the climate system is assessed to be **negative**, however including the positive impacts from the remaining stored CO_2 the summed impact is **positive**, with exception of the blowout scenario occurring 1 year after injection start in combination with an unsuccessful short track (15 days) installation of a relief well. The resulting consequences are then **significant positive** for the blowout occurring after 8 years, and **moderate negative** for the blowout occurring after 1 year combined with an unsuccessful short track installation of a relief well. As all CO_2 are conservatively assessed released in one of the 1-year scenarios, there will be a negative carbon footprint impact related the *Project Greensand Future* and from the remaining CCS loop.

13.2.2 Leakage from reservoir

As basis for the assessment of impact of CO_2 leakage at the *Project Greensand Future*, a number of cases found at a literature search has initially been described. The main impacts from CO_2 leakages on benthic or epibenthic communities has also been described. Finally, the results of the modelling done by DHI is presented for *Project Greensand Future*.

Reference cases

Based on a literature search, it has not been possible to find anything that indicates leakage from existing CCS sites, and it is therefore only possible to assess the potential effects and impacts based on modelling studies, laboratory experiments and studies of natural CO_2 seep sites.

Several studies have attempted to model the extent of a potential CO_2 leak and thereby understand the associated environmental risks (Amir Rashidi et al., 2020a, 2022; DNV GL, 2019; Vielstädte et al., 2019), see Table 13-7. None of the simulated leaks indicated transport of CO_2 gas to the surface and thereby no escape of CO_2 into the atmosphere. Changes in sea water pH was estimated to a maximum of 200 meter from a leakage point. These findings aligns well with the results from DHI-model presented later in this section.

Table 13-7 Case studies on CO_2 leakages.

Case studies	Observations
Sleipner CO_2 storage site, Norway Vielstädte et al. 2019 performed a study of hypothetic, but realistic leakage of CO_2 at the Sleipner CO_2 storage site located in the central North Sea to evaluate the detectability and environmental consequences of a CO_2 leak. They investigated leakage of CO_2 along a well that penetrates the subsurface CO_2 plume and leaks into the ~80 m deep water column, using a combination of experimental field data and numerical modelling.	The leakage rate of the in-situ field experiment was 31 t yr-1. The measurements showed increased levels of carbon dioxide (pCO_2) within ~30m downstream the leak. Additionally, simulation of the worst-case scenario (leakage rate of 55 t CO_2 yr-1) showed that the strongest acidification was found at bottom water with pH levels down to 6.0, and increased level of carbon dioxide (pCO_2) up to 120 m from the leak. CO_2 gas bubbles were completely dissolved within 2 m above the seabed in both the in-situ experiments and in the simulation.
Sarawak potential CO_2 storage site, Malaysia Two simulation studies have been performed for the potential CO_2 storage site Sarawak in Malaysia (Amir Rashidi et al., 2020a, 2022). A far-field modelling was conducted with a leakage rate of either 6 t CO_2 yr^{-1} and 500 t CO_2 yr^{-1}.	The modelling showed that the pH changes were either undetectable or neglectable, as the pH values was predicted to fall within the natural variation of the seawater acidity with varying climatic conditions. The modelling studies suggested that the plume where pH falls below 6.5 would be confined within 1-200 m radius from the leak. For all scenarios, the CO_2 gas were predicted to be fully dissolved within 5 m above the seabed.
Northern Light CO_2 storage project, Norway In the environmental risk assessment for the Northern Lights CO_2 storage project, an assessment of possible leakage scenarios, migration paths and rates were identified (DNV GL, 2019). The leakages rates were determined based on migration path and were estimated as either <1 t CO_2 d^{-1} or <10 t CO_2 d^{-1}.	For the low leakage rate, the pH change would be highest within the first 4 m from the centre of the leak (a change of -2 to -2.2) and the pH change would be detectable up 13 m from the centre (a change between -0.2 to -2.2). For the high leakage rate, the pH change would be highest within the first 13 m from the centre of the leak (a change between -2 to -2.2) and would be detectable up to 42 m from the leak (a pH change between -0.2 to -2.2). The simulation has not taken ocean currents into account can therefore be considered conservative.

Biological responses to CO_2 leakage

The main impacts from CO_2 leakages are expected to be found in benthic or epibenthic communities as the dissolution of CO_2 gas bubbles will occur rapidly and within the first 2-5 m above the seabed (Amir Rashidi et al., 2020a; Vielstädte et al., 2019). The biological impact is driven by the physiological response of the organisms to reduced levels of pH and the consequent indirect impacts such as changes in a range of ecosystem functions and ecological drivers (Queirós et al., 2014). The CO_2 leak is expected to mainly impact immobile organisms or slowly moving organisms that are not able to migrate to unaffected areas.

Calcifying organisms (echinoderms, molluscs and crustaceans) require calcium carbonate ($CaCO_3$) for their shells and skeletons and are vulnerable to seawater acidification. The formation of $CaCO_3$ relies on available carbonate ions (CO_3^{2-}) to react with calcium (Ca^{2+}) but with a surplus of CO_2, the consumption of carbonate ions impedes calcification. A continuous release of CO_2 will affect the buffering capacity of the sediments and dissolve sedimentary carbonate as observed at a natural CO_2 seep site (Molari et al., 2018). Thus, calcifying organisms are at risk of dissolution in response to acidification and non-carbonated sediments (ECO2, 2016a).

Some species can tolerate shorter periods of moderate acidification. The physiological response involves adapting respiration rates, activity level and reproducing output may provide temporary protection against CO_2 leakages as hydrodynamics affects the direction and exposure duration. However, the compensation is only doable for a certain amount of time as the energy is reallocated away from essential biological functions and acidification exposure for longer periods will eventually lead to death (ECO2, 2016a).

It may occur that tolerant species increase in abundance as a response to less competition and high food availability as pH-sensitive species may not survive. This will affect community composition and structure and may lead to local biodiversity loss of non-tolerate species. Changes in community composition and structure has been studied at the natural CO_2 seep site in the Mediterranean. The continuous high CO_2 fluxes dissolved all sedimentary carbonate and increased mineral weathering and nutrient flux of silicate and iron. The increase in nutrient flux enhanced microphytobenthos growth (photic environment) and created a local shift in bacterial communities but also showed a decline in density and composition of benthic meiofauna and macrofauna (particularly the most abundant taxa, nematodes and polychaetes were affected). Thus, natural CO_2 seeps has led to altered ecosystem functions in terms of remineralization and carbon transfer along the food web and declines in species densities and composition (Molari et al., 2018).

Exposure to low pH levels may also reduce other essential ecosystem functions such as bioturbation by the very common burrowing brittle stars (*Amphiura filiformis)* (Hu et al., 2014). A pH of 7.0 may be the threshold for this particular species. *A. filiformis* counted 200 individuals per m^2 at the main investigated area at the Nini field and a drop in pH to <7 would most likely affect this echinoderm species at the CCS site.

The EU-funded project ECO2 was established to assess the risks associated with CSS. Based on their findings for North Sea fauna, they tried to define impact categories across simulated pH changes within the first 20 years of a leakage event to evaluate the biological respond (Figure 13-12) (ECO2, 2016a). The exact positioning of each category in relation to pH is not definitive as variations will occur across ecosystems and faunal components, however it provides an indication of the impact level. Low level leaks where pH does not change more than -0.4 unit will only have minimal impact on the benthic community across the assessed simulation period. However, as the pH drops even further, this may lead to changes in community structure, selective mortality at a pH change of -1.0 unit and eventually mortality if the pH drops below -1.3 unit after approximately two years of exposure. These findings correspond well with the threshold value of -0.5 pH defined for the Northern Light CSS project (DNV GL, 2019).

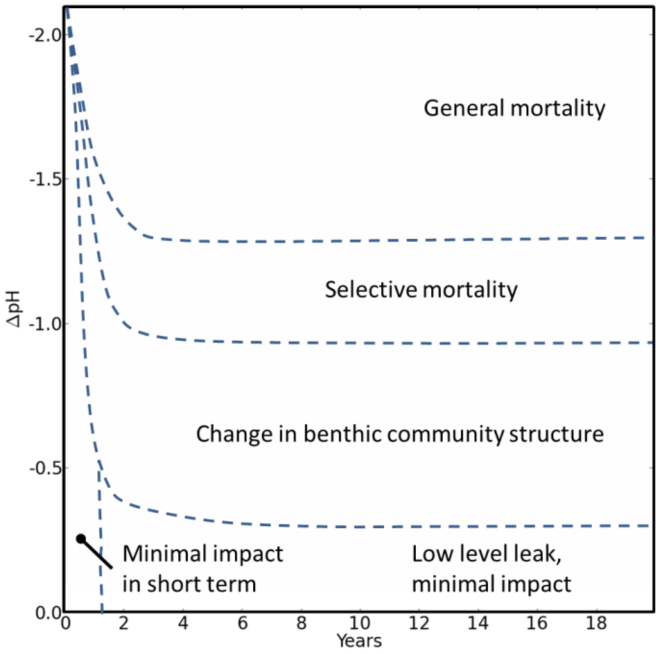

Figure 13-12 Benthic fauna impact categories of simulated pH changes across a 20-years CO_2 exposure period.

Project Greensand Future modelling

The analysis of the geological layers in the Nini Field have shown no evidence of any migration of gases through the cap rock, and that faulting do not extend to the overburden. Thus, no faulting and thereby no CO_2 leak from the reservoir to the seabed is expected. This, combined with high sealing capacity, indicates that the primary seal in the project area represents an effective barrier for containing CO_2 (section 4.1.3). Based on the preliminary investigations and analyses of the geological layers, CO_2 leakage from the reservoir is therefore highly uncertain and only leakage from legacy wells is considered to pose a risk in *Project Greensand Future*.

To evaluate the potential effects of a unlike CO_2 leakage is defined a leakage of ~0.1% of the worst-case blow-out scenario: ~0.26 kg/s or 5.68 mol/s. This corresponds to a leakage of 22 tons/d, for comparison are the largest rate found in the reference cases 10 tons/d. As mentioned in section 13.2.1 is the worst-case scenario based on higher storage capacities than in the *Project Greensand Future*, and therefore the resulting CO_2 release rates will be even lower.

Leakage from an abandoned legacy well Nini-4/4A, has been evaluated based on the data listed in Table 13-8. Two different seasons has been selected for the simulations. March and June have been chosen to reflect typical seasonal variation in metocean conditions.

Table 13-8 Leakage from legacy well – worst case scenario (INEOS Energy, 2023).

Fracture size (mm)	CO_2 Leakage rate (Kg s^{-1})	Pressure (bar)	Temperature (°C)	Physical state
10	0.26	180	18	Liquid

The leakage simulation conditions are highly varying over time and pH-values then varies significant. This is reflected in Figure 13-8 showing timeseries of the simulated pH at the outlet and 40-50 m away.

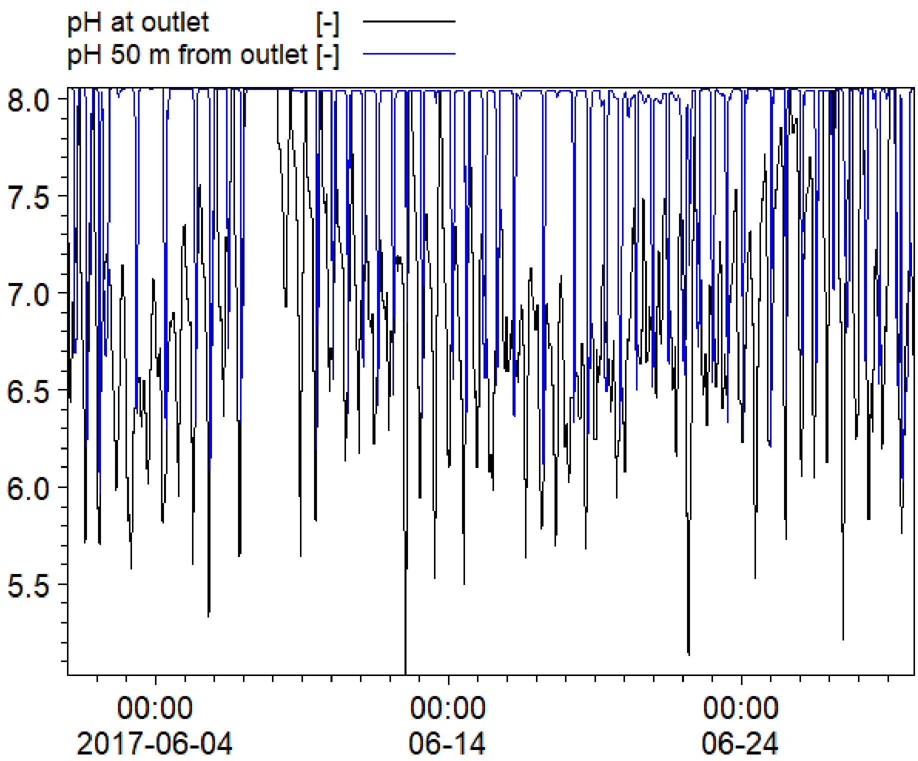

Figure 13-13 Timeseries of simulated pH close to the water surface in June.

Figure 13-14 shows the statistical minimum pH-values across the simulation period of 30 days. The simulation indicates that the pH, for a 30-day period, as a maximum drops 1 pH unit in an area ~600 meter wide and drops 2 pH unit as a maximum in an area ~150-200 m wide. The relative low impact is more clearly illustrated by Figure 13-15 showing the statistical mean values across the simulation period of 30 days. Around the leakage point the area with lowered pH values is very small, this is addressed further below. In Figure 13-16 and Figure 13-17 the vertical profile of minimum and mean pH-values is shown.

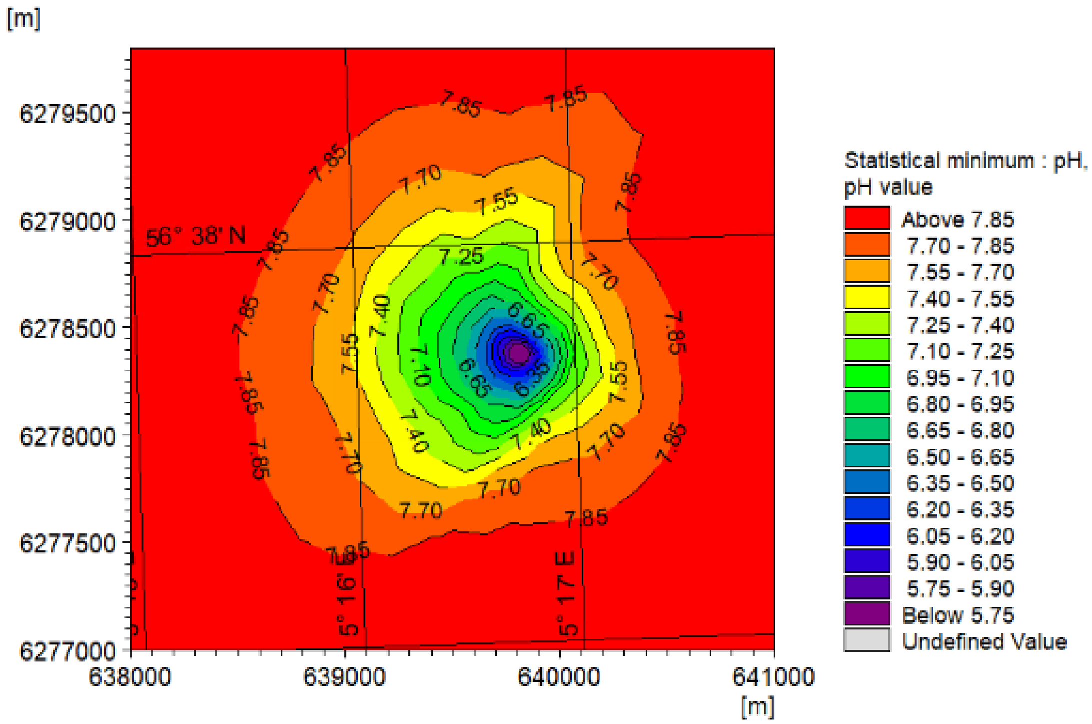

Figure 13-14 Seabed pH values (1 meter above). Statistical minimum value across a period of 30 days.

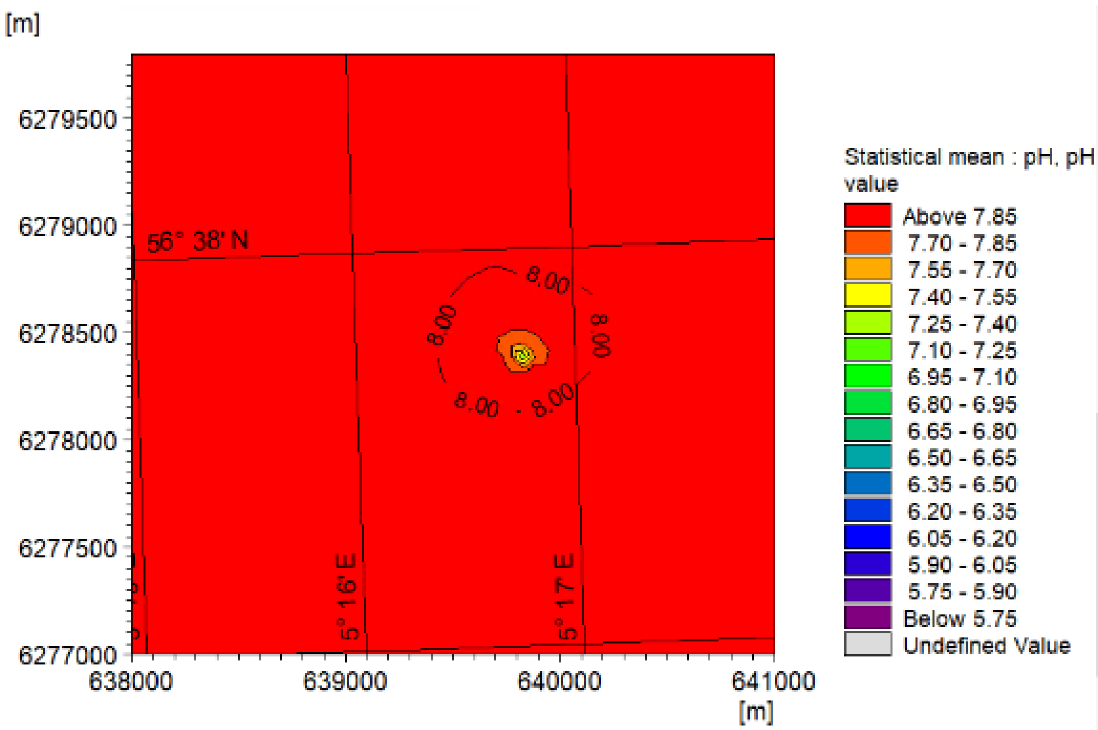

Figure 13-15 Seabed pH values (1 meter above). Statistical mean value across a period of 30 days.

The simulations indicating the pH drop is isolated to just above the seabed, and especially the mean pH-values illustrating that only a small area is impacted for a longer period of time. Note, the scales in Figure 13-16 and Figure 13-17 are not alike.

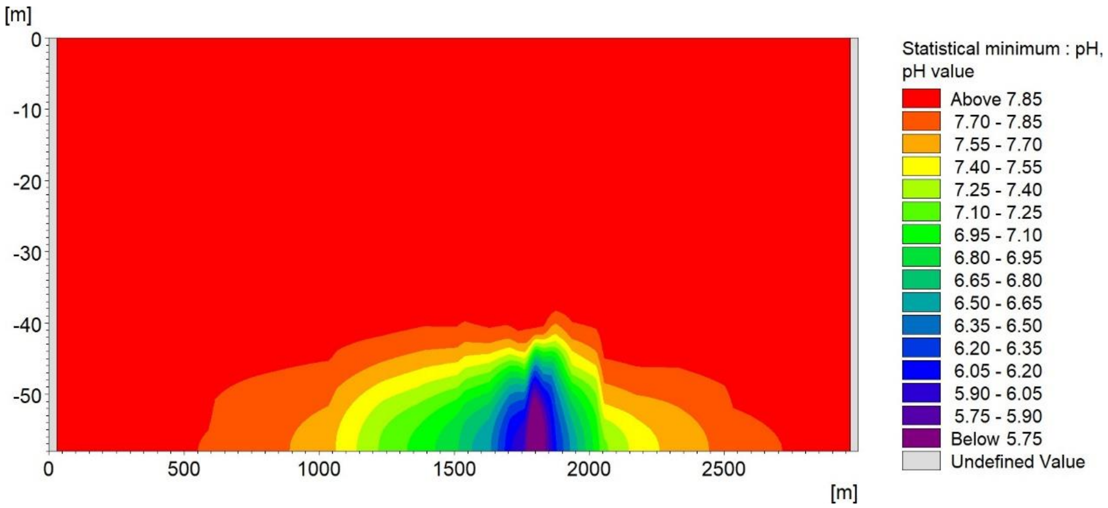

Figure 13-16 Vertical profile of pH. Statistical min value across a period of 30 days.

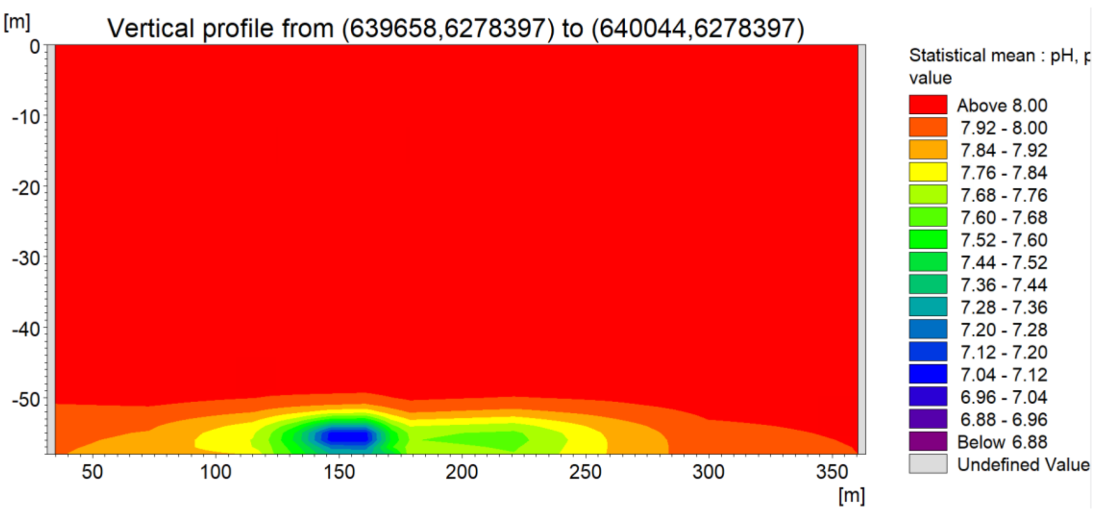

Figure 13-17 Vertical profile of pH. Statical mean data across a period of 30 days.

The frequency of the impact on the seawater pH from CO_2 leakage are shown by the data in Table 13-9 (March) and Table 13-10 (June). It's clearly that there is only a very small zone impacted frequently by pH drops.

Table 13-9 Frequency in percentage of various pH-levels at seabed, at distances the 0 – 600 meters from a point of leakage during a month (March).

pH	0 m	50 m	100 m	200 m	400 m	600 m
<7.5	81	16	9	7	0.3	0.3
<7.0	48	13	3	1.5	0	0
<6.5	19	3	0.4	0.1	0	0
<6.0	6	0.4	0	0	0	0

Table 13-10 Frequency in percentage of various pH-levels at seabed, at distances the 0 – 600 meters from a point of leakage during a month (June).

pH	0 m	50 m	100 m	200 m	400 m	600 m
<7.5	82	16	10	8	0.7	0.3
<7.0	52	12	4	2	0	0
<6.5	25	4	0.1	0	0	0
<6.0	6	0.1	0	0	0	0

The results from the modelling of leakage at Nini aligns very well with the reference cases. The DHI model are including the local hydraulic impacts at Nini and are presumable representing a reliable worst case leakage scenario. As seen from Table 13-9 and Table 13-10. A pH-drop of 1 may occur at a frequency of 12-13% at 50 metre and pH drop of 0.5 at a frequency of 9-10% at 100 metres.

The environmental consequences, risks and effects of a CO_2 leak to the marine environment would depend on both the intensity and longevity of the leak and would be reflected by an increase in DIC and a decrease in seawater pH from its natural level (Amir Rashidi et al., 2020; ECO2, 2016).The modelling results indicate that significant pH changes are local and only at a high frequency below 50 m from the leakage.

CO_2 leakage from the reservoir is found highly uncertain based on the comprehensive preliminary investigations of the geological layers and only leakage from legacy wells is considered to pose a risk. The probability of a leakage is assessed to be very low. **No significant impact** on the North Sea benthic fauna community is expected as only a relatively small area will be affected. As the impact will occur within the **immediate vicinity**, no impact further up the food chain (fish and marine mammals) is expected. The duration of a leak is expected to be **permanent** or **long term**, depending on how long the injection has lasted and its geological origin. The overall consequence of the impact is assessed to be **limited**.

13.2.3 Leakage from offloading operation

During the offloading procedure from the vessel to the well there are a number of potential accidental scenarios that could lead to emissions of CO_2 to the environment as a result of e.g., hose rupture or accidental disconnection. These include but are not limited to:

- Injection vessel damaging the offloading hose system.
- Accidental disconnection from the offloading system due to twisting of flexible hose.
- Incorrect depressurisation during operation

The likelihood of these accidental events to occur are low and generally in the range of 10^{-4} to $<10^{-3}$ i.e., they could occur once per 1.000-10.000 loading operation (Rambøll, 2023).

The injection systems on the offloading or platform support vessel (PSV) and the Nini A platform are designed with insulation valves or Emergency Shut Down Valves (ESDV's) at strategic locations that closes automatically. This prevents or reduces a release in case of accidental/unwanted events and the release is limited to the CO_2 volume in the flexible hose, subsea pipe and the riser connecting to the well on the platform. The maximum emission volume is therefore approximately 11.5 tonnes CO_2 (Brandt, 2024).

The environmental impact would be limited to the **immediate vicinity** of the release point. The impact duration would be **short term** and the impact on planktonic and pelagic species in the near vicinity would be negligible as the released volumes are expected only to cause a short-term impact on water quality before equilibrium is established. The bulk of the released CO_2 will reach the sea surface and enter the atmosphere. The impact would be reversible, and the overall consequence of the impact is assessed to be **negligible**. Further, the impact on the climate system is assessed as **limited** as an accidental release of 11.5 tonnes CO_2 is a very low mass compared to the CO_2 stored in the reservoir.

13.3 Ship collisions

It is assumed that CO_2 will be loaded onto a PSV modified for CO_2 transport at Esbjerg harbour in Denmark. The sailing distance transported to the Nini A platform is expected to be 127 nm (235 km).

It is expected that one CO_2 vessel will be used for the transports, and that it will perform a maximum of 130 injection cycles per year. Depending on the origin of the transports, shipping routes will change and hence represent different collision risks.

The shipping route is shown in Figure 13-18 and as indicates the shortest route between the Nini A platform and a port of Esbjerg on the west coast of Jutland.

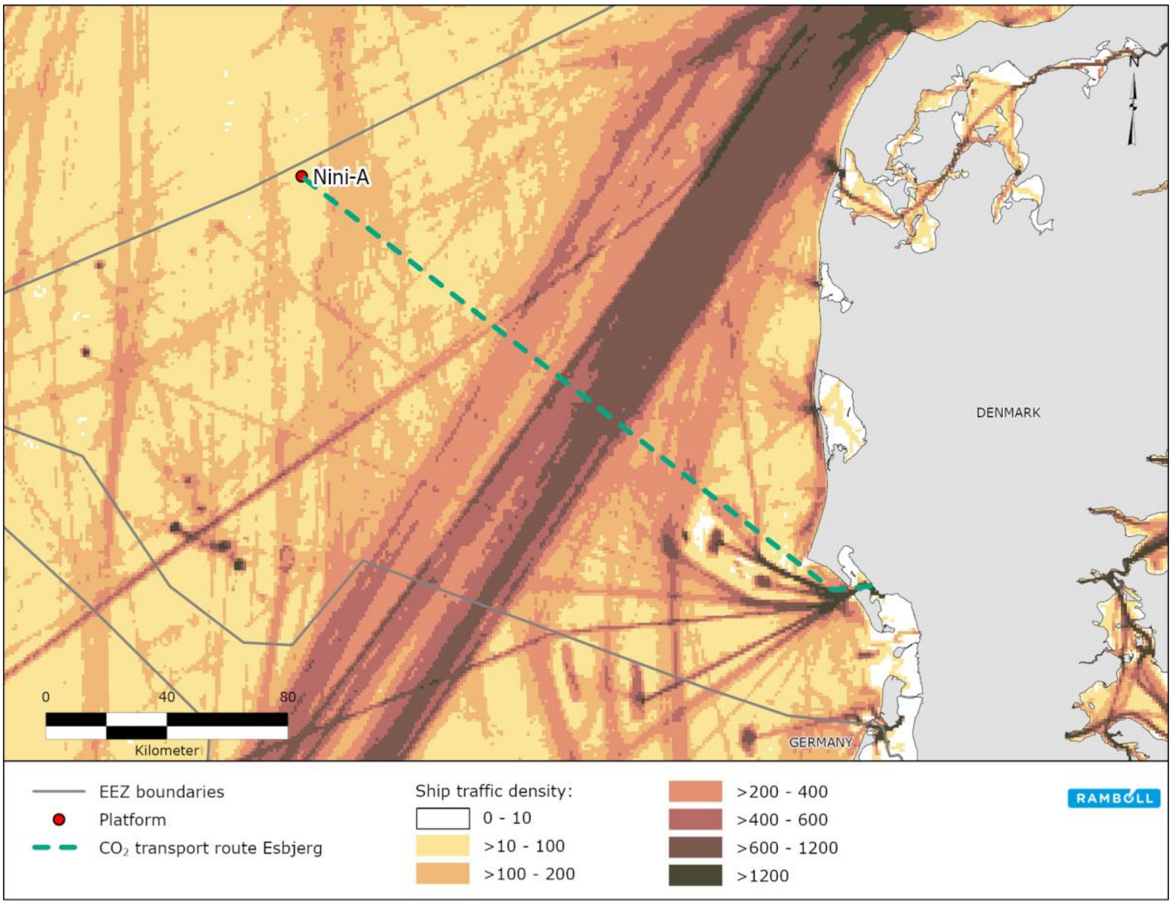

Figure 13-18. CO_2 transport route.

The CO_2 transport route is comparable to the routes currently originating from harbours at the Danish west coast and going to and from offshore structures in the North Sea. The main risk is assessed to be the crossing situation where default COLREG rules apply in the interaction with crossing ship traffic.

It is to be noted that ongoing and future development of wind energy in the North Sea as well as future guidance and regulation of ship traffic will also affect the CO_2 vessel. The general safety of shipping is ensured through environmental impacts assessments for offshore construction projects and coordination between these projects and the Danish Maritime Authority (DMA). Hence, for the transports of CO_2, it is assumed that the CO_2 vessel follows the defined shipping corridors, where relevant, and carry pilot as required. It is emphasized that the CO_2 transports – as any other ship traffic – must coordinate with potential ongoing construction projects and navigate according to updated sea charts to interact correctly with offshore structures.

It is noted that a maximum of 130 injection cycles per year are assessed to be insignificant compared to the ship traffic along the transport routes. It is also noted that transport of CO_2 under pressure only occurs for the part of the trips towards the Nini A platform whereas the CO_2 vessel is in ballast when returning to port. Considering use of pilot where required and following ordinary COLREG rules for safe navigation, the additional ship collision risk imposed by the CO_2 vessel is assessed to be low.

Connecting the vessels to the offloading system at the Nini A platform shall be coordinated through the operational procedures. The offloading system is placed within the 500-meter safety zone of the Nini A platform.

14. WATER FRAMEWORK DIRECTIVE

14.1 Introduction

The Water Framework Directive (WFD) is implemented in Denmark by the Act on Environmental Objectives (Consolidation Act no. 692 of 26/05/2023) and the Act on Water Planning (Consolidation Act no. 126 of 26/01/2017) and detailed in the Danish River Basin Management Plans (RBMPs), which are described in chapter 7. The overall objective of the WFD is to ensure the quality of surface waters (lakes, streams, transitional and coastal waters) and groundwater by achieving good ecological status and good chemical status by 2027. As the scope of this EIA contains exclusively offshore activities, only impacts to coastal waters are relevant and analysed in the following.

The objective to achieve good ecological status applies within the 1 nm zone from shore while the objective to achieve good chemical status applies within the 12 nm zone from shore. For coastal waters, the ecological status is generally determined based on the quality elements and associated indicators shown in Table 14-1. Together, the ecological and chemical status make up the overall status of a water body.

Table 14-1 Quality elements and indicators for assessing the ecological status of coastal waters cf. the WFD.

Quality element	Indicator
Phytoplankton	Concentration of chlorophyll a
Macroalgae and angiosperms	Depth limit of rooted macrophytes (eelgrass or pond weed)
Benthic fauna	Danish quality index for benthic fauna (DKI)
National specific environmentally hazardous substances in sediment and biota	CF. order no. 796 of 13/06/2023 (Miljøministeriet, 2023).

However, for coastal waters along the coastline of Jutland, only phytoplankton and benthic invertebrates are used to assess the ecological status since growth of rooted macrophytes are inhibited by a high level of physical exposure in that area. The biological quality elements are supported by physico-chemical parameters including light, oxygen, salinity, and temperature.

The chemical status is determined based on concentrations of priority substances and whether they exceed the relevant Environmental Quality Standards (EQS) established in the Environmental Quality Standards Directive 2008/105/EC (as amended by the Priority Substances Directive 2013/39/EU).

14.1.1 Potential impacts

Potential impacts to the WFD relate to impacts to water quality assessed from the biological quality elements; phytoplankton, macroalgae and angiosperms, and benthic invertebrates along with concentrations of priority substances and environmentally hazardous substances.

Activities in the *Project Greensand Future* which are expected to potentially impact the water quality and thereby impede the fulfilment of WFD's objectives are:

- Chemical discharges: in the construction phase, chemical discharges relate to the preparation of the offloading system, where fluorescent and corrosion inhibitor chemicals with seawater is flooded through the subsea pipeline. As the WFD is only applicable within the 1 nm mile limit (ecological status) and 12 nm limit (chemical status) from shore, it is assessed that these discharges cannot reach areas where the WFD applies, since impacts will occur in the immediate vicinity around the platform, see section 11.5.

Potential impacts from accidental events on the objectives within the WFD are:

- Oil spill in connection with CO_2 blowout is considered to pose a risk to objectives set within the WFD (see section 13.1).

Impacts from a CO_2 leakage were assessed to only occur in the immediate vicinity of a leak (approx. 170 km from shore) with no significant impacts to the environment and will therefore not affect the WDF (see section 13.2). The likelihood of an oil spill related to blow out event is low.

As described in section 13.1.3 the drift time from Nini A to the shoreline will be more than 20 days, in case of an oil spill lasting 90 days (worst case). The stranded oil will mostly be in the form of tar balls. The risk of a blow-out is very low and assessed to not be able to impact the quality elements phytoplankton, macroalgae and angiosperms and benthic fauna, and they are therefore not described further.

14.1.2 Methods and data

The CO_2 vessel will sail from the port of Esbjerg. The port of departure for the other supporting vessels are unknown, so it is not possible to assess the status and potential impacts on a site-specific level. The baseline of this assessment will therefore assess the general status for Danish coastal waters under the WFD.

Impacts on the WFD are assessed according to the impact on the ecological status i.e., to the following biological quality elements: phytoplankton, macroalgae and angiosperms, and benthic fauna and the impact on the chemical status with regard to priority substances and environmentally hazardous substances in sediment and biota. The assessment is based on the third generation RBMPs covering the period from 2021-2027 as well as the current status of Danish river basins which are available through the Danish Environmental Protection Agency GIS-database (Miljøstyrelsen, 2023a).

14.1.3 Assessment of impacts

Only five coastal waters out of a total of 109 are assessed to have good ecological status and 6 have a good chemical status according to the newest status of Danish river basins (Miljøstyrelsen, 2023a). This means that there is a reasonable chance that vessels may ship out from harbours located in coastal waters that are currently not living up to the target in the WFD. Impacts from other discharges are assessed for each quality element in the table below.

Based on the assessment shown in Table 14-2 it is assessed that *Project Greensand Future* will not delay nor hinder the WFD's objective of achieving good ecological and good chemical status in Danish coastal waters.

Table 14-2 Assessment of impacts to the biological quality elements in Danish coastal waters.

Biological quality element and chemical parameters	Impact assessment	Overall consequence
Macroalgae and angiosperms	As assessed in section 11.5, impacts from chemical discharges are expected to occur in the immediate vicinity of the project area without significant implications to the water quality. No impacts from chemical discharges are therefore expected within the 1 nm limit which may affect macroalgae and angiosperms.	**None**
Benthic fauna	As assessed in section 11.5 and 11.6, impacts from chemical discharges are expected to occur in the immediate vicinity of the project area without significant implications to the water quality. No impacts from chemical discharges are therefore expected within the 1 nm limit which may affect benthic fauna.	**None**
Phytoplankton	As assessed in section 11.5, impacts from chemical discharges are expected to occur in the immediate vicinity of the project area without significant implications to the water quality. No impacts from chemical discharges are therefore expected within the 1 nm limit which may affect phytoplankton.	**None**
National specific environmentally hazardous substances in sediment	OSPAR regulations (see section 7.2) apply. Chemical discharges are only associated with leak test of the offloading system. The discharge plume that could affect the objectives of the WFD is restricted to a local area with a maximum impact range of a few meters. The effect would be reversible within a short timeframe and the consequence of chemical discharge on sediment is therefore assessed as negligible. Unplanned events Oil spill from blow out might lead to an impact on the coast and coastal areas. The oil will most likely reach the beach area as tar balls, which can be cleaned up and the risk of a blow-out is very low with several safety procedures in place to ensure that the blow out is stopped. The risk of an impact is therefore very low.	**Negligible**
National specific environmentally hazardous substances in biota	OSPAR regulations (see section 7.2) apply. Chemical discharges are only associated with leak test of the offloading system. The discharge plume that could affect the objectives of the WFD is restricted to a local area with a maximum impact range of a few meters. Some plankton are sensitive to toxic effects, however, at the same most plankton have a fast turn-over rate, and the concentration of plankton close to the seabed is low. The effect would be reversible within a short timeframe and the consequence of chemical discharge on plankton and benthic fauna is therefore assessed as negligible. Unplanned events Oil spill from blow out might lead to an impact on the coast and coastal areas. The oil will most likely reach the beach area as tar balls, which can be cleaned up and the risk of a blowout is very low with several safety procedures in place to ensure that the blow out is stopped. The risk of an impact is therefore very low.	**Negligible**
Concentrations of priority substances	OSPAR regulations (see section 7.2) apply. Chemical discharges are only associated with leak test of the offloading system. The discharge plume that could affect the objectives of the WFD is restricted to a local area with a maximum impact range of a few meters. The effect would be reversible within a short timeframe and the consequence of chemical discharge is therefore assessed as negligible. Unplanned events Oil spill from blowout might lead to an impact on the coast and coastal areas. The oil will most likely reach the beach area as tar balls, which can be cleaned up and the risk of a blowout is very low with several safety procedures in place to ensure that the blowout is stopped. The risk of an impact is therefore very low.	**Negligible**

15. MARINE STRATEGY FRAMEWORK DIRECTIVE

15.1 Introduction

The Marine Strategy Framework Directive (MSFD) aims to protect the marine environment through an ecosystem-based approach where the overall objective is to achieve good environmental status (GES) in the Member States' Sea areas. The directive is implemented in Danish legislation through The Marine Strategy Act, Consolidation Act no. 123 af 01/02/2024, which defines 11 descriptors which collectively assess GES for the North Sea (including Kattegat) and the Baltic Sea. GES is determined based on a set of criteria set forth by the EU-commission in the GES-decision from 2017 (Den Europæiske Unions Tidende, 2017).

In Table 15-1 the 11 descriptors are listed together with relevant environmental targets, criteria, and the current environmental status for each descriptor in the North Sea. The environmental status was last assessed in April 2019 under the Marine Strategy II (Miljø- og Fødevareministeriet, 2019).

The descriptors embrace both receptors and sources of impacts for identifying human impact on marine ecosystems. This combination of causes and effects are described in rather general terms. The MSFD does not include clear criteria that define "good" environmental status. The impact assessment of *Project Greensand Future* on the descriptors in the MSFD is therefore anchored on more specific thresholds (i.e., the OSPAR convention).

Marine strategy Areas

Marine Strategy areas are designated in the North Sea with the objective of protecting the benthic environment. The following activities is prohibited in all areas (Miljøministeriet, 2021):

- Fishing with bottom trawling gear (including boom trawl, bottom trawl and seine, etc.).
- Offshore wind and energy islands (including constructions, seismic surveys, etc.).
- Oil and gas activities (including constructions, drilling, seismic surveys, etc.).
- Extraction of raw materials (including seismic surveys, etc.).
- Dumping.
- CO_2 storage (including constructions, drilling, seismic surveys, etc.).
- Aquaculture (including mariculture (fish farming), shellfish farming and seaweed farms).
- New transport infrastructure (including bridges and tunnels, etc.).
- Geological / seismic surveys not related to
  - scientific research or nature conservation management.
  - installation and maintenance of cables, pipes, wires, etc.

In the strictly protected marine strategic areas, in addition to the above, additional constrains on fishing with all gear (both commercial fishing and leisure/recreational fishing) is also implemented.

Construction and maintenance of cables, pipes, wires, etc. will continue to be possible in both types of protected areas, but it is incumbent on the approval authority to do so with the greatest possible consideration for the protected marine strategic areas. This assessment will also be able to take social and economic considerations into account. Seismic studies in relation to this will be possible.

The restrictions are introduced within the protected and strictly protected Marine Strategic Areas, thus no restrictions are set in relation to activities that take place outside the areas, regardless of whether they can cause an impact into the areas (Miljøministeriet, 2021).

The nearest MSFD area is located approx. 17 km from the project area (Figure 10-22). The use of the area is required to comply with the objectives of the MSFD of achieving GES for the 11 descriptors found in Table 15-1. Part of the area is further imposed by strict protection meaning that fishery (both commercial and recreational) is prohibited. No prohibited activities take place inside Marine Strategy Areas and therefore *Project Greensand Future* comply with the legislation.

15.1.1 Potential impacts

The list of receptors and impact mechanisms described in section 9.1.2 can be directly related to the descriptors set within the Marine Strategy Framework Directive (MSFD; chapter 7). Potential impacts from planned activities in *Project Greensand Future* on the descriptors within the MSFD are:

- Underwater noise: in the construction phase, underwater noise is expected from vessels carrying out installation of the offloading system and flowline. In the operation phase, underwater noise is expected from seismic, the CO_2 leakage monitoring system, the seismic survey vessel, support vessels carrying out maintenance and from the CO_2 vessel.
- Disturbance from vessels: in the construction phase, disturbance from vessels required for transport in relation to installation activities. In the operation phase, disturbance from vessels is expected from the CO_2 vessel and from the vessel carrying out seismic and from vessels carrying out maintenance.
- Physical footprint: in the construction phase and throughout the operation phase, a physical footprint is expected from the offloading system and from the CO_2 leakage monitoring system.
- Physical disturbance of seabed: in the construction phase, physical disturbance is expected from resuspension of sediment when the subsea pipeline and concrete mattresses are placed on the seabed.
- Light: in the construction phase, light emissions are expected from the Nini A platform and vessels. In the operation phase, light emissions are expected from the Nini A platform, CO_2 vessel and the vessel carrying out seismic and maintenance operations.

Potential impacts from accidental events on the descriptors within the MSFD are:

- Oil spill in connection with CO_2 blowout.

15.1.2 Methods and data

The following impacts assessment of the present project on MSFD descriptors is based on the assessments as described in chapter 11, 12 and 13, which is supported by a baseline survey of the project area, underwater noise modelling, existing data and best available scientific literature as well as previous environmental impact assessments of similar projects.

The MSFD embraces both the nature of sources and the receptors for identifying impacts on marine ecosystems. The descriptors presented in the MSFD are meant as general criteria used to define environmental status. These assessments embrace direct effects on the receptors identified while more indirect effects are difficult to unravel in detail. No clear elaborated and standardized methods exist for describing the severity of environmental impacts on the functioning of the ecosystem. Therefore, a more detailed understanding on how the system reacts on different external impacts is needed for a proper assessment of different cumulative impacts on system level. Based on the assessment of the project the potential impacts are limited and for the most part temporary.

The data basis of this assessment is therefore considered to be sufficient to assess impacts on an ecosystem level.

15.1.3 Assessment of impacts

The receptors identified in this EIA are especially related to the MSFD state descriptors i.e., D1, D4, and D6 which more specifically relate to biodiversity (seabirds, marine mammals, non- commercially exploited fish, and pelagic habitats i.e., plankton), the marine food web and benthic habitat types.

The impact mechanisms of planned activities and accidental events are related to the MSFD pressure descriptors D5, D6, D7, D8, D9 and D11 which more specifically relate to eutrophication, seafloor integrity (loss and physical impacts), hydrographical changes, contaminants (including discharge of contaminants and oil spill events as well as contaminants in seafood for human consumption), and underwater noise. The impacts from these mechanisms are assessed for the relevant receptors in chapter 11, 12 and 13. The pressure descriptors D2 (non-indigenous species) and D10 (marine litter) are assessed as irrelevant to the current project as all vessels follow the standards and procedures for the management and control of ships' ballast water and sediments in accordance with the Ballast Water Management Convention (BWM, see chapter 7), which will prevent the spread of harmful aquatic organisms from one region to another, while all waste is shipped to shore where it is treated according to current legislation. No marine litter is therefore expected from the project.

The identified impacts of *Project Greensand Future* on the physical-chemical, biological and socio-economic environment have been generally summarized and further assessed for the overall impact in accordance with the descriptors of the MSFD, see Table 15-1.

No prohibited activities take place inside Marine Strategy Areas and therefore *Project Greensand Future* comply with the legislation. No significant impacts to any individual receptor have been identified and the data available is as being sufficient. Based on the above it is assessed that *Project Greensand Future* will not delay nor hinder the MSFD's goal of achieving Good Ecological Status for the descriptors contained in the MSFD.

Table 15-1 Relevant environmental targets and current status of the 11 descriptors in the North Sea and the overall assessment of potential impacts from the current project. Current status is based on data from the latest assessment of the North Sea ((Miljø- og Fødevareministeriet, 2019b)**.**

Descriptor	Relevant environmental target	Current environmental status	Overall assessment of impacts
Descriptor 1. Biodiversity - Birds: The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.	1.1 Incidental by-catch of birds is at a level that does not threaten the species in the long term 1.2 Populations and habitats for birds are conserved and protected in accordance with objectives under the Birds Directive 1.3 The Ministry of Environment and Food contributes to regional work regarding establishment of threshold values and determination of good environmental status and works to ensure that the status for biological diversity is in accordance hereto.	Good environmental status for birds corresponds to assessments under the Birds Directive. Data from the most recent report (2013) on breeding birds shows that certain species groups, such as herbivorous birds and birds that forage in the water column, are generally stable or increasing. For groups such as wading birds and birds that forage in the water surface, less than 75% of the species are stable or increasing. For overwintering birds, the majority of the species groups are stable, increasing or fluctuating; however not birds that forage on the sea floor.	Impacts on seabirds is assessed in Section 11.9. Potential impacts include: • Disturbance from vessels • Light Overall assessment: • Low/medium vulnerability • Immediate vicinity/local extent • Low intensity • Very short-term/permanent duration • **Negligible consequence** On that basis, no significant consequences are assessed for descriptor 1 (birds).
Descriptor 1. Biodiversity - Marine mammals: The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.	1.6 Incidental by-catch of harbour porpoise is reduced as much as possible, and as a minimum to a level below 1.7 % of the total population. 1.7 Incidental by-catch of seals is at an adequately low level that does not threaten populations in the long term. 1.8 Harbour porpoise, harbour seal and grey seal achieve favourable conservation status in accordance with the timeline laid down in the Habitats Directive.	Good environmental status for marine mammals corresponds to favourable conservation status under the Habitats Directive. Good environmental status has been achieved for harbour seal. Grey seal populations are increasing but did not achieve good status in 2013. The population of harbour porpoises in the North Sea is stable. Knowledge about bycatch is limited, especially for seals, but by-catch for harbour porpoise is deemed to be less than 1% of the population.	Impacts on marine mammals is assessed in Section 11.8. Potential impacts include: • Underwater noise • Disturbance from vessels • Light Overall assessment: • Low/medium vulnerability • Immediate vicinity/regional extent • Low/medium intensity • Short/permanent duration • **Negligible/limited consequence** On that basis, no significant consequences are assessed for descriptor 1 (marine mammals).

Descriptor	Relevant environmental target	Current environmental status	Overall assessment of impacts
Descriptor 1. Biodiversity - Fish: The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.	Only operational targets exist for fish that are not commercially exploited.	The status for fish that are not exploited commercially has been assessed on the basis of 14 selected species. In relation to fish mortality, a little less than 1/4 of the examined populations have good status. In relation to population density, just under half of the examined populations have good status.	Impacts to fish is assessed in Section 11.7. Potential impacts include: • Underwater noise • Physical footprint • Physical disturbance of the seabed • Light Overall assessment: • Low vulnerability • Immediate vicinity/local extent • Low/medium intensity • Short/permanent duration • **Negligible/limited consequence** On that basis, no significant consequences are assessed for descriptor 1 (fish).
Descriptor 1. Biodiversity - Pelagic habitats: The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.	1.13 The abundance of plankton follows the long-term average.	Overall, the phytoplankton biomass declined steadily in the North Sea from 1978-2016 with a slight increase after 2012. There is not enough data on zooplankton to assess the development.	Impacts on plankton is assessed in Section 11.5. Potential impacts include: • Chemical discharges Overall assessment: • Low vulnerability • Immediate vicinity • Low intensity • Very short-term duration • **Negligible consequence** On that basis, no significant consequences are assessed for descriptor 1 (pelagic habitats).
Descriptor 2 Non-indigenous species: Introduced by human activities are	2.1 The number of new non-indigenous species introduced through ballast water, ship fouling, and other relevant human activities is decreasing.	New non-indigenous species are still being registered in both the North Sea and the Baltic Sea. It is not likely that a drop in new introductions of non-indigenous species can be achieved before international	As all vessels follow the Ballast Water Management Convention, no impacts from discharge of ballast water are expected and has not been assessed in this EIA.

Descriptor	Relevant environmental target	Current environmental status	Overall assessment of impacts
at levels that do not adversely alter the ecosystems.	2.2 The distribution of certain invasive species is, as far as possible, at a level so that significant adverse effects are stable or decreasing. 2.3 The Ministry of Environment and Food contributes to regional work regarding establishment of threshold values and determination of good environmental status and works to ensure that the number of new nonindigenous species and impacts from invasive species are in accordance hereto.	interventions such as the United Nations Ballast Water Management Convention start to have an effect. In general, there is insufficient data, but it is likely that good environmental status has not been achieved in the Baltic Sea or the North Sea.	Consequences are therefore assessed as **irrelevant**.
Descriptor 3 Commercial fish and shellfish: Populations of commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.	3.1 The number of commercially exploited fished stocks regulated pursuant to the MSY principles in the Common Fisheries Policy is increasing. 3.2 Within the framework of the Common Fisheries Policy, fish mortality (F) is at levels that can ensure a maximum sustainable yield (Fmsy). 3.3 Within the framework of the Common Fisheries Policy, spawning biomass (B) exceeds the level that can ensure a maximum sustainable yield (MSY Btrigger).	The environmental status for commercially exploited fish stocks is generally considered not good. The assessment was carried out for 22 selected stocks of fish, crustaceans and shellfish. Ten stocks have good status, but the status for eight of the stocks is not good.	Impacts on fisheries is assessed in section 12.3. Potential impacts include: • Restricted zones Overall assessment: • Low vulnerability • Immediate vicinity • Low intensity • Permanent duration • **Negligible consequence** On that basis, no significant consequences are assessed for descriptor 3.

Descriptor	Relevant environmental target	Current environmental status	Overall assessment of impacts
Descriptor 4 Food webs: All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.	4.1 The Ministry of Environment and Food contributes to regional work regarding establishment of threshold values and determination of good environmental status and works to ensure that the anthropogenic impacts on the food web are in accordance hereto.	Marine food webs are assessed on the basis of organisms that represent different levels in the food web, i.e. plankton, fish, birds and marine mammals. Species diversity for plankton was calculated, where possible. Trends for biomass for plankton, fish, birds and mammals have been presented. The general picture for several of the indicators assessed is a slight increase in biomass in recent years. For birds, the picture is more mixed. Biomass for phytoplankton decreased steadily from 1978-2012, after which there was a slight increase. Despite assessments of the individual sub-components in the food web, it is not possible to assess whether the food web as a whole will have good environmental status in 2020.	Impacts to plankton, fish, marine mammals and seabirds are assessed in sections 11.5, 11.7, 11.8 and 220 and the overall assessment is reviewed above under descriptor 1. The overall consequence of potential impacts to these receptors are negligible or limited in both the construction and operation phase. On this basis, no significant consequence is assessed for descriptor 4.
Descriptor 5 Eutrophication: Human-induced eutrophication is minimized, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters.	5.1 The Ministry of Environment and Food contributes to regional work regarding establishment of threshold values and determination of good environmental status for the North Sea, including the Skagerrak, and works to ensure that anthropogenic eutrophication and its effects are in accordance hereto. 5.2 Danish inputs of nitrogen and phosphorus (TN, TP) comply with the maximum acceptable inputs stipulated under HELCOM. 5.3 Coastal waters: Target loads and needs for measures for fjords, estuaries and coastal waters determined in accordance with the Water Framework Directive are complied with. Targets and needs are described in the Danish River basin management plans.	With regard to eutrophication, the status is good in the open Danish marine areas located far from the coast in the North Sea, including the Skagerrak. However, good status has not yet been achieved in the open marine areas closer to the coast, and none of the coastal areas have met their targets.	Impacts to water quality is assessed in section 11.3. Potential impacts include: • Chemical discharges Overall assessment: • Low vulnerability • Immediate vicinity • Low intensity • Very short-term duration • **Negligible consequence** On that basis, no significant consequences are assessed for descriptor 5.

Descriptor	Relevant environmental target	Current environmental status	Overall assessment of impacts
Descriptor 6 Sea-floor integrity (losses and physical impacts): Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.	6.1 Ministry of Environment and Food contributes to work regionally and in the EU regarding establishment of threshold values and determination of good environmental status, and works to ensure that losses, physical disturbance and adverse effects on the sea floor are in accordance hereto.	The sea floor in Denmark is intensively utilised, with disturbance rates of around 85 % in the North Sea. Total loss is about 1 % for the North Sea, but for some habitat types, losses are high. Data from stone reefs and the soft seabed in open waters shows that light penetration in the sea has improved, and this optimises the conditions for benthic species. No threshold values for good status have yet been set, but on the basis of the above statistics, it is likely that the sea floor status is not good in terms of disturbance, or in terms of losses for some habitat types.	The total physical footprint from structures in the construction phase and operation phase is approx. 850 m^2, which result in permanent loss of seabed, as the structures remain for more than 8 years. The impact from physical loss and physical disturbance to the seafloor was also assessed in Section 9.1.1. Considering the relatively small dimensions of the physical footprint and physical disturbance in a homogenous area, no significant consequences are assessed for descriptor 6 (losses and physical impacts).
Descriptor 6 Sea-floor integrity (habitat types on the sea floor): Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.	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. 6.6 The northern Sound is designated as a marine protected area pursuant to the Marine Strategy Framework Directive, and new licences to extract mineral resources are stopped. This will not result in any changes in relation to the existing fisheries regulation. 6.7 The most important habitats contain the typical species and communities for Danish marine areas.	The sea floor in Denmark is intensively utilised, with disturbance rates of around 85 % in the North Sea. Total loss is about 1 % for the North Sea, but for some habitat types, losses are high. Data from stone reefs and the soft seabed in open waters shows that light penetration in the sea has improved, and this optimises the conditions for benthic species. No threshold values for good status have yet been set, but on the basis of the above statistics, it is likely that the sea floor status is not good in terms of disturbance, or in terms of losses for some habitat types.	The installed structures will occupy an area of approx. 850 m^2 and are considered to result in a permanent loss of seabed, as the structures remain for more than 8 years. The benthic broad habitat type within the project area consists entirely of "offshore circalittoral mud", which is the dominant habitat type around the project area along with "offshore circalittoral sand". Considering the relatively small dimensions of the physical footprint and physical disturbance in a homogenous area, no significant consequences are assessed for descriptor 6 (habitat types on the sea floor).

Descriptor	Relevant environmental target	Current environmental status	Overall assessment of impacts
Descriptor 7 Hydrographical conditions: Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.	7.1 Anthropogenic activities that are particularly associated with physical loss of the sea floor, and which cause permanent hydrographical changes - only have local impacts on the sea floor and in the water column, and - are designed to take account of the environment and what is technically possible and financially reasonable to prevent harmful effects on the seabed and in the water column.	Permanent alteration of hydrographical conditions has been identified in both the water column and on the seabed. The adverse effects of these changes are assessed to be insignificant. The greatest impact per habitat type occurs on infralittoral mixed sediments, infralittoral rocks and biogenic reefs.	Impacts to hydrography is assessed in Section 11.2. The installed structures will occupy an area of approx. 850 m^2 and are considered to result in a permanent loss of seabed, as the structures remain for more than 8 years. However, as assessed in Section 10.2, these structures will not affect the hydrography and no significant consequences are assessed for descriptor 7.
	7.2 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 hydrographical changes and the adverse effects of these.		
Descriptor 8 Contaminants (concentrations and species health) are at levels not giving rise to pollution effects.	8.1 Discharges of contaminants in the water, sediment and living organisms do not lead to exceeding of the environmental quality standards applied in current legislation	Outside territorial waters, there is generally good environmental status for the substances PFOS and Benzo(a)pyrene. Good environmental status has not been achieved for either mercury or the group of brominated flame retardants. Moreover, the content of both these substances in fish has increased over recent years. There are higher levels of TBT in several places, in particular around shipping lanes and in ports and harbours in the Baltic Sea and Kattegat. Levels of deformed young eelpout have increased, which indicates an environmental impact.	Potential impacts to the water quality with respect to contaminants was assessed in section 11.3. Potential impacts include: • Chemical discharges Overall assessment: • Low vulnerability • Immediate vicinity • Low intensity • Very short-term duration • **Negligible consequence** Furthermore, as no significant impact was assessed for plankton (section 11.5), no derived effects on higher trophic levels are assessed correspondingly. On that basis, no significant consequences are assessed for descriptor 8.
	8.2 Emissions, discharges and losses of PBDE and mercury are ceased or phased out.		
	8.3 The Ministry of Environment and Food contributes to work regionally and in the EU regarding establishment of threshold values and determination of good environmental status and works to ensure that the quantities of contaminants are in accordance hereto.		
	8.4 There is a gradual decrease in the levels of imposex/intersex in marine gastropods.		

Descriptor	Relevant environmental target	Current environmental status	Overall assessment of impacts
Descriptor 8 Contaminants (acute pollution events) are at levels not giving rise to pollution effects.	8.9 The spatial extent and duration of acute pollution events is gradually reduced as much as possible through prevention, monitoring and risk-based scaling of contingency and response facilities.	Good environmental status cannot be assessed for acute pollution events in the North Sea, as there are large annual variations over the period for oil and chemicals spills from oil and gas installations. Therefore, it is not possible to derive a trend over the years.	Oil spill from a blowout will might lead to an impact on water quality, benthic communities, fish, birds and marine mammals in a worst-case scenario see chapter 13. The risk of a blowout is very low with several safety procedures in place to ensure that the blowout is stopped. The risk of an impact on descriptor is therefore very low and not likely to have consequences for descriptor 8.
	8.10 Adverse effects on marine mammals and birds from acute pollution events are prevented and minimised as much as possible. For example, this may be secured by means of floating booms as well as through contingency plans for marine mammals and birds injured in oil spills.		
Descriptor 9 Contaminants in seafood: Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards.	9.1 Emissions of contaminants generally do not lead to exceeding of the maximum residue levels applicable in the food legislation for seafood.	There is good status regarding concentrations of the heavy metals lead, cadmium, mercury, as well as benzo(a)pyrene in fish and other seafood for human consumption. There are, however, too high concentrations of dioxins and PCB in mackerel, cod liver and salmon. Because of excessive concentrations, there is a ban on selling specific fish of a certain size caught in the Baltic Sea.	Potential impacts to the water quality with respect to contaminants was assessed in section 11.3 and 11.5. Potential impacts include: • Chemical discharges Overall assessment: • Low vulnerability • Immediate vicinity • Low intensity • Very short-term duration • **Negligible consequence** Furthermore, as no significant impact was assessed for plankton or benthic fauna from the release of contaminants from chemical discharge (section 11.5 and 11.6), no derived effects on higher trophic levels were assessed correspondingly. On that basis, no significant consequences are assessed for descriptor 9.
	9.2 Emissions of contaminants generally do not lead to exceeding of the maximum residue levels applicable in the food legislation for seafood.		

Descriptor	Relevant environmental target	Current environmental status	Overall assessment of impacts
Descriptor 10 Marine litter: Properties and quantities of marine litter do not cause harm to the coastal and marine environment.	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. 10.2 The Ministry of Environment and Food contributes to work regionally and in the EU regarding establishment of threshold values and determination of good environmental status and works to ensure that the quantities of marine litter are in accordance hereto. 10.3 Losses of fishing gear in Danish waters are prevented to achieve the UN goal that marine litter is prevented and significantly reduced by 2025.	Basically, litter should not be found in nature, and therefore it is assessed that there is currently too much litter in the marine environment. Primarily because of currents, marine litter is a particular problem on beaches along the west coast of Jutland, and plastic is the dominant litter type. The highest levels in 2015 were on Skagen beach. From 2012-2016, 95 % of fulmar (bird) had plastic in their stomach, while microparticles were found in 20-30% of the fish stomachs examined.	No activities resulting in marine litter is expected in this project and has therefore not been assessed in this EIA. Consequences are therefore assessed as **irrelevant**.
Descriptor 11 Energy including underwater noise: Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.	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 best knowledge currently available is on these species. However, it is likely that these limits will be revised as new knowledge on the area becomes available. The values are the sound-exposure level accumulated over two hours. 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.	A 2015 analysis shows that noisy activities with impulse sound were registered in the North Sea and the northern part of Kattegat. The sound level is high enough to have a harmful effect. The majority of Danish marine areas were affected by impulse noise for less than 10 days. Continuous low-frequency sound has not been surveyed in the North Sea.	Impacts from activities generating under water noise was assessed for fish and marine mammals in sections 11.7 and 11.8 respectively. Overall assessment: • Low/medium vulnerability • Immediate vicinity/regional extent • Low/medium intensity • Very short-/medium-term duration • **Negligible/Limited consequence** On that basis, it is assessed that underwater noise generated in this project does not give rise to adverse effects at the population level for fish or marine mammals.

Descriptor	Relevant environmental target	Current environmental status	Overall assessment of impacts
	11.3 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.		
	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.		
	11.5 The Ministry of Environment and Food 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.		

16. MARITIME SPATIAL PLAN

16.1 Introduction

The Maritime Spatial Planning Act (Executive Order no. 400 of 06/04/2020) implements EU Directive 2014/89/EU on the framework for maritime spatial planning, which obliges EU countries to prepare a maritime spatial plan.

The Maritime Spatial Plan implements a holistic spatial planning for the entire Danish marine area. The purpose of the Maritime Spatial Plan is to promote economic growth, development of marine areas and utilization of marine resources on a sustainable basis. The Maritime Spatial Plan covers the entire Danish marine area. That is, the territorial sea and the exclusive economic zone (EEZ).

The MSP must plan for the following uses and activities:

1. The energy sector at sea
2. Maritime transportation
3. Transportation infrastructure
4. Fisheries and aquaculture
5. Extraction of raw materials at sea and
6. Conservation, protection and improvement of the environment.

In addition, sustainable tourism, recreational activities, outdoor life and land reclamation can be planned for.[1]

Project Greensand Future is located within an area designated for oil and gas exploration and extraction, CO_2 storage and renewable energy and energy islands according to the Maritime Spatial Plan (MSP). The project area does not intersect important shipping corridors and is located outside areas with protective measures for aviation (see Figure 16-1).

[1] Danish Maritime Authority (URL: https://havplan.dk/da/om-havplanen last accessed 09.01.2025)

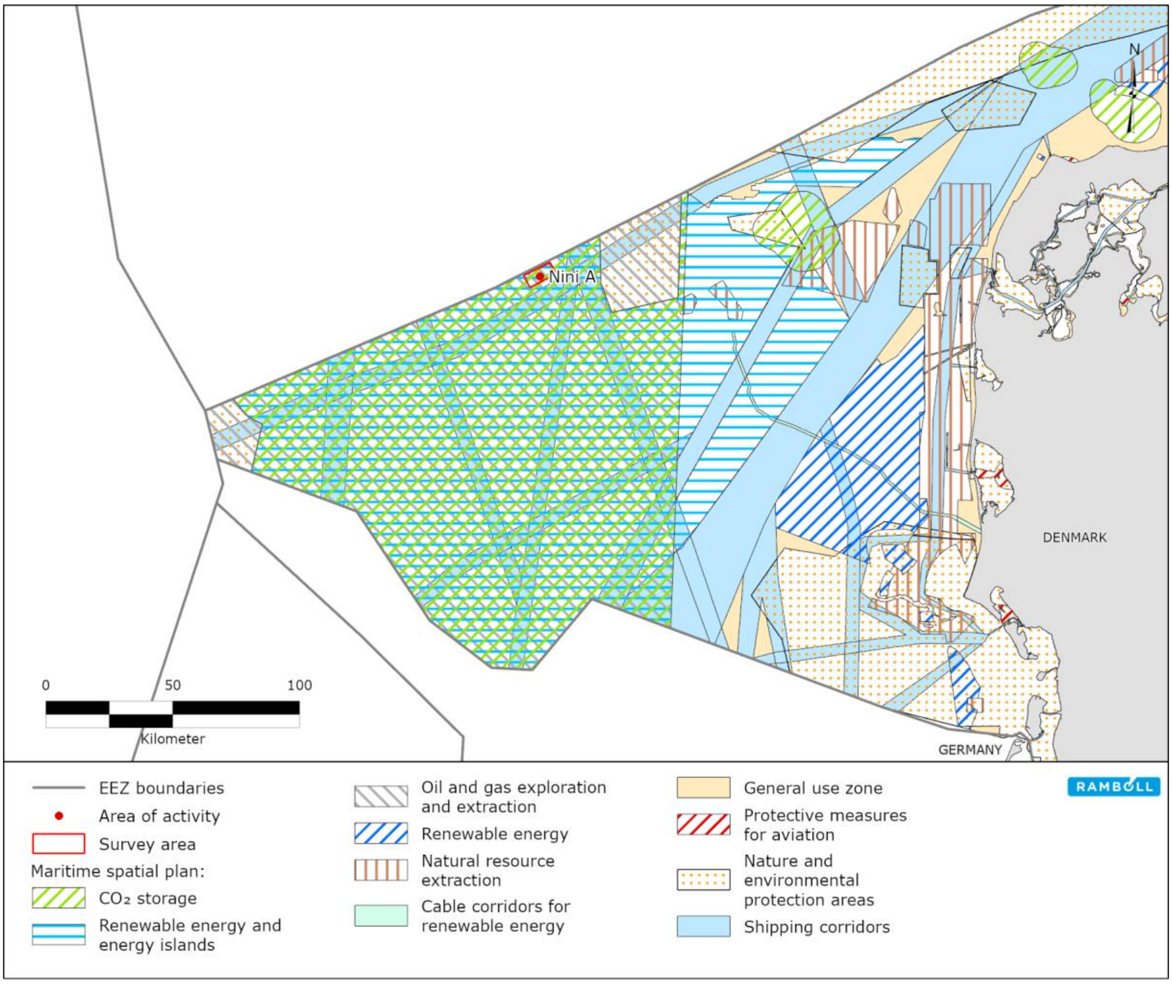

Figure 16-1 Danish Maritime Spatial Plan showing areas for designated activities.

16.1.1 Potential impacts

Potential impacts on marine spatial use are related to:

- Restricted zones

16.1.2 Methods and data

For the assessment of impacts from the current project on the Maritime Spatial Plan, designated areas c.f. the Maritime Spatial Plan has been mapped (Søfartsstyrelsen, 2021) and reviewed with regard to the location and objectives of *Project Greensand Future*.

16.1.3 Assessment of impacts

In the construction phase, an additional 300 m of subsea pipeline is planned in the current project which is within the 500 meters restricted zone of the Nini A platform. One navigation buoy will be placed to mark the CO_2 leakage monitoring system. This restriction point is made to prevent anchoring or trawling from damaging the CO_2 leakage monitoring system. This restricted point will remain throughout the operation phase.

The project area is located within a zone that has been designated for oil and gas exploration and extraction, CO_2 storage and renewable energy and energy islands and the new restriction zone does not interfere with other spatial usage zones according to the MSP. The new restriction point from the CO_2 leakage monitoring system is assessed to have no significant impact on the spatial use of the area. The overall impact on the MSP from restricted zones is assessed to be of **no significance**.

Transboundary impacts
No significant transboundary impacts have been identified.

Gaps in knowledge and limitations
Designated areas in the MSP, the project area, and the extent of the future imposed restricted zones are known to a high degree. No gaps in knowledge or limitations to this assessment has therefore been assessed. The conclusion of this assessment is therefore considered to be sound. Further the monitoring plan for the project will continuously be assessed and increased in extent if required to assess possible impact on other MSP areas.

17. NATURA 2000 ASSESSMENT

17.1 Introduction

The Natura 2000-network is the largest coordinated network of protected areas in the world, ensuring biodiversity by conserving natural habitats and wild fauna and flora in the territory of the EU. The network comprises special areas of conservation designated by EU States under the Habitats Directive on the conservation of natural habitats and of wild fauna and flora (92/43/EEC). Furthermore, Natura 2000 also includes special protection areas classified in accordance with the Birds Directive (2009/147/EC).

The directives implement the requirements of the Bonn Convention on the Conservation of Migratory Species and the Bern Convention on the Conservation of European Wildlife and Natural Habitats in community law. Natura 2000-sites are considered to be of international significance and are important to maintaining biodiversity in the EU. The purpose of Natura 2000-sites is to maintain or restore the favourable conservation status of habitats and species (both flora and fauna) in their natural range. The Natura
2000-network comprises:

- Special Protection Areas (SPAs): Areas for the conservation of bird species listed in the Birds Directive as well as migratory birds,
- Special Areas of Conservation (SACs): Areas for the conservation of habitat types and animal and plant species listed in the Habitats Directive,
- Sites of Community Importance (SCIs): Areas for the conservation of habitat types and animal and plant species listed in the Habitats Directive (sites that have been adopted by the European Commission but not yet formally designated by the government of each member state).

The objective of the Habitats Directive is to protect biodiversity by requiring member states to take measures to maintain or restore the favourable conservation status of natural habitats and wild species. The objective of the Birds Directive is to implement special measures to maintain the favourable conservation status of wild birds, focusing primarily on conserving the habitats of certain rare species of birds and regularly occurring concentrations of migratory birds. The Natura 2000 network protects t
e habitats listed in Annex I and the rare and vulnerable species listed in Annex II of the Habitats Directive, as well as the rare and vulnerable bird species listed in Annex I of the Birds Directive and regularly occurring concentrations of migratory birds.

The conservation status of a natural habitat is defined in the Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora) as "favourable" when:

- The habitat's natural range and areas it covers within that range are stable or increasing,
- The specific structures and functions necessary for long-term maintenance of the habitat exist and are likely to continue for the foreseeable future,
- The conservation status of the habitat's characteristic species is favourable.

The conservation status of a species is considered "favourable" when:

- Population dynamics data indicate that the species is maintaining itself as a viable component of its natural habitats on a long-term basis,
- The natural range of the species is not being reduced nor is it likely to be reduced for the foreseeable future,

- There is, and probably will continue to be, a sufficiently large habitat to maintain the population of the species on a long-term basis.

17.2 Methodology

An assessment of whether a project may result in significant impacts on Natura 2000 sites is required in accordance with Articles 6(3) and (4) of the Habitats Directive and Danish legislation concerning exploration, recovery and transport of hydrocarbons and geothermal energy (Executive Order no. 846 of 26/06/2024).

The initial step of the assessment is a screening for appropriate assessment, which identifies the potential impacts of a project on Natura 2000-sites, either alone or in combination with other projects or plans and considers whether these impacts are likely to be significant. If significant impacts cannot be ruled out, a further appropriate assessment is carried out.

A full assessment must include an assessment of the impact of the project or plan (either alone or in combination with other projects or plans) on the integrity of the Natura 2000 sites with regard to the conservation objectives of the sites and to their structure and function. It must be assessed if the impact will have adverse effects on the integrity of Natura 2000-sites, considering the conservation objective of the sites concerned. The appropriate assessment shall be based on the latest scientific kno
ledge and apply the precautionary principle.

If adverse impacts are likely or some degree of uncertainty remains, further assessments should be carried out, in the form of an assessment of alternative solutions and assessment where no alternative solutions exist, and adverse impacts remain.

This chapter is a screening for appropriate assessment of whether the project may result in significant impacts on Natura 2000-sites. The screening is based on the latest baselines and management plans for each Natura 2000-site. As Member States nationally implement the Directives differently, the conservation objectives will be described in relation to how they are listed in the individual management plans for the relevant Natura 2000-sites.

17.3 Identification of Natura 2000-sites

Natura 2000-sites nearest to the project area are shown in Table 17-1. The distances to the project area and the general description of what is designated for conservation for each Natura 2000-site (the designation list) are given in Table 17-1. Each of the relevant Natura 2000 sites will be assessed individually in the following sections.

Table 17-1 Natura 2000-sites close to the project area. The general characteristics of the designation basis for the areas are presented as well as the distance to the project area.

Natura 2000 (Site code/name)	**General characteristics of designation list**	**Distance**
DK00VA257 Jyske Rev, Lillefiskerbanke	Natural habitats	71 km
DK00VA347 Sydlige Nordsø	Natural habitats, habitat species and birds	147 km
DK00VA348 Thyborøn Stenvolde	Natural habitats	142 km

Natura 2000 (Site code/name)	**General characteristics of designation list**	**Distance**
DK00FX112 Skagens Gren og Skagerrak	Birds	102 km
DE1003301 Dogger Bank	Natural habitats and habitat species	121 km
NL2008001 Dogger Bank	Natural habitats and habitat species	156 km

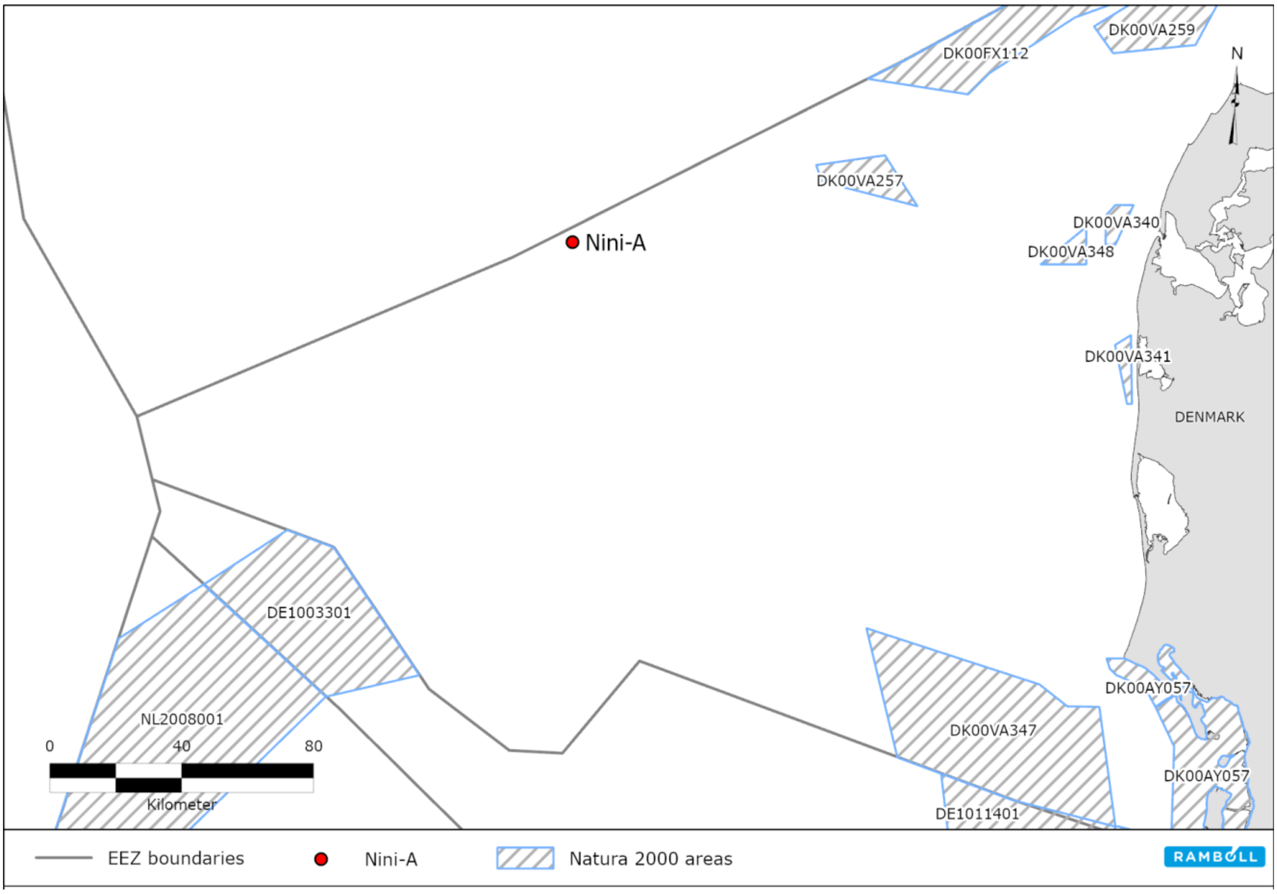

Figure 17-1 Nearest Natura 2000-sites to the project area at Nini- A.

17.3.1 DK00VA257 - Jyske Rev, Lillefiskerbanke

Designated habitats and species

The designated habitat for the Natura 2000-site Jyske Rev, Lillefiskerbanke (DK00VA257), is shown in Table 17-2. Information about this site is derived from Danish management plan and the baseline analysis (Miljøstyrelsen, 2020c, 2021a) as well as from the most recent Article 17 reporting to the European Commission on the conservation status of natural habitats and species (Fredshavn, Nygaard, Ejrnæs, Damgaard, Therkildsen, Elmeros, Wind, Sander, et al., 2019), where the marine habitat types and species are divided into two marine regions, the marine Atlantic region (including the North Sea, Skagerrak and the northern parts of the Kattegat) and the marine Baltic region (including the southern part of the Kattegat, the inner Danish waters and the Baltic Sea).

Table 17-2 Designation basis for the Natura 2000-site DK00VA257.

Designation basis for DK00VA257	
Natural habitats	Reefs (1170)

Conservation objectives

<u>Overall objective</u>
The natural habitats on the designation basis shall contribute to reaching favourable conditions on a biogeographical level. The objective is that the natural habitat reefs, which is currently assessed as in unfavourable condition, is secured with respect to species richness of plant- and animal life and the occurrence of species which are characteristic to the habitat type. Reefs are secured as they constitute a particular large occurrence in Denmark. The ecological integrity is furthermore secured throug

ensuring good water quality through actions in the RBMPs of reducing inputs of nutrients and environmentally hazardous substances.

<u>Specific objectives</u>

- The collective occurrence of natural habitats, and the habitats of species and birds in the Natura 2000-site, whether charted or not, shall be stable or progressing given that the natural conditions allow it.
- For the marine natural habitats, the condition and range shall be stable or progressing and they shall contribute to favourable conservation status on a biogeographical level.

Conservation status
In the most recent Article 17 reporting to the European Commission on the conservation status of natural habitats and species, reefs were generally considered to be stable in the Atlantic region. However, the structure and functioning of marine natural habitats, including reefs, were assessed as in highly unfavourable condition in Denmark.

Threats
The conservation status of the marine natural habitats including reefs is generally threatened by eutrophication from nutrient inputs which is handled through actions in the RBMPs. Furthermore, ship traffic and commercial fishing with bottom trawling and pelagic gear are also considered threats to the conservation objectives of marine natural habitats.

17.3.2 DK00VA347 - Sydlige Nordsø

Designated species and habitats
The designated species and habitat for the Natura 2000-site Sydlige Nordsø (DK00VA347), are shown in Table 17-3**.** Information about this site is derived from Danish management plan and the baseline analysis (Miljøstyrelsen, 2020d, 2021b) as well as from the most recent Article 17 reporting to the European Commission on the conservation status of natural habitats and species (Fredshavn, Nygaard, Ejrnæs, Damgaard, Therkildsen, Elmeros, Wind, Sander, et al., 2019), where the marine habitat types and species are divided into two marine regions, the marine Atlantic region (including the North Sea, Skagerrak and the northern parts of the Kattegat) and the marine Baltic region (including the southern part of the Kattegat, the inner Danish waters and the Baltic Sea).

Table 17-3 Designation basis for the Natura 2000-site DK00VA347.

Designation basis for DK00VA347	
Natural habitats	Sandbanks (1110)
Habitat species	Harbour porpoise (*Phocoena phocoena*) (1351) Grey seals (*Halichoerus grypus*) (1364) Harbour seal (*Phoca vitulina*) (1365)
Bird species	Red-throated loon (*Gavia stellata*) Black-throated loon (*Gavia arctica*) Little gull (*Hydrocoloeus minutus*)

Conservation objectives

Overall objective

The natural habitats and species on the designation basis shall contribute to achieving favourable conditions at biogeographical level. The objective is that the site's marine habitats ensure a species-rich flora and fauna with the presence of the characteristic species of the designation basis. Furthermore, the overall objective also includes:

- The marine habitat Sandbanks, which is currently assessed as in a very unfavourable condition, must ensure a well-developed fauna and bottom vegetation.
- The site is ensured as a good habitat for porpoises, grey seals, harbour seals and red-throated loons.
- The ecological integrity is secured by good water quality through a reduced supply of nutrients and environmentally hazardous substances, which is regulated through the RBMPs.

Specific objectives

- The collective occurrence of natural habitats, and the habitats of species and birds in the Natura 2000-site, whether charted or not, shall be stable or progressing given that the natural conditions allow it.
- For species without a status assessment system, the aim is to contribute to achieving favourable conditions at biogeographical level. The condition of the habitats (assessed in terms of occurrence and distribution) and the total area must be stable or improving.
- For migratory birds, that may appear in nationally significant occurrences in bird protection area, their roosting and overnight areas must be secured or improved, so that the area can also house a population of national importance in the future.
- For marine nature types, reference is made to the objectives in the RBMPs.
- For the marine habitats, the condition and area must be stable or improving and contribute to a favourable conservation status at the biogeographical level.

Conservation status

In the most recent Article 17 reporting to the European Commission on the conservation status of natural habitats and species, sandbanks were in general considered to be in progress in the Atlantic region.

The conservation status of Harbour porpoise has been assessed as favourable in the Atlantic region. The population size and species distribution are stable. The Grey seal has been assessed as in unfavourable condition in the Atlantic region but improving. The occurrence and breeding activity

in Denmark is very far from the carrying capacity compared with historical references, and it is assessed that the species is not as widespread in all suitable areas in terms of resting places on land as it potentially
could be. The conservation status of Harbour seal is assessed as favourable in the Atlantic region.

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- The conservation status of the designated bird species was assessed in 2018-2021. Black-throated loon and little gull were not present within the related bird protected area (F113) in the Natura 2000-site and has therefore not been assessed any further. The wintering population of the red-throated loon was stable in the period 2012-2017.

Threats

The conservation status of the marine natural habitats is generally threatened by eutrophication from nutrient inputs which is handled through actions in the RBMPs. Furthermore, ship traffic and commercial fishing with bottom trawling and pelagic gear are also considered threats to the conservation objectives of marine natural habitats. Fishing with bottom trawling gear can prevent the achievement or maintenance of favourable conditions for sandbanks. Furthermore, gill net fishing and fishing with other ty
es of bottom nets may result in bycatch and thus negatively affect marine mammals and birds in the area. Pelagic trawling and seine fishing pose a minor threat to marine mammals and birds.

17.3.3 DK00VA348 - Thyborøn Stenvolde

Designated species and habitats

The Thyborøn Stenvolde Natura 2000 area is an approx. 8-hectare marine habitat designated area, located in Danish territorial waters. Its purpose is to protect the rocky reef ecosystem, which is a mixture of hard and sandy substrates. The area contains significant rocky reefs that stand out from the seabed and has varying depths between 17 and 36 m. It is also part of the Marine Atlantic Region and is influenced by wave exposure and strong currents (Miljøstyrelsen, 2023c).

Designation basis for DK00VA348	
Natural habitats	Reefs (1170)

Conservation objectives

<u>Overall objective</u>

The habitat on the designation basis must contribute to achieving favorable conservation status at the biogeographical level. The goal is that the area's stone reefs (1170) with strong unfavorable conservation status in the biographical region is ensured a species-rich plant and animal life with the occurrence of the species characteristic species. The ecological integrity of the area is also ensured by good water quality through reduced nutrients and environmentally hazardous substances, which is regulated through the river basin plans (Miljøstyrelsen, 2023c).

<u>Specific objectives</u>

The specific objectives are based on groupings of habitat types. See appendix 1 for an overview of which habitats the different groups contain.
In general

- The total occurrence of the habitat type in the Natura 2000 area, regardless of whether it is mapped, must be stable or increasing if the natural conditions allow for it.

Marine habitat type

- For the marine habitat type, please refer to the objectives in the river basin management plan.
- For the marine habitat type, the condition and area must be stable or improving and contribute to favorable conservation status at biogeographic level.

Conservation status

In the most recent Article 17 reporting to the European Commission on the conservation status of natural habitats and species, reefs were generally considered to be stable in the Atlantic region. However, the structure and functioning of marine natural habitats, including reefs, were assessed as in highly unfavourable condition in Denmark.

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Threats

The conservation status of the marine natural habitats including reefs is generally threatened by eutrophication from nutrient inputs which is handled through actions in the RBMPs. Furthermore, ship traffic and commercial fishing with bottom trawling and pelagic gear are also considered threats to the conservation objectives of marine natural habitats.

17.3.4 DK00FX112 - Skagens Gren og Skagerrak

Designated species and habitats

The Natura 2000 area Skagens Gren and Skagerrak (N1) has a total area of 270,417 hectares, of which 269,703 ha is marine area and the rest is land (714 ha). The marine part of the area is mainly designated for harbour porpoise (Table 17-4). The species Twait shad and the habitat types sandbanks and reefs are also on the area's designation basis (Miljøstyrelsen, 2023b).Only the bird protection area F126 (Skagerrak, approx. 7.855,51 km^2) is approx. 102 km from the project area and will be further described.

Table 17-4 Designation basis for the Natura 2000-site DK00FX112.

Designation basis for DK00FX112		
Natural habitats	Sandbanks (1110)	Forest dune (2180)
	Reef (1170)	Dune lavage (2190)
	Forklit dune (2110)	Herbaceous lake bed (3130)
	White dune (2120)	Wreath algae lake (3140)
	Grey/green dune* (2130)	Nutrient-rich lake (3150)
	Dune heath* (2140)	Brown water lake (3160)
	Sea buckthorn dune (2160)	Watercourse (3260)
	Grey rice dune (2170)	
Habitat Species	Harbour porpoise (*Phocoena phocoena*) (1351)	
	Twait shad (*Alosa fallax*) (1103)	
Bird species (F126)	Northern fulmar (*Fulmarus glacialis*)	
	Great skua (*Stercorarius skua*)	

Conservation objectives

Overall objective
Habitat types and species on the designation basis must contribute to achieving favourable conservation status at the biogeographical level. The marine habitats sandbank (1110) and reef (1170), both of which have a highly unfavourable conservation status, are safeguarded. The aim is to secure the area as a good habitat for the high occurrence of harbour porpoise. In addition, the marine habitats are ensured a rich fauna and bottom vegetation. The ecological integrity of the area is ensured in the form of appropriate management/care and hydrology, a low nutrient load and good dispersal and establishment opportunities for the species. The ecological integrity of the area is also ensured by good water quality through reduced of nutrients and environmentally hazardous substances, which is regulated through the river basin management plans (Miljøstyrelsen, 2023b).

Specific objectives
- In general, the overall occurrence of habitat types and species in the Natura 2000 area, regardless if mapped, must be stable or increasing, provided that the natural conditions allow for it.
- For species without a status assessment system, the goal is to contribute to achieving favourable conservation status at the biogeographical level. The condition of habitats (assessed in terms of occurrence and distribution) and total area should be stable or improving.
- For marine habitats, the condition and area must be stable or improving and contribute to favourable conservation status at the biogeographical level.

Conservation status
In the most recent Article 17 reporting to the European Commission on the conservation status of natural habitats and species, reefs were generally considered to be stable in the Atlantic region. However, the structure and functioning of marine natural habitats, including reefs, were assessed as in highly unfavourable condition in Denmark.
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Threats
The conservation status of the marine natural habitats including reefs is generally threatened by eutrophication from nutrient inputs which is handled through actions in the RBMPs. Furthermore, ship traffic and commercial fishing with bottom trawling and pelagic gear are also considered threats to the conservation objectives of marine natural habitats.

17.3.5 DE1003301 - Dogger Bank (Germany)

Designated species and habitats
The designation basis for the German Natura 2000-site Dogger Bank (DE1003301), is shown inTable 17-5. Information about this site is derived from German management plan for the site (Kramer et al., 2020).

Table 17-5 Designation basis for the Natura 2000-site DE1003301.

Designation basis for DE1003301	
Natural habitats	Sandbanks (1110)
Habitat species	Harbour porpoise (*Phocoena phocoena*) (1351) Harbour seal (*Phoca vitulina*) (1365)
Bird species	Fulmar (Fulmarus glacialis) Lesser black-backed gull (*Larus fuscus intermedius*) Northern gannet (*Morus bassanus*) Kittiwake (*Rissa tridactyla*) Common guillemot (*Uria aalge*)

Conservation objectives

Overall objective

- The overall objective is to secure the maintenance or restoration of the habitat type sandbanks.
- Secure the Harbour porpoise and the Harbour seal in favourable conservation status.
- avoid deterioration of the conservation status of all conservation targets.

Specific objectives

The conservation objectives of DE1003301 Dogger Bank includes in particular:

- The preservation and restoration of specific ecological functions, the biological diversity and the natural hydrodynamics and morphodynamics of the area of national importance.
- A favourable conservation status of the habitat type sandbanks with its characteristic and endangered communities and species.
- A favourable conservation status of the Harbour porpoise and Harbour seal and their habitats.
- Its function as a particularly species-rich biogeographical border area between the northern and southern North Sea.

Conservation status

The conservation status of the German habitat types and species are classified on a three-stage scale with (A) excellent, (B) good or (C) medium to bad, see Table 17-6.

Table 17-6 The German classification of the conservation status of the designated habitats and species.

Habitat or species	Desired condition	Current condition
Sandbanks (1110)	B	C
Harbour porpoise (*Phocoena phocoena*) (1351)	A	B
Harbour seal (*Phoca vitulina*) (1365)	B	B

The conservation status of the habitat type sandbank is currently assessed as medium to bad (C), where the objective is to reach a good status (B). The Harbour porpoise is assessed as in good (B) conservation status, however to the objective is to obtain an excellent status (A). The conservation status of the Harbour seal is assessed as in a good status (B), which is also the objective for this species.

Threats

The condition of the sandbank is primarily a result of fishing with bottom gear which influence the physical habitat, and which may result in biotope change or loss and catching of target and non-target species. Other forms of fishing, hydrocarbon production and exploration, and the laying and operation of pipelines also contribute to the sandbanks' poor condition. Gill net fishing and fishing with other types of bottom nets may result in bycatch and thus negatively affect the Harbour porpoise and the Harb
ur seal.

17.3.6 NL2008001 - Dogger Bank (Netherlands)

Designated species and habitats

The designation basis for the Dutch Natura 2000-site NL2008001, is shown in Table 17-7. Information about this site and its respective habitats and species is derived from the Dutch management plan (Bravo et al., 2019).

Table 17-7 Designation basis for the Natura 2000-site NL2008001.

Designation basis for NL2008001	
Natural habitats	Sandbanks (1110)
Habitat species	Harbour porpoise (*Phocoena phocoena*) (1351) Harbour seal (*Phoca vitulina*) (1365) Grey seals (*Halichoerus grypus*) (1364)

Conservation objectives

<u>Overall objective</u>

- The national objective is to maintain size and improve habitat quality for the benefit of population conservation.

<u>Specific objectives</u>

- For sandbanks, the conservation objective concerns surface conservation and improvement of the quality of permanently flooded sandbanks.
- The target for Harbour porpoise, Grey seal and Harbour seal is committed to preserving the size and quality of the habitat for the preservation of the population.

Conservation status

The national conservation status of harbour porpoise in the Dutch North Sea is moderately unfavourable, because the quality of the habitat was assessed moderately unfavourable, measured by, among other things, unintentional bycatch and strandings of dead animals. Based on the available information, the causes of the nationally unfavourable conservation status cannot be linked to the individual areas, because the population in the Dutch North Sea is part of a larger population in the southern North Sea. It is important to note, that the moderately unfavourable condition does not apply to the project area of *Project Greensand Future*, as the project area is located in the Atlantic region in which the conservation status of harbour porpoise was assessed as favourable according to the latest article 17 reporting (Fredshavn, Nygaard, Ejrnæs, Damgaard, Therkildsen, Elmeros, Wind, Johansson, et al., 2019).

The national conservation status for the grey seal in the Dutch North Sea has been assessed as moderately unfavourable. This assessment is derived from the fact that grey seals depend on sandbanks that are not flooded at high tide for whelping and that such areas are scarce in the Netherlands.

The national conservation status for the Harbour seal has been assessed as moderately unfavourable. This is mainly based on the future perspective and the coastal areas around the resting areas. However, it should be noted that the Harbour seals around the Dutch Dogger Bank site count is less than 2% of the total population. It should likewise be noted that the moderately unfavourable conservation status for harbour seal does not apply to the project area as it is located in the Atlantic region in which the specie was assessed as favourable according to the latest article 17 reporting (Fredshavn, Nygaard, Ejrnæs, Damgaard, Therkildsen, Elmeros, Wind, Johansson, et al., 2019).

Threats

Threats are not specified in the Dutch management plan; however, it is expected that the threats to the designated habitat type and species are similar to the threats described for the other nearby Natura 2000 sites.

17.4 Natura 2000 screening

The screening is carried out to identify all those elements of the project, alone or in combination with other projects or plans that may have significant impacts on a Natura 2000 site. Planned activities in the project area have been described in Chapter 5 and the associated potential impact mechanisms have been assessed in Chapter 9. Other plans and projects have been accounted for in section 9.3 and it is assessed that there are no cumulative effects. No activities associated with *Project Greensand Future* are planned to occur within designated Natura 2000-sites and due to distance and the characteristics of the potential impacts from this project, no impacts are expected to extend into any Natura 2000-site. The longest impact distances that can potentially affect designated habitats is assessed to be underwater noise. As described in section 11.8, the avoidance distance for seals is up to 36.8 km and the closest haul-out site for harbour seal and grey seal is located approx. 178 km from the project area. As the nearest Natura 2000-site is located 71 km from the project area, no impacts on natural habitats are expected from this project. Impacts on designated habitats of nearby Natura 2000-sites is therefore not assessed further.

Although none of the potential impact mechanisms are expected to extend into any Natura 2000-site, significant impacts to designated species happening outside Natura 2000-sites may cause impacts to the conservation objectives if species are impacted at the population level. Species which occur on the designation basis for the nearest Natura 2000-sites include species of marine mammals and seabirds, as well as Annex IV species. In the following, potential impacts to marine mammals and seabirds are assessed

17.4.1 Marine mammals and Annex IV species

Impacts to marine mammals from planned activities and accidental events have been assessed as part of the EIA of this project in section 11.8 and chapter 13 and these impacts are also considered to be relevant for the Natura 2000 screening. Potential impacts from planned activities include:

- Underwater noise: In the construction phase, underwater noise is expected from vessels and the seismic surveys. In the operation phase, underwater noise is expected from seismic, the monitoring vessel and CO_2 vessel and vessels for maintenance operations with ROV.
- Disturbance from vessels: in the construction phase, disturbance from vessels required for transport in relation to seismic surveys and installation activities are expected to generate a disturbance. In the operation phase, disturbance from vessels is expected from the CO_2 vessel transporting CO_2 to the project area and from the vessel carrying out seismic surveys as well as vessels for maintenance operations.
- Light: in the construction and operation phase, light emissions are expected from the Nini A platform and vessels (installation, CO_2 transport and seismic surveys).

Potential impacts from accidental events are:

- Oil spill from CO_2 blowout: Only oil spill from a CO_2 blowout is considered to pose a risk to conservation objectives of marine mammals in nearby Natura 2000 sites as impacts from a CO_2 leakage were assessed to only occur in the immediate vicinity of a leak. It is therefore not likely that a potential oil contamination of the modelled blowout will significantly directly affect the population of the seals in the North Sea and oil spill is therefore not assessed further (see section 13.1).

All assessed impacts on marine mammals are temporary and reversible. Disturbance from vessels and light are expected to occur within 1 km from the source potentially affecting only a few individuals. Impacts are not expected to cause injury, increase mortality or cause loss of fitness or have any implications to the population dynamics of the designated marine mammal species. No impacts on the conservation objectives of any Natura 2000 site are therefore expected. On these grounds, any significant impact f
om disturbance from vessels and light on marine mammals on the designation basis of any Natura 2000 site is ruled out.

Underwater noise has a greater impact distance and may impose a potential risk to marine mammals on the designation basis of nearby Natura 2000 sites. As assessed in section 11.8.3, with the disturbance and noise emissions from vessels, there will be a very limited risk of injury (PTS or TTS) either in the construction phase or the operation phase from underwater noise. Underwater noise may cause avoidance up to a maximum distance of 36.8 km (see Table 11-17) from the project area so it will not impact marine mammals within Natura 2000-sites. The potential impact on the individual species on a population level outside Natura 2000 areas, is further assessed below.

Construction phase

As described in section 10.8 the transceiver system used on the ROV during pipeline laying may cause TTS up to 550 m and PTS up 35 m for Harbour porpoise due to the high frequency noise emitted. The transceiver systems are only turned on when the pipelaying vessel is present and since either species is unlikely to come within this close to vessels, it is assessed that there is no risk of TTS in Harbour porpoise or seals due to underwater noise from the transceiver systems. The transceiver may also cause avoidance up to 4.2 km from the source for harbour porpoise, However, as the area that is impacted is relatively small compared to the daily foraging habitat, the number of harbour porpoises affected would be limited to 70 individuals or less than 0.01 % of the total North Sea population. Results from the modelling of underwater noise related to seismic surveys are presented in Table 11 17 (3D) and Table 11 18 (2D). Avoidance behaviour for Harbour porpoise is modelled to be up to 6.1 km and for seals the avoidance distance is up to 36.8 km (Table 11 18). Both minke whales and white-beaked dolphin are expected to avoid an area up to 36.8 km away.

Furthermore, the area does not constitute important breeding grounds for harbour porpoise and any displacement of animals from this zone of impact will likely not result in adverse effects at the population level. No impacts on the conservation objectives of any Natura 2000 site are therefore expected.

Although other marine mammals may also be displaced, the impact would be short-lived and the impacted area too small to have any effect on the fitness of the animals as they are highly mobile when foraging. Furthermore, the project area does not constitute important breeding grounds for either species, and any impact to marine mammals is therefore not assessed to have implications at the population level. No impacts on the conservation objectives of any Natura 2000 site are therefore expected.

Operation phase

Both Harbour porpoise and seals are expected to be impacted by underwater noise in the operation phase. All impacts are temporary and reversible. In the operation phase, the largest impact zone stems from seismic monitoring, which can cause avoidance up to 6.1 and 36.8 km away from the source for harbour porpoise and seals respectively. As described in Section 9.5.4 the density of harbour porpoise is relatively low in the project area compared to other parts of the North Sea. An avoidance radius of 6.1 km would displace approximately 70 Harbour porpoise on average out of a population of around 345,000 animals, which is less than 0.01% of the population in the North Sea. Monitoring is carried out every other year lasting approximately 5-10 days per campaign every other year. The project area is not considered a high-density area and it is therefore assessed to be of no special importance as a breeding area. Any displacement of animals from this zone of impact will be short-termed and will likely not result in adverse effects at the population level. No impacts on the conservation objectives of any Natura 2000 site are therefore expected.

In the operation phase the seismic monitoring can cause avoidance of seals up to 36.8 km away from the source. The closest haul-out site for harbour seal and grey seal is located approx. 178 km from the project area and it is therefore likely that grey seals can be encountered foraging within the project area. Monitoring is carried out in area where density of seals is expected to be low and no resting or breeding areas occur in the project are. The impact is reversible and short-termed, since the survey period is only 5-10 days every other year. The area that is impacted is relatively small compared to the daily foraging habitat and will only affect a very limited number of seals. seismic monitoring in the operation phase is therefore assessed to have no impact on population level for seals. No impacts on the conservation objectives of any Natura 2000 site are therefore expected.

Based on the above, significant impacts to marine mammals on the designation basis of any Natura 2000 site from underwater noise generated in this project are ruled out. In conclusion, significant impacts on marine mammals on the designation basis of any Natura 2000 site from activities in the current project are ruled out.

17.4.2 Seabirds

Impacts to seabirds from planned activities and accidental events have been assessed as part of the EIA of this project in Section 11.9 and Chapter 13 and these impacts are also considered to be relevant for the Natura 2000 screening. Potential impacts from planned activities include:

- Disturbance from vessels: in the construction phase, disturbance from vessels required for transport in relation to installation activities are expected to generate a disturbance. In the operation phase, disturbance from vessels is expected from the CO_2 vessels transporting CO_2 to the project area and from the vessel carrying out seismic surveys as well as vessels for maintenance operations.
- Light: in the construction phase, light emissions are expected from safety lights on Nini A platform and all vessels. In the operation phase, light emissions are expected from the Nini A platform, CO_2 vessel and the vessel carrying out seismic surveys.

Potential impacts from accidental events are:

- Oil spill from CO_2 blowout: Only oil spill from a CO_2 blowout is considered to pose a risk to conservation objectives of seabirds in nearby Natura 2000 sites as impacts from a CO_2 leakage were assessed to only occur in the immediate vicinity of a leak with no significant impacts to the environment (see Chapter 13).

All assessed impacts on seabirds are temporary and reversible in both the construction and operation phase. Disturbance from vessels in both phases is expected to occur within 1 km from the source potentially affecting only a few individuals. Impacts are not expected to cause injury or increase mortality but rather induce a short-lived fleeing reaction which is expected to cease instantly once the vessels have passed. As the project area and adjacent areas offer suitable foraging and resting grounds for de
ignated species of nearby Natura 2000 sites, which may occur in the project area, any fleeing reaction is not assessed to cause loss of fitness or to impact species at the population level. No impacts are therefore expected to the conservation objectives of any Natura 2000 site.

Light emissions in the operation phase may cause an impact at a distance of up to 10 km from the source. Birds found on the designation basis of nearby Natura 2000 sites may potentially be attracted to these light sources resulting in a disruption of migratory behaviour. However, as effects are only temporary, no effects are expected at the population level for any species which may have implications for the conservation objectives of any Natura 2000-site.

Based on the above, significant impacts to designated species of seabirds in any Natura 2000 site from activities in the current project are ruled out.

17.5 Conclusion

Only designated species and Annex IV species have been assessed in this chapter and considered to be potentially impacted by this project. However, no impacts to marine mammals including Annex IV species or seabirds have been identified to cause adverse effects at the population level for either of the designated species in any Natura 2000 site. This implies that the conservation objectives of any Natura 2000-site are not subject to be affected by the project. Significant impacts to Natura 2000-sites resulting from *Project Greensand Future* is therefore ruled out.

18. DECOMMISSIONING

18.1 Introduction

The general decommissioning legislative context is described in section 7.4. A future decommissioning EIA will be assessing the activities in further detail and will be submitted as part of the authority approval of the decommissioning plans. The decommissioning activities and impact are described in high-level in this chapter.

After injection of CO_2 has been completed, the Nini A installation will be decommissioned. The facilities to be covered by the decommissioning scope is illustrated by the red line in Figure 18-1. In addition, the CO_2 offloading system installed for the Project Greensand Future is also part of the decommission scope. The interface between the Nini A/Nini B and Siri decommissioning programmes is given at the spool ends closest to the Siri platform. Spools and protection structures on the Siri-Nini A pipelines (concrete/GRP elements and concrete mattresses) will be removed at the Nini A end and spools and protection structures (concrete/GRP elements and concrete mattresses) at the Siri end will potentially be left until removal of the Siri platform, due to the closeness to other operational pipelines nearby that makes immediate removal impossible. All pipelines will be cut, and the open ends will either be dredged down or rock dumped.

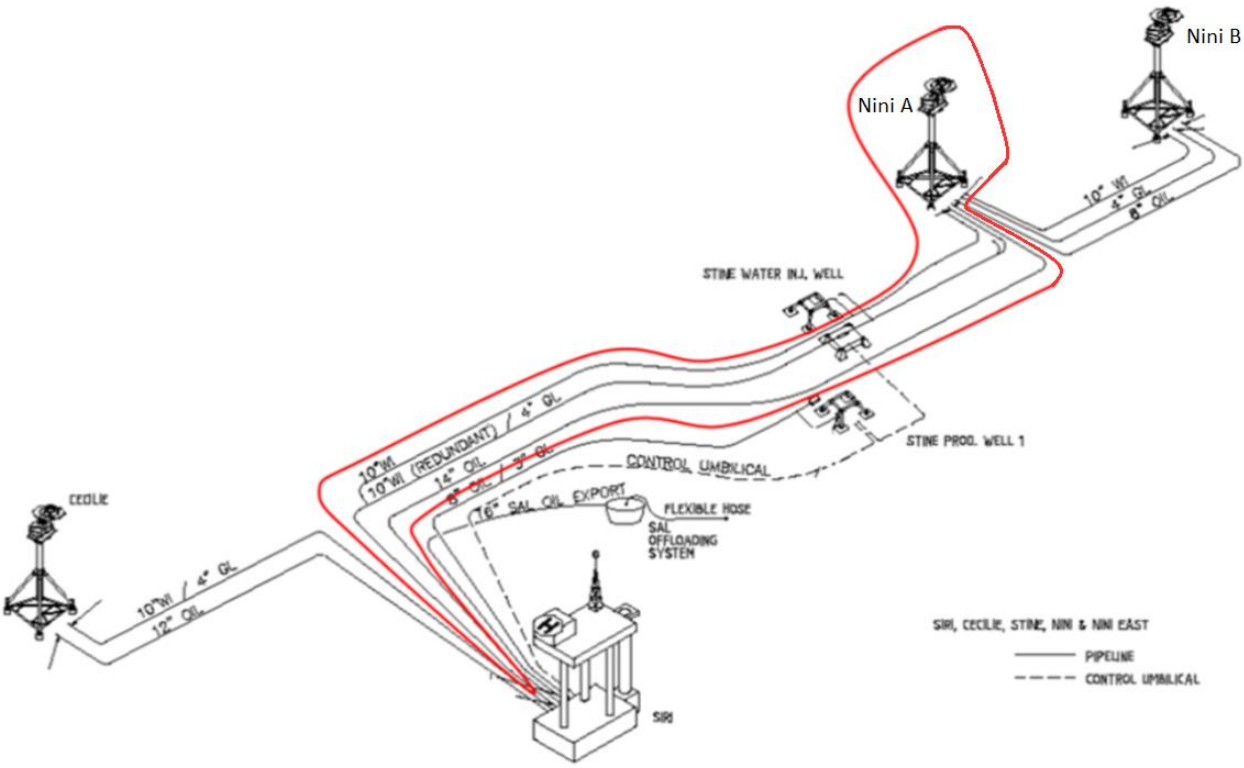

Figure 18-1 The decommissioning scope for Nini A is outlined by the red line (modified after (COWI, 2023b)).

The decommissioning activities at Nini A covers:

- Debris survey before plugging and abandonment (P&A) of wells – to ensure safe installation of drilling jack-up.
- P&A of 10 Nini A wells.

- Flushing, purging, and cleaning of topside and pipelines.
- Removal of Nini A topside and jacket including riser caisson.
- Removal of drilling template and parts of docking piles.
- Decommissioning of pipelines
- Removal of tie-in spools.
- Removal of pipeline stabilization features.
- Rock dump will be left in place.
- Remove Concrete protection structures and glass-fibre reinforced plastic covers.
- Decommissioning of CO_2 offloading system includes removal of:
    - The 6” fixed pipeline connected to Nini A
    - Concrete mattresses covering subsea pipeline.
    - Flexible riser with buoyancy element, and hose end valve.
    - 2 Anchor blocks – supporting the stability of the pipeline end (appears as yellow square boxes in figure above).
- Post decommissioning site survey and potential debris removal.

The onshore dismantling of the platform will only be described briefly as this will be covered by the environmental permits and other permits for the specific disposal yard.

18.2 The installations for decommissioning

Platform

Nini A is a Normally Unmanned Installation (NUI) wellhead platform. The mono tower platform was installed in 2003, with a topside minimum facility structure supported by a jacket structure. As part of the platform installation are risers, and subsea structures (drilling template and docking piles). When the Nini B platform was installed, minor modifications were made to the Nini A platform to ensure connection between the two platforms. There will be no major change to topside as part of the Greensand Future project. Detailed technical information on the installations and components to be covered by the decommissioning project are found in Table 18-1.

Table 18-1 Technical information for Nini A (COWI, 2023b).

Technical information	Unit	Nini A
Date of installation	Year	2003
Water depth (LAT)	m	57.5-62
Topside	Tons	779
Jacket	Tons	1,973
Number of legs	No.	3
Weight of docking piles (total)	Tons	522
Number of docking piles	No.	3
Length of the four Nini A to Siri pipelines	km	31.7
Spools on 4”-14” pipelines, length	m	35-71
Drilling template dimensions	m x m x m	7.8 x 5.0 x 1.5
Drilling template weight	Tons	18
Drilling template, piles, number at template	No.	1
Number of wells	No.	10

The Nini A topside structure comprises of five levels and a helideck as shown in Figure 18-2:

- Cellar Deck: manifolds, diesel storage and generators and lifeboats
- Access Deck: X-mas trees valves and manifolds
- Utility Deck: shelter, air compressors and pig launcher and receivers, metering, and test manifold
- Main Deck: platform cranes and wireline unit
- Helideck

Figure 18-2 The Nini A platform.

The mechanical and electrical components at the installations on Nini A include a variety of materials including various metals, plastics, cables and other materials. A general inventory is given in Table 18-2.

Table 18-2 Topside components inventory.

Material	Dry Weight (tons)	Fraction (%)
Main structure (Steel)	258	33.2
Secondary structure (Steel Low Alloy)	271	34.8
Mechanical	79.0	10.2
Piping	120	15.4
Elec. & Control Equipment	29.8	3.8
Electrical	20.5	2.6
Total	**779**	**100**

The Nini A topside are supported by a fixed three-legged 'tripod' with one centre column jacket (star jacket design), see Figure 18-3.

Figure 18-3 Jacket structure during installation.

The components shown in Table 18-3 are all included in the jacket installations. The weight also excludes marine growth. The jacket may be lifted whole or in parts suitable for the chosen lifting equipment.

Table 18-3 Jacket components and weights (excl. Piles) Nini A.

Major components	Dry Weight (tons)	Fraction (%)
Mudmat Top plate + Stiffs + Skirts	64	3.3
Conductor Guides	31	1.5
Upper Padeye	21	1.1
Anodes	61	3.1
Risers	62	3.1
Riser Caissons	52	2.7
Jacket excl. components	1,606	81.4
Various minor elements	77	3.9
Total	**1,973**	**100**

The jacket has been fixed by three docking piles with a total weight of 522 tons incl. concrete grout for each platform. Grout weight has been estimated to be 30 tons. The grout will be lifted with the jackets. There will be a part of the pile with grout attached to all skirt pile sleeves, which will add to the lifting weight.

Subsea structures

The drilling templates are placed on the seabed below the Nini A platform and consist of the drilling template of steel and docking piles: 10.9m x 9.9m x 6.1m and with a weight of 18 tons. The template has two docking piles. The total weight of the docking piles is approximately 90 tons whereas approximately 24 tons is to be removed with the template. An example of a drilling template is shown in Figure 18-4.

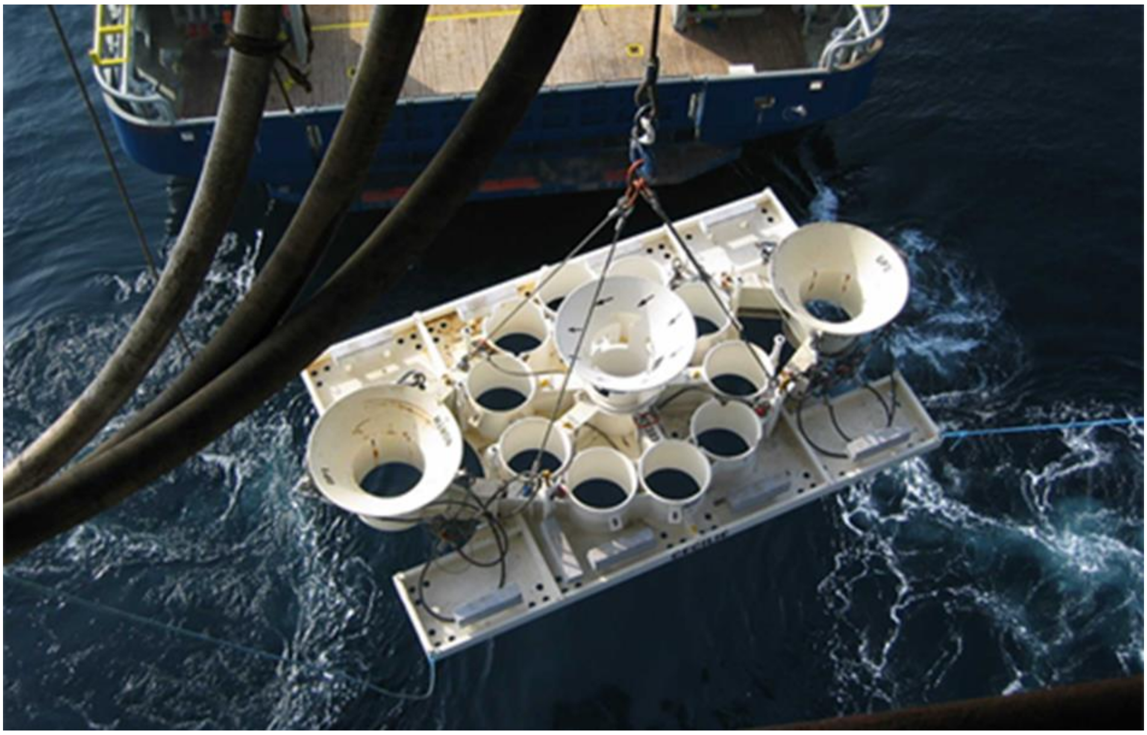

Figure 18-4 Example of drilling template structure during installation.

Wells

There are currently 10 wells in operation in connection to Nini A, see Table 18-4. As part of decommissioning the tubing and piping will be cut below seabed and the wells to be sealed up depending on the decided strategy, therefore the majority of the well construction casing- and tubular steel, and cement to remain in the wells.

It is expected that around 2,000 tons of steel from tubing, casings and conductor pipe will be recovered from the 10 Nini A wells and approximately 4,000 tons of steel will remain left in-situ in the wells. It is expected that ~250 tons of cement will be recovered and up to ~1,200 tons of cement will be left in-situ in the wells. ~160 tons of excess cement will be discharge to sea.

Table 18-4 The ten Nini A wells.

Well name	Function	Well Depth [m]	13 3/8" shoe depth [m]	Tubing size [in]	9 5/8" shoe depth [m]	Status
NA-1	Oil producer	3,296	821	5.5	2,315	Operational
NA-2B	Water injector	2,621	819	5.5	2,614	Plugg installed
NA- 3B	Oil producer	4,638	825	5.5	3,550	Operational
NA-4B	Water injector	3,219	890	5.5	2,911	Operational
NA-5	Water injector	4,560	835	5.5	4,272	Operational
NA-6C	Water injector	3,437	838	5.5	3,142	Operational
NA-7D	Oil producer	2,797	966	4.5	2,318	Operational *
NA-8	Oil producer	3,486	856	4.5	2,439	Operational
NA-9C	Water injector	2,555	929	5.5	2,318	Operational
NA 10	Oil producer	3,570	861	4.5	2,218	Operational

*Frigg reservoir plugged by retrievable plug.

Pipelines and pipeline installations

Nini A is connected to Siri via four pipelines; one 14" multiphase, pipeline, one 10" water injection pipeline, one 4" gas lift pipeline piggybacked to the redundant 10" water injection pipeline. The approximate weight of pipelines from Siri to Nini A is 12,716 tons. See more information in Table 18-5.

Table 18-5 Pipelines between Siri and Nini A, 31.7 km alignment.

<table>
<tr><th>Diameter (inches)</th><th>OD</th><th>WT</th><th>Coating</th><th>Anodes</th></tr>
<tr><td>14" Multiphase</td><td>355.6 mm</td><td>12.7 mm</td><td>Polypropylene (PP) and concrete</td><td rowspan="3">Aluminium and zinc</td></tr>
<tr><td>10" Water Injection</td><td>273.1 mm</td><td>18.3 mm</td><td rowspan="3">Fusion Bonded Epoxy (FBE) and polypropylene</td></tr>
<tr><td>10" Water Injection (Redundant)</td><td>273.1 mm</td><td>18.3 mm</td></tr>
<tr><td>4" Gas Lift (piggybacked to 10" redundant)</td><td>114.3 mm</td><td>11.1 mm</td><td>-</td></tr>
</table>

All pipelines are connected to the platform risers by spools, and in the Siri end all pipelines have one spool each.

The interface between the Nini A and Siri decommissioning programmes is at the spool ends closest to the Siri platform, the spools and protection structures on the Siri-Nini A pipelines (concrete/GRP elements and concrete mattresses) will be removed at the Nini A end and spools and protection structures (concrete/GRP elements and concrete mattresses) at the Siri end will potentially be left until removal of the Siri platform.

Telecommunication cables crossings

Three telecommunication cables are crossing the pipelines going from the Siri to Nini A platform. The cables are installed below seabed. The 14", 10" and 10"/4" pipelines are at telecommunication cables crossings placed above seabed covered by concrete mattresses and further protected by rock dumping. As decommissioning of cable crossings are delayed until decommissioning of the Siri platform, hence the concrete mattresses is not included in the total material summary to be decommissioned in this EIA.

Pipeline protection

At the Nini A platform the 10"/4" (piggybacked) pipelines are protected by 5 concrete tunnel elements and the approximate weight is 83.4 tons. At the Siri platform the 10"/4" (piggybacked) pipelines are protected by 11 concrete tunnel elements and the approximate weight is 157.2 tons. Decommissioning of these elements at Siri are delayed until Siri has been decommissioned.

At Nini A the 10" and 10"/4" (piggybacked) pipelines are protected by glass-fibre reinforced plastic (GRP) covers. The elements are covering the spool bends and are stabilised by rock dump. At Siri GRP elements are installed too. Decommissioning of these elements are delayed until decommissioning of Siri.

Further at the Nini A platform concrete mattresses are protecting the 14" spool piece. A rough estimate is that approximately 10 concrete mattresses are installed at the Nini A Platform. Assuming a weight of 15 tons of each concrete mattress result in ~150 tons of concrete to be decommissioned at Nini A. At the Siri platform multiple concrete mattresses are installed during multiple installation processes.

As part of the installation of the Nini A platform rock dump works were performed. Rock dumps are performed on the three telecommunication cable crossings, to prevent upheaval buckling and as spools protection. Additional rock dump was performed to fill two spud can holes close to the Nini A platform. During the Nini A platform installation in 2003 approximately 4,700 tons of 2-8" rock dump was performed at the spools ends. The pipelines are covered by ~200 m of rock dump. At the Nini A platform (towards Nini B platform) rock dump cover was performed covering ~200 m of rock dump.

Offloading system

The main additional components installed at Nini A as part of Greensand Future are the offloading system, where a subsea tie-in spools flow line is connected to a gravity base on the seabed and a flexible hose with buoyancy elements. The injection of CO_2 is planned completed after 8 years, and hereafter the offloading system is to be decommissioned together with the other Nini A facilities. The offloading facilities (subsea pipeline, concrete mattresses, anchors and flexible hose) are illustrated in Figure 18-5.

Figure 18-5 Illustration of the offloading system and concrete mattresses.

The main components as part of the offloading system are further described in Table 18-1.

Table 18-6 Components in the offloading system.

Description	Measurements
Pipeline (6'')	100-300 meters / 10-30 tons (total)
Anchor blocks	2 blocks / 50 tons (total)
Flexible riser with buoyancy element	120 meters / 6 tons
Hose End Valve	1 ton
Concrete mattress	45 units / 135 tons (total)

The offloading system consist of a variety of materials including concrete, various metals, and polymers. An inventory covering other offloading system elements are given in Table 18-7. The precise composition of the components will be defined as part of the later detailed engineering.

Table 18-7 General mechanical weight fractions.

Material	Weight (tons)	Fraction (%)
Steel	31	14.0
Concrete	185	83.3
Polymer	6	2.7
Total	**222**	**100**

18.3 Decommissioning plans

The timeline and scenario of the Nini field decommissioning will depend on future plans for the neighbouring facilities. In this EIA it is assumed to abandon the Nini A area immediately after Project Greensand Future injection has been completed, as this happens in +10 years, the plans outlined here are expected to be modified when the actual decommissioning planning will be initiated. A future decommissioning EIA will be assessing the activities in further detail and will be submitted as part of the authority approval of the decommissioning plans, as mentioned in the introduction.

Spools and protection structures on the Siri-Nini A pipelines (concrete/GRP elements and concrete mattresses) will be removed at the Nini A end, while at the Siri end, they will potentially be left until removal of the Siri platform, due to the closeness to other operational pipelines nearby that makes immediate removal impossible. All pipelines will be cut, and the open ends will either be dredged down or rock dumped.

After the final decision of field cessation, the platform will be closed, fully or partially. Hence, depending on the cessation plan, the platform will continue into a status of minimum operation, having only necessary safety and support systems in force. Otherwise, the platform will be made safe for an unmanned platform status.

It is foreseen that not fixed installations such at tote tanks will be removed separately before dismantling and returned for appropriate handling and reuse. Similarly, the lifeboat is expected to be removed separately for re-use/spare on the other platforms.

The pipeline and topside will be flushed and cleaned simultaneously. The fluid will be treated at the Siri platform.

The level of cleaning required on an installation depends on the removal methodology, as there may be opportunities to carry out much of the cleaning and decontamination as part of the onshore disposal.

As oil production ceases at Nini A (expected to be by end of 2026), the topside will be cleaned and made free of hydrocarbons. As part of the decommissioning, there is expected to remain hazardous materials to be handled, either as part of cleaning offshore or during demolition onshore:

- Fuels and lubricants: Will be drained onshore for re-use/disposal.
- Chemical containers: Any residual volumes of chemicals will be delivered back to the chemical supplier for re-use or destruction.
- Other hazardous materials: NORM scale, batteries etc. will re-use/disposal by appropriate methods during onshore demolition.
- Original paint coating: Painted items will be disposed of onshore with consideration given to any toxic components unless the items can be reused.
- AFFF foam extinguisher and equipment: Delivered back to supplier if acceptable or handled according to hazardous waste management.
- Asbestos and ceramic fibres: To the best of knowledge by INEOS there is no asbestos or other ceramic fibres to be found on Nini A.

18.3.1 Well plugging and abandonment (P&A)

Well decommissioning is the permanent isolation of any underground formation with hydrocarbons or/and flow potential, isolation of hazardous substances and the restoration of the seabed to its previous state.

The wells to be abandoned will be plugged downhole and cut below seabed in accordance with current legislative requirements and company standard of reference, OEUK.

The decommissioning of the wells will be conducted by retrieving the completion string, upper parts of the outer casing string and placing cement plugs as barriers in the wells.

There will be a minimum of two barriers in place between the surface and any hydrocarbon bearing layers or any formations which are capable of flowing. The well barriers are designed to ensure long-term integrity of the wells and to withstand any predictable exposures. The actual numbers of plugs and the setting depth intervals will depend on specific well barrier requirements.

Technical description of the P&A activities

The offshore P&A activities will be conducted with a jack-up rig. The rig will be towed to the Nini A platform and elevated to a position above sea level by supporting legs. The legs are equipped with spud cans to stabilize the rig on the seabed. The spud cans cover an area of around 200 m^2 and they can sink several meters into the seabed.

The completion string and the outer casings will be cut and retrieved in a sequential order. This will be done using an abrasive water jet cutter spread from within the centre of the casing strings (i.e., from inside the well) 3 m below the mudline. Therefore, no dredging or excavation is required.

The cut tubulars retrieved to surface will be checked for NORM and if detected, they will be shipped directly to shore for cleaning and storage of the NORM material at an approved storage site.

The annuli fluids may be filled with Water-Based Mud (WBM) or Oil-Based Mud (OBM). All OBM will be recovered on the rig and sent for onshore disposal. WBM is envisaged to be discharged to sea unless harmful chemicals are expected, in which case WBM will be sent for onshore disposal.

The integrity of the production casing and annulus cement column will be logged as validation as a well barrier. If the cement column is compromised, it may be required to establish access to the casing annuli to set a well barrier cement plug.

Once all tubulars have been cut and retrieved and all cement plugs have been set and validated, the conductor will be cut and retrieved below the seabed. This is done before the last cement plug near the surface is set. This seabed cement plug is not a well barrier but an "environmental barrier" and is set to prevent any future escape of drilling or completion fluids.

Use and discharge of chemicals

During P&A of wells several jobs will include the use of chemicals. Wells will be displaced to either WBM or OBM for setting of well barriers. The WBM and cementing chemicals will partly be left in the well, and the remainder will be discharged to sea. OBM will be circulated to surface and sent to shore for treatment/disposal.

A limited number of chemicals will be used on the rig (rig wash, jacking grease, pipe dope and BOP fluid). It is assumed that rig chemicals will be discharged to sea except for BOP fluid that is contained in a closed system. 'Rig wash' will be used for cleaning of rig equipment. 'Jacking grease' will be used when jacking the rig up and down. 'Pipe dope' will be used on equipment in the wells. Estimated use and discharge of chemicals during P&A of wells can be seen in Table 18-8. Further a few tons of mainly rig wash chemicals are assumed to be discharged (yellow chemicals), see Table 18-9.

Table 18-8 Estimated use and discharge of chemicals related to P&A activities on Nini A (10 wells).

P&A activities	Function	Planned use [tons]	Planned discharge [tons]	Sent to shore [tons]	Left in well [tons]	Colour code
WBM chemicals	Brine	187	146	0	41	G
	pH	6	5	0	1	G
	Viscosity	25	19	0	6	G
	Weight material	3,433	2,677	0	757	G
OBM chemicals	Weight material	3,800	0	3,800	0	G
	Base oil	2,123	0	2,123	0	Y
	Salinity	700	0	700	0	G
	Alkalinity	127	0	127	0	Y
	Emulsion	127	0	127	0	Y
	Viscosity	50	0	50	0	Y
	Viscosity	4	0	4	0	R
	Fluid loss	35	0	35	0	R
	Wetting agent	25	0	25	0	Y
Spacer	Cement cont.	227	227	0	0	G
	pH	227	227	0	0	G
Wash train	Base oil	243	243	0	0	Y
	Viscosity	8	8	0	0	G
	Surfactant	88	88	0	0	Y
	Solvent	100	100	0	0	Y
Slop chemicals	pH	13	13	0	0	G
	H_2S scavenger	13	13	0	0	Y
	Biocide	13	13	0	0	Y
	pH	6	6	0	0	G
Cementing chemicals	Anti-sedimentation	90	20	0	70	G
	Dispersant	25	10	0	15	G
	Viscosifier	3	3	0	0	G
	Dispersant	14	5	0	9	Y
	Anti-foam	4	3	0	1	Y
	Extender	11	4	0	7	G
	Accelerator	6	3	0	3	G
	Fluid loss control	27	7	0	19	Y
	Class G cement	833	217	0	617	G
	Weighting Agent	301	301	0	0	G
Total (excl. water)		**12,894**	**4,356**	**6,991**	**1,547**	
Total Red		**39**	**0**	**39**	**0**	
Total Yellow		**2,953**	**472**	**2,452**	**29**	
Total Green		**9,902**	**3,884**	**4,500**	**1,517**	

Table 18-9 Estimated use and discharge of utility chemicals related to P&A activities.

Utility chemicals	Planned use [tons]	Planned discharge [tons]	Colour code
BOP fluid	8.0	0.0	Y
Pipe dope	0.8	0.08	Y
Rig wash	20	20	Y
Jacking grease / skid grease	2.0	1.0	Y

Emissions to air during well P&A

Emissions to air in relation to P&A activities at Nini A are related to:

- Rig activities (mainly generator)
- Transport of rig (rig move)
- Crew transport activities by helicopter and standby boat
- Transport of goods by supply vessels

The estimated fuel consumption and emissions related to P&A of wells at Nini A are listed in Table 18-10.

Table 18-10 P&A of wells at Nini A – Fuel consumption and emissions estimate.

The sum is based on raw data including all decimal places.

Vessel	Numbers	Days	Fuel [m^3]	CO_2e [tons]	Nox [tons]	SO_2 [tons]	nmVOC [tons]
Jack-up rig	1	367	6,768	18,225	307	5.4	0.9
Supply vessel	1	107	749	2,018	34	0.6	0.1
Standby boat	1	367	1,100	2965	50.0	1	0.1
Tugs	3	20	1,200	3,233	54	1.0	0.1
Helicopters	1	161	184	499	1.0	0.6	0.0
Total	**-**	**-**	**10,001**	**26,940**	**446**	**8.6**	**1.2**

18.3.2 Platform incl. offloading system

Selection of the removal method for the topsides will generally be based on the removal contractors' proposals although operators should determine a strategy that optimises work routines and financial aspects.

The topsides were installed by a single crane lift. In principle, the similar method (in reverse) can be used for the decommissioning. The removal methods include a single lift by using a large lift vessel to remove the topsides as a single unit and transport onshore for dismantling. The decision of method is also related to the availability of various vessels and offered by contractors.

The jackets were installed as a dual crane lift, lifted horizontally from a cargo barge by using both cranes and lowered at the bottom into the water until it was vertical. Then the jacket was lowered into its final position and docked over two docking piles, which had been installed together with a pre-drilling template. The same vessel also installed the topsides. In principle a similar method (in reverse) can be used for the decommissioning. At the bottom of the jacket, the risers including the new riser installed as part of Project Greensand Future, will be disconnected and lifted together with the jacket.

Currently there are two principal methods for jacket removal, either including a single lift by using a large lift vessel to remove the jacket as a single unit and transport onshore for dismantling. The second option are piece-small removal by separating the jacket into smaller pieces offshore and transporting the waste to shore.

It shall be decided whether the jacket shall be cleaned for marine growth prior to the removal or if it shall be performed onshore. Projects with jackets, which have been previously removed with the marine growth, have reported odour problems on disposal yards near residential areas. It should be determined whether the disposal yards have such problems in the pre-qualification and the additional costs for cleaning the jacket offshore shall be taken into consideration.

The emissions to air have been calculated for a feasible decommissioning method. For the scenario all decommissioning activities except P&A of wells are included, i.e. removal of topside, jacket drilling template, docking piles, the offloading system, and activities related to decommissioning of pipelines, spools, and stabilisation features. Currently pipeline left in-situ options is the commercial well know methodology, other options is listed in section 18.3.3.

In the Table 18-11 is listed fuel consumption per vessel/activity and the resulting emissions to air are found in Table 18-12.

Table 18-11 Fuel consumption per vessel required for decommissioning of Nini A platform incl. offloading system (not including P&A of wells).

Decommissioning activity	Vessel	Numbers of vessels	Days	Fuel consumption [m^3/day]
Nini A decommissioning incl. seabed work	Heavy Lift Vessel (HLV)	1	34	47
	Offshore Construction Vessel (OCV)	1	120	20
	Transport barge 400	1	20	0
	30t bollard Pull Tug	1	20	5.5
	100t bollard Pull Tug	1	28	20
	Supply Vessel	1	11	7
	Survey Vessel	1	42	4
	Rock Dumping Vessel	1	3	27
	Pipe Trench/Jet Skid	1	10	30
Decommissioning of offloading system	Support vessel	1	7	20
	Standby vessel	1	7	3
	Helicopters	1	7	1.0

Table 18-12 Total emission to air for decommissioning of Nini A platform incl. offloading system (not including P&A of wells).

Nini decommissioning	Fuel consumption	Emissions				
	Total [m3]	CO_2 [ton]	NO_x [ton]	SO_x [ton]	CH_4 [ton]	nmVOC [ton]
Heavy Lift Vessel – Pipelines left in-situ	5,295	14,300	240	4	1	22
Removal of offloading system	308	853	18	0.47	-	0.55

There are several possibilities for removal of the drilling template and docking piles likewise as described in this section above. The principal method includes a single lift by using a crane vessel to remove the template and piles as a single unit and transport onshore for dismantling. Removal of the template structure are related to the choice of jacket removal method.

A final decision on the decommissioning method will be proposed following a commercial tendering process. Once the methodology for removal is confirmed the topsides and jacket can be prepared for lifting.

18.3.3 Pipeline and pipeline installations

A comparative assessment has been made for potential decommissioning options for the multiphase-, water injection- and gas lift pipelines. The decommissioning options to be considered for the pipelines include the following:

- Leave in-situ: The pipelines are left in place with no further action. Pipeline stabilisation features at telecommunication crossings and the Siri Platform will be decommissioned later.
- Remove by reverse reeling: The process by which rigid or flexible pipelines can be recovered from the seabed by reeling them from the seabed using a specialist reel vessel is known as "reverse reeling". These vessels are usually engaged in installation activities but can be adapted to recover pipelines as part of a decommissioning project.
- Remove by cut and lift: The pipelines are cut down in appropriate length pieces and lifted to vessel for transport to shore. Require removal of rock cover and opening of the trench where the pipeline is buried.

Summarised are these methods assessed most feasible:

- Concrete tunnel protection/GRP structures will be removed and returned to shore.
- Spools will be removed and returned to shore.
- Pipeline will be left in-situ and stabilised by rock-dumping if needed (250 tons per pipeline end), or dredging into/blow the seabed surface.
- Installed rock-placement will be left in-situ, this will also cover removed rock-dumping during excavation of pipeline ends and spools.

18.3.4 Debris surveys

Pre-decommissioning survey

Before the installation of the jack-up for P&A, seabed surveys by ROV are conducted, to ensure no debris implication from spud can installation. The survey area will be locally at Nini A.

Post decommissioning survey

After the completion of the abandonment work, a survey of the former platform site and the pipeline corridor will be performed to verify that the removal has been performed in accordance with the agreed plans, both in terms of the environmental aspects and the baseline survey for the in-situ decommissioned pipelines. The survey will include identification and recovery of debris within the platform 500 m zone and a 200 m wide corridor along each pipeline route.

Based on the information from these surveys a monitoring programme will be set up to follow the development of any findings from the baseline. The monitoring programme to be agreed with relevant authorities.

In the Table 18-13 is listed the estimated fuel consumption and emissions to air related to the 2 planned debris surveys.

Table 18-13 Fuel consumption and emission to air covering 2 x 1 debris surveys (pre and post decommissioning).

Debris surveys	Fuel consumption	Emissions				
	Total [m^3]	CO_2 [ton]	NO_x [ton]	SO_x [ton]	CH_4 [ton]	nmVOC [ton]
Support vessel 2 days incl. ROV	24	67	1.5	0.04	-	0.04

18.3.5 Transport to shore

There are several facilities with the required permits and decommissioning experience in proximity to North Sea infrastructure, located in e.g., Norway, UK, the Netherlands, and Denmark. During transportation from the location in the North Sea and until arrival at the disposal yard, INEOS will be responsible for the platform. The platform will be handed over to the disposal yard upon arrival at the port. INEOS will ensure that the transportation of the platform will be in accordance with legislation and provide required data to the relevant authorities. Transport emissions are included in Table 18-12.

18.3.6 Onshore dismantling facilities

The onshore disposal yard will have access to sea, offloading facilities and sample area for handling and demolition of structures, including warehouse and office facilities. The harbour area must be surrounded by sheltered waters, for various inshore marine activities. The quayside must be constructed to support skidding or trailing operations or from flat top barges.

The open land area must have facilities for environmental protection from liquid spillage, area for scrap handling, waste segregation and storage, lifting/crane support and safe driveways for transport and logistic operations. The area must be securely fenced in and protected from unwanted traffic and personnel movement.

The operator must hold relevant environmental permits and comply with any licenses from local and governmental authorities, to execute onshore demolition work at the dedicated area, licenses for any sort of waste treatment, storage, handling and transporting, including scrap handling.

18.4 Assessment of impact

The decommissioning activities will be relatively similar to the zero-scenario as described in a separate draft EIA (COWI, 2023b). Compared to the zero-scenario the decommissioning of structures and pipelines will be conducted later and after the Project Greensand Future in +10 years.

An overview of the planned decommissioning activities and related potential impact mechanisms is provided in Table 9-1. This is however not a final assessment, as a future decommissioning EIA will cover all potential impacts and activities in more detail. Potential accidental events are described in chapter 13.

Table 18-14 Overview of potential environmental impacts from Nini A decommissioning and effects on environmental receptors "X" marks the relevance for the impact assessment.

Potential impact mechanism related to decommissioning	Well P&A	Platform incl. offloading system	Pipeline	Debris surveys
Emissions	X	X	X	
Chemical discharge	X			
Underwater noise	X	X	X	X
Disturbance from vessels	X	X	X	X
Physical disturbance of the seabed	X	X	X	
Light emissions	X	X		
Solid waste	X	X	X	

The relevant receptors that have been assessed based on this chapter are summarized in Table 9-2.

Table 18-15 Potential impact mechanisms and relevant environmental receptors. "X" marks the relevance for the impact assessment.

Potential impact on environmental receptors	Underwater noise	Disturbance from vessels	Physical disturbance of seabed	Chemical discharges	Emissions	Light emissions	Solid Waste
Climate and air quality					X		
Water quality				X			
Sediment conditions			X				
Plankton				X			
Benthic fauna			X	X			
Fish	X		X				
Marine mammals	X	X					
Seabirds		X				X	

As mentioned in earlier, the current EIA covers the decommissioning activities in a high-level, while a detailed decommissioning EIA will be submitted in the future. The main impacts from decommissioning activities are assessed in the following sections. There are further receptors, that are not covered in the current sections, but is recommended addressed in the future decommissioning EIA, such as transport to shore and onshore dismantling, social impacts, accidental events and impacts on international directives (Water Framework Directive, Marine strategy Framework Directive, Natura 2000 and others).

18.4.1 Well plugging and abandonment (P&A)

P&A activities are assessed resulting in environmental impacts similar to the drilling operation activities. The assessment in this section is based to a large extent on the assessment of the relevant receptors in chapter 11.

During P&A activities there will be emissions to air in relation to rig operation. Emission related activities primarily include energy production at the jack-up rig and transportation of crew and materials by supply boat and helicopter. The estimated emissions from the P&A activities include a climate footprint of around 26,950 tons CO_2e, and emission of 450 tons NO_x and 9 tons SO_x. The climate footprint estimate doesn't include upstream footprint from material production.

Climate

The climate system vulnerability is **high**. The emission of greenhouse gasses will affect the climate on a **national/international** scale. The intensity of impact on climate during the P&A activities are **medium**. The duration of the P&A work is ~330 days (~33 days per well) and are then assessed having **medium-term** or **long-term** duration. The activity many be split into several campaigns over several years. The impact from emissions of greenhouse gasses is assessed irreversible. The combined impact from P&A is assessed having **moderate** consequences due to the relative low intensity.

Air quality

The air quality vulnerability, in the project area towards emissions of gasses and particles is assessed **low**. The geographical extent of the impact on air quality is **immediate vicinity/local**, as the majority of the activities will be within the project area. The intensity of impact on air quality are assessed as **low.** The activities are assessed having **medium-term** or **long-term** duration. The emissions of gasses and particles to the air will cause reversible impacts. The impact is expected to have **negligible** or **limited** consequences on air quality.

Chemical discharge

Discharges from the decommissioning activities will primarily be related to plug and abandonment (P&A) of wells. This will be done by a rig and thus constitute of rig chemicals and discharges from the well P&A (Section 18.3.1). A limited number of utility chemicals will be used at the rig during the P&A of the Nini A wells. It is assumed that 100% of the rig wash and 50% and 10% of Jacking grease and pipe dope respectively will be discharged to sea.

Modelling has been performed on similar short-term, batch-wise discharges for one P&A operation (COWI, 2023b). The modelling has only comprised the yellow used, not any green (red chemicals are not discharged) chemicals. The calculations include an assessment factor of 1000 i.e. the distances where the PEC/PNEC ratio exceeds 1 should be considered as conservative. The wash train chemicals will potentially exceed the PEC/PNEC ratio on longer distances (up to 5,000 m) over a short period of time. The discharge of chemicals will potentially affect pelagic species consisting of fish, fish larvae, zooplankton and phytoplankton in the affected area. However, as the duration of the impact is **short term** (within hours) and the intensity of the impact is **medium**, it is assessed that the impact of discharge on pelagic organisms is **limited**. The impact from P&A can only be preliminary assessed given that the activities and used chemicals can change when the specific decommissioning programme is completed.

Underwater noise
Underwater noise in relation to the P&A work from a drilling rig is comparable to noise from to installation and operation of the jack-up rig during drilling activities, which has been assessed in Section 4.4.1.

Measured underwater noise characteristics of a diamond wire cutting operation during the severance of a 0.76 m diameter conductor at an oil and gas platform in the North Sea (Pangerc et al., 2016). The conductor was cut approximately 10 m above the seabed using a ''36-inch'' (0.91 m) diamond wire cutting machine, in a water depth of approximately 80 m. The analysis revealed that the sound radiated from the diamond wire cutting of the conductor was not easily discernible above the background noise, which was present during the cutting operation (vessel activity). Increases of between around 4 dB and up to 15 dB were detectable for one-third octave band spectral levels at some frequencies, with the higher frequencies showing greater increase (above 5 kHz). The fact that the abrasive water jet cutter is working 3 meters below the seabed surface will further reduce the noise emissions.

The overall vulnerability of fish and marine mammals to underwater noise is assessed as **medium**. All impacts from underwater noise are assessed to happen in the **immediate vicinity** of the platform structures. The impact from underwater noise is assessed resulting in primarily reversible effects, the intensity of impact is assessed as **medium**. The duration of the impact from is expected to be **short termed**. The probability of an impact is assessed as high for fish and very high for marine mammals. The consequence of noise generated from decommissioning is assessed as **negligible.**

Physical disturbance of the seabed
The potential impacts on sediment conditions from the P&A work is related to:

- Physical footprint i.e., the area occupied by spud cans and legs from the jack-up rig, constitute to a loss of substrate.
- Sediment spill i.e., elevated concentration of suspended sediment in the water column and subsequent sedimentation. Sediment spill occurs from discharge of drilling mud.
- Chemical discharges i.e., from drilling mud and chemicals.

The vulnerability of the seabed to physical footprint from the above-mentioned activities are assessed as being **medium**. The physical footprint from loss of substrate under the structures is considered **local**. Based on the temporary placement and that no changes in the physical or chemical characteristics of the sediment are expected to happen, the physical impact on the covered sediments and the intensity is therefore assessed as **low**. The footprint from the spud cans and rig legs may however persist for longer than 300 days per year and is assessed as a **medium-term** or **long-term** impact. The probability of an impact assessed as very high, since the placement of structures on the seabed will inevitably lead to either temporary or permanent loss of substrate. No changes in physical or chemical composition of the sediment are expected. The physical footprint is only temporary and not expected to affect the physical or chemical conditions after the P&A has been completed. The impact from physical footprint is assessed to have **negligible** consequences for the sediment conditions in the project area.

Disturbance from vessels
During the P&A work, some disturbance from vessels to marine mammals and seabirds may occur. The vulnerability of these receptors is assessed as **low** as shown that harbour porpoises avoid vessels at a distance of 200-400 m (Bas et al., 2017), other whales and seals are estimated to have approximately the same avoidance distance from vessels. The impact is reversible as the marine

mammals and seabirds are expected to return to the area once the vessels have left and the disturbance ceases. The geographical extent is assessed to occur in the **immediate vicinity** of the vessels and rig. The intensity of disturbance is assessed as **low** and the duration of the impact is **short-term** (vessels) to **medium**- to **long-termed** for the rig operation. Overall, the impact of disturbance from vessels and rig to marine mammals and seabirds is assessed as **negligible**.

-
- *Light emissions*

Light from vessels and jack-up rig can potentially impact birds. The influence of light from offshore installations on seabirds is not well understood and the vulnerability of birds to light emissions is therefore conservatively assessed as **medium**. These sources of light are expected to only impact **locally**. The intensity of the impact from light on seabirds is therefore assessed as **low**. The impact from light on seabirds is assessed as **medium**- to **long-termed**. The probability of the impact is assessed as medium. Impacts from light is assessed to have **negligible** consequence with no impact at the population level for seabirds.

Solid waste

Waste is related to the tubing and casing pulled out of the wells. The tubing/casing will be checked for Naturally Occurring Radioactive Materials (NORM) and if required shipped onshore for proper handling and storage. The NORM waste fraction will be stored at an approved NORM storage facility. It is therefore assessed that there is no impact to the environment in relation to waste.

18.4.2 Platform incl. offloading system

Two methods are assessed for removal of the topside and jacket:

- Single-lift removal, where the topside and jacket are lifted in a single lift.
- Piece-small removal, where the jacket is cut into smaller pieces and the topsides and jacket are lifted in several lifts.

After removal of the jacket, the drilling template is removed. The offloading system removal is expected done as a reversed installation with cranes.

The impact related to removal of the platform structures by cutting and lifting are unknown as vessel and methods to be applied (in +10 years) will be clarified later. The high-level impact assessment in the following is a qualitative assessment based on assessments of receptors in chapter 10 and the decommissioning EIA (COWI, 2023b).

Climate

The climate system is vulnerable to emissions of greenhouse gasses is assessed **high** and the air is assessed having **low** vulnerability towards emissions of air quality parameters. The intensity of impact on climate during the platform structures removal and transport are assessed **medium** and **low** with respect to air quality. The activities are assessed having **medium/long** duration. The probability of the impact on the climate system is assessed to be high and low with respect to air quality. The combined impact from removal of the platform structures is assessed having **limited** consequences to the climate system and **negligible**/**limited** consequences on air quality due to the relative low intensity.

Air quality

The air quality vulnerability, in the project area towards emissions of gasses and particles is assessed **low**. The geographical extent of the impact on air quality is **immediate vicinity/local**, as the majority of the activities will be within the project area. The intensity of impact on air quality are assessed as **low.** The activities are assessed having **medium-term** duration. The emissions of gasses and particles to the air will cause reversible impacts. The impact is expected to have **negligible** or **limited** consequences on air quality.

Underwater noise
Removing the platform installations could require ROV and diving operations. Noise impacts related to ROV and diving operations are described in section 5.5.3.

Furthermore, the activity may require the use of hydraulic shears and a diamond wire saw to separate section of the jacket and topside of the platform. This equipment will be operated at low noise levels and are not expected to result in any physical damage or behavioural impact of marine mammals.

The overall vulnerability of fish and marine mammals to underwater noise is assessed as **medium**. All impacts from underwater noise are assessed to happen in the **immediate vicinity** of the platform structures. The impact from underwater noise is assessed resulting in primarily reversible effects, the intensity of impact is assessed as **medium**. The duration of the impact from is expected to be **short termed**. The probability of an impact is assessed as high for fish and very high for marine mammals. The consequence of noise generated from decommissioning is assessed as **negligible.**

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Disturbance from vessels
During the removal of the platform structures, some disturbance from vessels to marine mammals and seabirds may occur. The vulnerability of these receptors is assessed as **low/medium** as shown that harbour porpoises avoid vessels at a distance of 200-400 m (Bas et al., 2017), other whales and seals are estimated to have approximately the same avoidance distance from vessels. The impact is reversible as the marine mammals and seabirds are expected to return to the area once the vessels have left and the disturbance ceases. The geographical extent is assessed to occur in the **immediate vicinity** of the vessels. The intensity of disturbance from vessels is assessed as **low** as only few vessels are expected in the removal of the platform structures and the duration of the impact is **medium-term**. Overall, the impact of disturbance from vessels to marine mammals and seabirds is assessed as **low/negligible**.

Physical disturbance of the seabed
The removal of the platform structures will cause disturbance of the seabed and result in removal of hard substrate and associated fauna from the area. The vulnerability of the receptor is assessed **medium** and the physical footprint from loss of substrate under the structures is considered **local**. The intensity is assessed as **medium** during the decommissioning phase. The activities are assessed having **medium** duration. The probability of an impact is assessed as very high. Considering the low intensity and local impact from cutting piles, legs and offloading system, the impact from physical footprint during the decommissioning phase is assessed to have **negligible** consequences for the sediment conditions in the project area.

- *Light emissions*
- Light from vessels can potentially impact birds. The influence of light from offshore installations on seabirds is not well understood and the vulnerability of birds to light emissions is therefore conservatively assessed as **medium**. These sources of light are expected to only impact **locally**. The intensity of the impact from light on seabirds is therefore assessed as **low**. The impact from light on seabirds is assessed as **medium-termed** and will likely happen continuously. The

probability of the impact is assessed as medium. Impacts from light is assessed to have **negligible** consequence with no impact at the population level for seabirds.

Solid waste
Waste related to topside and jacket are mainly various metals, plastics, cables and other materials. This will be returned onshore for demolition and recycling.

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18.4.3 Pipeline and pipeline installations

Compared to the zero-scenario the pipelines from Siri to Nini A will be left in place and preserved for decommissioning after the Project Greensand Future.

The in-situ/left in place option is assumed the most feasible method and is the common practice in the industry for similar pipelines. Future assessment and - technologies may open for other decommissioning methods.

As for the removal of the platform the vessel and methods applied (in +10 years) for pipeline decommissioning have not been selected. The high-level impact assessment in the following is a qualitative assessment based on assessments of receptors in chapter 10 and the decommissioning EIA (COWI, 2023b).

Climate/Air Quality
The vulnerability towards emissions of greenhouse gasses is assessed **high** and **low** towards emissions of air quality parameters. The intensity of impact on climate and air quality during the in-situ pipeline decommissioning are assessed **low**. The activities are assessed having **short** duration. The probability of the impact on climate is assessed to be high and low with respect to air quality. The combined impact from in-situ pipeline decommissioning is assessed having **limited** consequences to the climate system and **negligible** consequences to air quality.

Underwater noise
Removing sections of the pipeline and related subsurface installations could require ROV and diving operations. Noise impacts related to ROV and diving operations are described in section 5.4.2 or 5.5.3.

Furthermore, the activity may require the use of hydraulic shears and a diamond wire saw to separate section of the jacket and topside of the platform. This equipment will be operated at low noise levels and are not expected to result in any physical damage or behavioural impact of marine mammals.

The overall vulnerability of fish and marine mammals to underwater noise is assessed as **medium**. All impacts from underwater noise are assessed to happen in the **immediate vicinity** of the platform structures. The impact from underwater noise is assessed resulting in primarily reversible effects, the intensity of impact is assessed as **medium**. The duration of the impact from is expected to be **short termed**. The probability of an impact is assessed as high for fish and very high for marine mammals. The consequence of noise generated from decommissioning is assessed as **negligible.**

Disturbance from vessels
During the removal of all installations placed above seabed, i.e., spools and pipeline stabilisation features, some disturbance from vessels to marine mammals and seabirds may occur. The

vulnerability of these receptors is assessed as **low/medium** and the impact is reversible as the marine mammals and seabirds are expected to return to the area once the vessels have left and the disturbance ceases. The geographical extent is assessed to occur in the **immediate vicinity** of the vessels. The intensity of disturbance from vessels is assessed as **low** as only few vessels are expected in the removal of the offloading system and the duration of the impact is **short-term**. Overall, the impact of disturbance from vessels to marine mammals and seabirds is assessed as **negligible**.

Physical disturbance of the seabed
Leaving the pipelines in place will cause no disturbance of the seabed, expect for the local areas requiring rocking dumping. The vulnerability of the receptor is assessed **medium** and the physical footprint from loss of substrate under the dumped rock is considered **local**. The intensity is assessed as **low**. The activities are assessed having **short** duration. The probability of an impact assessed as very high. Considering the very low intensity and local impact from rocking placement, the impact from in-situ decommissioning is assessed to have **negligible** consequences for the sediment conditions in the project area.

Solid waste
Waste related to pipelines are mainly the steel pipes, concrete tunnel elements at the ends, glass fibre reinforced plastic covers of spool bends, and the pipeline coating. The amount of waste is assessed to be minor in the left in-situ scenario.

18.4.4 Debris surveys

Underwater noise
Underwater noise is expected from vessels and ROV equipment. Marine mammals are expected to avoid the area and they are assessed to be insensitive to small displacement. There are no behavioural threshold values for minke whale and white beaked dolphin, both species are expected to avoid the area. With the initial disturbance from vessels, there will be a very limited risk of injury from underwater noise on marine mammals related to the use of high frequency ROV equipment. Noise impacts related to ROV operations are described in section 5.5.3.

The overall vulnerability of fish and marine mammals to underwater noise is assessed as **medium**. All impacts from underwater noise are assessed to happen in the **immediate vicinity** of the rock placement sites. The impact from underwater noise is assessed resulting in primarily reversible effects, the intensity of impact is assessed as **low**. The duration of the impact from is expected to be **short termed**. The probability of an impact assessed as high for fish and very high for marine mammals. The consequence of noise generated is assessed as **negligible.**

Disturbance from vessels
During the surveys, some disturbance from vessels to marine mammals and seabirds may occur. The vulnerability of these receptors is assessed as **low/medium** and the impact is reversible as the marine mammals and seabirds are expected to return to the area once the vessels have left and the disturbance ceases. The geographical extent is assessed to occur in the **immediate vicinity** of the vessels. The intensity of disturbance from vessels is assessed as **low** as only few vessels are expected used and the duration of the impact is **short-term**. Overall, the impact of disturbance from vessels to marine mammals and seabirds is assessed as **negligible**.

19. MONITORING

As *Project Greensand Future* is the first CO_2 storage project (>100 kt) in Denmark, monitoring of the reservoir and leak monitoring are planned as described in section 5.5 and 5.5.4 and have been assessed as an integrated part of the project. Additionally, a Monitoring, Measurement and Verification (MMV) plan is developed. This is in accordance with the CCS Directive (2009/31/EC on the geological storage of carbon dioxide) and §10 in the Executive Order No. 845 of 26/06/2024 on geological storage of CO_2, which states that monitoring of the injection well and reservoir is required to assess CO_2 migration or leakage from the reservoir as well as social or environmental impacts. Further as stated in §11 in the Executive Order No. 845, a monitoring programme shall be approved and covering the above topics. The programme is maintained and updated every five years to take into account any changes to the assessed risk of leakage, changes to the assessed risks to the environment and human health, new scientific knowledge, and improvements in the best available technology.

Since unplanned events, such as leaks of CO_2 from the sea floor (section 13.2) can lead to impacts on benthic fauna, although not significant, regular monitoring of benthic fauna and sediment chemistry during the lifetime of the project may be considered. A regular monitoring program will give an understanding of possible impacts to the benthic communities including microbes as a result of CO_2 leakage to the seabed surface. Therefore, a monitoring program with a 5-year interval starting from the first injection, similar to the baseline survey is suggested (DHI and Rambøll, 2023a).

As described in chapter 18 a post decommissioning survey will be performed to verify that the removal of all structures and elements from the offloading system has been completed. The survey will include identification and recovery of debris within the 500 m zone.

As described in chapter 11 and chapter 12 none of the planned activities leads to significant negative impacts on other environmental or social receptors and therefore no additional monitoring is required.

20. MITIGATION MEASURES

None of the identified impact mechanics from planned events have been assessed to result in significant negative impact on either the environmental or social receptors. Thus, no mitigation measures have been considered necessary in *Project Greensand Future*.

Waste and chemical discharges to sea should be managed in accordance with the International Maritime Organization (IMO) convention, the MARPOL convention, the ballast water management convention (BWM), the OSPAR convention and the Environmental Protection Act (all described in chapter 7).

Measures like the slow start and soft start procedure to minimize harm to marine mammals during ROV and diving operations and seismic surveys are considered standard procedures, and are described as part of the project description, see section 5.4.2, 5.5.3 and 5.5.4. With standard procedures in place, it has been assessed, that no further mitigation is necessary for marine mammals, see section 11.8.3. As part of the application for the monitoring programme, the need for additional mitigation measures shall be discussed with DEA.

In the event of oil spill blowout or CO_2 release from the reservoir, the response strategy described in chapter 13, respectively, needs to be followed.

21. CUMULATIVE EFFECTS

In this chapter all existing projects and plans as well as future projects and plans which have either been applied for or given a permit, and which may potentially result in cumulative effects with the current project, are listed and shown in Figure 21-1.

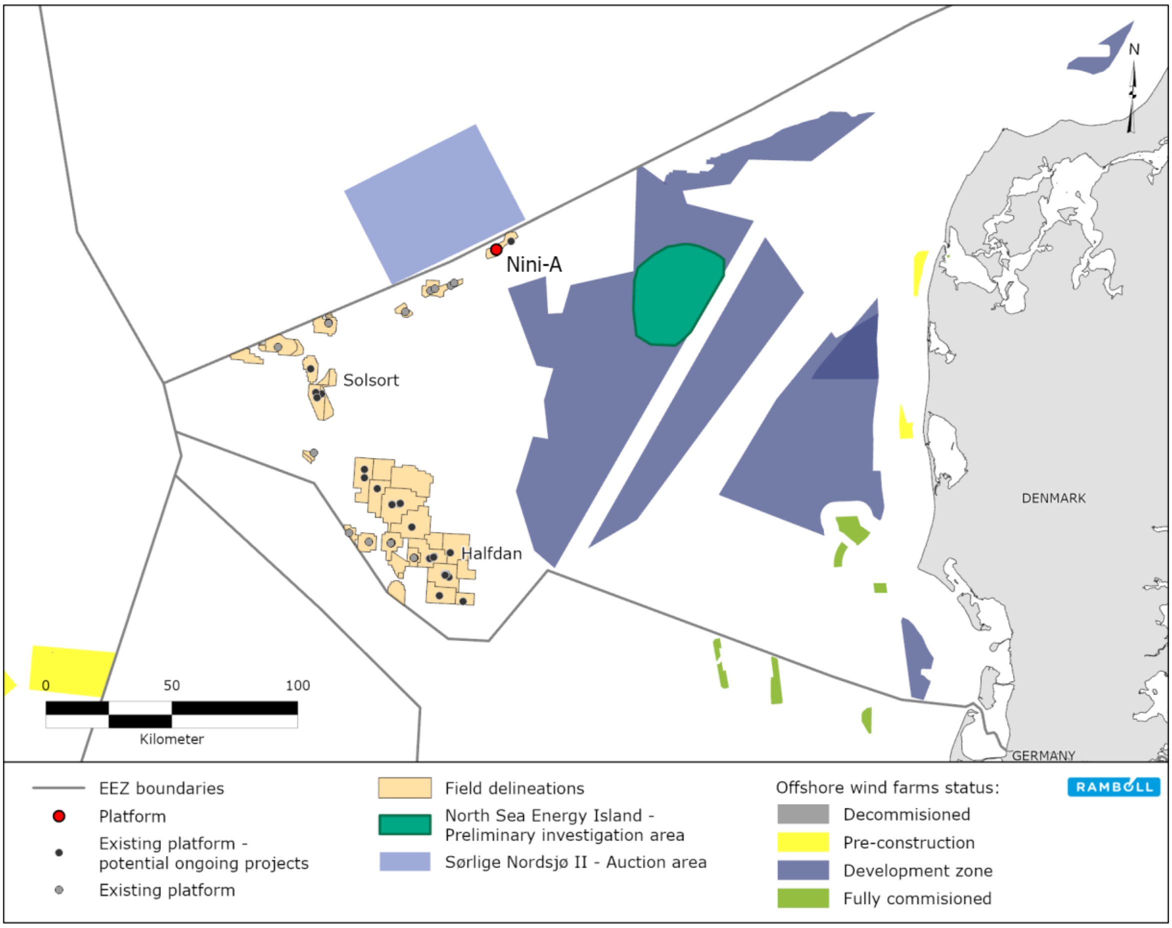

Figure 21-1 Existing and potential ongoing projects for oil and gas platforms and existing OWFs and development zones for OWF in the North Sea.

21.1 New production wells in the Halfdan Field

The Danish Energy Agency has decided that the establishment of four new production wells on the Halfdan field can take place. The construction work is expected to start in March 2023, and the boreholes in the Tor reservoir are expected to be commissioned in end of 2023 and the boreholes in the Ekofisk reservoir is expected to be commissioned in 2024 and 2025. Due to the distance of >100 km between the Nini field and the Halfdan field, no cumulative effects are expected.

21.2 Existing oil and gas activities in the North Sea

Existing oil and gas activities in the North Sea are not expected to result in cumulative effects with *Project Greensand Future* due to distance from the project area and the characteristics of potential impacts from the current project and from other oil and gas activities (Oil & Gas Denmark, 2017).

21.3 Offshore windfarm development zones

Furthermore, other projects and plans are in the pipeline in the North Sea such as:

- The Norwegian auction area, Sørlige Nordsø
- Other OWF development zones.

However, as these are not applied for or approved, they are not considered in this EIA with regard to cumulative effects. Overall, *Project Greensand Future* is not expected to cause any cumulative effects in relation to existing or planned projects. Additionally, impacts from other nearby planned projects do not temporally or geographically overlap with *Project Greensand Future*.

Sørlige Nordsjø II is a development zone for offshore wind farms that will deliver renewable energy to Norway and potentially Europe. The auction for the area was completed in March 2024. The goal is to have the first wind farm in production by 2030. No detailed planning is in place at this time. There is a potential risk of overlapping activities from the current project and the OWF development zone "Sørlige Nordsjø II" which can result in cumulative effects. No detailed planning is in place at this point for the OWF development zone, thus no cumulative effects can be identified at this stage. It needs to be taken into consideration for the future development of the OWF development zone "Sørlige Nordsjø II".

21.4 Baseline Monitoring

The baseline monitoring activities (seismicity and CO_2 leakage) are conducted in Q1-Q4 2025 and completed prior to first CO_2 injection. These activities are covered by separate application/permit. The baseline activity ends in Q4 2025 and the construction phase begins in Q3 2025, leading to a temporal overlap.

In Q1 2025 ocean bottom stations (OBS) for seismicity data acquisition baseline and the CO_2 leakage monitoring system (lander) for baseline monitoring will be deployed. OBSs and the lander will be retrieved in Q4 2025. Recovery of the baseline OBSs will require an ROV operation in which all 8 OBSs will be retrieved within 3 days. The retrieval of the baseline OBSs coincides with the deployment of OBSs for the continuous monitoring in the operation phase. Further offshore activities in Q3/Q4 2025 include installation of flowline on Nini A platform (1 month), installation of CO_2 offloading system (7 days + 1.5 days) and wireline work on CO_2 injection well on Nini A platform (1 month), which leads to an overlap in activities with the baseline monitoring activities.

Seismic survey and recovery of baseline OBSs are not planned to take place at the same time in proximity of each other. The impacts of the baseline monitoring activities are local, short-term, and temporary, and it is assessed that the risk of impact on Annex IV species and the integrity of Natura 2000 sites are not significant. Furthermore, the period where the baseline activities potentially coincide with other activities are very short (a few hours at the nearest station) and the impact is assessed negligible. Based on the above, it is concluded that there is no risk of cumulative effects from the activities.

22. GAPS AND LIMITATIONS

This chapter is a summary of the most significant uncertainties in the assessments of the planned activities and areas where there are limitations to existing knowledge. Details on the limitations are described in the assessment of each receptor in chapters 11 and 12. The receptors listed in this chapter are those where any gaps or limitations have been identified for the planned activities, while no limitations have been identified in the assessment of the remaining receptors.

Existing conditions and potential impacts

The basis for mapping existing conditions is assessed to be sufficient as the North Sea is quite well studied. Data exists from decades of monitoring and data on sediments and benthic fauna for *Project Greensand Future* has been surveyed in 2022, which gives a very good basis for assessing possible impacts to the benthic environment.

The impact paths are well known as the activities involved in the project are similar to those that take place in the oil and gas industry, therefore experience from decades of working with oil and gas can be transferred to *Project Greensand Future*. The range of possible impacts is therefore well known and from an environmental perspective the planned part of the project and the impacts from these are considered simple. Impacts from unplanned activities always have some degree of uncertainty, however, possible impacts have been modelled (oil spill and CO_2 release from blow out), see chapter 13. The basis for the assessment is considered sufficient to determine the consequence of an impact with high level of certainty.

Climate and air quality

The estimation of emissions of gasses and particles and the assessment of the impact on the climate and the air quality includes several limitations as emission factors are drawn from a database of standard emissions. Also, there is some level of uncertainty in this early stage of the project on use of materials and machinery. The estimates used are conservative and covers all the primary sources of emissions. The limitations of estimating emissions are therefore considered to be limited. The overall assessment is considered to be sound as is it based on the best available knowledge and include the primary sources off emissions.

Water quality

The water quality around the oilfields in the central North Sea is relatively well known as it has been a key focus during the years of offshore oil and gas extraction. Discharge of wastewater and other effluents from vessels and their impact on the water quality in the pelagic zone has not been investigated in detail and the amounts and frequencies of discharge are not known at this point. However, the impact on water quality with regard to nutrient enrichment and contaminants, which make up the main components of discharge expected from this project, is known on a general level and the data basis for this assessment is therefore considered sufficient.

Biodiversity

The distribution and biology of fauna in the central North Sea is relatively well known, and scientific research as well as previous impact assessments of similar project activities on plankton and benthic fauna are well documented in the literature. The data basis of this assessment is therefore considered to be sufficient.

The fish distribution and biology of the central North Sea is relatively well known, and the effect of underwater noise on fish is relatively well understood. Although the TTS threshold for fish is based on freshwater species, the knowledge drawn from other species applies to some extent, and considering the temporary nature off the impact, the conclusion of this assessment is regarded as sound. The effect of light emissions on fish in pelagic zones, namely safety lights from platforms and vessels, is not well understood. The effect of artificial light on fish in coastal urban developments has been studied broadly and may act as a proxy for assessing the effects of safety lights on fish. Overall, the conclusion of this assessment on fish is considered to be sound.

Knowledge on impacts on marine mammals and Annex IV species (whales) is well understood as they have been monitored from oil and gas installations for decades and guidelines for noise impacts are updated regularly, most recently in 2022 (Energistyrelsen, 2022b). There are no guidelines for avoidance from underwater noise for minke whale and white-beaked dolphin, but the value provided by (Tougaard, 2016) (145 dB re1UPa) is largely accepted by DEA to be applied to all marine mammals, that inhabits the Danish North Sea.

The distribution and biology of seabirds associated with the North Sea is relatively well known. However, considerable uncertainties are associated with the effect of artificial light on seabirds. Estimates of mortality of seabirds due to light emissions are often imprecise and difficult to translate into significance at the population level. Furthermore, knowledge on nocturnal migratory behaviour is generally lacking as well as an understanding of the underlying factors controlling annual variations in volumes of migrating birds. However, as the sources of artificial light are limited and temporary, the conclusion of this assessment is considered to be sound.

Cultural heritage

The seabed of the project area has been surveyed on multiple occasions during geophysical and debris surveys. An archival control from Moesgaard Museum will be carried out as an initial step to ensure a marine archaeological interpretation of the potential for CHOs in the project area.

Fisheries

The distribution of the activity from the different commercial fisheries are presented for the period 2015 to 2018. The dataset on fishing intensity in the EU waters was created in 2020 by COGEA for the EMODNET (EMODnet, 2021d). Fishing effort data are only shown for vessels >12 m having a VMS, which is not a limiting factor, because smaller vessels are not expected to commercially fish in the area far offshore. Overall, the data basis for the assessment is considered sufficient.

Overall assessment of gaps and limitations

Overall, the gaps and limitation in assessing the impacts from *Project Greensand Future* considered to be limited. The overall assessment is considered to be sound as is it based on the best available knowledge and include all relevant impacts.

23. TRANSBOUNDARY IMPACTS

23.1 Planned activities

In the impact assessment of planned activities (chapters 11 and 12), the seismic survey, ROV activities and diving operations have been identified to cause potential transboundary impacts.

No transboundary impacts are foreseen for planned activities on Natura 2000-sites (chapter 17), although there is a potential risk of impact on Danish Natura 2000-sites (section 17.4). Transboundary impacts from the seismic survey are described below.

Fish

The Norwegian SVO-area "the sand eel fields" is located relatively near the Danish-Norwegian EEZ border approx. 11 km from the project area and 4.6 km to the monitoring OBS (seismicity). Underwater noise (seismic) is the only impact mechanism which could potentially cause transboundary impacts.
In the operation phase, underwater noise from seismic with application of soft start procedure reduces PTS distance to 0 m. Applying soft start procedure does not remove the risk of mortal injury to larvae at a range of 0.9 km (SPLcum) from the source. This is however unlikely to have repercussions for reproduction and stock recruitment. The Norwegian sand eel fields are therefore not impacted at a distance of 11 km.

Marine mammals and Annex IV species

Impacts related to the use of ROV and diving operation equipment using high frequency sound may result in behavioural effects of marine mammals up to 4.8 km from the Nini A platform. Therefore, there could be a displacement of animals in Norwegian waters since the distance from the Nini A platform to the EEZ is approx. 4 km. However, since the impact is short-termed, reversible and only affects a very limited number of animals it is assessed to have negligible transboundary impacts.

In the operation phase the reservoir monitoring (seismic) takes place in a survey area where the closest distance is around 1,000 m from the Norwegian EEZ. Since the airguns used during the survey can cause avoidance behaviour for whales in a distance of up to 36.8 km there could be a displacement of animals into Norwegian waters (section 11.8.3). Since the impact is short-termed (5-10 days), reversible and only affects a very limited number of animals it is assessed to have negligible transboundary impacts. Likewise, the monitoring can displace seals in a 28.9 km radius, but since the distance to the Norwegian coast where haul-outs could occur is more than 100 km and few seals use the project area, it is assessed to not impact Norwegian seal populations.

23.2 Unplanned activities – oil spill blow-out

An impact assessment of accidental and unplanned events is presented in section 13.1. Based on an oil dispersion modelling from an unmitigated blowout potential impact on receptors have been evaluated and summarised in Table 13.1. The modelled scenario (spill (26,280 m^3 oil over 90 days) represents a very conservative estimate of the impact that could occur in case of a blow-out, as the release rate is at least 3 times higher than the worst-case scenario for the CO_2 injection well at the Nini A platform. The likelihood of such an event to occur is very low.

The model results indicate a risk of transboundary effects into Norwegian and Swedish waters. The receptors affected include:

- Air quality
- Water Quality
- Sediment conditions
- Plankton
- Benthic fauna
- Fish
- Marine mammals
- Seabirds
- Shorelines
- Natura 2000 and other protected areas

The potential impacts are summarised below. Further details are presented in Section 13.1

Air quality
The spill may result in fumes containing oil contaminants that could pose a safety hazard. However, Nini A is located far from coastal areas and manned platforms are more than 10 km away. The wind exposed area will also result in the air quality being less vulnerable to the evaporation of oil components. The area affected is expected to be regional as most of the evaporation will take place immediately after the release of the oil to sea. The impact would be restricted to Danish and Norwegian waters.

Water quality and plankton
The total concentration of oil at the surface is not expected to exceed 250 ppb except around the release site. At 30 m depth, the water column impact is restricted to Denmark and Norway only, and is predominantly less than 50 ppb, except around the release site. At 60 m depth, the water column impact is restricted to an area no more than 30 km from the release site and no greater than 50 ppb. The effect on water quality and plankton is therefore assessed to be restricted to Dani h and Norwegian waters.

Sediments and benthic fauna
Seabed habitats and flora and fauna may be affected depending on the extent of oil sedimentation in the area and the sensitivity of the associated flora and fauna. Sedimentation of oil could occur in Danish, Swedish and Norwegian waters. The oil contaminants will be mixed with the sediment over time and a natural biodegradation process will take place. The reversibility of the impact is uncertain and will be very site specific and highly dependent on the extent of the spill.

Sea birds
Seabirds are most often highly vulnerable to oil spills as they are regularly in contact with surface water. In the event of a blowout incident at Nini A, the oil will most likely be transported towards northeast with the prevailing currents and pass the internationally important bird areas in the north-eastern part of the North Sea. The emulsion thickness at the surface is expected to be less than 5 μm in most of the potentially impacted area while emulsion thickness above 5 μm will be restricted to areas closer to the blow-out location. The impacted area could include Danish, Swedish and Norwegian waters.

Marine mammals
Oil from a blowout may affect areas where harbour porpoise, minke whale, white-beaked dolphin, grey seals or harbour seal may be encountered. Whales and seals are generally less vulnerable to oil spill than birds (i.e., threshold for seals is estimated to an oil emulsion thickness of 10 μm while the threshold for cetaceans is 100 μm. Emulsion thickness above 100 μm is only expected within the immediate proximity of the blowout location. It cannot be excluded that seals in the Central North Sea may be affected, however, the area affected with emulsion thickness above 10 μm is

limited to the area in the vicinity of the blowout. The impact would be restricted to Danish and Norwegian waters.

Fish

Fish eggs and larvae are considered the most sensitive life stages of fish in terms of acute impacts of spilled oil. The Norwegian Oil Industry Association use 25 ppb as the concentration at which fish eggs- and larvae and other sensitive marine life begin to be affected by oil components. The risk of encountering surface oil concentrations above 25 ppb that may affect fish eggs and larvae would be present in the surface water within most of the Danish North Sea and along the southern coast of Norway. Important sand eel spawning grounds are found in Norway at the designated SVO area Vikingebanken located 11 km from the Nini A platform. It is almost certain that the area will be affected in the event of the modelled blowout scenario. The impact would be restricted to Danish and Norwegian waters.

Shorelines

The modelling showed, that in case of a blowout with surface release during summer, oil may strand on beaches along the west coast of Vendsyssel and Thy (likelihood 1-25%) (Figure 13-3). Oil may also strand on the south coast of Norway (likelihood 1-50%) and in a very small area in the northern part of the Swedish Skagerrak coast (likelihood less than 1%). The overall likelihood of shoreline impact of an unmitigated blow-out ranges between 80-98% for winter and summer releases, respectively. Shoreline oiling is likely to range between very light and moderate, as defined by ITOPF's recognition of shoreline oiling guidelines. Under the worst-case metocean conditions, the earliest impact o

the shoreline in Denmark will be two to three weeks. Shoreline impact may also happen in Norway (after three weeks) and Sweden (after 4 weeks). There will be no shoreline impact in UK, Germany or the Netherlands.

Natura 2000 and protected areas

It very likely (75-95 %) that Norwegian SVOs to the north of the Nini A platform may be affected by an unmitigated spill from a blowout. The SVOs "Vikingbanken", and "Tobisfelt" are spawning areas for mackerel and sand eel from May to July. The concentration of oil in these areas could be above 25 ppb, which is above the concentrations that are harmful to fish eggs and larvae. Spawning in this area is therefore at risk.

In the event of a blowout, the German and Dutch Natura 2000-sites south-south-west of Nini A are less likely to be affected by the spill (1-5 %). The German DE 1003301, Doggerbank, would have an exposure time of less than one day while maximum oil concentrations at the surface would reach 25-50 ppm. The Dutch NL2008-001, Doggerbank, is also less likely to be affected.

24. SUMMARY OF ENVIRONMENTAL IMPACT ASSESSMENT

24.1 Environmental and social receptors

The impacts of *Project Greensand Future* on environmental and social receptors are summarized in Table 24-1. For those receptors in which there are multiple impact mechanisms and thereby varying assessments of each assessment criteria (i.e., vulnerability, geographical extent, intensity, and duration) a range has been given in the table. The overall consequence for each receptor is based on the most unfavourable assessment for each impact mechanism (i.e. worst-case, if the consequence for fish with regard to underwater noise is assessed as *limited* and for light is assessed as *negligible*, then *limited* is noted). The overall impact on climate is assessed to have moderate consequences in both the construction and operation phase. The impact from the entire CCS loop is however assessed having significant positive consequences on the climate system.

Table 24-1 Summary of impacts from *Project Greensand Future* on environmental and social receptors divided into the construction and operation phase.

Impact	Vulnerability	Geographical extend	Intensity	Duration	Overall consequence
Construction Phase					
Climate	High	Global	Medium	Medium	Moderate
Air quality	Low	Immediate vicinity / local	Low	Medium	Limited / negligible
Hydrographic conditions	Low	Immediate vicinity	Negligible	Permanent	Negligible
Water quality	Low	Immediate vicinity	Low	Very short	Negligible
Sediment conditions	Low	Immediate vicinity	Low to high	Short to permanent	Negligible
Plankton	Low	Immediate vicinity	Low	Very short	Negligible
Benthic fauna	Low	Immediate vicinity	Low to high	Very short to permanent	Negligible
Fish	Low	Immediate vicinity	Low to medium	Short to permanent	Limited / negligible
Marine mammals	Low to medium	Immediate vicinity to local	Low to medium	Medium	Limited / negligible
Seabirds	Low to medium	Immediate vicinity to local	Low	Medium	Negligible
Annex IV	Low to medium	Immediate vicinity to local	Low to medium	Medium	Limited / negligible
Protected nature	-	-	-	-	None
Material assets	-	-	-	-	None
Cultural heritage	High	Immediate vicinity	Low to very high	Short to permanent	Limited
Fisheries	-	-	-	-	None
Operation Phase					
Climate	High	Global	Medium	Permanent	Moderate
Air quality	Low to medium	Regional to international	Low	Very short	Limited / negligible
Hydrographic conditions	Low	Immediate vicinity	Negligible	Permanent	Negligible
Water quality	-	-	-	-	None
Sediment conditions	Low	Immediate vicinity	High	Permanent	Negligible
Plankton	-	-	-	-	None
Benthic fauna	Low	Immediate vicinity	High	Permanent	Negligible

Impact	Vulnerability	Geographical extend	Intensity	Duration	Overall consequence
Fish	Low	Immediate vicinity to local	Low to medium	Short to permanent	Limited / negligible
Marine mammals	Low to medium	Immediate vicinity to regional	Low to medium	Short to permanent	Limited / negligible
Seabirds	Low to medium	Immediate vicinity to local	Low	Short to permanent	Negligible
Annex IV	Low to medium	Immediate vicinity to regional	Low to medium	Short to permanent	Limited / negligible
Protected nature	-	-	-	-	None
Material assets	Low	Immediate vicinity	Medium	Permanent	Negligible
Cultural heritage	High	Immediate vicinity	Very high	Permanent	Limited
Fisheries	Low	Immediate vicinity	Low	Permanent	Negligible

24.2 Accidental events

The accidental events oil spill in case of a blowout from injection well, CO_2 leakage in case of a blowout from injection well and ship collisions have been assessed. The impacts of *Project Greensand Future* from oil spill are summarized in Table 24-2. For those receptors in which there are multiple impact mechanisms and thereby varying assessments of each assessment criteria (i.e., vulnerability, geographical extent, intensity, and duration) a range has been given in the table.

Table 24-2 Summary of impacts from *Project Greensand Future* from accidental events.

Receptor	Vulnerability	Geographical extend	Intensity	Duration	Consequence
Air quality	Low	Regional	Medium	Short	Moderate
Water Quality	Medium	International	High	Short	Moderate
Sediment conditions	Medium	International	High	Medium	High
Plankton	Low	International	High	Medium	Moderate
Benthic fauna	Medium	International	High	Medium	High
Fish	Medium	International	High	Medium	High
Marine mammals	Low	International	High	Medium	Moderate
Seabirds	High	International	High	Medium	High
Natura 2000 / protected areas	-	-	-	-	Negligible to some risk

CO_2 leakage from the reservoir is found highly uncertain based on the comprehensive preliminary investigations of the geological layers and only leakage from legacy wells is considered to pose a risk. The probability of a leakage is assessed to be very low. As the impact will occur within the immediate vicinity, no impact further up the food chain (fish and marine mammals) is expected. The duration of a leak is expected to be permanent or long term, depending on how long the injection has lasted and its geological origin. The overall consequence of the impact is assessed to be limited.

During the offloading procedure from the vessel to the well there are a number of potential accidental scenarios that could lead to emissions of CO_2 to the environment. The impact duration would be short term and the impact on planktonic and pelagic species in the near vicinity would be negligible as the released volumes are expected only to cause a short-term impact on water quality before equilibrium is established. The likelihood of such an accidental event is low and the overall consequence of the impact is assessed limited towards climate and negligible towards environmental receptors.

The general safety of shipping is ensured through coordination between offshore projects and the Danish Maritime Authority (DMA). Hence, for the transports of CO_2, it is assumed that the CO_2 vessel follows the defined shipping corridors, where relevant, and carry pilot as required. The CO_2 transports must coordinate with potential ongoing construction projects and navigate according to updated sea charts to interact correctly with offshore structures. Considering use of pilot where required and following ordinary COLREG rules for safe navigation, the additional ship collision risk imposed by the CO_2 vessel is assessed to be low.

24.3 Water Framework Directive

It is assessed that *Project Greensand Future* will not delay nor hinder the objectives of the Water Framework Directive to achieve good ecological and good chemical status in Danish coastal waters.

24.4 Marine Strategy Framework Directive

It is assessed that *Project Greensand Future* will not delay nor hinder the objectives of the Marine Strategy Framework Directive to achieve good ecological status for the descriptors included in the Marine Strategy Framework Directive.

24.5 Maritime Spatial Plan

The overall impact on the Marine Spatial Planning from *Project Greensand Future* is assessed to be of no significance.

24.6 Natura 2000

No impacts to marine mammals or seabirds have been identified to cause adverse effects at the population level for either of the designated species in any Natura 2000 sites. Distance to sites with designated protected habitat types and the character of the impacts also rules out any impacts to designated habitats. This implies that the conservation objectives of any Natura 2000-sites are not subject to be affected by the project. Significant impacts to Natura 2000-sites resulting from *Project Greensand Future* can therefore be ruled out.

24.7 Decommissioning

The impacts of *Project Greensand Future* from decommissioning are based on the assessment of the impacts of the project. The consequence of underwater noise on fish and marine mammals is assessed as limited. The impact of disturbance from vessels to marine mammals and seabirds is assessed as negligible. The overall consequence of physical disturbance to sediment conditions and benthic fauna are assessed as negligible. The combined impact from removal of the offloading system is assessed having limited to moderate consequences to the climate system and negligible to limited consequences on air quality due to the relative low intensity. The amount of waste is assessed to be relative limited and having limited environmental consequence.

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APPENDIX 1 – UNDERWATER NOISE MODELLING REPORT

TECHNICAL NOTE

Project name	**Project Greensand Future EIA – Underwater noise modelling**
Client	**INEOS E&P A/S**
Version	**9**
Prepared by	**CRIM**
Checked by	**SSBH**
Date	- **June 2024: Underwater noise modelling** - **Update October 2024: Underwater noise modelling report for marine seismic surveys with towed streamer geometry and 2D and 3D data acquisition as background for Environmental Impact Assessment of Project Greensand Future**

Terms and abbreviations

Units			**Metrics**
°C	degree celcius	TL	transmission loss
µPa	micropascal	SPL$peak$	zero-to-peak sound pressure level
cu in.	cubic inch	SEL	sound exposure level
dB	decibel	SELcum	cumulative sound exposure level
Hz	hertz	SELss	sound exposure level single pulse/single strike
kHz	kilohertz	SPL	sound pressure level
km	kilometer	f	frequency
m	meter	V_f	fleeing speed
min	minute	RMS	root mean square
Pa	pascal	P	pressure
Ppt	parts per thousand	P0	reference pressure
s	second		

Abbreviations

DEA	Danish Energy Agency
EIA	Environmental Impact Assessment
EMODnet	European Marine Observation and Data Network
HF	high frequency
ICES	International Council for the Exploration of the Sea
LF	low frequency
PTS	permanent threshold shift
PCW	phocid carnivores in water, (earless) seals weighted sound level
TTS	temporary threshold shift
USBL	ultra short baseline (acoustic positioning device)
VHF	very high frequency

1. INTRODUCTION

INEOS is planning seismic surveys for the Project Greensand Future in the Nini complex area (Figure 1-1. This study is an underwater noise propagation modelling performed for some of the proposed activities. The purpose of this study is to provide the expected potential underwater noise levels and exposure levels to assess potential impact on marine mammals and fish and to provide relevant documentation as part of the permitting process.

A modelling of ROV and diving operations, as well as spot seismic was performed in June 2024. The spot seismic monitoring was replaced by 2D and 3D surveys in accordance with the DEA. The spot seismic will remain an option, but the current plan is to use 2D seismic with a 3D close out. For this, an update of the modelling was performed in October 2024. The following results will be indicated with the date of the modelling report to distinguish between the previous and the updated modelling.

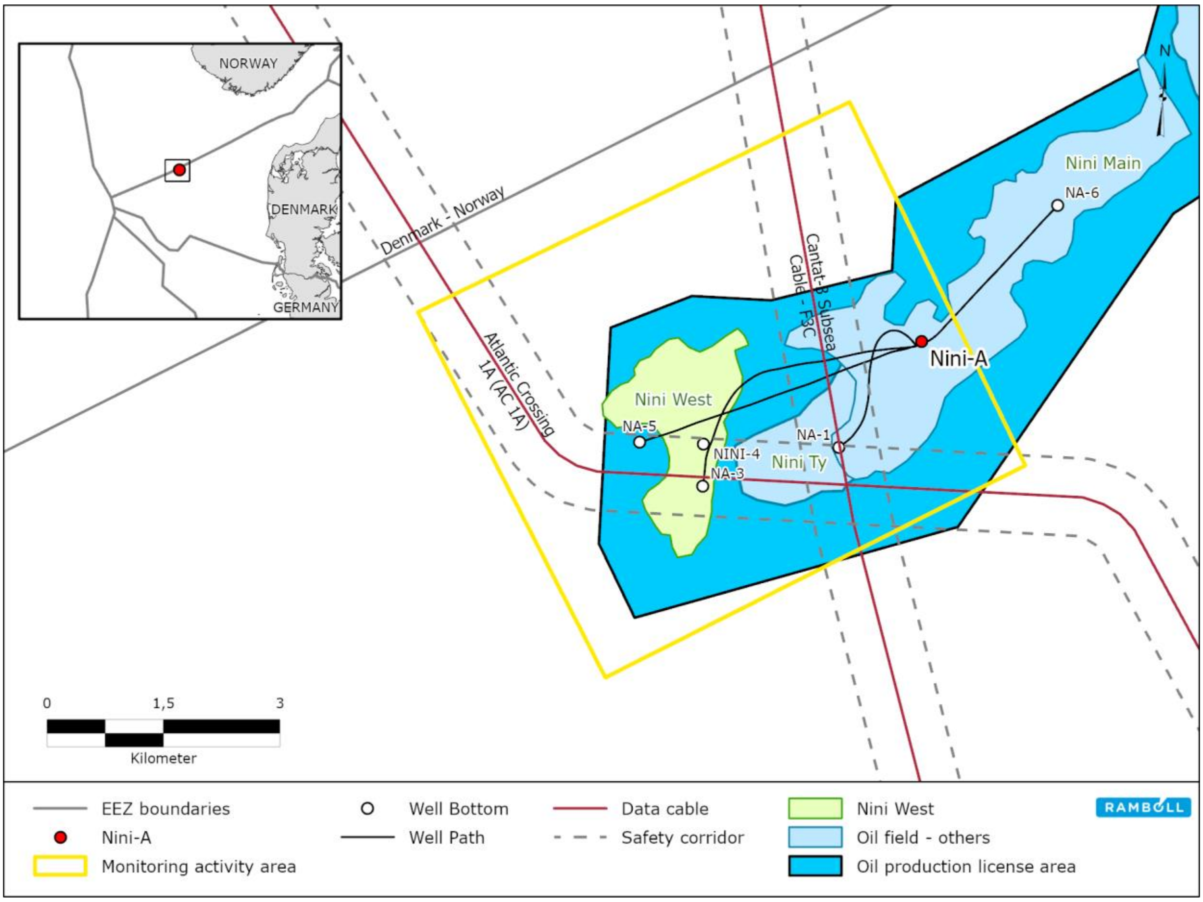

Figure 1-1 Greensand storage location and monitoring activity area. The yellow boundary marks the future monitoring activity area.

2. UNDERWATER SOUND

Underwater sound, like sound in the air, is disturbances from a source in a medium (here water) travelling in a 3-dimensional manner as the disturbance propagate with the speed of sound. Sound travels at different speed in different media. The speed of sound is determined by the density and compressibility of the medium. Density is the amount of material in a given volume, and compressibility is a measure of how much a substance could be compacted for a given pressure. The denser and the more compressible, the slower the sound waves would travel. Water is much denser than air, but since it is nearly incompressible the speed of sound is about four times faster in water than in air. The speed of sound can also be affected by temperature and salinity.

Underwater sound can be measured as a change in pressure, it is described as sound pressure and can be measured with a pressure sensitive device (hydrophone). Because of the large range pressure amplitudes of sound, it is convenient to use a decibel (dB) logarithmic scale to quantify pressure levels. The underwater sound pressure level in decibels is defined in the following equation:

$$\text{Sound Pressure Level (SPL)} = 20\log_{10}(P/P_0)$$

P is the pressure and P_0 is the reference pressure. The reference pressure is 1 micropascal (μPa) for underwater sound which is different for sound pressure levels in the air. For this reason, sound pressure levels in the water and air cannot be directly compared. Underwater sound levels vary in accordance to the sound source’s time signature and acoustic environmental conditions and can be future defined in terms of exposure, average and/or maximum levels. The following acoustic parameters are commonly used to assess the noise impact from underwater noise sources for the identified local marine life.

2.1 Applicable acoustic parameters

The following key terms are used in this document:

Sound Pressure Level (SPL) – quantifies the magnitude of a sound at a given point, i.e. how loud it is, and is measured in decibels (dB). As a relative unit dB is quoted relative to 1 micropascal in underwater studies (so, dB re. 1 μPa).

Sound Exposure Level (SEL or SELss) – is a decibel measure for describing how much sound energy a receptor (e.g. a marine mammal) has received from an event (single pulse/single strike) and is normalized to an interval of one second (quoted in dB re. 1 $\mu Pa^2 s$). It can be thought of as a logarithmic measure of Sound Exposure and hence a 3 dB increase in SEL equates to a doubling of sound energy; dB re. 1 $\mu Pa^2 s$.

Cumulative Sound Exposure (SEL(cum)) – is the time integral of the squared pressures over the duration of a sound or series of sounds. It enables sounds of differing duration and level to be characterized in terms of total sound energy normalized to an interval of one second (quoted in dB re. $Pa^2 s$).

Peak pressure level (SPL_{peak} or PEAK) – the zero-to-peak sound pressure level (dB re. 1μPa) at a given point in time.

Root mean square (RMS) – the sound pressure averaged over a given time (dB re. 1µPa); The RMS SPL is commonly used to evaluate the effects of continuous noise sources. The RMS sound pressure level or SPL is the mean square pressure level.

Pulsed/impulsive sound – a discontinuous sound source comprising one or more instantaneous sounds as during munitions clearance.

Continuous sound/non-impulsive sound – sound source, like a vessel engine, or humming as in drilling operation; the amount of sound radiated by a sound source.

Sound Source Level (SSL) – is defined as the intensity of the radiated sound at a distance of 1 meter from the source, where intensity is the amount of sound power transmitted through a unit area in a specified direction. Source level is given as a relative intensity in units named decibels (dB). In underwater sound, decibels are referenced to a pressure of 1 micropascal (µPa). Therefore, source level is reported in units of dB re. 1 µPa @ 1 m.

3. METHOD

3.1 Underwater sound propagation model

The underwater sound propagation model calculates estimates of the sound field generated from underwater sound sources. The modelling results are used to determine the potential impacts distances from the identified significant underwater noise sources for the various identified marine life for the area. Based on source location and underwater source sound level, the acoustic field at any range from the source is estimated using dBSEA's acoustic propagation model (Parabolic equation method (≤1.000 Hz), methodologies described in Jensen 2011 and ray tracing (> 1.000 Hz)). The sound propagation modelling uses acoustic parameters appropriate for the specific geographic region of interest, including the expected water column sound speed profile, the bathymetry, and the bottom geo-acoustic properties, to produce site-specific estimates of the radiated noise field as a function of range and depth. The acoustic model is used to predict the directional transmission loss from source locations corresponding to receiver locations. The received level at any 3-dimensional location away from the source is calculated by combining the source level and transmission loss, both of which are direction dependent. Underwater acoustic transmission loss and received underwater sound levels are a function of depth, range, bearing, and environmental properties. The output values can be used to compute or estimate specific noise metrics relevant to safety criteria filtering for frequency-dependent marine mammal hearing capabilities.

Underwater sound source levels are used as input for the underwater sound propagation program, which computes the sound field as a function of range, depth, and bearing relative to the source location. The model assumes that outgoing energy dominates over scattered energy and computes the solution for the outgoing wave equation. An approximation is used to provide two-dimensional transmission loss values in range and depth, i.e. computation of the transmission loss as a function of range and depth within a given radial plane is carried out independently of neighbouring radials (reflecting the assumption that sound propagation is predominantly away from the source).

The received underwater sound levels at any location within the region of interest are computed from the 1/1-octave band source levels by subtracting the numerically modelled transmission loss at each 1/1-octave band centre frequency and summing across all frequencies to obtain a broadband value.

Bathymetry data is provided from EMODNET (The European Marine Observation and Data Network). Water column data (average salinity = 34 ppt, average temperature = 5°C, average speed of underwater sound = 1,473 m/s, depth) is provided from ICES (International Council for the Exploration of the Sea) HELCOM specific measurement stations positioned close to the selected modelling positions. Seabed Conditions (sand, clay, depth) are provided from geological survey data for areas close to the modelling position. For a detailed description of the environmental baseline, it is referred to the corresponding chapters in the EIA (Chapter 9).

Predictions have been performed **for <u>winter</u> water column conditions** which have different underwater sound propagation characteristics which are more conservative than the conditions during summer and show the maximum underwater noise level of the whole sea depth.

Sound speed is higher in the warmer, less dense water near the surface than in the colder, denser water near the seafloor. However, temperature and salinity differences in the water column create thermocline and haloclines, causing spreading and/or attenuation of the sound. This results in underwater sound transmission loss as an underwater sound wave propagates outwards from a source. Therefore, the difference in the speed of sound from top to bottom during summer conditions in the North Sea, generally reduces the sound propagation compared to winter conditions with a more even speed of sound profile from top to bottom.

The sound propagation model will run with the source levels, activity time and environmental parameterization. The following acoustic parameters for each of the identified sound sources were used:

- SELcum, Cumulative Sound Exposure Level, dB re. 1µPa^{2}s
- SELpeak, dB re. 1µPa
- SEL (single pulse), Sound Exposure Levels, dB re. 1µPa^{2}s

The results of the acoustic modelling are reported in terms of the underwater sound levels of each specific acoustic metric for distances up to 50 km.

3.2 Slow start procedure for ROV and diving operations

Slow start is used for ROV and diving activity to minimize underwater noise impacts on marine mammals and fish. A minimum of 5 minute and 13-minute slow start was modelled, where one single individual vessel transponder signal (ping) is emitted every 20 seconds for 5 or 15 minutes respectively. The ping is released at a low power setting as described in Table 6-2 and Table 6-3. The 5-minute slow start applies for ROV activities using a USBL transmitter and one transponder placed on the ROV (Table 6-2) whereas the 15-minute slow start is used for diving operations i.e. scenarios with multiple transponders on divers, ROV and supporting equipment (Table 6-3). The calculated slow start periods are taking into account that the presence of the vessel will deter the animals to be at least 100 meters away from the sound source.

3.3 Soft start procedure for seismic monitoring

For the protection of marine mammals, a soft start procedure must be used for seismic surveys in accordance with the procedure described in "Standardvilkår for forundersøgelser til havs, August 2018" (Energistyrelsen, 2018a), see Figure 3-1.

Spot seismic is conducted with smaller airguns than typically used for standard seismic surveys (3x200 cubic inch). For the Greensand Future project, the airguns will be active for approximately one hour at each location. Based on the sound characteristics for spot seismic the noise modelling has calculated that a 15 min soft start will be sufficient to prevent physical damage of marine mammals incl. Annex IV species in the area. The soft start is based on a fleeing speed of 1.5 m/s for marine mammals. If impacts are to be avoided on fish a soft start of 35 min has been modelled. The prolonged soft start period is due to the slower fleeing speed of juvenile fish (0.38 m/s).

In the October 2024 update, seismic monitoring is conducted in either a 2D or 3D setup using towed streamers behind a moving vessel and an airgun size of 2500 cubic inch. inch and 1750 cubic inch. inch, respectively (see chapter 6.1 for more detail). Based on the sound characteristics for the proposed seismic survey the noise modelling has calculated that a 35- and 40-minute soft start for a 3D and 2D seismic, respectively, will be sufficient to prevent physical damage of marine mammals incl. Annex IV species in the area. The soft start is based on a fleeing speed of 1.5 m/s for marine mammals (Tougaard 2016).

The standard soft start method used here is where power is built up slowly from a low energy start-up (e.g. starting with the smallest airgun shooting every 20 seconds over at least 15 minutes) to give adequate time for the species to leave the vicinity.

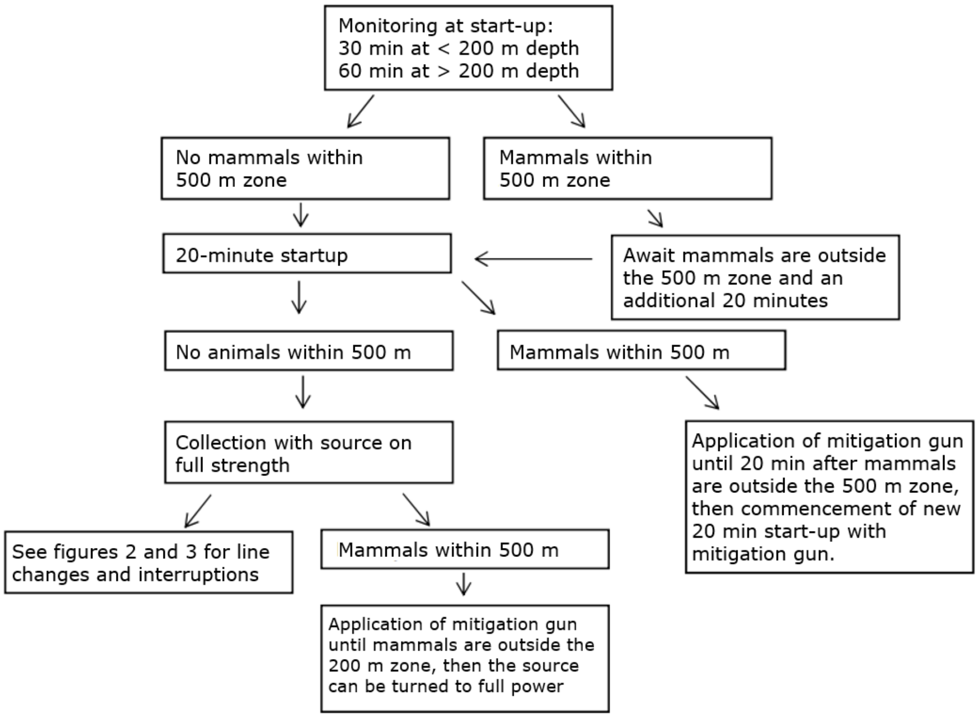

Figure 3-1 Soft start procedure for seismic monitoring, the box "see figures 2 and 3" refers to the line change and case of interruption procedure for towed seismic surveys and are not relevant for spot seismic ("Standardvilkår for forundersøgelser til havs, Energistyrelsen, 2018).

4. BASELINE FOR UNDERWATER NOISE IMPACT ASSESSMENT

The source sound pressure levels and associated impact zones can be viewed as indicative precautionary ranges. It is important to note that it is highly unlikely that any marine mammal would stay at a stationary location or within a fixed radius of a vessel (or any other noise source). The behaviour of receivers (animals) is included in a model of exposure. A simple model for animal escape, includes a threshold for reaction followed by movement in a straight line radically away from the sound source (1.5 m/s) (Energistyrelsen, 2022c). The integration of exposure into the model is described in section 4.4.

4.1 Marine Mammals

The marine mammal species covered by the presented model are:

- Harbour Porpoise
- White-beaked Dolphin
- Minke Whales
- Seals

Generally, the effect of noise on marine mammals can be divided into four broad categories (detection, masking, behavioural change and physical damage) that largely depend on the individual's proximity to the sound source. The limits of each zone of impact (according to the categories) are not sharp, and there is a large overlap between the zones. The four categories are described below, based on (B. L. Southall et al., 2008).

- **Detection** ranges depend on background noise levels as well as hearing thresholds for the animals in question.
- **Masking** occurs when noise interferes with an animal's ability to perceive (detect, interpret, and/or discriminate) a sound. There are still many uncertainties regarding how masking affects marine mammals.
- **Behaviour**: The occurrence and significance of a **behavioural change** varies by individual, species, and circumstances. Some sounds may not cause any response, while others may result in minor to significant changes in a variety of behaviours, such as diving, surfacing, vocalizing, feeding, and/or mating.
- **Physical damage** to marine mammals relates to damage to the hearing apparatus which may lead to permanent changes in the animals' detection threshold (permanent threshold shift, PTS). This can be caused by the destruction of sensory cells in the inner ear, or by metabolic exhaustion of sensory cells, support cells or even auditory nerve cells. Hearing loss is usually only temporary (temporary threshold shift, TTS) and the animal will regain its original detection abilities after a recovery period. For PTS and TTS, the sound intensity is an important factor for the degree of hearing loss, as is the frequency, the exposure duration, and the length of the recovery time.

The proposed criteria for PTS, TTS and behavioural response in this report are based on results presented in scientific literature and/or commonly and currently used in environmental impact assessments of underwater sound.

4.2 Marine Mammal Auditory Weighting Function

The ability to hear sounds varies across a species' hearing range. Most mammal audiograms have a typical "U-shape," with frequencies at the bottom of the "U" being those to which the animal is more sensitive, in terms of hearing. Auditory weighting functions best reflect an animal's ability to hear a sound (and do not necessarily reflect how an animal will perceive and behaviourally react to that sound). To reflect higher hearing sensitivity at particular frequencies, sounds are often weighted. Auditory weighting functions have been proposed for marine mammals, specifically associated with PTS/TTS acoustic thresholds expressed in the SELcum metric, which take into account what is known about marine mammal hearing (Southall, 2019). Very High Frequency (VHF) weighted impact threshold limits are applicable to Harbor Porpoises. Phocid Carnivores in Water (PCW) weighted impact threshold limits are applicable to seals.

4.3 Distances to applicable assessment threshold level limits

The following tables summarize the results of the acoustic modelling in terms of the maximum average radial distances from the source to where threshold levels are attained. Thresholds are specified in Section 4.5. Due to the varied seafloor bathymetry, the underwater sound does not propagate equally in all directions. In order to give a better representation of the range of the radial distance from the activities to the impact threshold limits, the maximum distances are given.

4.4 Cumulative SEL(SELcum) calculation

By combining the underwater sound propagation, source levels, pulse frequency and an animal flee factor, a minimum distance from the activity is calculated for the TTS and PTS impact threshold limits. This is the distance that a marine mammal needs to be away from a source to not exceed the PTS and TTS threshold limits.

The applied slow- and soft start procedures with fewer pings/shots in a low power mode gives the animals time to flee out to a certain distance before the onset of regular activity. Fleeing for all marine mammals is assumed to take place radially away from the activity with a constant speed, v f = 1.5 m/s as suggested in (Energistyrelsen, 2022c). In a study, increased vessel activity led to a significant decrease in Harbour porpoise acoustic detections and activity at distances of up to 4 km (Benhemma-Le Gall et. al 2021). However, studies using sound and movement recording tags that can detect finer-scale responses highlight that porpoise foraging may be disrupted at greater distances of up to 7 km (Benhemma-Le Gall et. al 2023). On a fine-temporal scale the occurrence of Minke whales has been shown to be reduced by vessel traffic (Wisniewska et. al 2018). Due to the presence of the vessel, it is expected that marine mammals will be a minimum of 100 meters away from the activity before onset.

As the animal is fleeing away from the activity, the sound levels would decrease from distance attenuation. This combination of fleeing speed, distance, time and pinging rate is part of the cumulative sound exposure calculation. The cumulative SEL is calculated as the summation of the total sound energy to which the receptor is exposed during the duration of the activity.

The model increases the initial animal start distance until the cumulative SEL is below the threshold limits specified. This corresponds to an area/distance from the sound source within which the animal would potentially experience exceedance of the SEL threshold limits for the duration of the activity.

4.5 Marine mammal noise impact criteria

Table 4-1 summarizes criteria for assessing impacts for marine mammals. The criteria are associated with different impacts and limits. These threshold values for impact have been determined by an assessment of available values from the most recent scientific literature and accepted limits. (Energistyrelsen, 2022c) (Tougaard, 2016) (E. B. L. Southall et al., 2019).

Table 4-1 Noise threshold limits for different marine mammal hearing groups (Impulsive/Non-impulsive)

Marine mammal hearing group	**TTS SELcum** (weighted) [1] dB re1 µPa2s SELcum	**TTS Peak** (unweighted) [1] dB re1 µPa	**PTS SELcum** (weighted) [1] dB re1 µPa2s SELcum	**PTS Peak** (unweighted) [1] dB re1 µPa	**Behavior single pulse**
Low Frequency Minke whale	168 dB/ 179 dB	213 dB	183 dB/ 199 dB	219 dB	145 dB re1 µPa2s SELss (unweighted) [2]
High Frequency White-beaked dolphin	170 dB/ 178 dB	224 dB	185 dB/ 198 dB	230 dB	145 dB re1 µPa2s SELss (unweighted) [2]
Very High Frequency Harbour Porpoise	140 dB/ 153 dB	196 dB	155 dB/ 173 dB	202 dB	103 dB (VHF weighted) [3] rms 125 ms dB re1 µPa
Phocidae carnivores in water (PCW) seals	170 dB/ 181 dB	212 dB	185 dB/ 201 dB	218 dB	151 dB (unweighted) [4] dB re1 µPa2s SELss (impulsive)

[1] (E. B. L. Southall et al., 2019) *Marine Mammal Noise Exposure Criteria*
[2] (Tougaard, 2016) – *(based on harbor porpoise limits as instructed by DEA)*
[3] (Energistyrelsen, 2022c).
[4] (Russell, 2016)

SEL (Sound Exposure Level)*: this is a decibel measure for describing how much sound energy a receptor (e.g. a marine mammal) has received from an event and is normalized to an interval of one second (quoted in dB re 1 µPa^{2}s). It can be thought of as a logarithmic measure of Sound Exposure and hence a 3 dB increase in SEL equates to a doubling of sound energy.*

SEL (cum)*: this is the time integral of the squared pressures over the duration of a sound or series of sounds. It enables sounds of differing duration and level to be characterized in terms of total sound energy (quoted in Pa^{2}s).*

4.6 Fish noise impact criteria

Sound, at higher intensities, may have a diverse range of effects on fish. These may include death, hearing impairment, damage to anatomical structures, and changes in physiology, neural function, behavior, and development.

Research on impacts to fish from underwater noise is relatively scarce and has only been carried out for a few fish species. The modelling is based on the best available data and includes two species (herring (*Clupea harengus*) and cod (*Gadus morhua*)) and two life stages of fish (juvenile and adult cod) found in the project area that represent different sensitivities to noise, some of which is considered to exhibit the highest sensitivities. However, the temporary threshold shift (TTS) value for fish has been based on freshwater species and some uncertainty exists for the applicability of these threshold values to saltwater species. As the modelling is based on the most sensitive species and life stages, the data basis of this assessment is considered to be sufficient to assess the impacts on fish from underwater noise as it is based on a worst-case approach dealing with the response from the most sensitive species and life stages of fish found in the project area.

The hearing ability of fish is generally confined to lower frequencies, often to no more than 800–1000 Hz, but this is species dependent (Popper et al., 2019). However, some clupeid fish species may be able to detect sound in frequency ranges above 20 kHz (Mann et al., 1997) while others do not (Mann et al., 2005). It has been speculated that some herring species are able to show avoidance behavior towards echolocation equipment and thereby questioning the use of this type of equipment for stock assessment for these types of species (Mann et al., 2001). Impact thresholds for high frequency noise have not been specified for the herring in the North Sea, however, earlier studies indicate that hearing threshold increases significantly around 5 kHz making them less likely to detect noise above 20 kHz (Enger, 1967).

Table 4-2 summarizes criteria associated with different impacts and limits for assessing impacts for fish from seismic airguns. Exposure distances for herring and cod including fleeing 1.04 m/s (herring juvenile/adult),0.38 m/s (cod juvenile) and 0.9 m/s (cod adult). These threshold values for impact have been determined by an assessment of available values from the most recent scientific literature and accepted limits (A. N. Popper et al., 2014). Noise can impact fish in several ways, including:

- *Mortality and mortal injury:* Immediate or delayed death.
- *Recoverable injury*: Injuries, including hair cell damage, minor internal or external hematoma, etc. None of these injuries are likely to result in mortality.
- *Temporary Threshold Shift (TTS):* Short- or long-term changes in hearing sensitivity that may or may not reduce fitness.
- *Behavioural effects:* Change in behaviour i.e., feeding, mating, etc., or by means of avoidance.
- *Masking:* Refers to the interference of anthropogenic noise with the fish ability to hear a sound that is of biological importance to them

Table 4-2 Threshold criteria level and impact distances for fish according to (A. N. Popper et al., 2014).

Species	Impact type	Fleeing speed [m/s]	Impulsive noise criteria [dB] Peak	Impulsiv noise criteria [dB] SELcum	Continuous noise criteria [dB] SELcum
Fish	Mortal injury	1.04 Herring 0.38 Cod (juvenile) 0.9 Cod (adult)	207	207 (SELcum)	-
Fish	Recoverable injury	1.04 Herring 0.38 Cod (juvenile) 0.9 Cod (adult)	207	203 (SELcum)	222 (SELcum) 48 hours, 170 RMS
Fish	TTS	1.04 Herring 0.38 Cod (juvenile) 0.9 Cod (adult)	-	186 (SELcum)	204 (SELcum) 12 hours, 158 RMS
Larvae	Mortal injury	N/A	207	210 (SELcum)	-
For continuous noise criteria a value with designation rms is used. RMS stands for Root Mean Square and is a type of average sound for a given sound source. Exposure distances for herring and cod are shown including escape rates. For herring this study will use 1.04 m/s and for cod this study has used 0.38 m/s (juvenile) and 0.9 m/s (adult).					

Cumulative SEL(SELcum) calculation
The SELcum calculation is described for marine mammals in section 4.4 and applies as well for fish.

4.7 Background noise levels from shipping traffic

The North Sea west of Denmark has a significant amount of shipping traffic as there is numerous harbors along the coasts and a large amount of shipping routes to other parts of the ocean.

Based on the amount of shipping traffic in the area and data from baseline underwater noise measurements, the average background underwater noise levels from shipping are about 100 dB (> 500 m away) to 120 dB when near the shipping lanes (ICES, see Figure 3).

The following figure gives an indication of the average underwater noise levels as broadband, 10 Hz to 20 kHz. Figure 3 shows that this part of the ocean has a lot of noise from shipping.

Figure 4-1 shows that there is already very high levels of ambient noise levels in the sea. This should be taken into account in an assessment of the results for survey vessel noise.

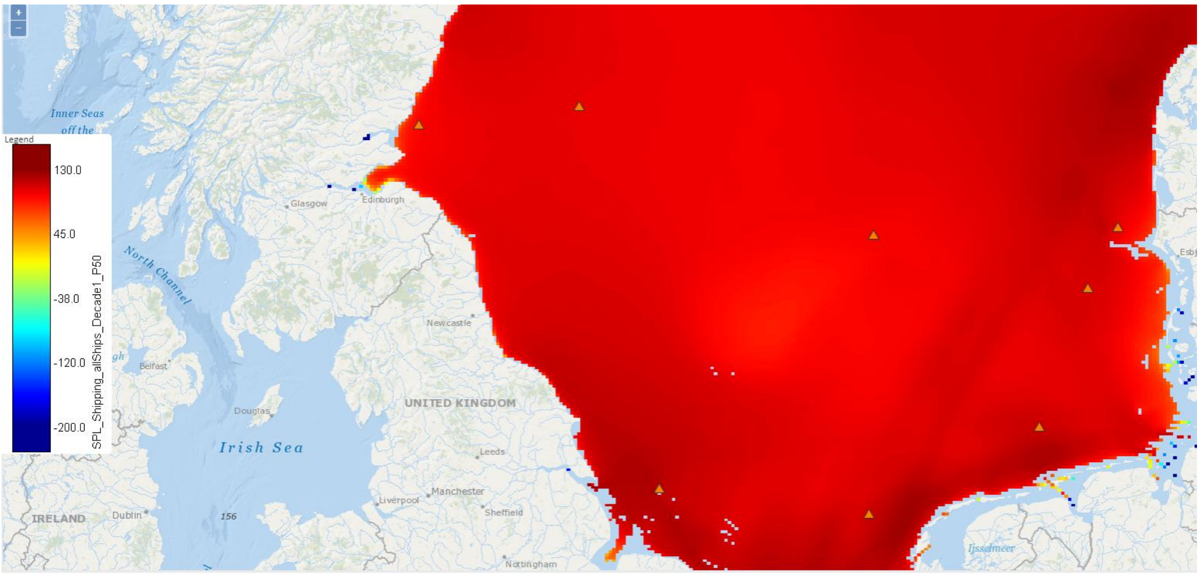

Figure 4-1 Indication of the average underwater noise levels from shipping traffic for July 2019 in the North Sea.The map is generated from ICES: https://underwaternoise.ices.dk/continuous/viewonmap, with parameters; 2019, July, 10 to 20000 Hz, P50, Shipping, last accessed 23-10-2024.

5. SURVEY AREA AND SOURCE LEV FOR 2D AND 3D SEISMIC SURVEYS

The following section presents the significant underwater noise sources for each phase of the project and give their respective sound source levels, characteristics, and frequency spectrum. These parameters were determined based on available measurement data or supplier technical specifications and adjusted to meet the proposed project concepts and were used as input to the underwater noise propagation model. Sources and activities that can cause underwater noise include the survey vessel, 3D and 2D seismic in the survey area. The survey area layout is presented in Figure 5-1.

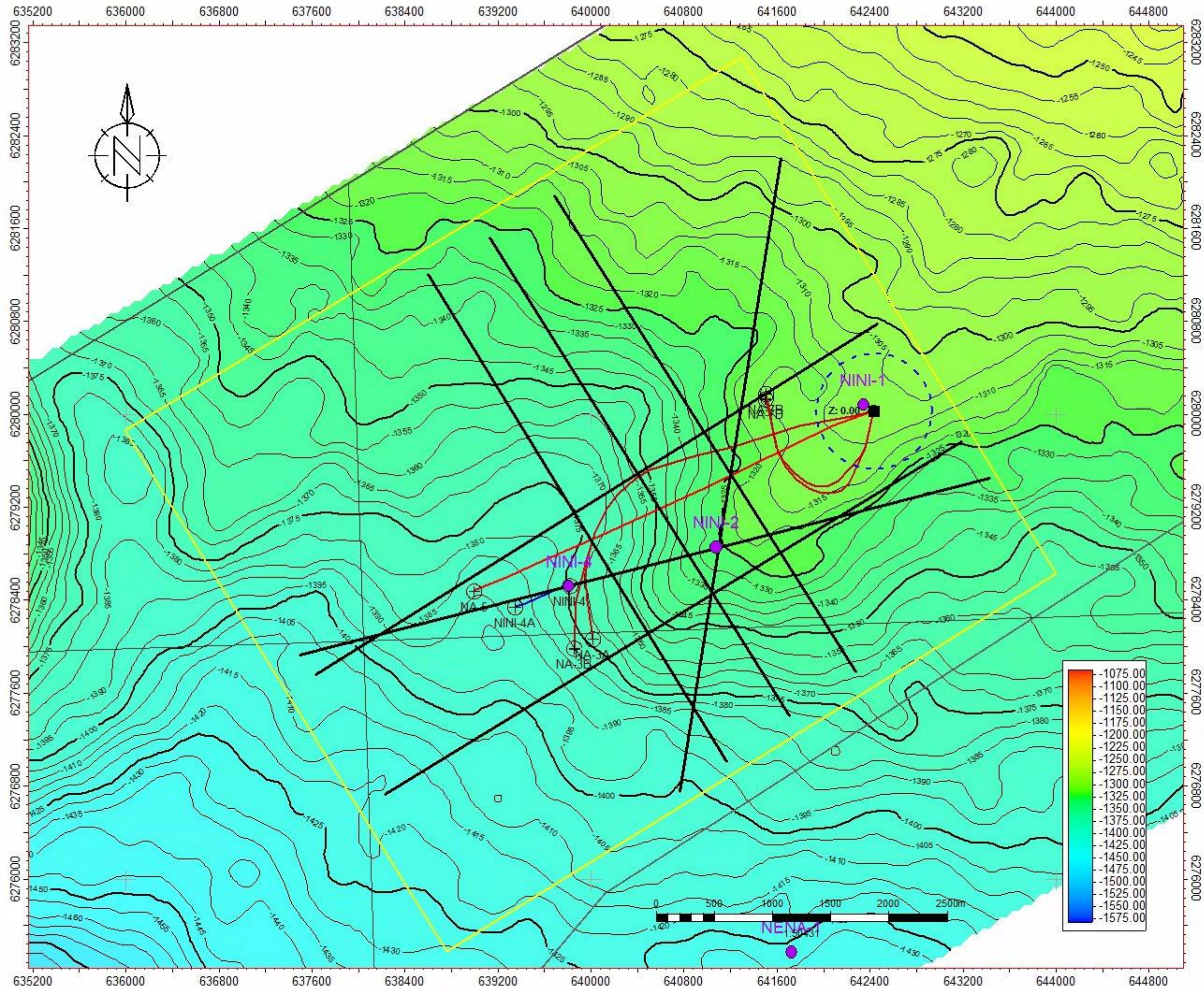

Figure 5-1 Survey area layout (yellow marking). Seven 2D lines (bold black lines) inside acquisition area for 3D.

The Streamer length is ~ 5 km and will be fitted with hydrophones that record the reflected noise from the subsea formation. The nearest shots to the Norwegian EEZ will be ~ 800 m. The streamer outline would be ± 500 m from the vessel sail line in crossline direction and will not be reaching into Norwegian waters. The characteristics of the two surveys with 2D and 3D seismic, has been described in Table 5-1 and illustrated in Figure 5-2.

Table 5-1 Seismic survey with towed streamers for reservoir monitoring.

Characteristics	Survey Type	
Data acquisition	2D	3D
Area size	38 Lkm	32 km^2
Shots/km^2		120
Source size (in^3)	2500	1760
Source depth (m)	5	5
Line distance (m)	See Figure 5-2	500
Soft-start (min)	40	35
Vessel speed (knots)	9.11	9.11
Number of seconds between shots (second/shot)	4	4
Time of year	spring	spring
Survey lines/ patterns/ shape files	lines	lines

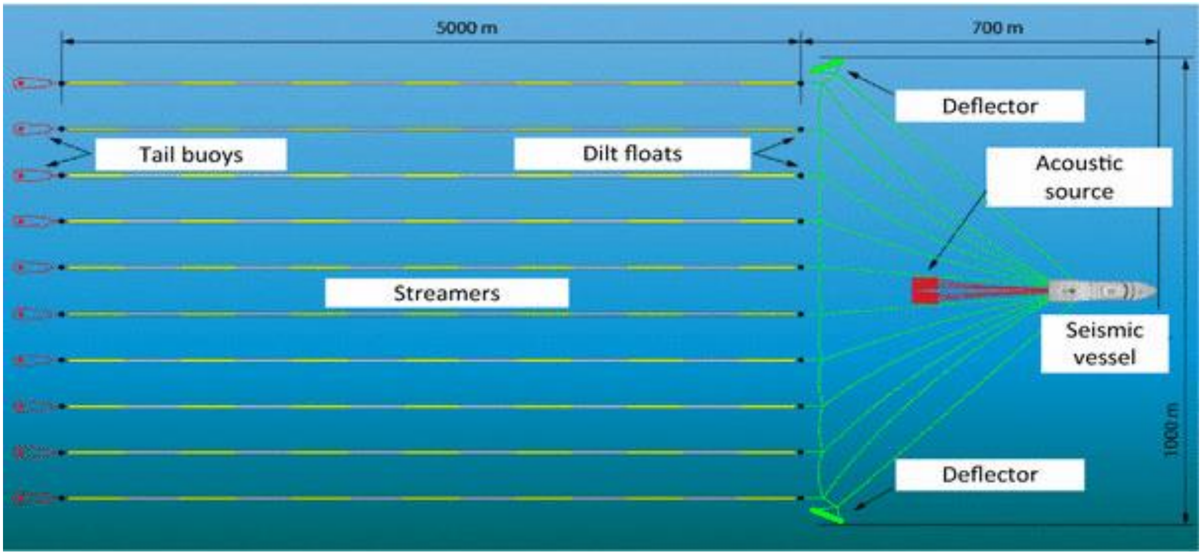

Figure 5-2 Example of marine seismic survey using towed streamers.

6. UNDERWATER NOISE SOURCE LEVELS AND CHARACTERISTICS

6.1 2D and 3D

The sound source levels are based on expected product specifications and available literature where measurements have been conducted to determine the source levels. The specifications for the airguns in Table 6-1 are calculated values and it shows the identified source levels that will have an impact on their surroundings.

Table 6-1 Survey investigation underwater sound source levels and characteristics.

Source	Duration	Survey vessel speed	Sound characteristics	SPLrms (re 1 µPa m)	SEL (re 1 µPas2@1 m)	SPLpeak re 1 µPa m)	Beam Width Angle (degrees)
Survey Vessel (Wyatt 2008)	24 hours	Stationary	Continuous	172 dB (average)	172 dB	177 dB	Omni directional
Seismic Airgun 1760 in³	24 hours	Mobile 9 knots	Impulsive	246 dB	236 dB	252 dB	Omni directional (assumed worst case)
Seismic Airgun 2500 in³	24 hours	Mobile 9 knots	Impulsive	248 dB	238 dB	254 dB	Omni directional (assumed worst case)

6.2 ROV inspection survey

Table 6-2 Noise characteristics of the equipment used during ROV surveys that is within audible range of some marine mammals.

[1] Low power mode with directivity factor

Model	Frequency range	SPLrms (re 1 µPa m)	SEL ss (re 1 µPa2s@1m)	SPLpeak (re 1 µPa m)	"Pulse"duration (ms)	Repeated rate (Hz)	emission (degree)
Kongsberg USBL HiPAP® 501 (Low power setting, -18 dB) Location: Vessel	21-31 kHz	176 dB, min [1]	167 dB, min [1]	182 dB min [1]	30	1	75
Kongsberg Cnode Location: ROV	21-31 kHz	182 dB	173 dB	188 dB	2 – 6	1	Omni

6.3 Diving operation

Table 6-3 Underwater typical equipment used during diving operations and their respective operating frequency and source level. 1 Low power mode with directivity factor

Model	Frequency range	SPLrms (re 1 µPa m)	SEL ss (re 1 µPa2s@1m)	SPLpeak (re 1 µPa m)	"Pulse" duration (ms)	Repeated rate (Hz)	emission (degree)
HPT 5000/7000 USBL Transceiver Sonardyne Type 8142 Location: - transceiver (vessel)	20 – 34 kHz	178 dB [1]	169 dB [1]	184 dB [1]	8	0,33	90
Nano Transponder Sonardyne Type 8262 Location: - transponder (ROV)	20-34 kHz	180 dB	169 dB	184 dB	8	0,33	Omni
Wideband Sub-Mini 6+ (WSM 6+) transponder Sonardyne Type 8370 Location: - DP positioning beacon (seabed) - dive bell transponder - 3 diver transponders	20 – 34 kHz	180 dB	169 dB	184 dB	8	1	Omni

6.4 Optional spot seismic

Table 6-4 Underwater noise source levels and characteristics for spot seismic activities

Source	Duration (h pr. day)	Model (reference)	Source depth (m)	Dominant Freq. range	SPLrms (re 1 µPa m)	SEL ss (re 1 µPa2s@1m)	SPLpeak (re 1 µPa m)	Repeated rate (Sec)	emission (degree)
Spot seismic Airgun	one hour per position	600 in^3 Airgun	6 meters	1 – 500 Hz	233 dB	223 dB	239 dB	45	Omni

7. MODELLING RESULTS

In this section the results of the underwater propagation modelling for the general noise from sound sources is presented. The results show distances to both behavioral and hearing loss thresholds for marine mammals and fish. All results refer to the scientific references named in those sections. The standard soft start method used here is where power is built up slowly from a low energy start-up (e.g. starting with the smallest airgun in the array and gradually adding in others) to give adequate time for marine mammals to leave the vicinity.

7.1 Marine mammals

7.1.1 3D survey

The modelling results in Table 7-1 show the impact distances for marine mammals using 1760 cu. in. airgun positioned 5 m beneath the sea surface with a maximum survey line length of 5 km (3D survey).

Table 7-1 Results of impact distances for marine mammals from 1760 cu. in. seismic airgun (with 35 minute soft-start, values in parenthesis indicate distances without soft-star).

Marine Mammal group	**TTS SELcum** (weighted) dB re. Pa^2s	**TTS Peak** (un-weighted) dB re 1 μPa	**PTS SELcum** (weighted) dB re. Pa^2s	**PTS Peak** (un-weighted) dB re 1 μPa	**Behavior single pulse average/maximum** (RMS 125 ms, VHF weighted) (SELss for LF, HF, PCW, un-weighted)
LF distances Minke Whales	0 m* (10,000 m*)	0 m (260 m)	0 m* (7,000 m*)	0 m (120 m)	27.4 / 33.2 km
HF distances White-beaked Dolphin	0 m* (10 m*)	0 m (60 m)	0 m* (0 m*)	0 m (30 m)	27.4 / 33.2 km
VHF distance Harbour Porpiose	0 m* (60 m*)	0 m (2,300 m)	0 m* (5 m*)	0 m (1,150 m)	4.9 / 5.3 km
PCW distances Seals	0 m* (6,000 m*)	0 m (300 m)	0 m* (600 m*)	0 m (140 m)	18.0 / 20.3 km

* Includes animal fleeing at 1.5 m/s and ship movement 9 knots (maximum survey line length of 5 km)

With regard to impulsive noise (cumulative noise (SELcum, weighted) and peak noise exposure (unweighted)). TTS = temporary threshold shift, PTS = permanent threshold shift, LF = Low Frequency, HF = High Frequency, VHF = Very High Frequency, PCW = Phocid Carnivores in Water

7.1.2 2D survey

The modelling results in Table 7-2 show the impact distances for marine mammals using 2500. cu. in. airgun positioned 5 m beneath sea surface with a maximum survey line length 5 km (2D survey).

Table 7-2 Results of impact distances for marine mammals from 2500 cu. in. seismic airgun (with 40 minute soft-start).

Marine Mammal group	**TTS SELcum (weighted)**	**TTS Peak (un-weighted)** (dB re 1 μPa)	**PTS SELcum** dB re. Pa^2s **(weighted)**	**PTS Peak (un-weighted)**	**Behavior single pulse average/maximum** (RMS 125 ms, VHF weighted) (SELss for Seals, un-weighted)
LF distances Minke Whales	*0 m** *(13.000 m*)*	*0 m* *(320 m)*	*0 m** *(10.000 m*)*	*0 m* *(150 m)*	30.1 / 36.8 km
HF distances White-beaked Dolphin	*0 m** *(13 m*)*	*0 m* *(90 m)*	*0 m** *(10 m*)*	*0 m* *(45 m)*	30.1 / 36.8 km
VHF distance Harbour Porpiose	*0 m** *(80 m*)*	*0 m* *(3.000 m)*	*0 m** *(8 m*)*	*0 m* *(1.400 m)*	*5.7 / 6.1 km*
PCW distances Seals	*0 m** *(9.000 m*)*	*0 m* *(400 m)*	*0 m** *(800 m*)*	*0 m* *(185 m)*	*23.2 / 28.9 km*

* Includes animal fleeing at 1.5 m/s and ship movement 9 knots (maximum survey line length of 5 km)

With regard to impulsive noise (cumulative noise (SELcum, weighted) and peak noise exposure (unweighted)). TTS = temporary threshold shift, PTS = permanent threshold shift, LF = Low Frequency, HF = High Frequency, VHF = Very High Frequency, PCW = Phocid Carnivores in Water

7.1.3 Survey vessel

The results in Table 7-3 show the impact distances for marine mammals from general noise from survey vessels. For mike whales, white-beaked dolphins and seals there are no behavioural distances from the DEA guidelines, thus Table 7-3 indicates “NA” for those species. However, due to the presence of the vessel, it is expected that marine mammals will be a minimum of 100 meters away from the activity before onset (see section 4.4).

Table 7-3 Results of impact distances for marine mammals from Survey vessel (Wyatt 2008).

Marine Mammal group	**TTS SELcum (weighted)** (dB re1 µPa2s SELcum)	**PTS SELcum** dB re. Pa^2s **(weighted)**	**Behavior** (RMS 125 ms, VHF weighted)
LF distances Minke Whales	*0 m**	*0 m**	NA
HF distances White-beaked Dolphin	*0 m**	*0 m**	NA
VHF distance Harbour Porpiose	*0 m**	*0 m*	*800 m (RMS VHF)*
PCW distances Seals	*0 m**	*0 m**	*NA*

* Includes animal fleeing at 1.5 m/s.

With regard to impulsive noise (cumulative noise (SELcum, weighted) and peak noise exposure (unweighted)). TTS = temporary threshold shift, PTS = permanent threshold shift, LF = Low Frequency, HF = High Frequency, VHF = Very High Frequency, PCW = Phocid Carnivores in Water

7.1.4 ROV inspection survey

Table 7-4 Impact distances for marine mammals with and without slow start. Modelling results are shown in the table. The results show the impact distances for marine mammals using 1 vessel transponder and 1 ROV transponder. Impact distances by implementing a slow start procedure are also indicated. Impact threshold limits for marine mammals and associated impact distances for impulsive noise (cumulative noise (SELcum, weighted) and peak noise exposure (unweighted)). LF = Low Frequency, HF = High Frequency, VHF = Very High Frequency, PCW = Phocid Carnivores in Water.

Marine Mammal group	**TTS SELcum (weighted)** [2,3]	**TTS Peak (unweighted)** [2,3]	**PTS SELcum** dB re. Pa^2s **(weighted)** [2,3]	**PTS Peak (unweighted)** [2,3]	**Behavior single pulse**
LF distances Minke Whales	0 meter	0 meters	0 meters	0 meters	60 meters [4]
HF distances White-beaked Dolphin	0 meters	0 meters	0 meters	0 meters	60 meters [4]
VHF distance Harbour Porpoise	550 meters 0 meters [6]	0 meters	35 meters 0 meters [6]	0 meters	4,200 meters [1]
PCW distances Seals	0 meters	0 meters	0 meters	0 meters	0 meters [5]

[1] (DEA, 2022).
[2] (E. B. L. Southall et al., 2019) *Marine Mammal Noise Exposure Criteria*
[3] *Includes animal fleeing at 1.5 m/s*
[4] (Tougaard, 2016)
[5] (Russell, 2016)
[6] *with 5-minute slow start and vessel disturbance of 100 m*

7.1.5 Diving operations

Table 7-5 Impact distances for marine mammals with and without slow start. Modelling results are shown in the table. The results show the impact distances for marine mammals using 1 Vessel Transponder, 3 Diver Transponders, 1 ROV Transponder, 1 Dive Bell transponder, 1 DP Beacon transponder). Impact threshold limits for marine mammals and associated impact distances with regard to impulsive noise (cumulative noise (SELcum, weighted) and peak noise exposure (unweighted)). LF = Low Frequency, HF = High Frequency, VHF = Very High Frequency, PCW = Phocid Carnivores in Water.

Marine Mammal group	**TTS SELcum (weighted)** [2,3]	**TTS Peak (unweighted)** [2,3]	**PTS SELcum** dB re. Pa^{2}s **(weighted)** [2,3]	**PTS Peak (unweighted)** [2,3]	**Behavior single pulse** (RMS 125 ms, VHF weighted) (SELss for Seals, un-weighted)
LF distances Minke Whales	0 meters	0 meters	0 meters	0 meters	60 meters [4]
HF distances White-beaked Dolphin	0 meters	0 meters	0 meters	0 meters	60 meters [4]
VHF distance Harbour Porpoise	1,200 meters 0 meters [6]	0 meters	80 meters 0 meters [6]	0 meters	4,850 m [1]
PCW distances Seals	0 meters	0 meters	0 meters	0 meters	60 meters [5]

[1] (Energistyrelsen, 2022c).
[2] (E. B. L. Southall et al., 2019) *Marine Mammal Noise Exposure Criteria*
[3] *Includes animal fleeing at 1.5 m/s*
[4] (Tougaard, 2016) – *(based on harbor porpoise limits as instructed by DEA)*
[5] (Russell, 2016)
[6] *With 15-minute slow start and vessel disturbance of 100 m*

7.1.6 Optional spot seismic

Table 7-6 Impact distances for marine mammals with and without soft start. Modelling results are shown in the table. The results show the impact distances for marine mammals using 600. in. (3x200) Airgun positioned 6 m beneath sea surface. For threshold limits, see Table 4 1. (Cumulative noise (SELcum, weighted) and peak noise exposure (unweighted)). LF = Low Frequency, HF = High Frequency, VHF = Very High Frequency, PCW = Phocid Carnivores in Water)

Marine Mammal group	TTS SELcum (weighted) [2,3]	TTS Peak (unweighted) [2,3]	PTS SELcum (weighted) [2,3]	PTS Peak (unweighted) [2,3]	*Marine strategy limit values for PTS in marine mammals[7], SELcum [7]*	Behavior
LF distances Minke whale	*1,200 meters* *0 meters [6]*	*120 meters* *0 meters [6]*	*50 meters* *0 meters [6]*	*20 meters* *0 meters [6]*	NA	15,000 meters [4]
HF distances White-beaked Dolphin	*5 meters* *0 meters [6]*	*15 meters* *0 meters [6]*	*0 meters* *0 meters [6]*	*0 meters* *0 meters [6]*	NA	15,000 meters [4]
VHF distance Harbour Porpoise	*0 meters* *0 meters [6]*	*150 meters* *0 meters [6]*	*0 meters* *0 meters [6]*	*70 meters* *0 meters [6]*	*200 meters* *0 meters [6]*	*1,500 meters[1]*
PCW distances Seals	*70 meters* *0 meters [6]*	*40 meters* *0 meters [6]*	*5 meters* *0 meters [6]*	*5 meters* *0 meters [6]*	*30 meters* *0 meters [6]*	*35,000 meters[5]*

[1] (Energistyrelsen, 2022c).
[2] (E. B. L. Southall et al., 2019) *Marine Mammal Noise Exposure Criteria*
[3] *Includes animal fleeing at 1.5 m/s*
[4] (Tougaard, 2016) – *(based on harbor porpoise limits as instructed by DEA)*
[5] (Russell, 2016)
[6] *With 15-minute soft start and vessel disturbance of 100 m*
[7] *Havstrategien grænseværdier for PTS i havpattedyr*

7.2 Fish

Based on the available information it is assessed that there will be very limited impacts on fish in relation to the ROV noise emissions, however, it cannot be excluded that herring may show avoidance behaviour within a few hundred meters from ROV operation or other activities using high frequency equipment.

7.2.1 3D survey

The modelling results in Table 7-7 show the impact distances for fish using 1760 cu. in. airgun positioned 5 m beneath the sea surface with a maximum survey line length of 5 km and animal fleeing and ship movement 9 knots.

Table 7-7 Results of impact distances for fish from 1750 cu. in. seismic airgun (with 35 minute soft-start). *Includes animal fleeing and ship movement 9 knots (maximum survey line length of 5 km)

Receptor	Impact type (Popper et al. 2014)	Fleeing speed [m/s]	Radial distance to threshold limits
Fish	Mortal injury	Herring 1.04 Cod(j) 0.38 Cod 0.9	*0 m** *0 m** *0 m**
Fish	Recoverable injury	Herring 1.04 Cod(j) 0.38 Cod 0.9	*0 m** *0 m** *0 m**
Fish	TTS	Herring 1.04 Cod(j) 0.38 Cod 0.9	1 km* 1.5 km* 1 km*
Larvae	Mortal injury	0	1.5 km (SPLpeak)/ 0.8 km (SELcum)

7.2.2 2D survey

The modelling results in Table 7-8 show the impact distances for fish using 2500 cu. in. airgun positioned 5 m beneath the sea surface with a maximum survey line length of 5 km and animal fleeing and ship movement 9 knots.

Table 7-8 Results of impact distance for fish from 2500 cu. in. seismic airgun (with 40 minute soft-start).

Receptor	Impact type (Popper et al. 2014)	Fleeing speed [m/s]	Radial distance to threshold limits
Fish	Mortal injury	Herring 1.04 Cod(j) 0.38 Cod 0.9	*0 m** *0 m** *0 m**
Fish	Recoverable injury	Herring 1.04 Cod(j) 0.38 Cod 0.9	*0 m** *0 m** *0 m**
Fish	TTS	Herring 1.04 Cod(j) 0.38 Cod 0.9	1.5 km* 2.0 km* 1.5 km*
Larvae	Mortal injury	0	2 km (SPLpeak) / 0.9 km (SELcum)

7.2.3 *Survey vessel*

The results in Table 7-9 show the impact distances for fish from general noise from survey vessels with continuous activity modelling results/radial distance to threshold limits, average maximum for fish.

Table 7-9 Results of impact distances for fish from survey vessel (Wyatt 2008).

Receptor	Impact type (Popper et al. 2014)	Survey vessel (24 hour)
Fish	Mortal injury	0 m
Fish	Recoverable injury	0 m
Fish	TTS	0 m
Larvae	Mortal injury	0 m

7.2.4 *Optional spot seismic*

The model is taking into account that the presence of the vessel will deter the animals to be at least 100 meters away from the sound source. Table 7-10 shows the modelling results with a 35-minute soft start and Table 7-11 without a soft start.

Table 7-10 Spot seismic airgun activity modelling results radial distance from the activity to threshold limits, maximum incl. 35-minute soft start for impulsive noise criteria see Table 7-1.

Receptor	Impact type (A. N. Popper et al., 2014).	Fleeing speed [m/s]	Spot seismic airgun, distance to impact threshold limits from airgun
Fish	Mortal injury	Herring 1.04 Cod(juv.) 0.38 Cod(adult) 0.9	0 meters (peak) / 0 meters (SELcum)
Fish	Recoverable injury	Herring 1.04 Cod(juv.) 0.38 Cod(adult) 0.9	0 meters (peak) / 0 meters (SELcum)
Fish	TTS	Herring 1.04	0 meters (SELcum)
		Cod(juv.) 0.38	0 meters (SELcum)
		Cod(adult) 0.9	0 meters (SELcum)
Larvae	Mortal injury	N/A	90 meters (peak) / 100 meters (SELcum)

Table 7-11 Spot seismic airgun activity modelling results radial distance from the activity to threshold limits, maximum, without soft start for impulsive noise criteria see Table 7-1.

Receptor	Impact type (A. N. Popper et al., 2014)	Fleeing speed [m/s]	Spot seismic airgun, distance to impact threshold limits from airgun
Fish	Mortal injury	Herring 1.04 Cod(juv.) 0.38 Cod(adult) 0.9	90 meters (peak), 15 meters (SELcum) 90 meters (peak), 20 meters (SELcum) 90 meters (peak), 15 meters (SELcum)
Fish	Recoverable injury	Herring 1.04 Cod(juv.) 0.38 Cod(adult) 0.9	90 meters (peak), 20 meters (SELcum) 90 meters (peak), 25 meters (SELcum) 90 meters (peak), 20 meters (SELcum)
	TTS	Herring 1.04 Cod(juv.) 0.38 Cod(adult) 0.9	500 meters (SELcum) 800 meters (SELcum) 600 meters (SELcum)
Fish	Mortal injury	0	90 meters (peak), 85 meters (SELcum)
	Mortal injury	Herring 1.04 Cod(juv.) 0.38 Cod(adult) 0.9	90 meters (peak), 15 meters (SELcum) 90 meters (peak), 20 meters (SELcum) 90 meters (peak), 15 meters (SELcum)
Larvae	Mortal injury	N/A	90 meters (peak), 100 meters (SELcum)

8. CONCLUSION ON 2D AND 3D SEISMIC MONITORING

Seismic monitoring is conducted in either a 2D or 3D data acquisition using towed streamers behind a moving vessel and an airgun size of 2500 cu. inch and 1760 cu. inch, respectively. Based on the sound characteristics for the proposed seismic survey the noise modelling has calculated that a 35- and 40-minute soft start for 3D and 2D survey, respectively, will be sufficient to prevent physical damage of marine mammals incl. Annex IV species in the area.

The results reveal that there is no risk of hearing damage, PTS or TTS, to marine mammals i.e. Minke whale, White-beaked dolphin, Harbour porpoise and Seals, regardless of the activity. The vessel, 2D and 3D survey could, however, lead to behavioral responses.

The 3D survey leads to same behavioral response for Minke-whale and White-beaked dolphin, as it shows a distance to threshold for behavior at around 27.4 or 33.2 km (SELss, average and maximum). The distance to threshold for a behavioral response of Harbour porpoise is expected around 4.9 km or 5.3 km (RMS VHF, average and maximum) during the 3D survey. The results also indicate that seals may show a behavior response within a distance of 18 or 20.3 km (SELss, average and maximum) from the sound source. Fish will, dependent on their life stage, experience TTS to the 3D survey in a distance of up to 1 km for adult fish and 1.5 km for juvenile fish. There is a risk of fish larvae mortality within a distance of 1.5 km (SPLpeak) and 1 km (SELcum) from the sound source.

The 2D survey leads to same risk for behavioral response for Minke-whale and White-beaked dolphin within a distance 30.1 and 36.8 km (SELss, average and maximum) from the sound source, respectively. The distance to threshold for behavior response of Harbour porpoise is expected around 5.7 km or 6.1 km (RMS VHF, average and maximum) during the 2D survey. The results also show that seals may show a behavior response within a distance of 23.2 or 28.9 km (SELss, average and maximum) from the sound source. Fish will, depending on their life stage, be exposed to risk of TTS within 1.5 km from the sound source for adult fish and 2 km for juvenile. There is a risk of fish larvae mortality within a distance of 2 km (SPLpeak) and 0.9 km (SELcum) from the sound source.

Lastly the survey vessel could lead to a behavioral response for Harbour porpoise at a distance of up to 0.8 km (RMS VHF).

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