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MAERSK OIL ESIA-16
ENVIRONMENTAL AND SOCIAL IMPACT STATEMENT - TYRA

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ENVIRONMENTAL AND SOCIAL IMPACT STATEMENT - TYRA

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LIST OF ABBREVIATIONS

ALARP	As low as reasonably practicable
API	American Petroleum Institute gravity. An industry standard used to determine and classify oil according to its density
BAT	Best available technique
BEP	Best environmental practice
BOPD	Barrels of oil per day
BWPD	Barrels of water per day
CO_2	Carbon dioxide
DEA	Danish Energy Agency [Energistyrelsen]
DEPA	Danish Environmental Protection Agency [Miljøstyrelsen]
DNA	Danish Nature Agency [Naturstyrelsen]
DUC	Danish Underground Consortium, a joint venture with A. P. Møller – Mærsk, Shell, Chevron and the Danish North Sea Fund
EIA	Environmental impact assessment
EIF	Environmental impact factor
ESIA	Environmental and social impact assessment
ESIS	Environmental and social impact statement
FTEE	Full time employee equivalent
GBS	Gravity-based structure
Hz	Hertz
ITOPF	International tanker owners pollution federation
KSCF	1000 standard cubic foot of gas
MBES	Multibeam echo sounder
MMO	Marine mammal observer
MMSCFD	Million standard cubic feet of gas per day
NMVOC	Non methane volatile organic compounds
NORM	Naturally occurring radioactive material
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	NOX is a generic term for mono-nitrogen oxides NO and NO_2 (nitric oxide and nitrogen dioxide)
OSPAR	Oslo-Paris convention for the protection of the marine environment of the North-East Atlantic
PAM	Passive acoustic monitoring
PEC	Predicted environmental concentration
PLONOR	Pose little or no risk
$PM_{2.5}$	Particulate matter less than 2.5 microns in diameter
PNEC	Predicted no-effect concentration based on ecotoxicity data
PPM	Parts per million
RBA	Risk-based approach
ROV	Remote operated vehicle
SO_2	Sulphur dioxide
SO_x	Refers to all sulphur oxides, the two major ones being sulphur dioxide and sulphur trioxide
SSS	Side scan sonar
STB	Standard barrels

1. INTRODUCTION

1.1 Background

In connection with ongoing and future oil and gas exploration, production and decommissioning activities by Maersk Oil in the Danish North Sea, an environmental and social impact assessment (ESIA-16) is prepared. The overall aim of the ESIA-16 is to identify and assess the impact of the Maersk Oil activities on environmental and social receptors.

ESIA-16 shall replace the EIA conducted in 2010 /1/ which is valid for the period 1st January 2010 to 31st December 2015. The ESIA-16 covers the remaining lifetime of the ongoing projects, and the whole life time from exploration to decommissioning for planned projects.

The ESIA-16 consists of five independent project-specific environmental and social impact statements (ESIS) for TYRA, HARALD, DAN, GORM and HALFDAN including seven generic technical sections that describe the typical activities (seismic, pipelines and structures, production, drilling, well stimulation, transport and decommissioning; provided in appendix 1) in ongoing and planned Maersk Oil projects. Drilling of stand alone exploration wells and replacement of existing pipelines are not included in ESIA-16 and are screened separately in accordance with Order 632 dated 11/06/2012.

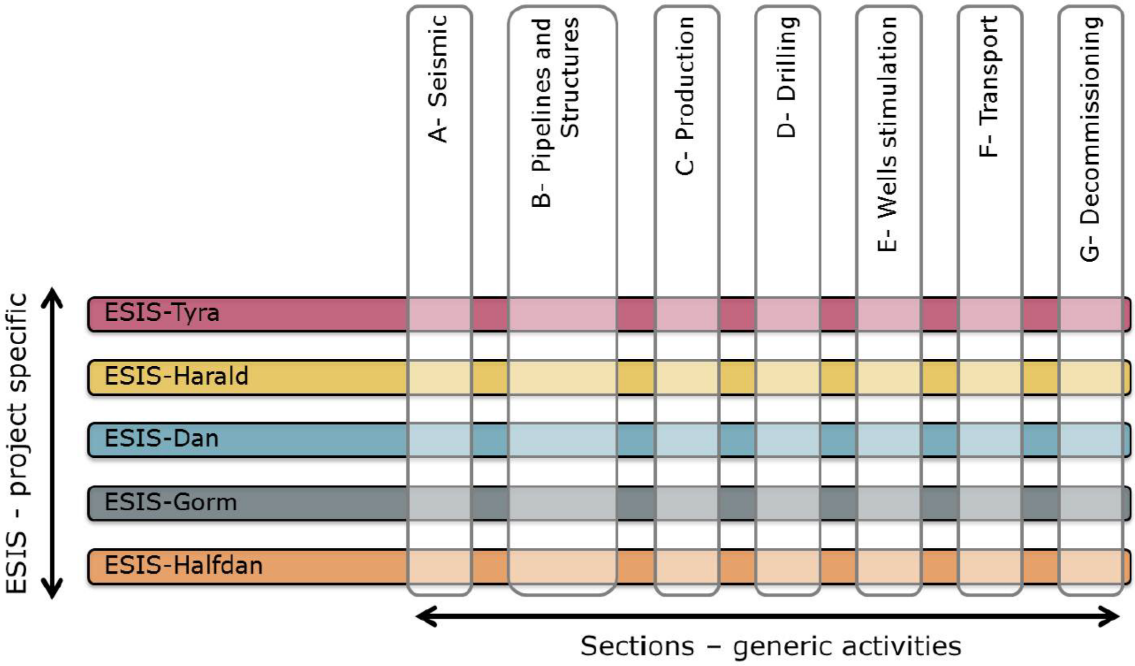


Figure 1-1 Matrix for Maersk Oil ESIA-16, showing the seven generic technical sections and the five ESIS.

The environmental and social impact statement for the TYRA project covers the activities related to existing and planned projects for the Tyra (East and West) facilities and their satellite platforms Tyra South East, Valdemar A, Valdemar B, Roar and Svend. The platforms are located in the North Sea about 230 km from the west coast of Jutland, Denmark (Figure 1-2).

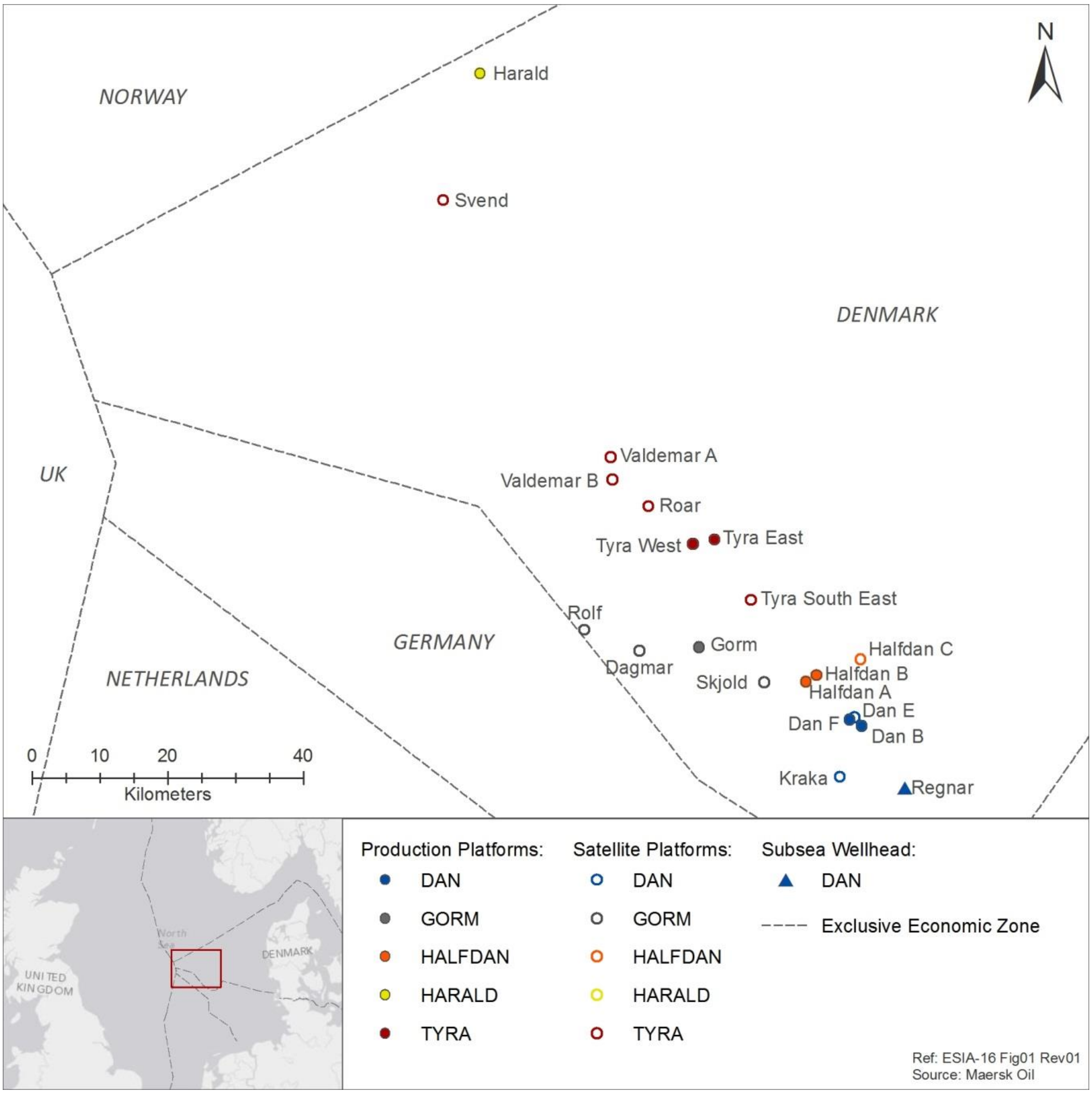


Figure 1-2 Project-specific environmental and social impact statement (ESIS) are prepared for the North Sea projects TYRA, HARALD, DAN, GORM and HALFDAN, respectively.

2. LEGAL BACKGROUND

2.1 EU and national legislation

2.1.1 Environmental impact assessment directive (EIA directive)

The directive on the assessment of the effects of certain public and private projects on the environment (directive 85/337/EEC), as amended by directives 7/11/EC, 2003/35/EC and 2009/31/EC, requires an assessment of the environmental impacts prior to consent being granted. For offshore exploration and recovery of hydrocarbons this directive is implemented in Denmark as executive order 632 dated 11/06/2012. The order is under revision to implement amendments following directive 2014/52.

This ESIA-16 has been prepared in accordance with order 632 dated 11/06/2012 on environmental impact assessment (EIA) and appropriate assessment (AA) for the hydrocarbon activities [Bekendtgørelse om VVM, konsekvensvurdering vedrørende internationale naturbeskyttelsesområder og beskyttelse af visse arter ved efterforskning og indvinding af kulbrinter, lagring i undergrunden, rørledninger, m.v. offshore]. The ESIS includes:

- Transboundary significant adverse impacts are addressed (section 8), in accordance with article 8 and the ESPOO convention.
- Protection of certain species mentioned in the directive article 12 (section 6)
- A Natura 2000 screening is presented in this ESIS (section 10), in accordance with article 9 and 10.

The ESIS and its non-technical summary shall be made available for public consultation on the web page of the Danish Energy Agency. Public consultation shall be for a period of at least 8 weeks, in accordance with article 6.

2.1.2 Protection of the marine environment

The consolidation act 963 dated 03/07/2013 on protection of the marine environment aims to protect the environment and ensure sustainable development.

The consolidation act and associated orders regulate e.g. discharges and emissions from platforms. Relevant orders include: Order 394 dated 17/07/1984 on discharge from some marine constructions, order 270 dated 18/04/2008 on discharges of blackwater, order 9840 dated 12/04/2007 on prevention on air pollution from ships, and order 909 dated 10/07/2015 on contingency plans.

2.1.3 Natura 2000 (Habitats and Bird protection directive)

The "Natura 2000" network is the largest ecological network 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 under the directive on the conservation of natural habitats and of wild fauna and flora (Habitats Directive, Directive 1992/43/EEC). Furthermore, Natura 2000 also includes special protection areas classified pursuant to the Birds Directive (Directive 2009/147/EC). The directives have been transposed to Danish legislation through a number of orders (or regulatory instruments).

The Natura 2000 protection is included in the order 632 dated 11/06/2012 (section 2.1.1).

2.1.4 National emissions ceiling directive

The national emission ceiling directive (directive 2001/81/EC) sets upper limits for each Member State for the total emissions of the four pollutants nitrogen oxide NO_x, volatile organic compound (VOC), ammonia (NH_3) and sulphur dioxide (SO_2). The directive is under revision to include particulate matter less than 2.5 microns in diameter ($PM_{2.5}$). The directive has been implemented by order 1325 dated 21/12/2011 on national emissions ceilings.

2.1.5 Marine strategy framework directive

The marine strategy framework directive (Directive 2008/56/EC) aims to achieve "good environmental status" of the EU marine waters by 2020. The directive has been implemented in Denmark by the act on marine strategy (act 522 dated 26/05/2010). A marine strategy has been developed by the Danish Nature Agency with a detailed assessment of the state of the environment, with a definition of "good environmental status" at regional level and the establishment of environmental targets and monitoring programs (www.nst.dk).

2.1.6 Industrial emissions directive

The industrial emissions directive (directive 2010/75/EU) is about minimising pollution from various industrial sources. The directive addresses integrated pollution prevention and control based on best available technique (BAT). The directive has been implemented by the consolidation act 879 dated 26/06/2010 on protection of the environment and with respect to offshore, order 1449 dated 20/12/2012.

2.1.7 Emission allowances

The European Union Emissions Trading Scheme was launched in 2005 to combat climate change and is a major pillar of EU climate policy. Under the 'cap and trade' principle, a cap is set on the total amount of greenhouse gases that can be emitted by all participating installations.
The trading scheme is implemented by act 1095 dated 28/11/2012 on CO_2 emission allowances.

2.1.8 Safety directive of oil and gas operations

The directive 2013/30/EU on safety of offshore oil and gas operations aims to ensure that best safety practices are implemented across all active offshore regions in Europe. The directive has recently been implemented by act 1499 dated 23/12/2014 on offshore safety.

2.2 International conventions

2.2.1 Espoo convention

The convention on environmental impact assessment in a transboundary context (Espoo Convention) entered into force in 1991. The convention sets out the obligations of Parties to assess the environmental impact of certain activities at an early stage of planning. It also lays down the general obligation of States to notify and consult each other on all major projects under consideration that are likely to have a significant adverse environmental impact across national boundaries.

The Espoo convention is implemented in the EIA Directive. In Denmark, the Ministry of Environment administrate the Espoo Convention rules and is the responsible authority for the process of exchanging relevant information from the projcet owner to the potentially affected countries and possible comments from those countries in connection with the Espoo Consultation Process.

2.2.2 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.

2.2.3 Convention for the control and management of ships' ballast water and sediments

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.

2.2.4 Ramsar convention

The Ramsar convention aims at the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world.

2.2.5 The convention for the protection of the marine environment of the North-East Atlantic

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.

A number of strategies and recommendations from OSPAR are relevant to the TYRA project, most notably:

- Annual OSPAR report on discharges, spills and emissions from offshore oil and gas installations.
- Reduction in the total quantity of oil in produced water discharged and the performance standard of dispersed oil of 30 mg/l (OSPAR Recommendation 2001/1).
- Harmonised mandatory control system for the use and reduction of the discharge of Offshore chemicals (OSPAR decision 2005/1).
- List of substances/preparations used and discharged offshore which are considered to pose little or no risk to the environment (PLONOR) (OSPAR decision 2005/1).
- To phase out, by 1 January 2017, the discharge of offshore chemicals that are, or which contain substances, identified as candidates for substitution, except for those chemicals where, despite considerable efforts, it can be demonstrated that this is not feasible due to technical or safety reasons (OSPAR Recommendation 2006/3).
- Risk based approach to assessment of discharged produced water (OSPAR recommendation 20012/5).
- Decision 98/3 on the disposal of disused offshore installations.

2.2.6 Convention on access to information, public participation in decision-making and access to justice in environmental matters

The UNECE convention on access to information, public participation in decision-making and access to justice in environmental matters (Aarhus convention) was adopted in 1998. The convention is about government accountability, transparency and responsiveness. The Aarhus convention grants the public rights and imposes on parties and public authorities obligations regarding access to information and public participation. The Aarhus convention is among others implemented in Denmark by the Subsoil Act 960 dated 13th September 2013.

2.3 Industry and national authority initiatives

2.3.1 Offshore action plan

An offshore action plan was implemented by the Danish Environmental Protection Agency and the Danish operators in 2005 in order to reduce the discharge of chemicals and oil in produced water. A revised action plan for 2008-2010 was implemented to reduce emissions to air and further reduce discharges.

2.3.2 Action plan on energy efficiency

An action plan on energy efficiency was implemented by the Danish Energy Agency and the Danish oil and gas operators for 2008-2011 and 2012-2014 to improve energy efficiency for the oil and gas industry. More specifically, the action plan included measures on energy management and initiatives to reduce flaring and energy consumption.

3. DESCRIPTION OF THE PROJECT

The project description for the TYRA project is based on site specific input from Maersk Oil and the technical sections (appendix 1). The TYRA project refers to the existing and planned activities for the Tyra East and West facilities and the satellite platforms Tyra South East, Valdemar (A and B), Roar and Svend. The TYRA project (capital letters) refers to the project, while Tyra refers to the platforms.

3.1 Existing facilities

3.1.1 Overview

The main processing and production facilities Tyra East and West and the satellite platforms Tyra South East, Valdemar (A and B), Roar and Svend are connected by subsea pipelines, through which oil, gas and water are transported between the TYRA facilities and to Gorm E (oil) and to the Netherlands (gas) for further processing or export to shore. Pipelines departing from the Tyra (East, West and South East), Valdemar (A and B), Roar and Svend platforms are considered part of the TYRA project.

An overview of the existing pipelines and structures for the TYRA project is provided in Figure 3-1.

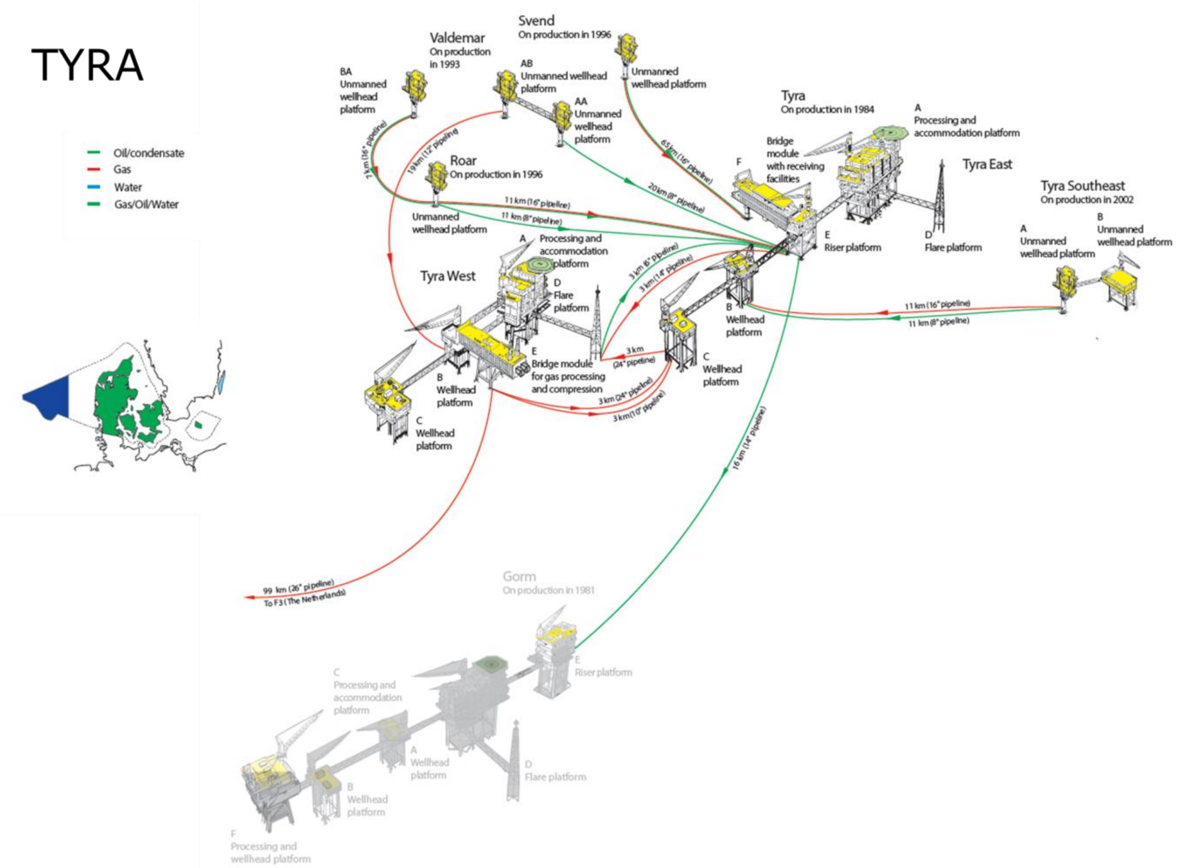


Figure 3-1 Overview of existing facilities at the TYRA project (not to scale).

3.1.2 Pipelines and structures

3.1.2.1 Tyra

Tyra is located in the South-Western part of the Danish sector of the North Sea, approximately 230 km west of Esbjerg. The water depth at Tyra is 39-41 m.

There are two main processing facilities for the TYRA project: Tyra East (Figure 3-2) and Tyra West (Figure 3-3).

Tyra East consists of six platforms, which are connected by bridges, where all interconnecting pipes and services are run.

- Tyra East A (TEA) is the main platform which holds accommodation facilities, utility and life support systems as well as processing facilities for treatment of the gas/condensate production from the Tyra East reservoir and facilities for receiving and treatment of the raw well production from the Valdemar, Roar, Svend and Tyra SE satellites and condensate from Tyra W.
- Tyra East B (TEB) is a wellhead platform which accommodates 24 well slots.
- Tyra East C (TEC) is a wellhead platform which accommodates 12 well slots.
- Tyra East D (TED) is a flare platform.
- Tyra East E (TEE) is a riser platform for the subsea pipelines from Roar, Valdemar and Tyra W as well as for the gas pipelines from Dan FB and Gorm E.
- Tyra East F (TEF) is a bridge module which serves as support for the gas and liquid receiving module TEE and as riser platform for the Svend/Harald pipeline.

Figure 3-2 Tyra East.

Tyra West consists of five platforms, which are connected by bridges where all interconnecting pipes and services are run.

- Tyra West A (TWA) is the main platform which holds accommodation facilities, utility and life support systems as well as processing facilities for treatment of the gas/condensate production from the western flank of the Tyra reservoir, wet gas from Valdemar AB, Low Pressure (LP) gas from Roar and Tyra SE, High Pressure (HP) gas from Halfdan (mixed with gas from Dan) and raw gas from Tyra East including its satellites and Harald, Lulita and Trym (Norwegian field).
- Tyra West B (TWB) is a wellhead platform which accommodates 12 well slots and riser platform for the incoming 18 km 12" gas pipeline from Valdemar AB.
- Tyra West C (TWC) is a wellhead platform which accommodates 24 well slots.
- Tyra West D (TWD) is a flare platform.
- Tyra West E (TWE) is a combined bridge module and riser platform which holds the main gas compression and gas conditioning facilities module and serves as riser platform for two gas pipelines to Tyra East C; the gas pipeline from Halfdan BA and the gas export pipeline to F3 (NOGAT).

Figure 3-3 Tyra West.

The Tyra East and West platforms form the export centre for all gas produced by Maersk Oil in Denmark. The bulk of the gas produced is compressed and exported in two ways; either via Tyra East to Nybro in Denmark, or from Tyra West through the NOGAT pipeline to Den Helder in the Netherlands.

Continuous control and monitoring of the satellite platforms Tyra South East, Roar, Valdemar and Svend is carried out remotely from Tyra East and West.

3.1.2.2 Tyra South East

Tyra South East is situated ca. 10 km Southeast of Tyra East. The water depth at Tyra SE is 38 metres.

The Tyra Southeast facilites has been developed as a satellite to Tyra East. Tyra Southeast includes TSA an unmanned wellhead STAR platform with no helideck and TSB a wellhead platform installed in 2014 (Figure 3-4). After separation, the production is transported to Tyra East in two pipelines to be processed and subsequently exported ashore.

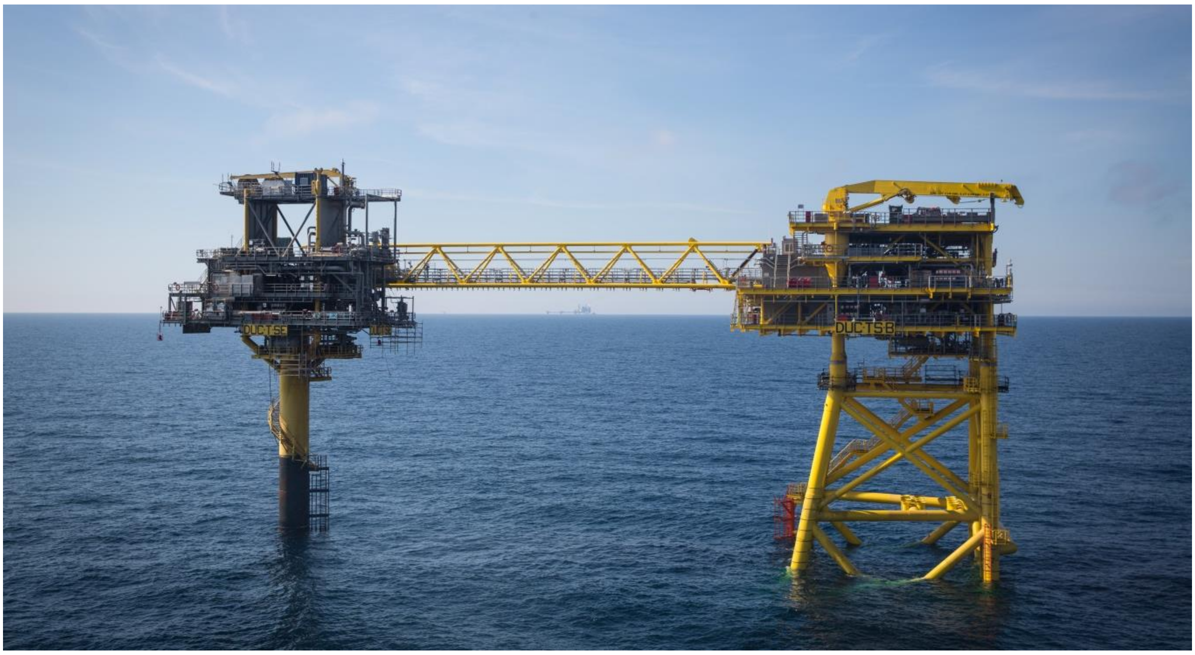


Figure 3-4 Tyra South East.

3.1.2.3 Roar

Roar is situated ca. 11 km Northwest of Tyra East. The water depth at Roar is 41 metres.

Roar is a satellite platform to the Tyra East installation. Roar is an unmanned wellhead STAR platform with no helideck. After separation, the hydrocarbons produced are conveyed through two pipelines to Tyra East for processing and export.

Figure 3-5 Roar.

3.1.2.4 Valdemar

Valdemar is situated ca. 17 km Northwest of Tyra East. The water depth at Valdemar is 40 m. Valdemar aretwo satellite installations to Tyra East, Valdemar A and Valdemar B.

Valdemar A comprises two unmanned wellhead STAR platforms (VAA and VAB) with no helideck, connected by a bridge. After separation the production is transported to Tyra West for processing and transportation ashore/export, while condensateis transported to Tyra East for processing and export ashore.

Figure 3-6 Valdemar A.

Valdemar B comprises an unmanned wellhead STAR platform (VBA) with no helideck, about 4 km from the Valdemar VAA/VAB facility. The production from Valdemar VBA is conveyed to Tyra East via Roar through a multiphase pipeline. The production from the Valdemar VBA platform is transported to Tyra East for processing and export ashore.

Figure 3-7 Valdemar B.

3.1.2.5 Svend

Svend is situated ca. 64 km northwest of Tyra East. The water depth at Svend is 64 meters.

The Svend Field is produced through a satellite platform to Tyra East. Svend is an unmanned STAR wellhead platform with no helideck (Figure 3-8). The hydrocarbons produced are conveyed to Tyra East for processing and export.

Figure 3-8 Svend.

3.1.2.6 Pipelines

The production facilities are connected by subsea pipelines, through which oil, gas and water are transported. Pipelines are trenched to a depth of 2 m or covered by rocks where above the seafloor. An overview of the existing pipelines and their content is provided in Figure 3-1.

3.1.3 Wells

The TYRA project currently has a total of 111 wells: 36 at Tyra East, 36 at Tyra West, 7 at Tyra SE, 5 at Svend, 4 at Roar, 14 at Valdemar A and 9 at Valdemar B.
There are 24 free well slots which are available for drilling: 16 at Tyra South East, 2 at Svend, 3 at Roar, 2 at Valdemar A and 1 at Valdemar B.

3.1.4 Processing capabilities

The processing capabilities of the TYRA facilities (Tyra West and Tyra East) are provided in Table 3-1. The facilities are designed for continuous operation 24 hours a day. Maintenance is generally planned, so only part of the facility is shut down, thus only reducing the production. The facilities will only be shut down in case of major emergencies or major maintenance operations.

Table 3-1 Processing capacity of the TYRA facilities (Tyra West and Tyra East).

Process	Unit	Tyra West	Tyra East
Liquid separation	BOPD	94,350	182,410
Gas separation	MMscfd	634	933
Produced water treatment	BWPD	82,399	88,060
Gas dehydration	MMscfd	933	709
HP gas compression	MMscfd	933	597
LP gas compression	MMscfd	485	n/a
Hydrocarbon dew point control	MMscfd	n/a	597
Stabilization	BPD	n/a	70,448

At the Tyra West facility, there are 2 main processes:

- Separation process
- Gas compression and dehydration process including water dehydration and hydro-carbon stabilization.

The drawing shown in Figure 3-9 shows the overall process as a simplified process block diagram of the oil condensate and gas production facilities on Tyra West.

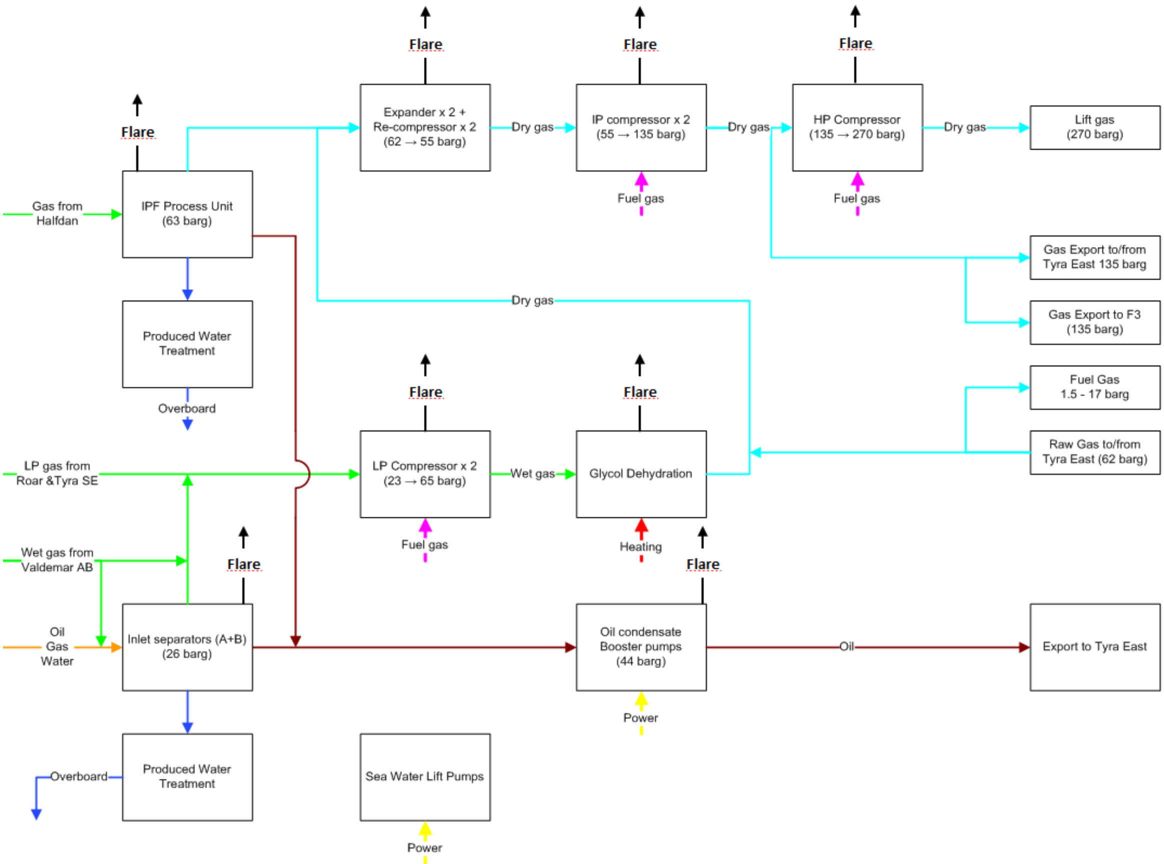


Figure 3-9 Simplified diagram of the process at Tyra West.

At the Tyra East facility, there are 2 main processes:

- Separation process
- Gas compression and dehydration process

The drawing shown in Figure 3-10 shows the overall process as a simplified process block diagram of the oil and gas production facilities on Tyra East.

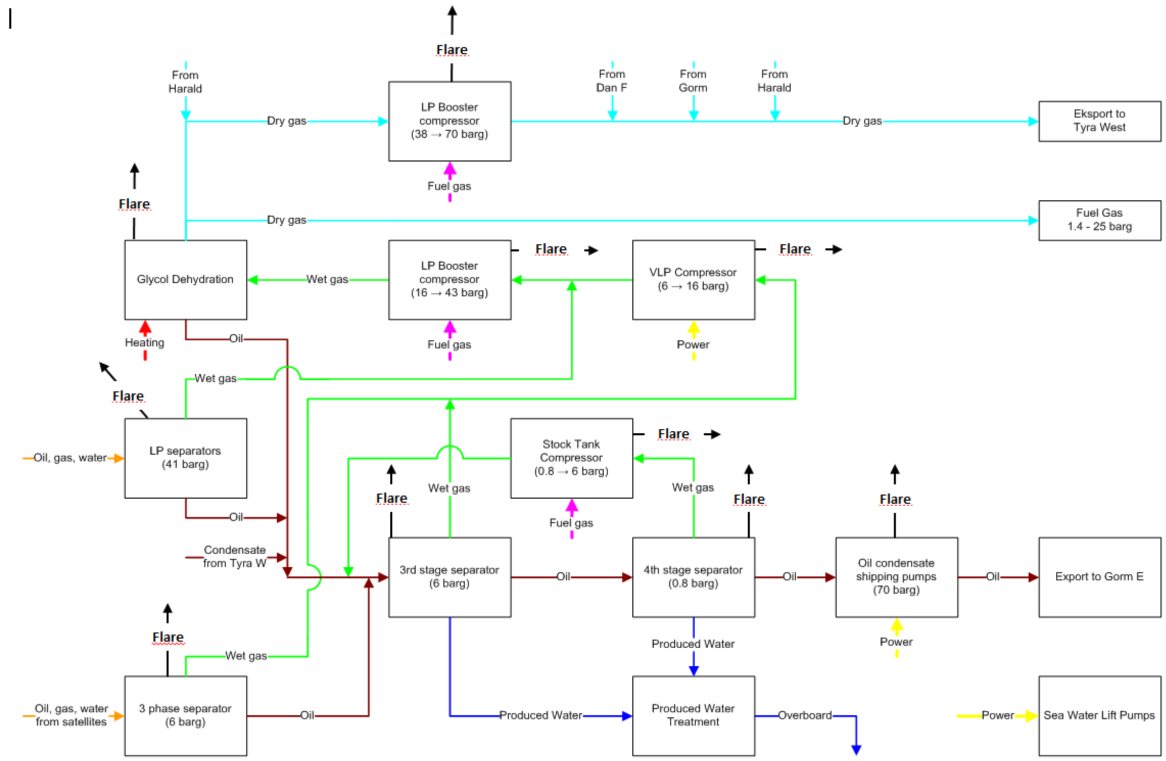


Figure 3-10 Simplified diagram of the process at Tyra East.

The energy supply to the TYRA facilities consists of self-produced natural gas, and diesel supplied by ship.

Natural gas is used as fuel gas in gas turbines operating as drives for e.g. power generators, gas compressors and high-pressure water injection pumps.

Diesel is used in dual-fuel gas turbines, for cranes and for emergency equipment such as fire pumps.

Flaring of gas at compressor inlet/outlet might be required for short periods of time in relation to to planned and controlled process operations (e.g. start up) and for safety reason in relation with unforeseen process upsets which causes overpressure of process equipment and emergency depressurization of platform equipment.

3.1.5 Waste

Maersk Oil transports all waste from its Danish North Sea facilities to shore where it is recycled, incinerated or landfilled in accordance with current legislation. The last five years, an average of about 10,000 tons of waste were collected and brought onshore from all Maersk Oil facilities. In the last five years, about 99 % of the waste was recycled or incinerated. Landfilled waste is partly made up of sandblasting materials. Since 2014, most of the sand is being reused for roads construction and other building materials leading to a significant reduction in the amount of landfilled waste.

3.1.6 Naturally occurring radioactive material (NORM)

Naturally occurring radioactive material (NORM) such as sand, scale, cleanup materials from tubing, valves or pipes are collected and brought onshore, where they are treated to remove traces of hydrocarbons or scale formation. After treatment, the NORM is securely stored. The total average quantity of NORM stored in 2013-2014 was approximately 70 tons. The quantity of NORM is expected to increase as fields are maturing and Maersk Oil is currently evaluating the best options for handling of NORM waste.

3.1.7 Discharges

A number of discharges are expected to occur as part of the planned activities, including drilling mud and cuttings, produced water and cooling water. These are described in section 3.2 and Appendix 1.

In addition, main liquid effluents generated by the vessels and platforms will comprise:

- Greywater (water from culinary activities, shower and laundry facilities, deck drains and other non-oily waste water drains (excluding sewage)
- Treated blackwater (sewage)
- Drainage water
- Service water / vessel engine cooling water.

Discharges comply with requirements set out in the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78) and its annexes.

3.2 Planned activities

Here, the planned activites for the TYRA project are presented with reference to the seven technical sections (appendix 1).

3.2.1 Seismic

Seismic surveys are performed to provide information about the subsurface geological structure to identify the location and volume of potential hydrocarbon reserves, and to ensure that seabed and subsurface conditions are suitable for planned activities (e.g. drilling and construction of production facilities).

For the TYRA project, several types of seismic data acquisition may be carried out:

- 4D seismic surveys are 3D seismic surveys repeated over a period of time, and can take several months to complete. A 4D seismic covering an area of a few hundred km^2 is planned for 2016 or 2017, and expected to be repeated about every 4 years.
- Drilling hazard site surveys (one per year expected) may include 2D high-resolution multi-channel and single-channel seismic, side scan sonar, single and multi-beam echo-sounder, seabed coring and magnetometer. Typical duration of such a survey is 1 week covering an area of 1x1 km.
- Borehole seismic surveys (one per year expected) are conducted with a number of geophones that are lowered into a wellbore to record data. The duration is usually one to two days.

3.2.2 Pipelines and structures

Regular maintenance of the existing pipelines and structures at the TYRA project will be undertaken including external visual inspections by remotely operated vehicles (ROVs) and an internal inspection/cleaning of pipelines (pigging). If inspection surveys reveals that the replacement of existing pipelines is necessary, a separate project and environmental screening will be carried out.

For the TYRA project, nine development projects are considered. The aim of the projects is to optimise the current TYRA production and possibly access new resources. The development projects are not specified in details at this stage, and only an outline is provided:

- Valdemar LC development optimization: a wellhead platform (SLIC type, 8 well slots) with 6 new oil producing wells, and a 1 km multiphase pipeline to the existing Valdemar BA platform.
- Valdemar LC gas injection: a wellhead platform (SLIC type, 10 well slots) with 10 new gas injection wells, and 2 new gas pipelines (each 18 km) to Tyra.
- Boje development: a wellhead platform (STAR type, 8 well slots) with 6 new oil producing wells, and a 8 km multiphase pipeline to the existing Valdemar AA platform.
- Bo South development: a wellhead platform (SLIC type, 4 well slots) with 4 new oil producing wells, and a 5 km multiphase pipeline to the existing Valdemar BA platform.
- Adda Phase I + II: a wellhead platform (4 legged type, 16 well slots) with 8 new wells (7 gas producing and one oil producing), and 2 new gas pipelines (each 12 km) to Tyra.
- Tyra LC development: a wellhead platform (SLIC type, 4 well slots) with 3 new oil producing wells (no new pipelines).
- Tipo (Svend): a wellhead platform (SLIC type, 10 well slots) with 10 ioil producing wells, and a 1 km multiphase pipeline to the existing Svend platform.
- Ella (Svend): a wellhead platform (SLIC type, 6 well slots) with a new gas producer, and a 20 km gas pipeline to the existing Tyra platform.
- Farsund: a wellhead platform (SLIC type, 40 well slots) with 40 new oil producing wells, and a 10 km multiphase pipeline to the existing Valdemar BA platform.

3.2.3 Production

Tyra production was initiated at Tyra in 1984, , Valdemar in 1993, Roar in 1996, Svend in1996 then later at Tyra South East in 2002. The production for the TYRA project from 1984 to 2014 adds to a total of 338 millions barrels of oil (stbo) and 4,418 billions standard cubic feet of gas (125 bm^3). The total annual production for the TYRA project peaked in 2005 and is now on a natural decline. This reflects the fact that the majority of the fields are in a relatively mature stage in the production cycle. In 2014, TYRA had an annual production of 10 millions barrels of oil and 74 billions standard cubic feet of gas.

Throughout their productive life, most oil wells produce oil, gas, and water. Initially, the mixture coming from the reservoir may be mostly hydrocarbons but over time, the proportion of water increases and the fluids processing becomes more challenging. Processing is required to separate the fluid produced from the reservoirs.

The maximum total expected production of oil, gas and water from the TYRA project is shown in Figure 3-11. There is currently no re-injection as part of the TYRA project.

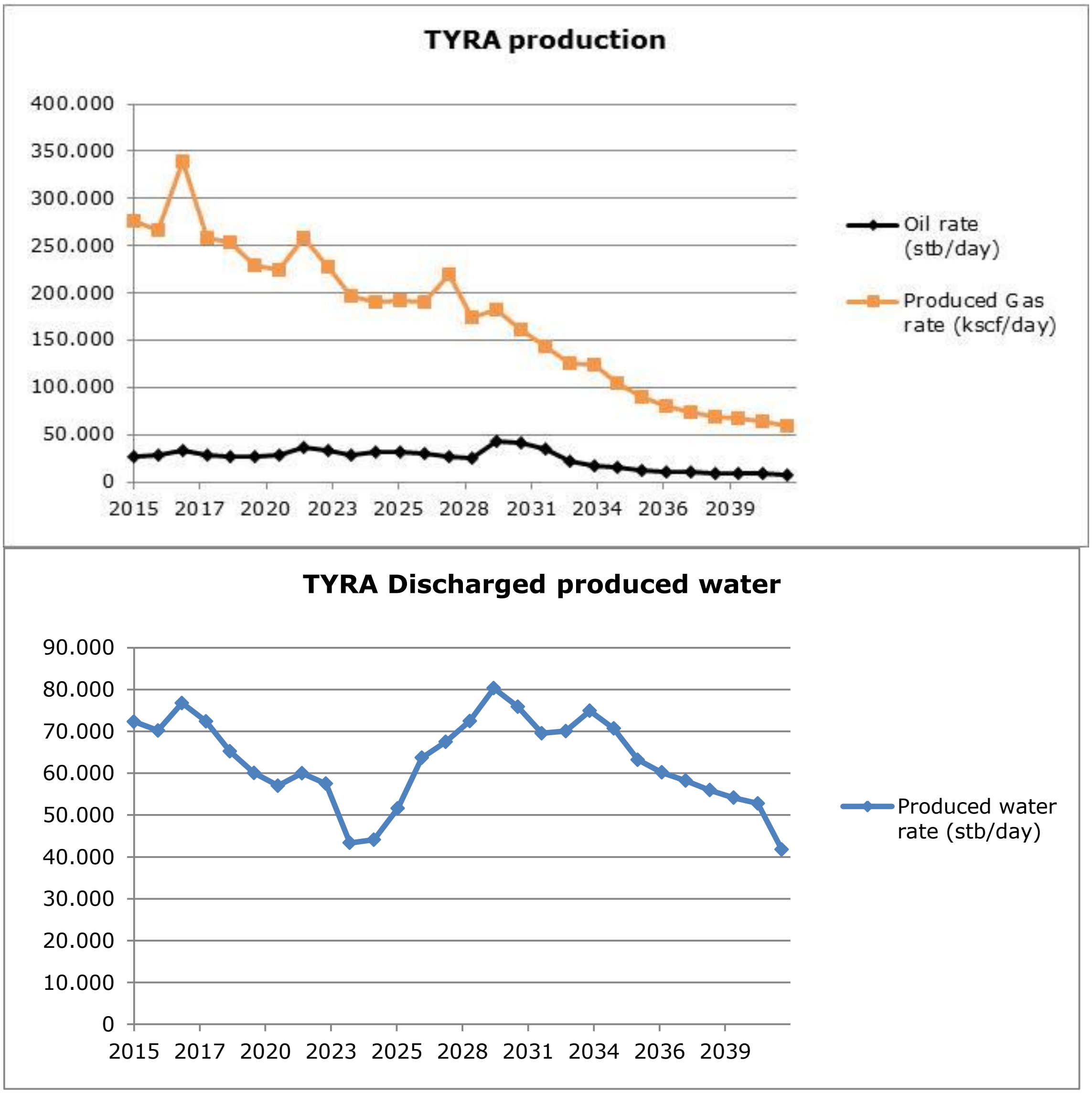


Figure 3-11 Maximum total expected production of oil, gas and water from the TYRA project. Oil and water rates are provided as standard barrels per day, while the gas rate is provided as 1000 standard cubic feet of gas per day. No re-injection is undertaken at the TYRA project, and all produced water is discharged. The rise in the volume of discharged produced water is due to simultaneous development projects at Tyra and Roar.

Maersk Oil uses production chemicals (e.g. H_2S scavenger, biocides) to optimise the processing of the produced fluids. The inventory of the main chemicals used by Maersk Oil, their general use and partitioning in water/oil phase is presented in appendix 1. A fraction of the oil and chemicals is contained in the treated produced water which is discharged. Discharges of produced water to sea is permitted only after authorisation from the Danish Environmental Protection Agency (DEPA)

The nature, type and quantities of chemicals that are used in production and discharged to sea are expected to be adjusted to follow changes in production and technical development. In 2013-2014, about 2,575 tons of chemicals were used for production at the TYRA project and about 1,850 tons of chemicals were discharged to sea. The amount of chemical used, is somewhat related to the volume of produced water. For the TYRA project, the amount of produced water discharge is expected to decrease until 2023, then increase with a peak in 2029 and subsequently decrease (Figure 3-12). In the future, Maersk Oil will continue to aim at reducing the environmental risk asociated with the production discharges on the marine environment, by reducing of the volume of chemicals discharged, improving of the treatment processes or selecting alternative chemicals (see mitigating measures in section 8).

The nature, type and quantities of chemicals that are used and discharged to sea are reported to the DEPA.

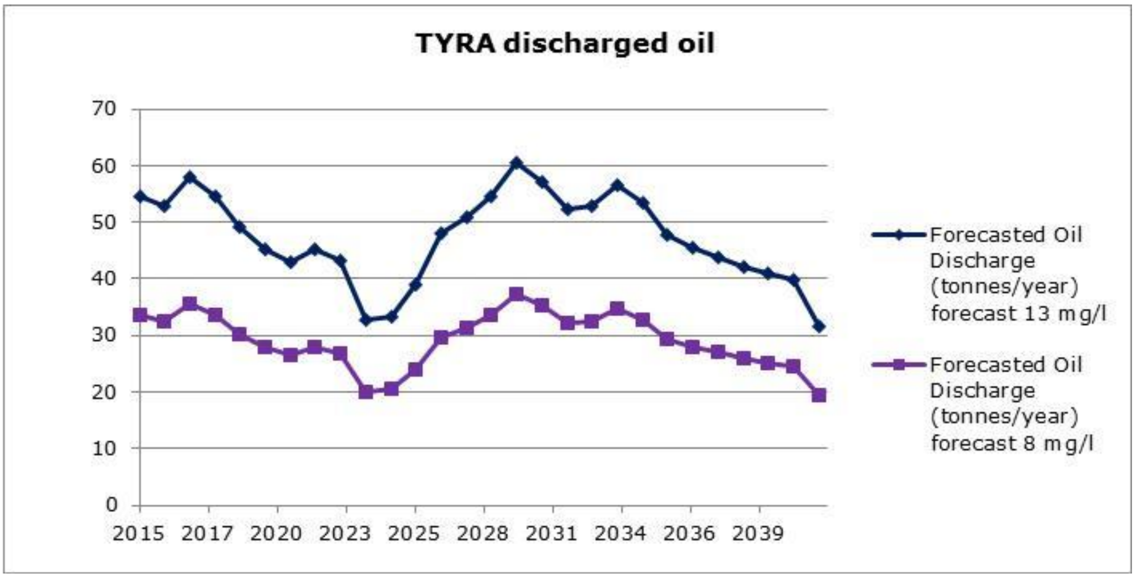


Figure 3-12 Amount of oil discharged for the TYRA project. The oil content in discharged produced water is expected to range between 8 mg/l and 13 mg/l).

The TYRA project contributes to the total amount of oil in produced water discharges to sea. The estimates of oil discharges (average and maximum, Figure 3-11) are based on produced water discharge forecasts and historical oil in water figures at the TYRA project. Oil content in produced water is regulated by the DEPA based on OSPAR regulations.

Maersk Oil has placed flowmeters that measures continuously the volume of discharged produced water, and water samples are taken daily for measurement of oil content.

The amount of oil in produced water discharged to sea is reported to the DEPA.

3.2.4 Drilling

Drilling of wells is necessary for extracting oil and gas resources. Wells are used for transporting the fluid (a mixture of oil, gas, water, sand and non-hydrocarbon gasses) from the geological reservoir to Maersk Oil installations, where fluid processing takes place. Wells are also used for injection of water (seawater or produced water) or gas to increase reservoir pressure and enhance the oil and gas recovery rate.

For TYRA, 24 existing well slots are available for drilling (16 at Tyra South East, 2 at Svend, 3 at Roar, 2 at Valdemar B and 1 at Valdemar A). Maersk Oil has not decided whether these free well slots will be drilled. In addition, up to 106 well slots are expected to be drilled in relation with the possible TYRA development projects. For the TYRA project, no wells are expected to be subjected to slot recovery or re-drill.

Typical well types are presented in appendix 1. It has not been decided which type of well will be applicable for the TYRA project. Drillling is performed from a drilling rig, which is placed on the seabed (with an expected area of a few hundred m^2). A new well will typically take up to 150 days to drill. Different types of drilling mud will be used based on the well and reservoir properties. Water-based mud and cuttings will be discharged to the sea, whereas oil-based mud and cuttings will be brought onshore to be dried and incinerated. Discharges to sea is permitted only after authorisation from the Environmental Protection Agency. Water-based drilling mud and drill cuttings may contain traces of oil from the reservoir sections. The oil content in the water-based drilling mud and drill cuttings is monitored regularly to ensure it does not exceed 2%, on average. It is estimated that on average 7 tons of oil per 1,000 m reservoir section can be discharged to sea corresponding to a maximum discharge of 28.8 tons of oil per well (type 2 and 4 with a 5,000 m reservoir section).

3.2.5 Well stimulation

The purpose of well stimulation is to improve the contact between the well and reservoir, thereby facilitating hydrocarbon extraction (for a production well) or water injection (for an injection well). Well testing is performed to evaluate the production potential of a well after stimulation.

At the TYRA project, the new wells (up to 24 in existing well slots, and up to 106 wells in new structures) may be subjected to matrix acid stimulation or acid fracturing. The existing wells at the TYRA project may be subjected to matrix acid stimulations (in total up to 2 per year). Use and discharge (e.g. drilling and maintenance) of chemicals are presented in appendix 1. Discharges to sea is permitted only after authorisation from the DEPA.

3.2.6 Transport

Personnel and cargo are transported daily to support Maersk Oil's production and drilling operations via helicopters, supply vessels and survey vessels. Standby vessel may be employed in connection with drilling and tasks requiring work over the side of the installation.

3.2.7 Decommissioning

Decommissioning will be done in accordance with technical capabilities, legislation, industry experience, international conventions and the legal framework at the time of decommissioning. Decommissioning will be planned in accordance with the OSPAR decision 98/3 on the disposal of disused offshore installations.

It is expected that:

- Wells will be permanently plugged towards the reservoir and the casing above the seabed will be removed.
- The platform facilities and jackets will be cleaned, removed and brought to shore for dismantling. Hydrocarbons and waste will be sent to shore for disposal.
- Buried pipelines will be cleaned, filled with seawater and left in situ.

Decommissioning of the TYRA facilities is expected to generate up to 81,500 tons of waste which will be brought onshore and treated accordingly. The main source of waste is expected to be from the steel carbon from the jacket and the topside facilities.

3.3 Accidental events

The accidental events, considered here, are accidents that could take place during exploration, production and decommissioning activities at the TYRA project that can lead to environmental or social impacts.

Small operational accidental spills of oil or chemical or gas release could also occur.

Major loss of primary containment (oil, gas or chemical) may also occur. Generally, the sequence of events leading to such events are unlikely, complex and several scenarios can be envisioned (e.g. /136//137/).

The scenarios associated with Maersk Oil activities at the TYRA project that can lead to accidents with a major significant impacts are listed in the technical sections and include vessels collisions, pipeline rupture due to corrosion, erosion or impact, well blow out and impact on major platform equipment.

3.4 Project alternatives

Maersk Oil has considered several alternatives for planned activities. The alternatives have been evaluated based on technical, financial, environmental and safety parameters.

3.4.1 0 alternative

The 0 alternative (zero alternative) is a projection of the anticipated future development without project realization, and describes the potential result if nothing is done. For the TYRA project, this would mean that the production would cease.

The offshore oil and gas production is important to Danish economy. Thousands of people are employed in the offshore industry, and tax revenue to the state of Denmark is significant. The state’s total revenue is estimated to range from DKK 20 to DKK 25 billion per year for the period from 2014 to 2018.

The Danish government has set a target of 30 % of the Danish energy use is provided from renewable energy by 2020. As part of a long-term Danish energy strategy, the oil and gas production is considered instrumental in maintaining high security of supply. Denmark is expected to continue being a net exporter of natural gas up to and including 2025 and Maersk Oil has a license to operate until 2042 /35/.

If no production is undertaken by Maersk Oil for the TYRA project in the North Sea, there will be no contribution to the Danish economy or security of supply from the TYRA project.

3.4.2 Technical alternatives

Technical alternatives for seismic, pipelines and structures, production, drilling, well stimulation, transport and decommissioning are presented in appendix 1.

4. METHODOLOGY

The ESIS is based on the 2014 North Sea Atlas, technical reports, EIAs, peer-reviewed scientific literature, Maersk monitoring reports and industry reports.

4.1 Rochdale envelope approach

The adoption of the Rochdale Envelope approach allows meaningful ESIA to take place by defining a ’realistic worst case’ scenario that decision makers can consider in determining the acceptability, or otherwise, of the environmental impacts of a project.

The Rochdale Envelope Approach allows a project description to be broadly defined. The project can be described by a series of maximum extents – the ‘realistic worst case’ scenario. The detailed design of the scheme can then vary within this ‘envelope’ without invalidating the corresponding ESIA.

Where a range is provided, e.g. amounts of produced water or volume of drilling mud, the most detrimental is assessed in each case. For example, the impact assessment for the TYRA project is based on the maximum volume of discharged produced water, the maximum number of wells and the maximum number of new structures.

4.2 Methodology for assessment of impacts

The potential impacts of the TYRA project on the environmental and social receptors (e.g. water quality, climate and fishery) are assessed for exploration, production and decommissioning.

The assessment covers the direct and indirect, cumulative and transboundary, permanent or temporary, positive and negative, impacts of the project. Impacts are evaluated based on their nature, type, reversibility, intensity, extent and duration in relation to each receptor (social and environmental).

The proposed methodology used for assessment of impacts includes the following criteria for categorizing environmental and social impacts:

- Value of the receptor
- Nature, type and reversibility of impact
- Intensity, geographic extent and duration of impacts
- Overall significance of impacts
- Level of confidence

4.2.1 Value of receptor

Various criteria are used to determine value/sensitivity of each receptor, including resistance to change, rarity and value to other receptors (Table 4-1).

Table 4-1 Criteria used to assess the value of receptor.

Value	
Low	A receptor that is not important to the functions/services of the wider ecosystem/socioeconomy or that is important but resistant to change (in the context of project activities) and will naturally or rapidly revert to pre-impact status once activities cease.
Medium	A receptor that is important to the functions/services of the wider ecosystem/socioeconomy. It may not be resistant to change, but it can be actively restored to pre-impact status or will revert naturally over time.
High	A receptor that is critical to ecosystem/socioeconomy functions/services, not resistant to change and cannot be restored to pre-impact status.

4.2.2 Nature, type and reversibility of impacts

Impacts are described and classified according to their nature, type and reversibility (Table 4-2).

Table 4-2 Classification of impacts: Nature, type and reversibility of impacts

Nature of impact	
Negative	Impacts that are considered to represent an adverse change from the baseline (current condition).
Positive	Impacts that are considered to represent an improvement to the baseline.
Type of impact	
Direct	Impacts that results from a direct interaction between a planned project activity and the receiving environment.
Indirect or secondary	Impacts which are not a direct result of the project, but as a result of a pathway (e.g. environmental). Sometimes referred to as second level or secondary impacts.
Cumulative	Impacts that result from incremental changes caused by past, present or reasonably foreseeable human activities with the project.
Degree of reversibility	
Reversible	Impacts on receptors that cease to be evident after termination of a project activity.
Irreversible	Impacts on receptors that are evident following termination of a project activity.

4.2.3 Intensity, geographic extent and duration of impacts

Potential impacts are defined and assessed in terms of extent and duration of an impact (Table 4-3).

Table 4-3 Classification of impacts in terms of intensity, extent and duration

Intensity of impacts	
None	No impacts on the receptor within the affected area.
Small	Small impacts on individuals/specimen within the affected area, but overall the functionality of the receptor remains unaffected.
Medium	Partial impacts on individuals/specimen within the affected area. Overall, the functionality of the receptor will be partially lost within the affected area.
Large	Partial impacts on individuals/specimen within the affected area. Overall, the functionality of the receptor will be partially or completely lost within and outside the affected area.
Geographical extent of impacts	
Local	Impacts are restricted to the area where the activity is undertaken (within 10 km).
Regional	There will be impacts outside the immediate vicinity of the project area (local impacts), and more than 10 km outside project area.
National	Impacts will be restricted to the Danish sector.
Transboundary	Impacts will be experienced outside of the Danish sector.
Duration of impacts	
Short-term	Impacts throughout the project activity and up to one year after.
Medium-term	Impacts that continue over an extented period, between one and ten years after the project activity.
Long-term	Impacts that continue over an extented period, more than ten years after the project activity.

4.2.4 Overall significance

The definition of the levels of overall significance of impact are separated for environmental and social receptors (Table 4-4).

Table 4-4 Classification of overall significance of impacts.

Overall significance	Impacts on environmental receptors	Impacts on social receptors
Positive	Positive impacts on the structure or function of the receptor	
None/Negligible negative	No measurable impacts on the structure or function of the receptor.	
Minor negative	Impact to the structure or function of the receptor is localised and immediate or short-term. When the activity ceases, the impacted area naturally restores to pre-impact status.	Impact that is inconvenient to a small number of individual(s) with no long-term consequence on culture, quality of life, infrastructure and services. The impacted receptor will be able to adapt to change with relative ease and maintain pre-impact livelihood.
Moderate negative	Impact to the structure or function of the receptor is local or regional and over short- to medium-term. The structure or ecosystem function of the receptor may be partially lost. Populations or habitats may be adversely impacted, but the functions of the ecosystem are maintained. When the activity ceases, the impacted area restores to pre-impact status through natural recovery or some degree of intervention.	Impact that is inconvenient to several individuals on culture, quality of life, infrastructure and services. The impacted receptor will be able to adapt to change with some difficulties and maintain pre-impact livelihood with some degree of support.
Major negative	Impact to the structure or function of the receptor is regional, national or international and medium- to long-term. Populations or habitats and ecosystem function are substantially adversely impacted. The receptor cannot restore to pre-impact status without intervention.	Impact that is widespread and likely impossible to reverse for. The impacted receptors will not be able to adapt or continue to maintain pre-impact livelihood without intervention.

4.2.5 Level of confidence

It is important to establish the uncertainty or reliability of data that are used to predict the magnitude of the effects and the vulnerability of the receptors, as the level of confidence in the overall level of significance depends on it.

There are three levels of confidence for the impact:

- Low: Interactions are poorly understood and not documented. Predictions are not modelled and maps are based on expert interpretation using little or no quantitative data. Information/data have poor spatial coverage/resolution.
- Medium: Interactions are understood with some documented evidence. Predictions may be modelled but not validated and/or calibrated. Mapped outputs are supported by a moderate negative degree of evidence. Information/data have relatively moderate negative spatial coverage/resolution.
- High: Interactions are well understood and documented. Predictions are usually modelled and maps based on interpretations are supported by a large volume of data. Information/data have comprehensive spatial coverage/resolution.

5. ENVIRONMENTAL AND SOCIAL BASELINE

The environmental and social baseline contains a general description of each potential receptor, and site-specific information to the TYRA project where applicable.

The baseline includes the following potential receptors:

- **Environmental**
  - Climate and air quality
  - Bathymetry
  - Hydrographic conditions
  - Water quality
  - Sediment type and quality
  - Plankton (phytoplankton and zooplankton)
  - Benthic communities (fauna and flora)
  - Fish
  - Marine mammals
  - Seabirds

- **Social**
  - Cultural heritage
  - Protected areas (Natura 2000, UNESCO world heritage, national nature reserves)
  - Marine spatial use
  - Fishery
  - Tourism
  - Employment
  - Tax revenue
  - Oil and Gas dependency

5.1 Climate and air quality

The North Sea is situated in temperate latitudes with a climate characterised by large seasonal contrasts. The climate is strongly influenced by the inflow of oceanic water from the Atlantic Ocean and by the large scale westerly air circulation which frequently contains low pressure systems /10/.

Air quality in the North Sea is a combination of global and local emissions. Industrialisation of the coast and inshore area adjacent to certain parts of the central North Sea has led to increased levels of pollutants in these areas which decrease further offshore, though shipping and platforms provide point sources of atmospheric pollution /141/.

5.2 Bathymetry

The North Sea is a part of the north-eastern Atlantic Ocean, located between the British Isles and the mainland of north-western Europe. The western part of the Danish North Sea is relatively shallow, with water depths between 20 – 40 m, while the Northern part is deeper (e.g. the Norwegian Trench and the Skagerrak; Figure 5-1).

The TYRA project is located in the shallowest part of the Maersk oil activity area, with depths ranging from about 38 - 64 m /3/.

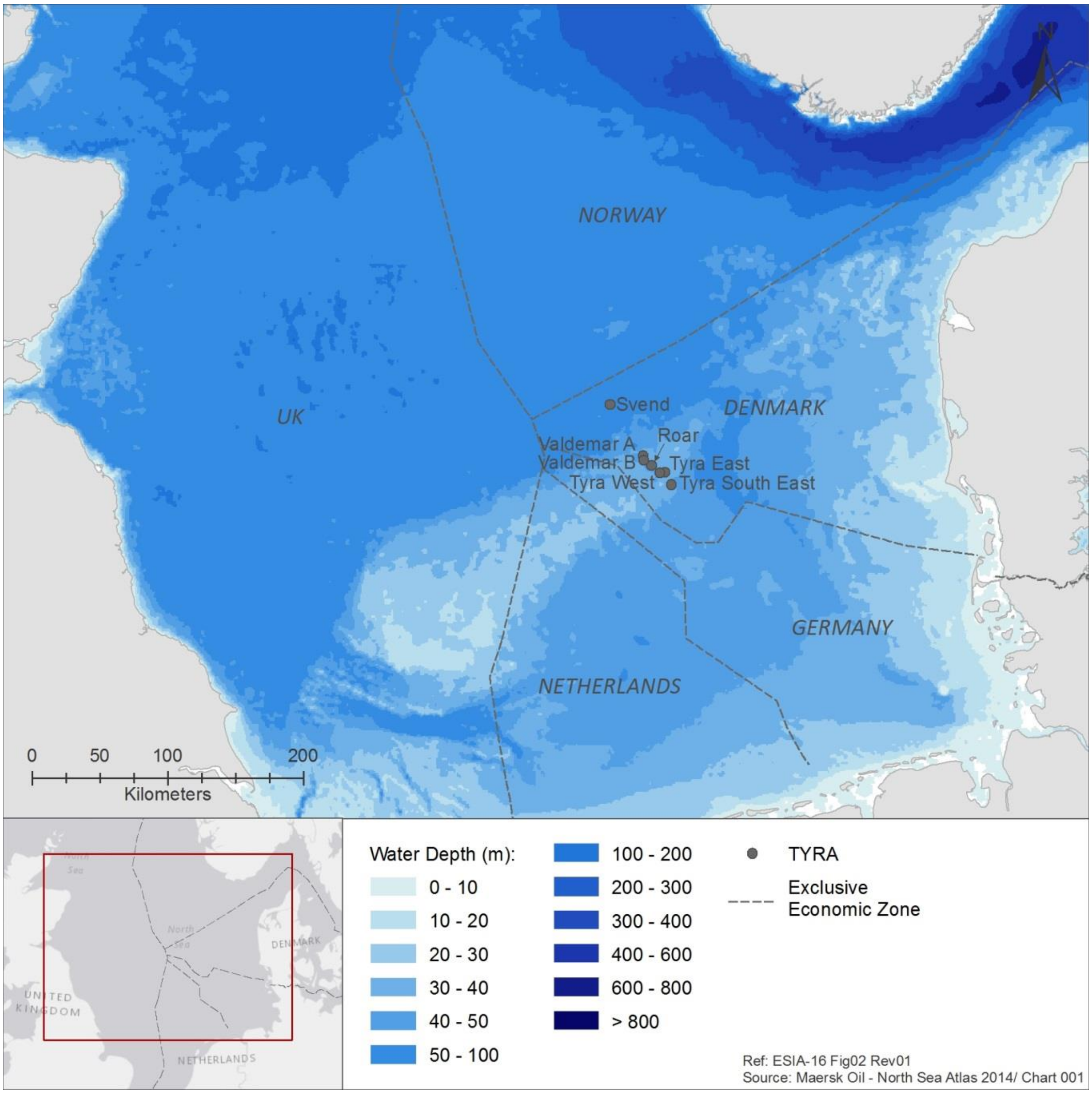


Figure 5-1 Bathymetry of the North Sea. Figure redrawn from Maersk Oil Atlas /3/.

5.3 Hydrographic conditions

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 5-2). These inputs of water, in close interaction with tidal forces and wind and air pressures, create a complicated flow pattern in the North Sea. The TYRA project is in the central North Sea, where the dominant water circulation is eastward.

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 ecosystems. No potential for hydrographic fronts has been identified in the central North Sea where the TYRA project is located.

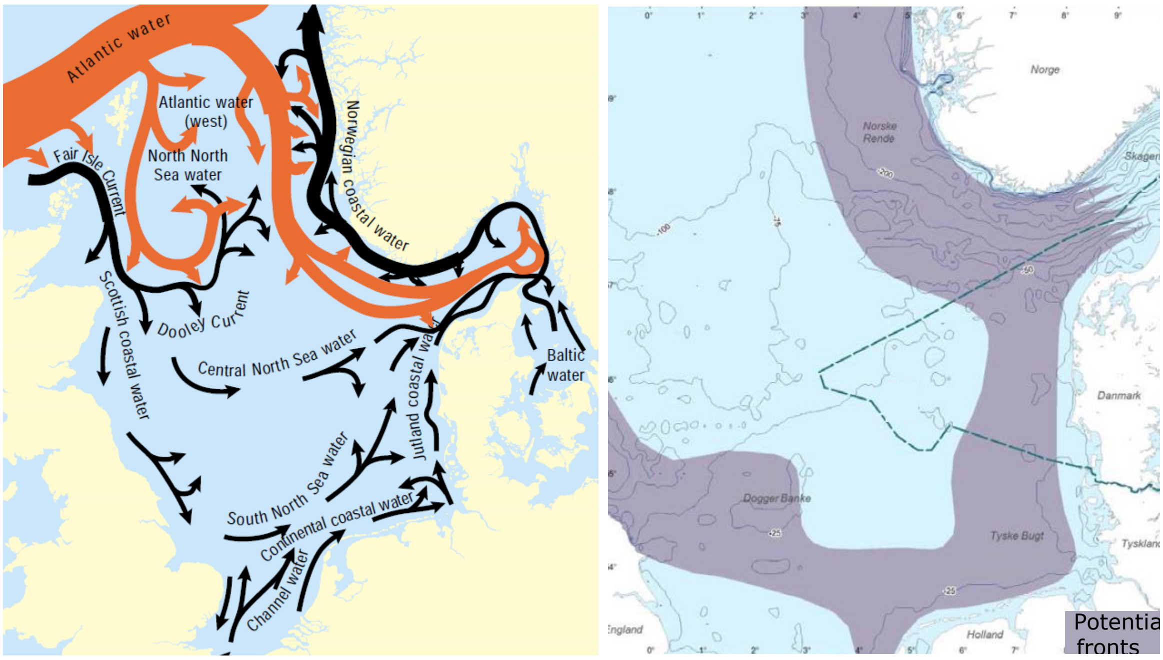


Figure 5-2 Left: General water circulation in the North Sea. The width of arrows is indicative of the magnitude of volume transport /10/. Right: Potential for hydrographic fronts in the North Sea /10//2/.

5.4 Water quality

Salinity: Salinity in the North Sea varies from saline water in the west to brackish water along the coastal areas in the East. In the TYRA project area, the salinity does not show much seasonal variation with surface and bottom salinity of 34-35 psu /3/.

Temperature: Temperature in the North Sea varies seasonally. The lowest temperatures are found in the Northern part of the North Sea, and the highest temperature in the shallower areas in the Southern North Sea. In the TYRA project area, the surface temperature is approximately 7 °C in winter (January) and between 15-19 °C in summer (August), while the bottom temperature varies from 6-8 °C in winter (January) and 8-18 °C in summer (August) /3/.

Nutrients: Concentrations of nutrients in the North Sea surface layer have been modelled /3/. The concentrations are highest (>0.04 mg/l for phosphate, and >0.30 mg/l for nitrate) along the coastal areas, near output of large rivers. The concentrations in the surface layer in the TYRA project area ranges between 0.025-0.035 mg/l for phosphate and between 0.1-0.15 mg/l for nitrate/3/.

Heavy metals: Water concentrations of metals in North Sea for cadmium ranges 6-34 ng Cd/l, copper 140-360 ng Cu/l, lead 20-30 ng Pb/l, mercury 0.05-1.3 ng Hg/l and nickel 100-400 ng Ni/l /29/. Metal cycles in the ocean are governed by seasonally variable physical and biological processes. The biologically driven metals (Cd, Cu, Ni) follow nutrient like distributions with higher concentration found in deep water. Certain metals, including Cd and Cu, exhibit higher concentrations near and on the shelf compared to the open sea areas /29/. No site-specific information on metals in seawater is available.

5.5 Sediment type and quality

The Danish sector of the North Sea is generally characterized by sediments consisting of sand, muddy sand and mud, with smaller areas of till with coarse sediments. The TYRA project is situated in an area with the substrate types "mud to sandy mud" and "sand to muddy sand" (Figure 5-3).

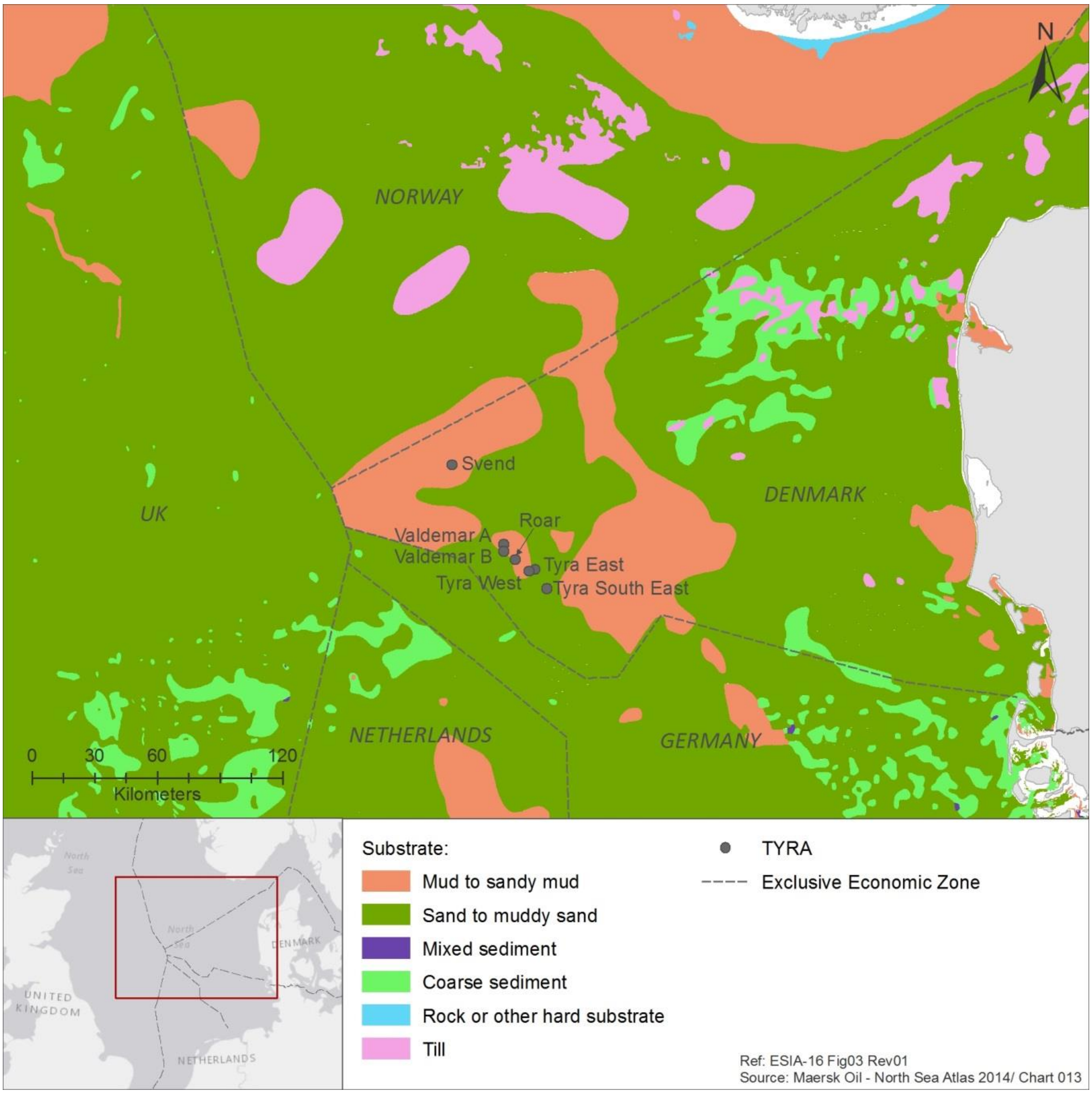


Figure 5-3 Seabed sediments in the North Sea. Figure redrawn from North Sea Atlas /3/.

Monitoring in May 2009 at the Tyra E platform shows that the surface consists of medium to fine sand with a median grain size between 0.15 - 0.31 mm. The silt/clay content of the sediment is generally below 1 % of the dry matter (DM) content. The dry matter content of the sediment is high, about 80%, which is typical for sand. The content of organic matter measured as loss on ignition (LOI) is below 0.5% of the dry matter of the sediment. The content of total organic carbon (TOC) is low and varies between <0.50 and 1.4 g/kg DM /6/.

The concentrations of THC in the surface sediment is between <1 - 18 mg/kg DM, the concentration of polycyclic aromatic hydrocarbons (PAH) are low, between <0.001-0.003 mg/kg DM while the concentrations of alkylated aromatic hydrocarbons (NPD) in general are below the detection limit (0.001 mg/kg DM) /6/.

Concentrations of metals (Cd, Cr, Cu, Pb and Zn /6/) are below the Lower Action Levels for dumping of seabed material defined by the Danish EPA, and thus characterised as having average background levels or insignificant concentrations with no expected negative impact on marine organisms /8/.

5.6 Plankton

The plankton community may be broadly divided into a plant component (phytoplankton) and an animal component (zooplankton). Plankton constitutes the main primary and secondary biomass in marine ecosystems and plays a fundamental role in marine food-webs.

In the North Sea, the phytoplankton is mainly light-limited in winter and nutrient-limited in the water above the thermocline in summer /10/. Figure 5-4 shows the phytoplankton colour index (PCI) for the North Sea over the course of the year. PCI is a visual estimation directly related to the biomass and abundance of the phytoplankton. The highest biomass and abundance of phytoplankton is found in the Eastern and Southern parts of the North Sea. The TYRA project is in an area with an average biomass and abundance in comparison with the rest of the North Sea, and the phytoplankton community is dominated by dinoflagellates and diatoms /3/.

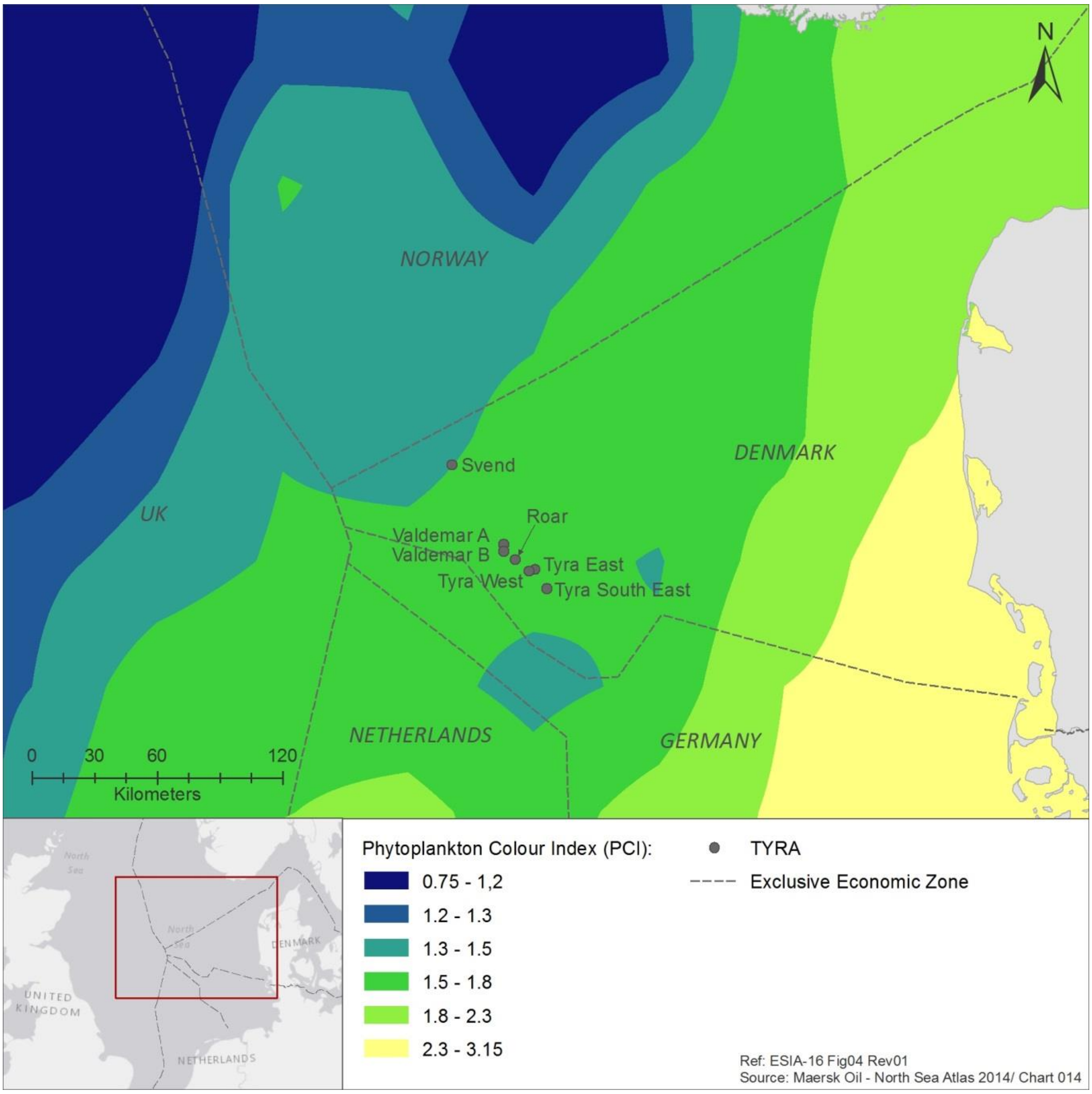


Figure 5-4 Phytoplankton colour index (PCI) for the North Sea. Figure redrawn from North Sea Atlas /3/.

Zooplankton forms the link in the food web whereby the primary production by phytoplankton is channelled to the highest trophic levels through plankton-feeders such as herring (*Clupea harengus*), mackerel (*Scomber scombrus*), and sandeels (*Ammodytes* spp.). Generally, zooplankton abundance varies between areas owing to differences in production, predation, and transport. Nevertheless, the zooplankton community in the central North Sea is generally homogeneous /12/.

The zooplankton communities in the North Sea are dominated in terms of biomass and productivity by copepods, particularly *Calanus* species such as *C. finmarchicus* and *C. helgolandicus* /3/. 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. In the TYRA project area, the abundance of copepods is intermediate compared to the North Sea, with 5.5 – 9.5 ind/m^3 of *C. finmarchicus* and 6.5 – 12 ind/m^3 for *C. helgolandicus* /3/.

The larger zooplankton, known as megaplankton, includes euphausiids (krill), thaliacea (salps and doliolids), siphonophores and medusae (jellyfish). Meroplankton comprises the larval stages of benthic organisms and fish that spend a short period of their lifecycle in the pelagic stage before settling on the benthos. Important groups within this category include the larvae of starfish and sea urchins, crabs and lobsters and some fish /11/.

5.7 Benthic communities

5.7.1 Benthic flora

Macrophytes (macroalgae and higher plants) grow in conditions that feature exceptionally diverse and dynamic light regimes. The water clarity and hydrodynamic conditions have profound effects on the quantity and quality of the light available for marine plants at specific localities, thus directly influencing the biomass and species composition of the benthic communities in the North Sea. The depth of the photic zone for benthic plants is traditionally defined as the depth where 1 % of the surface irradiance is available for photosynthesis /10/.

The water depth at the TYRA project and in its vicinity is approximately 40 m (64 m at Svend). At this depth, it is highly unlikely that any macrophytes are to be found.

5.7.2 Benthic fauna

The benthic fauna consists of epifauna and infauna (organisms living on or in the seabed, respectively) such as crustaceans, molluscs, annelids, echinoderms.

The 50 m, 100 m, and 200 m depth contours broadly define the boundaries between the main benthic communities in the North Sea, with local community structure further modified by sediment type /13//14/. Descriptions of the spatial distribution of infaunal and epifaunal invertebrates show that the diversity of infauna and epifauna is lower in the southern North Sea than in the central and northern North Sea. Epifaunal communities are dominated by free-living species in the south and sessile species in the north. Large-scale spatial gradients in biomass are less pronounced /15/.

Biological monitoring in May 2009 in the TYRA project area recorded a total of 82 species in 154 samples collected around the Tyra E platform and reference stations. With respect to species richness the benthic fauna was dominated by polychaetes followed by crustaceans, bivalve and other taxonomic groups (sea anemones, phoronids and nemerteans) (/6/).

Polychaetes accounted for 46% of the benthic abundance, crustaceans for 22%, other taxa, for 12% and echinoderms for 11%. Bivalves and gastropods contributed with 6% and 3%, respectively, of the abundance. Bivalves were the most important component of the benthic biomass (42%), followed by echinoderms (29%) and crustaceans (21%).

Table 5-1 Composition of the benthic fauna around Tyra E in May 2009 /6/.

Taxonomic group	Number of species*		Abundance		Biomass	
	2.2 m^{-2}	%	ind.m^{-2}	%	$gDWm^{-2}$	%
Polychaeta	31	38	281	46.3	1.3	5.4
Bivalvia	13	16	36	5.9	10.4	42.4
Gastropoda	5	6	20	3.3	0.18	0.7
Crustacea	18	22	133	21.8	5.2	21.1
Echinodermata	7	9	64	10.6	7.0	28.5
Other taxa	8	10	73	12.0	0.42	1.8
Total	**82**	**100**	**607**	**100**	**24.4**	**100**

* Sum of species in the 154 samples collected (143 cm^2 each = 2.2 m^2)

Figure 5-5 shows benthic fauna in the North Sea by indicator species. The TYRA area is classified by the to indicator species *Ophelia borealis* and *Nephtys longosetosa* (both polychates).

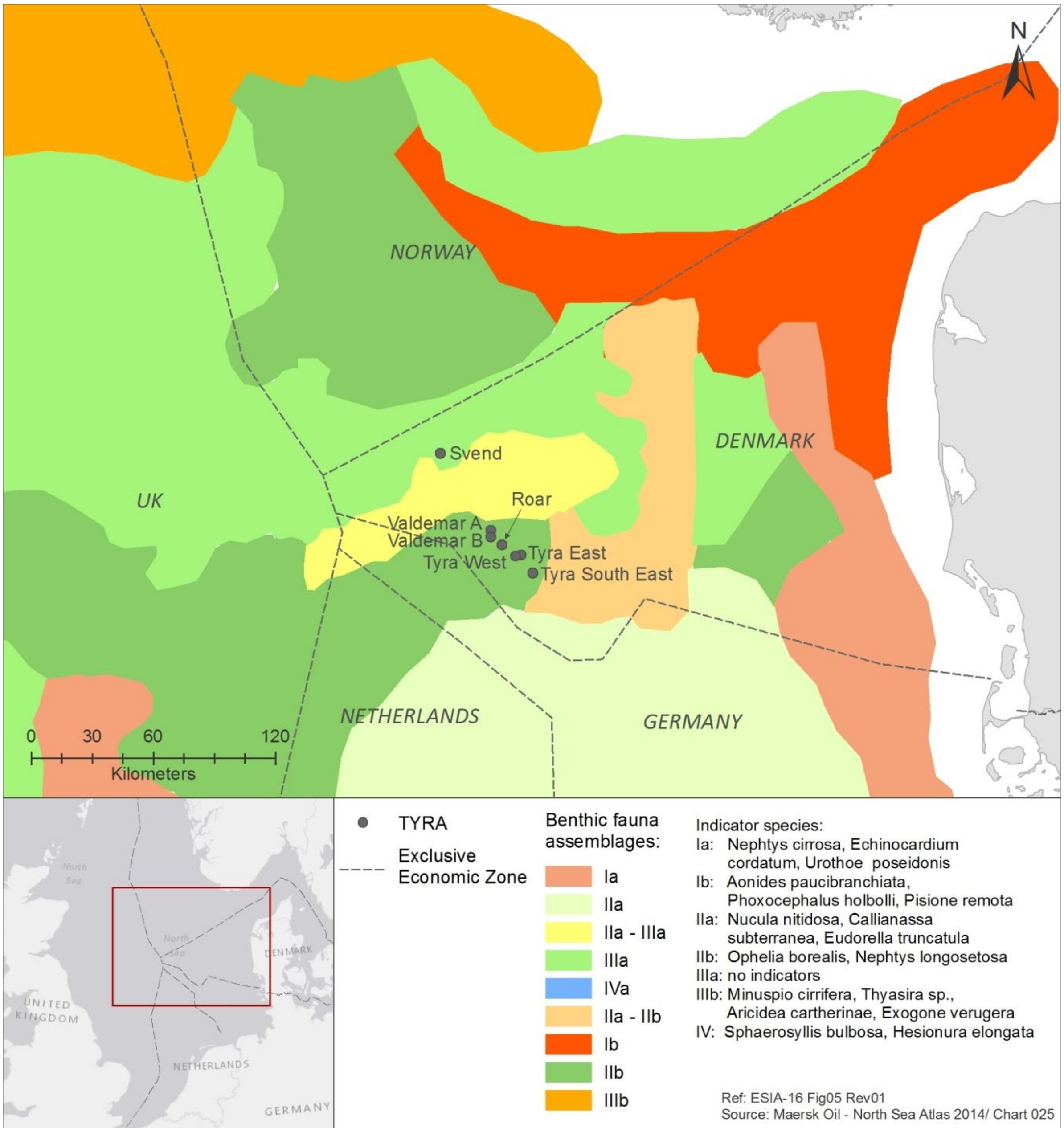


Figure 5-5 Assemblages of the benthic fauna in the North Sea. Figure redrawn from North Sea Atlas /3/.

5.8 Fish

Approximately 230 species of fish are found the North Sea. Fish species diversity is low in the shallow southern North Sea and eastern Channel and increases westwards. Species diversity is also generally higher close to shore as the habitat diversity increases. Most of the variability of the fish stocks is due to variation in egg and larval survival which is thought to be regulated by a number of factors, such as sea temperature and currents affecting larval drift to nursery grounds, as well as density-dependent predation on the eggs and larvae. Annual variability in recruitment of juveniles can differ by a factor of 5 for plaice, 50 for sole and more than 100 for haddock. Most species show annual or inter-annual movements related to feeding and spawning /10/.

A fish survey was carried out in the period from November 2002 to July 2003 at the Halfdan platform located about 25 km from the TYRA project (Tyra East and Tyra West). A total of 16 species of fish were registered: Eight pelagic or semi-pelagic (Atlantic horse mackerel, Atlantic mackerel, cod, grey gurnard, herring, sandeel, sprat, whiting), and eight benthic species (American plaice, common dab, common dragonet, European plaice, haddock, hooknose/armed bullhead, lemon sole, lumpfish) /19/.

The dominating species were: sprat, herring, whiting, grey gurnard, Atlantic horse mackerel, Atlantic mackerel, common dab, American plaice and European plaice. Herring and sprat were registered during autumn, whereas Atlantic horse mackerel and Atlantic mackerel were registered in the summer period. Common dab, American plaice and grey gurnard were registered all time of the year.

The abundance of fish in the central North Sea is relatively low in comparison to other parts of the North Sea. The fish fauna is characterised by common dab, grey gurnard and whiting /150/.

The biology of the dominating species registered in the area is described in Table 5-2.

Table 5-2 Distribution and biology of the dominating species registered in the area /23//24/. Further information on spawning areas and catch are presented for selected species in /3/.

Species	Distribution and biology
Atlantic horse mackerel *(Trachurus trachurus)*	Horse mackerel has a restricted distribution during summer, with the greatest densities in the south-eastern North Sea and adults also being found along the shelf edge in the northern North Sea. The species is notably absent from the central North Sea. Juvenile horse mackerel are pelagic feeders that prey on planktonic organisms. Larger individuals feed on small fish (e.g. herring, cod and whiting). Peak spawning in the North Sea falls in May and June. Spawning occurs off the coasts of Belgium, the Netherlands, Germany, and Denmark.
American plaice *(Hippoglossoides platessoides)*	American plaice can be found throughout the North Sea. It prefers soft bottoms. Larvae feed on plankton, diatoms and copepods. Preferred food items for larger fish incudes sea urchins, brittle stars, polychaetes, crustaceans and small fish. Spawning takes place during spring at 100-200 meter depth.
Atlantic mackerel *(Scomber scombrus)*	Mackerel are widespread throughout the North Sea. Mackerel feed on a variety of pelagic crustaceans and small fish. In the North Sea, mackerel overwinter in deep water along the edge of the continental shelf and, in the spring, adult mackerel migrate south to the spawning areas in the central North Sea with extensions along the southern coast of Norway and in the Skagerrak. Spawning takes place between May and July.
Common dab *(Limanda limanda)*	Dab is a demersal fish. It lives on sandy bottoms down to depths of about 150 metres. Preferred food items incudes sea urchins, brittle stars, polychaetes, crustaceans, mussels and small fish. In the North Sea spawning takes place between April and June.
European plaice *(Pleuronectes platessa)*	European plaice has a preference for sandy sediments although older age groups may be found on coarser sand. During summer juvenile plaice are concentrated in the Southern and German Bights and also occur along the east coast of Britain and in the Skagerrak and Kattegat. Juveniles are found at lower densities in the central North Sea and are virtually absent from the north-eastern part. Plaice is an opportunistic species which primarily forage on molluscs and polychaetes. Plaice spawns in winter from January to March. Spawning areas occur in the central part of the North Sea and in the English Channel.

Species	Distribution and biology
Grey gurnard *(Eutrigla gurnardus)*	Grey gurnard occurs throughout the North Sea. Most common on sandy bottoms, but also on mud, shell and rocky bottoms. During winter, grey gurnards are concentrated to the northwest of the Dogger Bank at depths of 50-100 m, while densities are low in areas off the Danish coast, and in the German Bight and eastern part of the Southern Bight. Juveniles feed on a variety of small crustaceans. The diet of older specimens mainly consists of larger crustaceans and small fish. The distribution maps indicate a marked seasonal northwest-southeast migration pattern that is rather unusual. The population is concentrated in the central western North Sea during winter and spreads into the southeastern part during spring to spawn. In the northern North Sea, such shifts appear to be absent. Spawning takes place in spring and summer.
Herring *(Clupea harengus)*	Within the North Sea herring may be found everywhere. The pelagic larvae feed on copepods and other small planktonic organisms while juvenile mainly feeds on Calanoid copepods but euphausids, hyperiid amphipods, juvenile sandeels and fish eggs are also eaten. Larger herring also consuming predominantly copepods with small fish, arrow worms and ctenophores as an aside. 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 western areas of the North Sea. Herring is a demersal spawner on relatively shallow water depositing sticky eggs on coarse sand, gravel, shells and small stones. The fish congregate on traditional spawning grounds, many of which are on shoals and banks and in relatively shallow water.
Sprat *(Sprattus Sprattus)*	Sprat is most abundant south of the Dogger Bank and in the Kattegat. Larvae feed on diatoms, copepods and crustacean larvae. After metamorphosis larger planktonic organisms are also eaten. Spawning occurs in both coastal and offshore waters during spring and late summer, with peak spawning between May and June.
Whiting (*Merlangius merlangus)*	High densities of both small and large whiting may be found almost everywhere throughout the North Sea. The species is typically found near the bottom in waters at 10 to 200 m depth. 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 takes place from January in the southern North Sea to July in the northern part.

There are two main forms of spawning: Demersal and pelagic spawning.

Demersal spawners lay their eggs on the seafloor, algae or boulders. The preferred habitat for demersal spawners is species specific.

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 move 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. current, wind and temperature.

A fish survey was carried out in the period from November 2002 to July 2003 at the Halfdan platform located about 25 km from the TYRA project area (Tyra East and Tyra West). Fish eggs from the following 13 species were registred: Common dab, European plaice, American plaice, cod, lemon sole, Atlantic mackerel, whiting, turbot, greater weever, grey gurnard, Mediterranean scaldfish, Arctic rockling and common dragonet /19/. Since Halfdan and the TYRA project is relatively near each other (25 km) it is likely that these species also spawn at the TYRA project.

The TYRA project is in an area designated as a relatively important spawning ground for cod and whiting. Mackrel and plaice are also know to be spawning in the area (Figure 5-6), but it does not seem to be an important spawning and nursery area for other commercial species /3//22/.

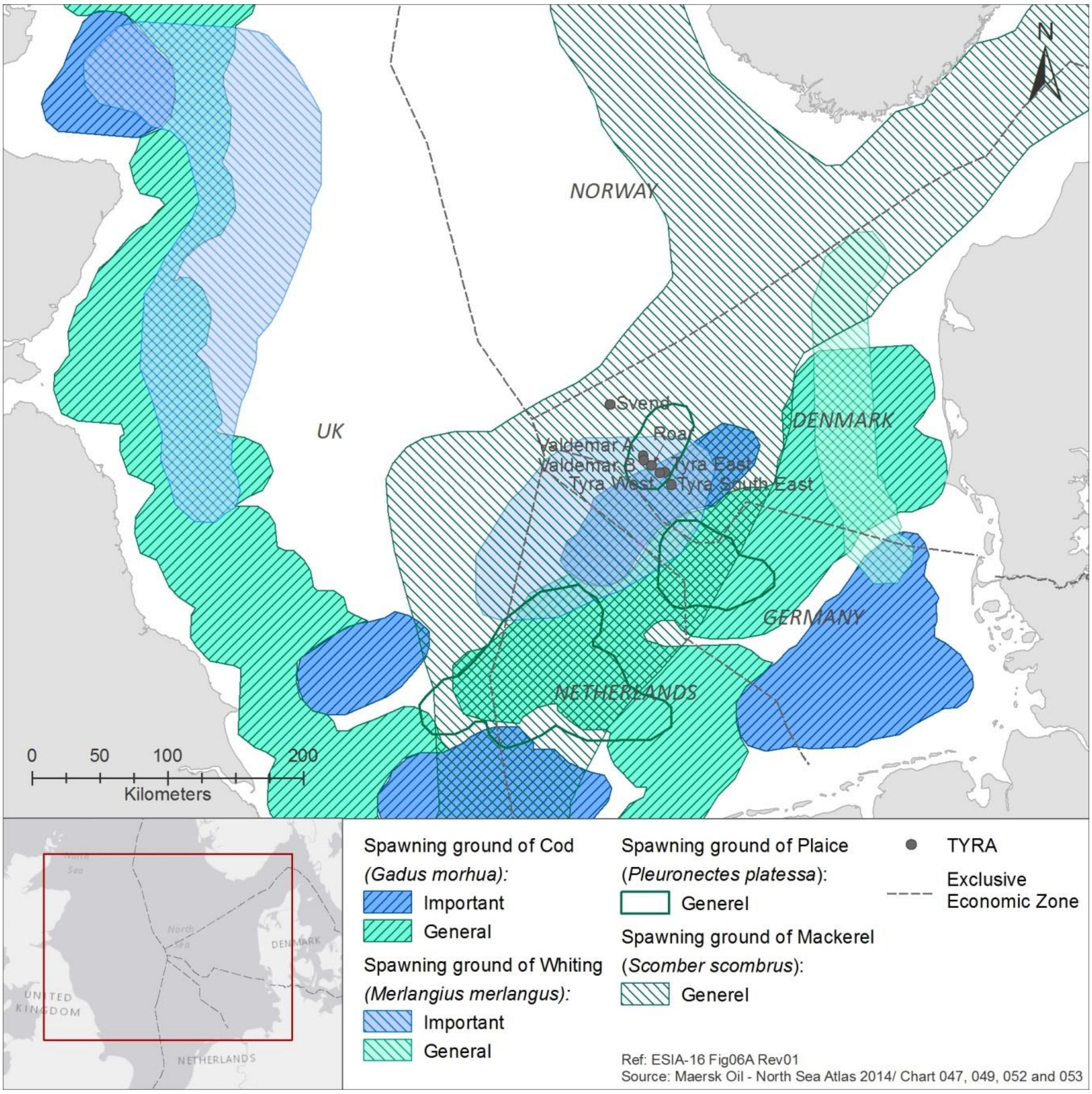


Figure 5-6 Spawning grounds for cod, whiting, mackerel and plaice in the North Sea. Figure redrawn from North Sea Atlas /3/.

5.9 Marine Mammals

Harbour seal, grey seal, white-beaked dolphin, minke whale and harbour porpoise are the most common marine mammals in the North Sea /28/. The distribution and biology of these species as well as their habitat preference are described in Table 5-3.

Table 5-3 Distribution and biology of the most common marine mammals; harbour seal, grey seal, harbour porpoise and white-beaked dolphin /30//31//32//33//40/.

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 /30/.
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 /32/.
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 /33/. Two white-beaked dolphins were observed during aerial surveys in the Southern Maersk area in March 2008. No animals have been registered by acoustic monitoring, and the species is considered uncommon in the Southern Maersk area /40/.
Harbour porpoise (*Phocoena phocoena*)	Harbour porpoise 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 /31/. Harbour porpoise is the most common whale species in the North Sea, and the only marine mammal which frequently occurs in the Maersk Oil area /40/. They are mostly found in the eastern, western and southern parts of the North Sea, and generally found in low densities in the central part of the North Sea (Figure 5-7). The TYRA project area is not of particular importance to harbour porpoise, and few individuals are observed. Aerial surveys in the Southern Maersk area in May show densities of 0.25-0.4 harbour porpoises/km^2 near the platforms, and few animals in autumn. However, acoustic monitoring show high activity in autumn /40/. A recent study at the Dan platform /139/ showed that harbour porpoises are present around the platform all year with the highest echolocation activity during fall and winter.
Minke whale (*Balaenoptera acutorostrata*)	The minke whale is a cosmopolitan species found in all oceans and in virtually all latitudes, including the Northeast Atlantic. Minke whale occurs in both coastal and offshore waters and preys on a variety of species in different areas. Less than 0.025 animlas/km2 is expected in the central North Sea /33/

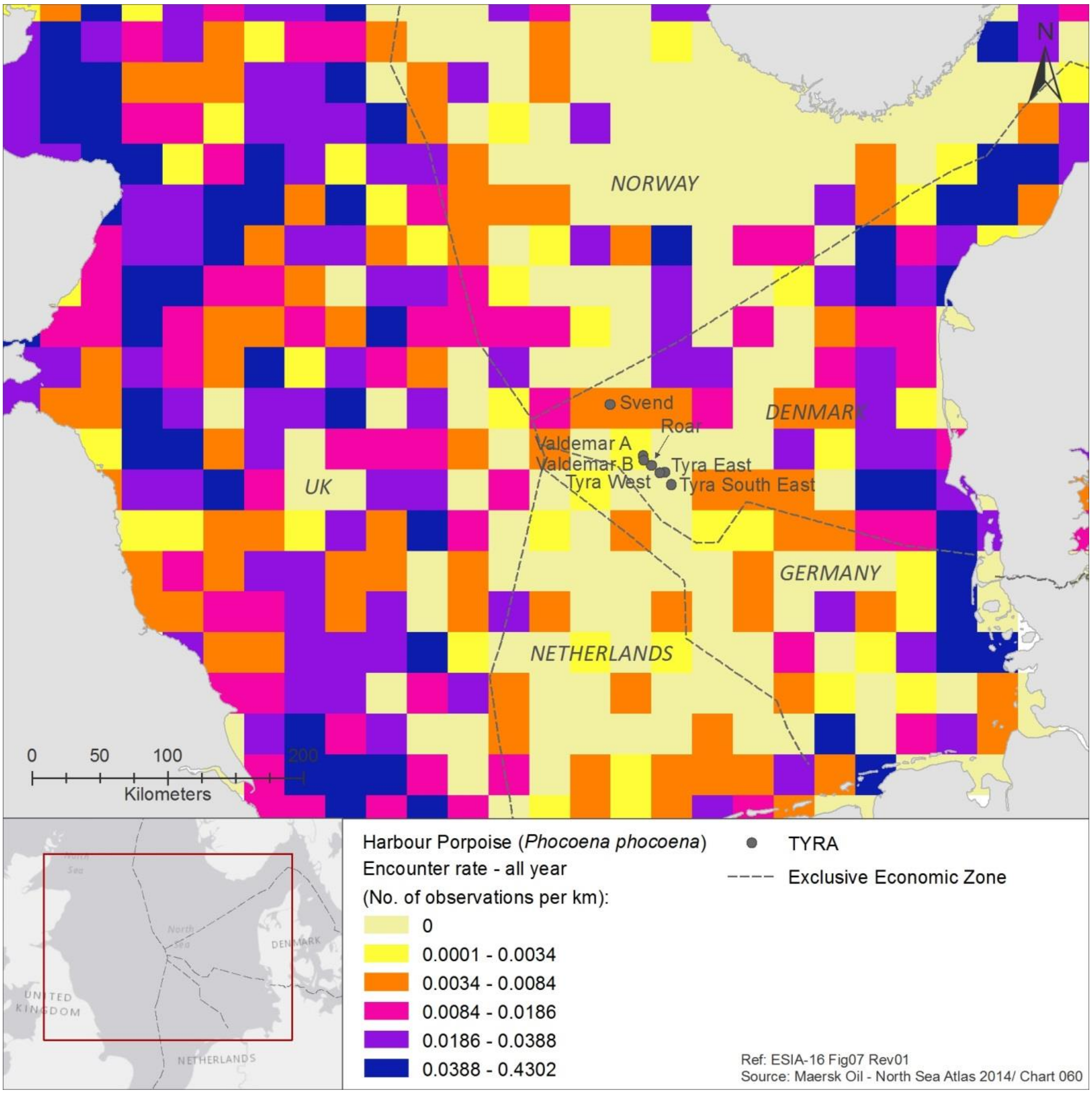


Figure 5-7 Distribution of harbour porpoise in the North Sea. Figure redrawn from North Sea Atlas /3/.

The periods where the animals may be vulnerable to disturbance are related to the reproductive cycle (Table 5-3). The reproductive cycle of seals is primarily on land, while harbour porpoise is at sea.

Table 5-4 Time of year where animals are breeding (B), moulting (M) or mating (A). No data available for the other species.

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

5.10 Seabirds

Seabirds spends most of their life at sea but breed on rocky coasts and cliffs. In the North Sea region, common seabirds include fulmars, gannets and auk species, kittiwakes and skuas.

The spatial distribution of the key species of seabirds is summarized in Table 5-5, based on the distribution presented in the North Sea Atlas /3/ and a three-year aerial seabird monitoring survey in 2006-2008 covering the the TYRA project area /40/.

Table 5-5 Spatial distribution of key species /3//40/.

Species	Spatial distribution and biology in the North Sea
Red and black-throated diver (*Gavia stellata, G. arctica*)	The two species, which are sensitive to oil pollution due to their pursuit-diving behaviour and low fecundity rate, are non-breeding visitors to the North Sea. Their sensitivity to oil pollution increases during October-November (Red-throated) and March-April (Black-throated) when the birds are undergoing moult of their flight feathers. In spring, the highest densities of red- and black-throated divers are found along the coast of Denmark, in the Wadden Sea and in the English Channel. In winter, the distribution is more restricted and the highest densities are found along the coast of Denmark and northern part of the shallow area off the Wadden Sea. Almost all birds are found in waters of riverine influence shallower than 35 m, and both species are rare (0 birds/km^2) in the TYRA project area /3/, with few observations during the aerial survey /40/.
Northern fulmar (*Fulmarus glacialis*)	The species is the most abundant seabird in the North Sea. In summer, relatively high densities of Northern fulmar are found at many locations throughout the North Sea with the peak densities located along the southern edge of the Norwegian Trench. In winter, the highest densities are found west of Norway and northwest of Jutland Bank. In the southern part of the North Sea Northern Fulmars are found in lower densities in winter than during summer. In the TYRA project area, Northern Fulmar occurs at relatively high densities (up to 24 birds/km^2 /40/ or up to 10 birds/km^2 /3/).
Northern gannet (*Morus bassanus*)	Northern gannets are found in high densities east and north of the UK from spring to autumn. In late summer-autumn high density areas are also found near the German and Dutch coasts. In winter, the northern gannet is patchily distributed and found at low to high densities throughout the North Sea. In the TYRA project area, northern gannets occur mainly in low densities (< 0.5 birds/km^2) all year round /3//40/, but relatively high densities (up to 23 birds/km^2) were observed during autumn /40/.
Great skua (*Stercorarius skua*)	Great skua occurs in low densities from northeast of Greater Fisher Bank to the Norwegian Trench, north of the UK coast, and in few small isolated patches. Unlike in spring-summer, the great skua occurs over much of the North Sea during late summer-autumn. In the TYRA project area, the species occurs in low densities (0-0.1 birds/km^2 /3/), with few observations during the aerial surveys /40/.
Common gull (*Larus canus*)	The common gull is not observed over much of the North Sea, but with intermediate to high densities along the eastern part of the North Sea (e.g. Wadden Sea, German Bight, Jutland Bank, and some isolated patches bordering the eastern UK coast). In the TYRA project area, the species is rare (0 birds/km^2 /3/).
Lesser black-backed gull (*Larus fuscus*)	Lesser black-backed gulls are largely absent from much of the central and north-western parts of the North Sea, and are concentrated mostly in the eastern parts of the North Sea. In the TYRA project area, the species occurs in low densities (0 birds/km^2 /3/).
Herring gull (*Larus argentatus*)	The herring gull occurs throughout most of the coastal areas in the eastern North Sea, particularly around Norway and in Skagerrak. Relatively high densities are found in the German Bight, off the coast of the Netherlands, and in winter also in areas further offshore like areas around Dogger Bank: Both the distribution and the abundance of herring gulls seem mainly to be determined by working trawlers. The species is rare in the TYRA project areas (0 birds/km^2 /3/).

Species	Spatial distribution and biology in the North Sea
Great black-backed gull (*Larus marinus*)	The distribution and the abundance of great black-backed gull in the activity areas seems mainly to be determined by working trawlers. The species is common throughout the North Sea during winter, and the highest densities are found south and west of the Dogger Bank. In the TYRA project area, the species is rare (0 birds/km^2 /3/) .
Black-legged Kittiwake (*Rissa tridactyla*)	In summer, the species is concentrated primarily in the western North Sea. Outside the breeding season, the species occurs throughout the North Sea with widespread intermiate to high density areas. Most extensive concentrations are found along the southern edges of the Norwegian Trench, northwest of Dogger Bank, off Borkum and in the Channel. In the TYRA project area, the species is found in intermiate density (0–5 birds/km^2 /3//40/), and in spring and autumn large flocks are observed /40/.
Sandwich tern (*Sterna sandvicensis*)	The species is mainly distributed in coastal waters on both sides of the North Sea. In spring highest densities are found off the German coast and the Netherlands. In summer-autumn highest densities are shown off the British coast just north of the Wash. In the TYRA project area, the species is rare (0 birds/km^2 /3/), and the few observations during the aerial surveys confirm the low densities /40/
Common tern (*Sterna hirundo*)	The species is absent throughout most of the offshore parts of the North Sea. In spring highest densities are found off the northern German coast and the Netherlands. In late summer highest densities are found off the Danish coast and the Netherlands. In the TYRA project area, the species is rare (0 birds/km^2 /3/), and the few observations during the aerial surveys confirm the low densities /40/
Common guillemot (*Uria aalge*)	The common guillemot is the second most abundant seabird in the North Sea. In early summer, high densities are found in the western parts, whereas the species is found in lower densities in other parts of the North Sea. In late summer, the species occurs in high densities in the central and eastern parts as they move across the North Sea to moulting areas south of the Norwegian Trench. The species is very sensitive to oil pollution due to its pursuit diving behaviour, and during August and September both the adults and the accompanying young are flightless, and hence highly sensitive to pollution. As seen for many other species of seabirds, the highest numbers in the activity areas seem to be associated with the areas of lowest water depth. In the TYRA project areas, the species occurs in interediate densities (0-5 birds/km^2) /3/.
Razorbill (*Alca torda*)	In early and late summer, the razorbill is largely absent in most of the North Sea and the birds are concentrated in its western part. Higher densities are observed in late- than in early-summer. The razorbill is largely absent in most of the northern and central North Sea in winter when most birds are found in the Skagerrak and Kattegat and off the coasts of the UK and NL. In the TYRA project area, the species is found in densities of up to 2.5 birds/km^2
Little auk (*Alle alle*)	The little auk is concentrated along the Norwegian Trench and NW of Dogger Bank during winter, and the species occurs in intermediate densities (<5 birds/km^2 /3/) in the TYRA project area.

The four species of gulls (common gull, lesser black-backed gull, herring gull, great black-backed gull) are presented as rare (0 birds/km^2) /3/. However, aerial surveys show frequent observations and density estimates for gulls range up to 11 gulls/km^2, with the highest densities in autumn /40/.

5.10.1 International Bird Areas (IBAs)

Important Bird Areas (IBAs) are key sites for future conservation. A site is recognised as an IBA only if it meets certain criteria, based on the occurrence of key bird species that are vulnerable to global extinction or whose populations are otherwise irreplaceable. The Wadden Sea (in Dutch, German and Danish waters) and Skagerrak/Southwest Norwegian trench are both recognised as important areas for birds, more than 100 km from the TYRA project. There are no IBAs in the central North Sea /34/.

5.11 Cultural heritage

Cultural heritage in the North Sea includes submerged prehistoric sites that were once land, other coastal features such as early fish-traps, submerged structures from defending coast in the World Wars, and shipwrecks from all ages. Part of the seabed of the North Sea is submerged land, and quite a number of villages in the Southern Bight have been submerged by the sea.

5.12 Protected areas

Protected areas are shown in Figure 5-8. Protected areas include Natura 2000 sites, Ramsar sites, UNESCO world heritage sites and nationally designated areas.

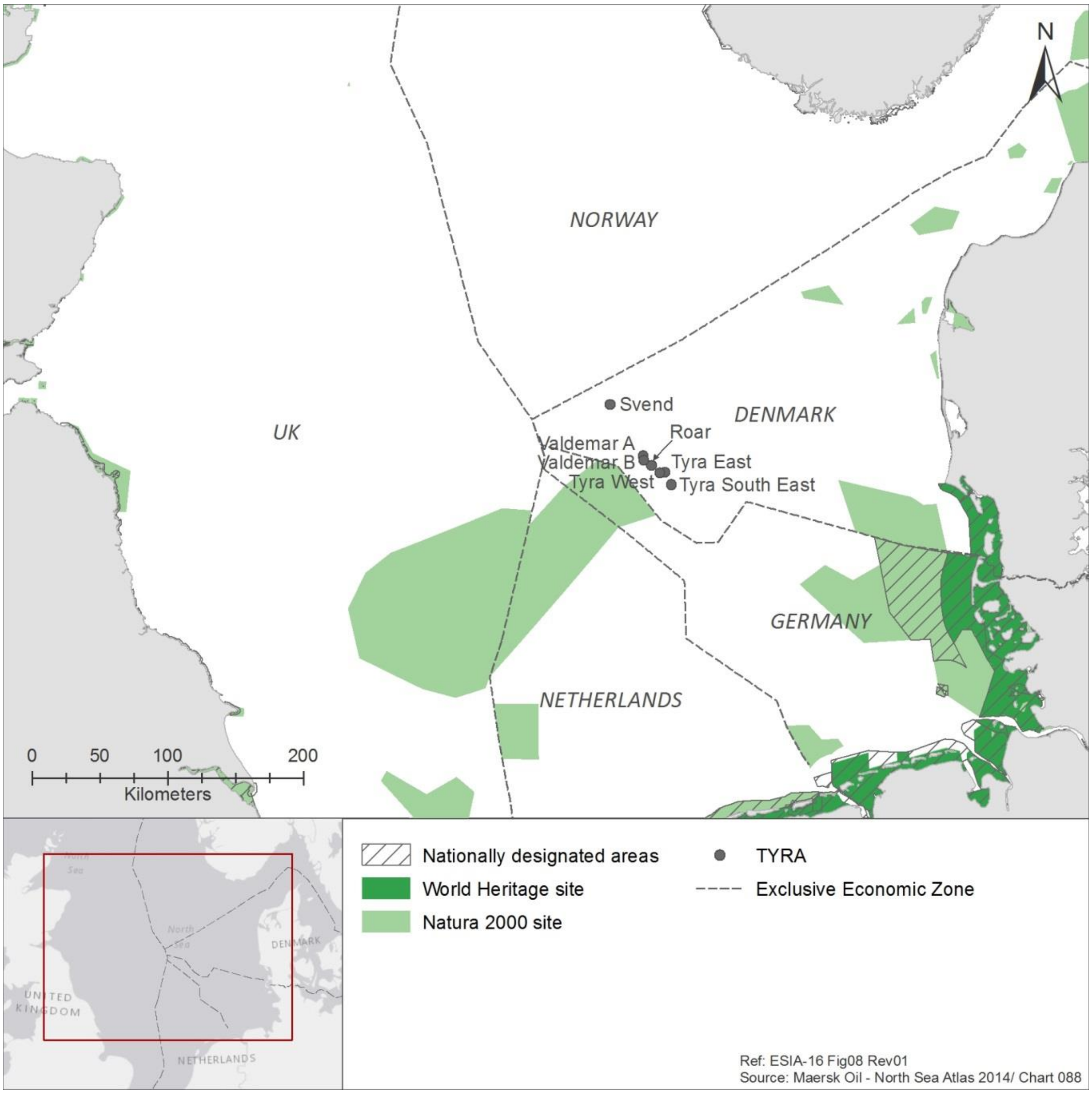


Figure 5-8 Protected areas. Figure redrawn from North Sea Atlas /3/.

5.12.1 Natura 2000 sites

The Natura 2000 network comprises:

- Habitats Directive Sites (Sites of Community Importance and Special Areas of Conservation) designated by Member States for the conservation of habitat types and animal and plant species listed in the Habitats Directive
- Bird Directive Sites (Special Protection Areas) for the conservation of bird species listed in the Birds Directive as well as migratory birds

Natura 2000 sites have been designated in the central North Sea for Dogger Banke in UK, the Netherlands and Germany (Figure 5-8). The basis for designation is presented in section 10.

5.12.2 Ramsar sites

Ramsar sites are wetlands of international importance, and are present in coastal areas of the North Sea. The Ramsar Convention requires Contracting Parties to 'formulate and implement their planning so as to promote the conservation of the wetlands included in the List, and as far as possible the wise use of wetlands in their territory' (article 3.1).

All Ramsar sites in the Danish sector of the North Sea are also designated Natura 2000 areas.

5.12.3 UNESCO world heritage sites

The Wadden Sea in Denmark, Germany and the Netherlands have been appointed UNESCO world heritage site (Figure 5-8).

The Wadden Sea is the largest unbroken system of intertidal sand and mud flats in the world. It is a large, temperate, relatively flat coastal wetland environment, formed by the intricate interactions between physical and biological factors that have given rise to a multitude of transitional habitats with tidal channels, sandy shoals, seagrass meadows, mussel beds, sandbars, mudflats, salt marshes, estuaries, beaches and dunes. The area provide a habitat for numerous plant and animal species.

5.12.4 Nationally designated areas

In Denmark, the Wadden Sea is designated as a national park. In addition, several nature reserves ("natur- og vildtreservat") have been appointed in Denmark along the west coast of Jutland, several inshore nature reserves (e.g. Nissum Fjord and Ringkøbing Fjord) (Figure 5-8).

5.13 Marine spatial use

The TYRA project is not in an area with important shipping routes for the largest ships equipped with automatic identification systems (Figure 5-9, < approximately 100 per year) /3/.

The infrastructure of oil and gas and wind includes both existing and planned installations. In the North Sea, a number of oil and gas facilities are operational, and additional facilities are planned. Operational wind farms are only present in Danish waters off Esbjerg, while a number of wind farms are planned in UK and German waters. Pipelines and cables connecting platforms are not shown in the figure, but should also be considered when planning new projects.

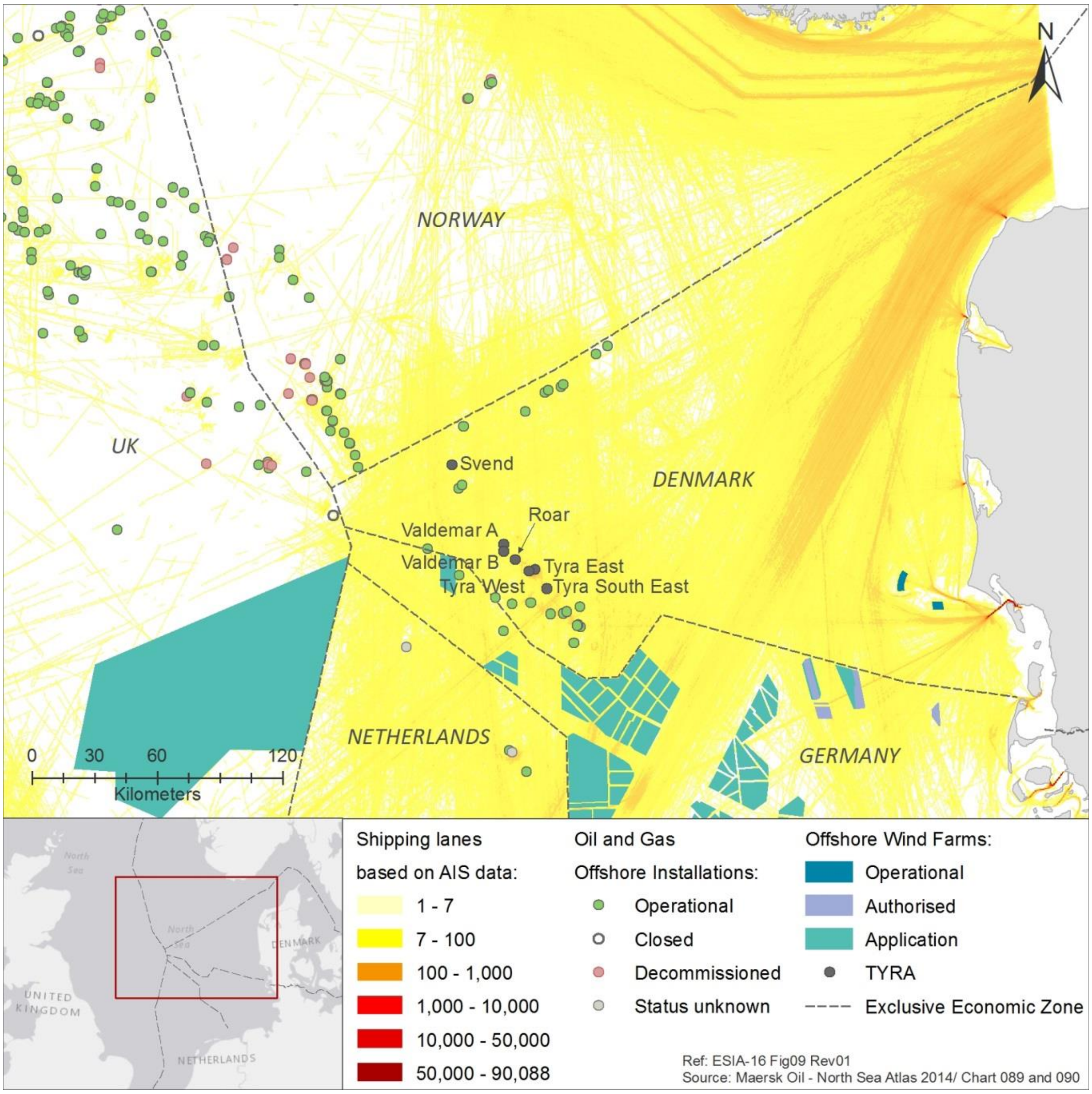


Figure 5-9 Ship traffic and infrastructure in 2012. Figure redrawn from North Sea Atlas /3/. Ship traffic is based on all ships fitted with AIS system i.e. ships of more than 300 gross tonnage engaged on international voyages, and cargo ships of more than500 gross tonnage not engaged on international voyages and all passengers ships irrespective of size. Missing data in the middle of the North Sea is due to poor AIS receiving coverage and not lack of ships. Germany does not participate in the North Sea AIS data sharing program.

Further spatial restrictions include military areas, dump sites and reclamation areas. Dump sites and reclamation areas are mainly located at a relatively short distance from the coast, and are not present in the central North Sea. Military uses constitute a small part of the sea-borne and coastal activities around the North Sea. There are extensive exercise areas, mainly in the United Kingdom, but also along the west coast of Jutland (Denmark).

5.14 Fishery

Fishery is an important industry in the North Sea. The main targets of major commercial fisheries are cod, haddock, whiting, saithe, plaice, sole, mackerel, herring, Norway pout, sprat, sandeel, Norway lobster, and deep-water prawn. Norway pout, sprat and sandeel are predominantly the targets of industrial fisheries for fish meal and oil, while other species are the targets of fisheries for direct human consumption /10/.

A historic overview of production, trade, employment and fleet size for fishery in Denmark is provided in Table 5-6 /36/.

Table 5-6 Historic overview of production, trade, employment and fleet for fishery in Denmark /36/.

	1990	2000	2010
Production (thousand tonnes)			
Inland	36	37	23
Marine	1482	1541	840
• Aquaculture	42	44	35
• Capture	1476	1534	828
Total	1518	1578	863
Trade (USD million)			
Import	1116	1806	2958
Export	2166	2756	4140
Employment (thousands)			
Aquaculture	0	0.8	0.4
Capture	6.9	4.6	2.4
Total	6.9	5.4	2.9
Fleet (thousands)			
Total	3.8	4.1	2.8

Landings of sandeel, European plaice, herring, cod, sprat and Norway pout are presented in the North Sea Atlas /3/. The landings are presented for one year (2013), and show that the central North Sea, including the TYRA project area, has some importance to the Danish fishery for sandeel. In addition, some fishery takes place in the central North Sea, in particular for cod, sprat and European plaice.

As inter-annual variation can be significant, fishery data for a period of ten years have been extracted from the Danish AgriFish Agency /37/. The data has been extracted for Danish vessels for area IVB, which covers an area of 280,000 km^2 from the west coast of Jutland to the Eastern coast of the UK.

Estimated value for the landing from Danish vessels in the North Sea for the last ten years shows that the area IVB, where the TYRA project is located, is important for the fishing industry (Table 5-7) /37/.

Table 5-7 Total landings and value of fishery, as landed catch for important commercial species in the central North Sea (area IVB) /37/.

	Overall		Species-species landed catch (tonnes)			
	Total landed catch (tonnes)	Total value (DKK)	Sandeel	Cod	Sprat	European plaice
2005	405,067	824,527,622	129,776	4,365	233,306	9,382
2006	376,174	894,837,171	239,144	3,556	97,208	9,721
2007	239,469	700,252,302	142,309	2,317	64,047	6,918
2008	320,488	696,990,031	231,321	2,596	62,680	6,854
2009	409,143	652,075,835	272,865	2,792	110,650	6,827
2010	344,744	858,381,192	250,676	3,359	68,827	7,837
2011	388,927	990,124,457	263,971	2,736	98,484	9,932
2012	160,556	746,792,906	47,439	2,547	70,907	9,557
2013	263,373	875,992,562	183,330	1,917	46,258	10,707
2014	328,063	855,349,857	147,963	2,712	135,366	9,551

5.15 Tourism

Tourism is a multi-disciplinary feature, and includes both traditional tourism such as hospitality as well as events within conferences, music and sports. Tourists in Denmark are primarily Danish and German, and to a minor extent tourists from Sweden, Norway and the Netherlands.

Based on recent report with 2012 data from VisitDenmark /38/, tourism creates 122,500 FTEE (full time employee equivalent), which corresponds to ~4 % of the total FTEE in Denmark. These jobs are typically within hospitality, transport and trade. Tourism creates a direct economic added value of 24 billion DKK.

Tourism is associated with land and the coast, and no tourism is present in the central North Sea.

5.16 Employment

According to Statistics Denmark /39/, the largest employment sectors in 2013 are the public sector and trade/transport.

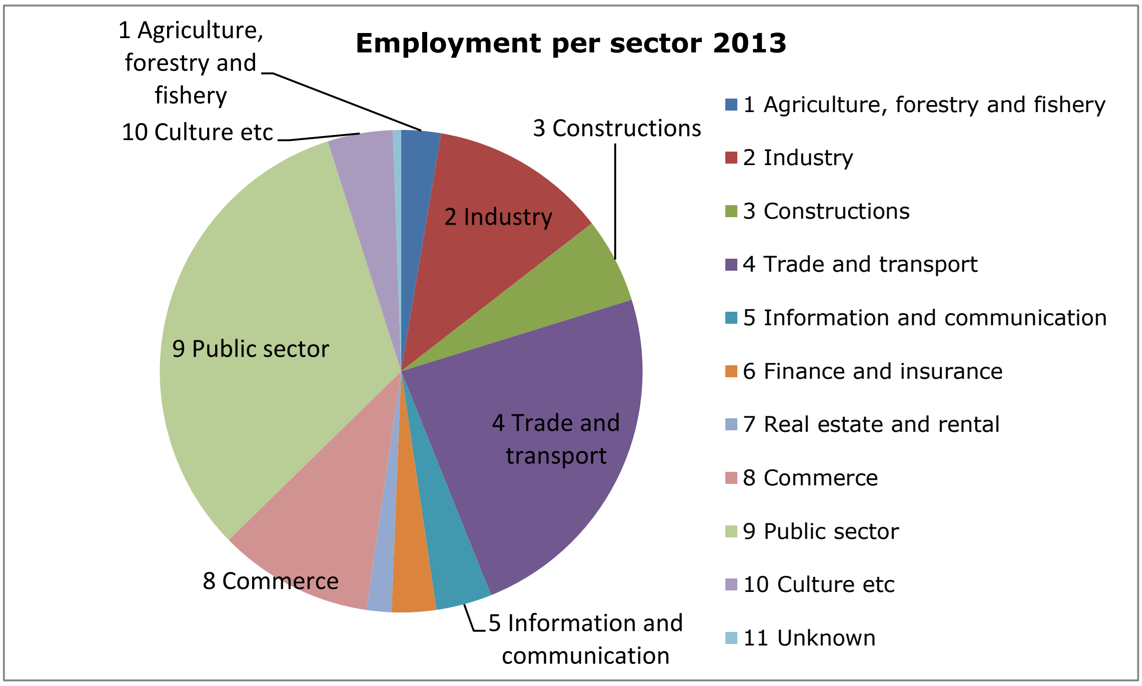


Figure 5-10 Employment per sector in Denmark in 2013 /39/.

Oil and gas activities in the North Sea create a significant number of workplaces both on-and offshore /35/. The oil and gas sector employs approx. 15,000 persons in Denmark /53/. Of these, approx. 1,700 employees are directly employed at the oil companies. This means that when one employee is employed in the oil and gas companies, approx. 8 jobs are created in related industries. A large part of the indirect activities lies in e.g. the engineering consultancy and other consulting assistance. Employment in the sector ranges widely across types of job, but generally a high level of education is seen and approx. 60% of the jobs are located around Esbjerg.

5.17 Tax revenue

Tax revenue and the profits made by the oil and gas sector have a positive impact on the danish economy. The state's total revenue is estimated to range from DKK 20 to DKK 25 billion per year for the period from 2014 to 2018 /35/.

The sector's impact in relation to taxes and dues are also substantial, as is the business sector, which by far contributes the largest share of taxes and dues. In 2010, the total contribution of direct taxes and dues was approx. DKK 24 billion /53/.

5.18 Oil and gas dependency

Denmark has been supplied with gas from its North Sea fields since the 1980s and has also exported natural gas, primarily to Sweden and Germany. This production has significantly impacted the security of supply and balance of trade. Denmark is expected to continue being a net exporter of natural gas up to and including 2025 and Maersk Oil has license to operate until 2042 /35/.

As part of a long-term Danish energy strategy, the oil and gas production is instrumental in maintaining high security of supply, at the same time as renewable energy represents an increasing share of the Danish energy mix /53/.

6. IMPACT ASSESSMENT: PLANNED ACTIVITIES

6.1 Impact mechanisms and relevant receptors

6.1.1 Potential impact mechanisms

Potential impact mechanisms associated with the planned activities at the TYRA project are summarised based on the project description (section 3) and the technical sections (appendix 1).

Potential impact mechanisms include:

- Underwater noise
- Physical disturbance of seabed
- Suspended sediment
- Discharges (physical and chemical)
- Solid waste
- Emissions
- Light
- Resource use
- Restricted zones
- Employment and tax revenue
- Oil and gas dependency

The source of the potential impact mechanisms is provided in Table 6-1. The sources of impacts are related to the activities described in the seven technical sections (appendix 1).

Table 6-1 Sources of potential impact mechanisms for the TYRA project. "X" marks relevance, while "0" marks no relevance.

Potential impact mechanism	Sesimic	Pipelines and structures	Production	Drilling	Well stimulation	Transport	Decommissioning
Underwater noise	X	X	X	X	X	X	X
Physical disturbance of seabed	X	X	0	X	0	0	X
Suspended sediment	X	X	0	X	0	0	X
Discharges	X	X	X	X	X	X	X
Solid waste	X	X	X	X	X	X	X
Emissions	X	X	X	X	X	X	X
Light	X	X	X	X	X	X	X
Presence/removal of structures	0	X	X	0	0	0	X
Resource use	X	X	X	X	X	X	X
Restricted zones	X	X	X	X	0	0	X
Employment and tax revenue	X	X	X	X	X	X	X
Oil and gas dependency	X	X	X	X	X	X	X

6.1.2 Relevant receptors (environmental and social)

The relevant environmental and social receptors described in the baseline for the TYRA project are listed below.

- Environmental receptors: Climate and air quality, hydrographic conditions, water quality, sediment type and quality, plankton, benthic communities (flora and fauna), fish, marine mammals, seabirds.
- Social receptors: Cultural heritage, protected areas, marine spatial use, fishery, tourism, employment, tax revenue, oil and gas dependency.

The relevant receptors have been assessed based on the project description (section 3) and the potential impact mechanisms (section 6.1). Relevant receptors for the impact assessment are summarised in Table 6-2.

Table 6-2 Relevant receptors for the impact assessment of planned activities for the TYRA project. "X" marks relevance, while "0" marks no relevance.

	Environmental Receptors									Social Receptors							
Potential impact mechanism – planned activities	**Climate and air quality**	**Hydrographic condition**	**Water quality**	**Sediment type and quality**	**Plankton**	**Benthic communities**	**Fish**	**Marine mammals**	**Seabirds**	**Cultural heritage**	**Protected areas**	**Marine spatial use**	**Fishery**	**Tourism**	**Employment**	**Tax revenue**	**Oil and gas dependency**
Underwater noise	0	0	0	0	X	X	X	X	X	0	0	0	0	0	0	0	0
Physical disturbance of seabed	0	0	0	X	0	X	X	0	X	X	0	0	X	0	0	0	0
Suspended sediment	0	0	X	0	X	X	X	0	X	0	0	0	0	0	0	0	0
Discharges	0	0	X	X	X	X	X	X	X	0	X	0	0	0	0	0	0
Solid waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Emissions	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Light	0	0	0	0	X	0	X	X	X	0	0	0	0	0	0	0	0
Presence/removal of structures	0	X	0	X	0	X	X	X	0	0	0	0	0	0	0	0	0
Resource use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Restricted zones	0	0	0	0	0	0	0	0	0	0	0	X	X	X	0	0	0
Employment and tax revenue	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X	X	0
Oil and gas dependency	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X

6.1.3 Marine strategy frameworks directive - descriptors

The list of receptors and impact mechanisms described in the ESIS can be directly related to the descriptors set within the Marine Strategy Framework Directive (MSFD; section 2.1.5). The MSFD outlines 11 descriptors used to assess the good environmental status of the marine environment. The environmental status of the Danish North Sea waters is described in details in /158/.

1. Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.
2. Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems.
3. 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.
4. 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.
5. Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters.
6. 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.
7. Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.
8. Concentrations of contaminants are at levels not giving rise to pollution effects.
9. Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards.
10. Properties and quantities of marine litter do not cause harm to the coastal and marine environment.
11. Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

The receptors identified in the ESIS are related to the MSFD status indicators hydrography (D7), fish, harbour porpoise and benthic communities (D1, D6). The impact mechanisms for planned activities in the ESIS are related to the MSFD pressure indicators seabed (D6), discharges (D6, D8, D9) and underwater noise (D11). Each impact mechanism is further assessed for the relevant receptors in the following sections 6.2 and 6.3.

6.2 Assessment of potential environmental impacts

Impact assessment for planned activities for each relevant environmental receptor is presented in the following sections.

6.2.1 Climate and air quality

Impacts on climate and air quality relate to atmospheric emissions.

6.2.1.1 Emissions

Emissions have been estimated for the planned activities at the TYRA project, and are presented in Table 6-3 for each of the activities.

Table 6-3 Overview of estimated emissions for planned activities at the TYRA project, provided per activity or per year. The maximum emissions have been used. Estimates have been calculated by Ramboll based on input from Maersk Oil. "-" refers to an emission which has not been quantified.

Activity (frequency)	**Unit** for which estimate is provided (duration)	**Emissions**					
		CO_2 (tonnes)	**NO_x** (tonnes)	**N_2O** (tonnes)	**SO_2** (tonnes)	**CH_4** (tonnes)	**nmVOC** (tonnes)
Seismic							
4D seismic (Every 4 years)	Per survey (~1 month)	3,330	60	0.2	2	0.3	2.5
Site survey (Every year)	Per survey (1 week)	40	0.7	0.003	0.02	0.003	0.03
Borehole seismic (Every year)	Per survey (2 days)	11	0.2	0.001	0.007	0.001	0.01
Pipelines and structures							
New SLIC/STAR structures (8 platforms)	Per platform	3,300	61	0.2	2.1	0.2	2.5
New 4–legged structures (1 platform)	Per platform	3,500	65	0.2	2.2	0.3	2.6
New pipelines (105 km)	Per 1 km pipeline	1170	22	0.1	0.7	0.1	0.9
Drilling							
Drilling (24 free well slots, 106 new wells)	Per well (150 days)	8,450	150	0.6	6	0.6	7
Well test, workover	Not quantified	-	-	-	-	-	-
Well stimulation							
Matrix acid well stimulation (2 per year)	Per well stimulation (2 weeks)	625	12	0.04	0.4	0.05	0.5
Production							
Flaring, fuel, vent	Per year	492,900	1375	34	5	2207	44
Transport							
Vessels, helicopters	Per year*	27.6	0.5	0.002	0.02	0.002	0.03
Decommissioning							
Well abandonment (111 wells)**	per well (20 days)	1,125	20	0.08	0.8	0.08	0.9
Cleaning and removal of structures**	Total for all TYRA project platforms	76,200	1,420	5	48	6	58

* Note that the calculation for vessels and helicopters are assuming 20% for each of the five ESIS projects.
** note that decommissioning only includes existing structures and wells. If new structures are decommissioned, this will lead to emissions corresponding to 150% of the emissions described under pipelines and structures.

Emissions are primarily caused by venting, flaring of gas and the use of fossil fuels for production.

Table 6-4 provides an overview of the estimated annual emissions (from production, well stimulation, transport and seismic), and total emissions for drilling, new structures and decommissioning from the TYRA project, along with the annual Danish emissions 2012.

Table 6-4 Emissions from activities at the TYRA project and national emissions numbers for Denmark /20//21/. "-" refers to an emission which has not been quantified.

Emissions	**Annual Danish emissions 2012** (tonnes)	**Total annual emissions at TYRA (excluding new structures, drilling and ecommissioning)** (tonnes)	**Total emissions for new structures and pipelines at Tyra**	**Total emissions for drilling 130 wells at TYRA** (tonnes)	**Total emissions for decommissioning existing 111 wells and structures at TYRA*** (tonnes)
CO_2	39,412,000	497,550	152,800	1,097,380	201,075
N_2O	-	35	11	76	14
NO_x	116,071	1,460	2,845	19,760	3,640
SO_x	12,510	8	95	750	137
CH_4	-	2,210	12	81	15
nmVOC	-	45	115	910	158

* note that decommissioning only includes existing structures and wells.

6.2.1.2 CO_2, N_2O and CH_4 emissions

Greenhouse gases such as CO_2, N_2O and CH_4 have a direct impact on climate and air quality.

The greenhouse gasses have different warming potential /141/, as some have a longer lifetime in the atmosphere and a higher heat absortion than others. Per definition, CO_2 has a global warming potential (GWP) of 1, whereas the GWP is 21 of CH_4 and 310 of N_2O/141/. By re-calculating the estimated emissions to a GWP, it is seen that CO_2 constitutes the largest emission of greenhouse gasses.

The annual emissions at the TYRA project (excluding new structures, drilling and decommissioning) contributes up to 1.2 % of the total annual CO_2 emission for Denmark until 2042 (percentile will depend on the development of annual Danish emissions). The impact is considered to be of small intensity, a transboundary extent and long-term duration. The overall impact on climate change from emissions at the TYRA project is assessed to be of moderate negative significance.

6.2.1.3 NO_x, SO_x and nmVOC emissions (air pollution)

NO_X and SO_x are air pollutants which are spread by the wind and deposited in the surroundings. The compunds have acidification effects, that can impact the environment in terms of defoliation and reduced vitality of trees, and declining fish stocks in acid-sensitive lakes and rivers. nmVOCs, can have a number of damaging impacts on human health. Some have direct toxic effects (e.g. carcinogenic), but nmVOCs can also have indirect effects on health by contributing to the formation of ground-level ozone, which causes respiratory and cardiovascular problems.

Emissions of NO_x from the TYRA project production corresponds to 1.2 % and SO_x corresponds 0.06 % of total annual emission for Denmark until 2042 (percentile will depend on the development of annual Danish emissions). The impact is considered an impact of small intensity, a transboundary extent and long-term duration. The overall impact on air pollution from emissions at the TYRA project is assessed to be of moderate negative significance.

6.2.1.4 Overall assessment

The overall assessment of impacts on climate and air quality from planned activities at the TYRA project is summarised in Table 6-5.

Table 6-5 Potential impacts on climate and air quality from planned activities at the TYRA project.

Impact mechanism	Intensity	Extent	Duration	Overall significance	Level of considence
CO_2, N_2O, SO_x and CH_4 emissions (climate change)	Small	Transboundary	Long-term	Moderate negative	Medium
NO_x, SO_x and nmVOC emissions (Air pollution)	Small	Transboundary	Long-term	Moderate negative	Medium

6.2.2 Hydrography

Impacts on hydrography relate to presence and removal of structures.

6.2.2.1 Presence and removal of structures

The TYRA project consist of a number of structures and pipelines in the central North Sea. New structures and/or pipelines are planned for the TYRA project, including up to nine platforms and 105 km new pipelines. Pipelines can cause water to accelerate in front of the pipeline thus eroding the seabed in front or depositing in back or the pipeline can get free-spans. Jackets may cause the water to accelerate around the piles, creating a scour hole around the base The changes may only visible due to the scouring near seabed which leads to the erosion or deposition of sand close to the pipeline or jackets The impact to hydrography of new structures is assessed to be of small intensity, local extent and of a short-term duration. The overall impact to hydrography from presence of structures is assessed to be of minor negative significance.

When the TYRA project is decommissioned, the existing platforms will be removed and disposed, while pipelines will be left in situ. The impact to hydrography of removal of the existing structures is assessed to be of small intensity, local extent and of a short-term duration. The overall impact to hydrography from presence of structures is assessed to be of positive significance.

6.2.2.2 Overall assessment

The overall assessment of impacts on hydrogrpahy from planned activities at the TYRA project is summarised in Table 6-5.

Table 6-6 Potential impacts on hydrography from planned activities at the TYRA project.

Impact mechanism	Intensity	Extent	Duration	Overall significance	Level of considence
Presence of structures	Small	Local	Long-term	Minor negative	Medium
Removal of structures	Small	Local	Short-term	Positive	Medium

6.2.3 Water quality

Potential impacts on water quality (turbidity, chemical composition etc.) are related to suspended sediment and chemical discharges.

6.2.3.1 Suspended sediment

Various activities at the TYRA project are expected to lead to sediment resuspension. New pipelines are trenched and buried to a depth of ca. 1.5-2 m below the seabed surface. Trenching of the pipeline into the seabed is done either by ploughing, water jetting or as mechanical cutting. During this process sediment are suspended into the water column. Based on experience from other pipeline projects, it is estimated that the suspended sediment will settle within a few hundreds meters of the disturbed area /131//159/. During decommissioning, physical disturbance will be related to removal of the existing jacket.

The impact to water quality is assessed to be of small intensity, local extent and of a short-term duration. Overall, the impact to water quality from suspended sediment at the TYRA project is considered to be of minor negative significance.

6.2.3.2 Discharges

Chemical use is necessary to optimise the production and drilling operations. Traces of chemicals and oil will be present in the produced water. Maersk Oil is frequently re-evaluating the best practical options to more environmentally friendly solutions (see mitigation measures in section 8). Before any chemicals can be permitted for use and discharge offshore, an application must be submitted to the Danish authorities (DEPA).

The discharged chemicals are primarily classified as OSPAR category ‘green’, which pose little or no risk to the environment, or ‘yellow’, which does not bioaccumulate and degrade relatively rapidly (section 8.1.3). The discharge of red chemicals is not expected, but may occur in a very limited amount. Red chemicals are only used if safety, technological and environmental considerations cannot be met by alternative products.

Maersk Oil has since 2008 been phasing out the use of red chemicals which contains components that bioaccumulate or degrade slowly (section 8.1.3).

Chemicals use and discharge to sea is only permitted after authorisation from the DEPA.

Discharges during production

The forecast volume of discharged produced water and oil at the TYRA project is shown in Figure 3-12 (section 3.2.3). Produced water may contain traces of production chemicals and oil.

Traces of production chemicals may be present in the produced water. The discharged production chemicals are typically categorized as ‘green’ or ‘yellow’ chemicals, which can usually be discharged without significant impact to the environment (section 8.1.3). Under special circumstances, red chemicals may also be used. A list of production chemicals, their function and their partitioning in oil/water phase is presented in appendix 1.

The content of oil in produced water at the TYRA project is expected to be between 8 mg/l and 13 mg/l. The expected amounts of oil and chemicals are provided in section 3. Flowmeters measure continuously the volume of produced water discharged, and water samples are taken daily for analysis of the oil content in the produced water.

Produced water may have toxic effects to the marine environment. Results from laboratory experiments suggest that the existing discharge of production water should be diluted from 10 to 10,000 times to reach a concentration where no acute toxic effects are expected. The toxicity of the water produced is determined , inter alia, the content of dispersed oil , BTEX , PAH and residues from chemicals used. Emissions of substances that are persistent or bioaccumulative, will in principle increase the general background level of the substance, but due to the relatively small amounts discharged, it is expected that such increases will not be measured in practice /1/.

A hydrodynamic dispersion modelling of produced water for the TYRA project suggests that produced water discharges are diluted relatively rapidly /42/. The modelling further suggests that there could be an environmental risk up to a distance of 14 km from the Tyra platform /42/. It should be noted that the calculations are highly conservative and that monitoring data in other areas of the North Sea have demonstrated that the environmental impacts of produced water discharges are local, confined to within 1-2 km from the outlet, and that the environmental risk from the discharges is low /46/.

The impact to water quality is assessed to be of small intensity, with a local to regional extent and of a short-term duration due to dilution. Overall, the impact to water quality from discharge of produced water at the TYRA project is assessed to be of minor negative significance.

During production other minor negative discharges take place, these include discharges from vessels, and cooling water from production platforms. These discharges are considered negligible in comparison with the produced water, and are not assessed further.

Discharges during drilling

There are currently 24 free well slots at the TYRA project and the planned development projects includes the construction up to 9 satellite wellhead platforms, with a total of 106 new well slots. Typically a well takes between 60 and 150 days to drill. Water-based mud and cuttings will be discharged to the sea, whereas oil-based mud and cuttings will be brought onshore to be dried and incinerated.

Cuttings from the formation collected in the water-based mud section of the well will be discharged to the sea, along with the drilling mud and material used for cementing (mostly cement and chemicals).

Discharges of cuttings can amount to 1,800 tons of cuttings per well (appendix 1). When discharged to the sea water-based mud and cuttings, which are slurries of particles of different sizes and densities in water containing dissolved salts and organic chemicals, form a plume that dilutes rapidly as it drifts away from the discharge point with the prevailing water currents. Field studies of the concentration of suspended solids in plumes of drilling mud and cuttings at different distances from the drillactivity have confirmed this pattern, concluding that the concentration of suspended drill cuttings and mud in the water column drops very quickly due to sedimentation and dilution of the material /45//46/.

Discharges of drilling mud and cement per well are shown in Table 6-7. The discharges shown are based on the worst case - defined as the well that leads to the largest amount of discharges. Chemicals expected to be used are categorized as 'green' or 'yellow' chemicals in accordance with OSPAR (section 2.2.2 and 8.1.3). Green chemicals pose little or no risk to the environment and yellow chemicals degrade rapidly or do not bioaccumulate (OSPAR).

Table 6-7 Use and discharge of drilling mud and cement per well – worst case discharge scenario. The classification colour code is explained above.

		Usage per well	Discharge per well
	Classification	Tons	Tons
Drilling mud		2421	2421
		994	994
Cement		631	76
		14	1.7

Based on a review of results of modeling and field studies of drilling mud and cuttings it has been concluded, that offshore discharges of water-based mud and associated cuttings will have little or no harmful effects on water column organisms. This conclusion is based on the rapid dilution in the water column and low toxicity to marine organisms of water-based mud and cuttings /45/. The chemicals discharged to sea during Maersk Oil drilling have been modelled in the EIA for Adda and Tyra /2/. The modelling was performed for a typical well and showed that the predicted effect concentration in the water column extended up to 7 km downstream from the platform /2/. These estimates are very conservative. Monitoring results in other areas of the North Sea confirms that the environmental impacts of drilling discharges are local, in general confined to within 1 - 2 km from the point of discharge /46/.

The impact to water quality is assessed to be of small intensity, local extent and of a short-term duration due to dilution. Overall, the impact to water quality from discharge of drilling mud and cuttings at the TYRA project is assessed to be of minor negative significance.

Discharges during well stimulation

The potential 130 new wells at the TYRA project may be subjected to well stimulation. In addition to stimulation of the new wells, it is anticipated that approximately two well stimulations of existing wells may take place per year at the TYRA project.

Expected discharges of chemicals during well stimulation at the TYRA project include chemicals categorized as 'green' or 'yellow' chemicals which can usually be discharged without significant impact to the environment. Typical discharges during well stimulation are presented in Table 6-8.

Table 6-8 Use and discharge of chemicals per well stimulation. The classification colour code is explained above.

		Usage per well	Discharge per well
	Classification	Tons	Tons
Matrix well stimulation	(green)	220	140
	(yellow)	2603	522
Acid fracturing well stimulation	(green)	194	134
	(yellow)	2816	564

The amount of discharge per well stimulation (Table 6-8) is significantly less than discharges during drilling (Table 6-7). The impact to water quality is assessed to be of small intensity, local extent and of a short-term duration due to dilution. Overall, the impact to water quality from discharges during well stimulation at the TYRA project is assessed to be of minor negative significance.

Discharges during testing of new pipelines

During pre-commissioning the pipeline is flooded with treated seawater that contains low concentration of corrosion inhibitor (typically max 500 ppm) to prevent pipeline damage. Thereafter, the pipeline is cleaned and impurities are removed by pigging. After cleaning, the pipeline is pressure-tested using treated seawater. During those operations a total volume of treated seawater, corresponding to about 305 % of the pipeline volume, is discharged to the sea.

It is estimated that the discharge associated with the precommissioning of a 11.6 km pipeline could have an environmental risk to a distance up to 2.8 km from the discharge /2/.

The impact to water quality is assessed to be of small intensity, local extent and of a short-term duration due to dilution. Overall, the impact to water quality from discharges during pre-commissioning at the TYRA project is assessed to be of minor negative significance.

Discharges during decommissioning

Minor discharges are expected during decommissioning activities. In general, all structures (jacket and topside) will be cleaned, before transport to shore. The minor discharges during decommissioning (e.g. cooling water, grey wastewater from vessels) is assessed to be of small intensity, local extent and of a short-term duration due to dilution. Overall, the impact to water quality from discharges during decommissioning at the TYRA project is assessed to be of minor negative significance.

6.2.3.3 Overall assessment

The overall assessment of impacts on water quality from planned activities at the TYRA project is summarised in Table 6-9.

Table 6-9 Potential impacts on water quality from planned activities at the TYRA project.

Impact mechanism	Intensity	Extent	Duration	Overall significance	Level of confidence
Suspended sediment	Small	Local	Short-term	Minor negative	High
Discharges	Small	Local/Regional	Short-term	Minor negative	High

Minor cumulative effects on the water quality between the production, drilling and construction discharges cannot be ruled out, however due to the low toxity of the discharges and the rapid dilution the impact is estimated to be local and short-term. A review of the cumulative impact of discharges from the Norwegian offshore petroleum industry based on monitoring data demonstrates that the cumulative impacts of discharges remains local, in general confined to few kilometres from the platforms /46/.

6.2.4 Sediment type and quality

Potential impacts on the sediment type and quality are related to physical disturbance on the seabed and discharges settling on the seabed that may affect the chemical and physical composition.

6.2.4.1 Physical disturbance on the seabed

Physical disturbance on the seabed may occur during site surveys, 4D seismic, drilling, installation of platforms and pipelines and decommissioning. The physical disturbance is not expected to occur simultaneously.

During site surveys, which are expected to occur annually, seabed coring will be undertaken and disturbance of seabed will occur where the sample is acquired, typically with an area of 0.1-0.25 m^2. During 4D seismic surveys, presence of bottom nodes and cables may impact the seabed. The area of such nodes and cables is expected to be small, as each node is 40-50 cm. During drilling (up to 130 wells), a drilling rig will be present. The rig legs will be placed on the seabed, and are expected to sink 1–2 m into the seabed. The rig legs typically covers a few hundred m^2.

New pipelines are trenched and buried to a depth of ca. 1.5-2.0 m below the seabed surface. Minor amounts of sediment will be resuspended during installation of new platforms. When the supporting jackets are placed on the seabed. During decommissioning, physical disturbance will be related to removal of the existing structures.

Disturbance of small areas of sandy sediments is expected to be short term, as sand will rapidly re-settle in the disturbed areas as a consequence of natural erosion, deposition and resuspension. The impact to sediment type and quality is assessed to be of small intensity, local extent and of a short-term duration. The overall impact to sediment type and quality from physical disturbance is therefore assessed to be of minor negative significance.

6.2.4.2 Discharges during drilling

Water-based drilling mud and drill cuttings are expected to be discharged to sea from up to 130 wells. The discharges may settle on the seabed and impact the sediment quality.

Several field studies that have measured the concentration of suspended solids in plumes of drilling mud and cuttings at different distances from the drill rigs have confirmed that the concentration of suspended drill cuttings and mud in the water column drops very quickly due to sedimentation and dilution of the material /45//46/.

Modelling of drilling mud and cuttings sedimentation for a typical Maersk Oil well shows that drilling mud will settle on the seabed at a thickness of less than 1 mm. Most of the drilling mud will settle in vicinity of the discharge location (1 - 2 km), depending on the current (Figure 6-1).

Drill cuttings are heavier than the drilling mud and will settle more rapidly. Model data shows that for a similar well discharge, a 50 mm-layer of cuttings could be expected within 50 m of the well. The thickness of the layer is expected to decrease to <1 mm beyond 200 m of the discharge (Figure 6-2).

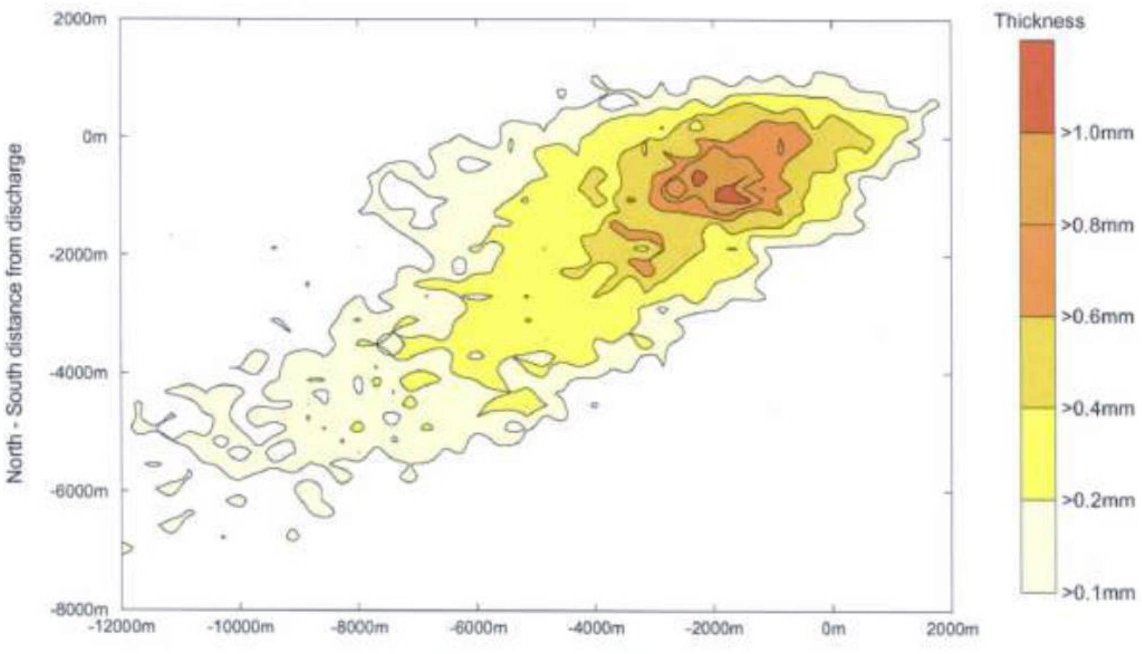


Figure 6-1 Sedimentation of discharged water based drilling mud modelled for a typical well /1/.

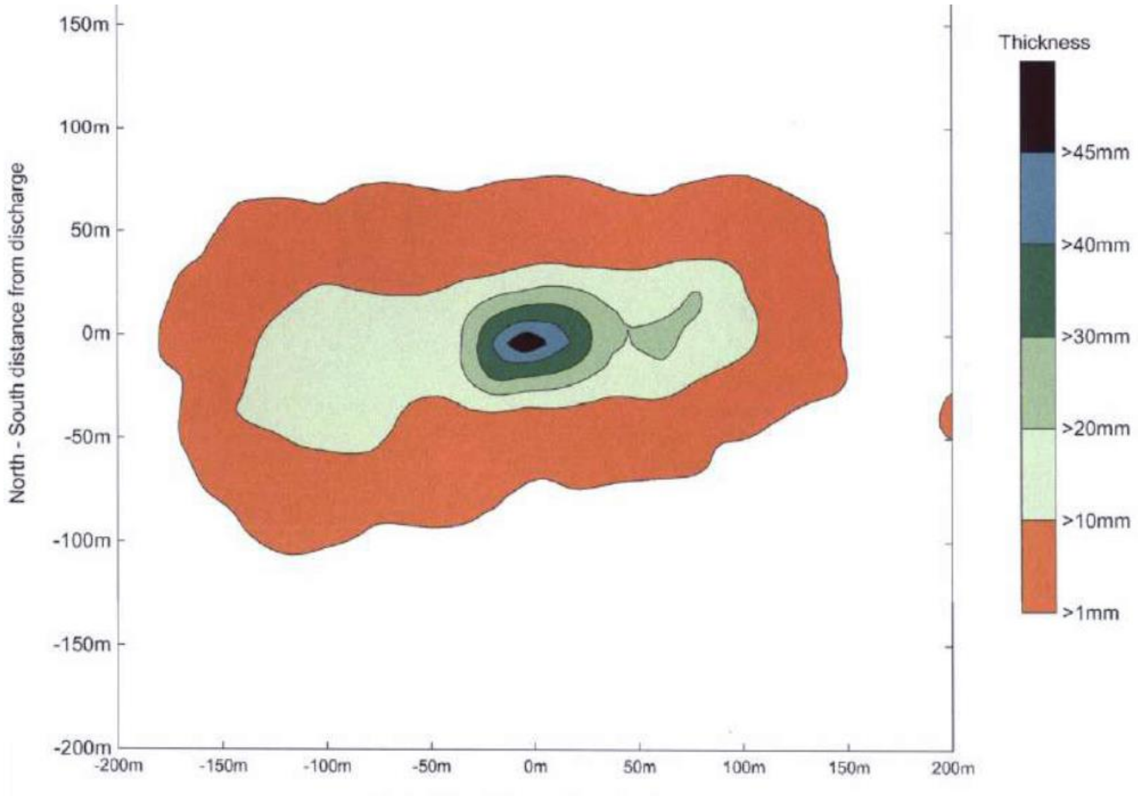


Figure 6-2 Sedimentation of water based drill cuttings modelled for a typical well /1/.

Worst case scenario discharges from drilling of one well is approximately 1,800 tons of cuttings and approximately 3500 tons of water based drill mud and cement. If all 130 well slots at the

TYRA project (24 existing slots and 106 slots in new structures) are being used it would result in a total discharge of 234,000 tons of cuttings and 455,000 tons of water based drill mud. The worst case scenario is estimated to be the case where the wells are drilled consecutively. However, it shall be noted that the wells are located at 14 different locations at distances of 4-64 km (see section 3).

The chemicals which are discharged with the mud and cuttings are categorized as 'green' or 'yellow' chemicals which can normally be discharged without significant effects on the environment (section 6.2.2.1). The mud usually contains barite or trace of heavy metals, while the cuttings may contain small quantities of oil. Chemical and biological seabed monitoring around Tyra E shows that elevated concentrations of metals, THC, PAH and NPD in the sediment are local (typical within a few hundreds meters) and rapidly decreasing in all directions with increasing distance from the platform /6/.

Sedimentation of drilling mud and cuttings may change the sediment grain size. However, seabed monitoring shows that the median grain size variation after drilling at Tyra E and Valdemar platform fall within the natural range /6/.

The water based drilling mud may contain biodegradable organic additives, which may stimulate growth of microbial communities leading to depletion of oxygen in the sediments. Anaerobic, sulphate-reducing bacteria may further degrade the organic matter, producing hydrogen sulphide /45/. The seabed monitoring campaign of the seabed around the Tyra E platform reported that sulphide was detected at a few of the station closest to the platform (less than 1 km) /6/.

Based on the modelling results, the type of chemicals in the drilling mud and cuttings and the results from the seabed monitoring, the impact is assessed to be of small intensity, local extent and of a long-term duration. In conclusion, the overall impact to sediment type and quality from discharges is assessed to be of minor negative significance.

6.2.4.3 Presence/removal of structures

Existing pipelines and structures (topsides, jacket) are present in the area. Areas which were previously sand has been altered to contain a hard substrate in the water column. Nine new structures and 106 km pipelines are planned for the TYRA project. The existing structures will be removed as the TYRA project is decommissioned. The impact to sediment quality from the presence and removal of stuctures include e.g. altered surface sediment.

The impact to sediment type and quality is assessed to be of small intensity, local extent and of a short-term duration. The overall impact to sediment type and quality from presence of structures is assessed to be of minor negative significance.

6.2.4.4 Overall assessment

The overall assessment of impacts on sediment type and quality from planned activities at the TYRA project is summarised in Table 6-10.

Table 6-10 Potential impacts on sediment type and quality from planned activities at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Physical disturbance on seabed	Small	Local	Short -term	Minor negative	Medium
Discharges of drill cuttings	Small	Local	Long-term	Minor negative	High
Presence/removal of structures	Small	Local	Short-term	Minor negative	High

Minor cumulative effects between the various discharges at the TYRA project can take place e.g. from sedimentation of drilling mud and cuttings, which may settle on top of the previous discharged drilling mud and cuttings (when drilling in the same area). However, based on Maersk Oil knowledge from surveys of structures it is known that the cuttings and mud are eventually dispersed. Overall, the cumulative impacts are estimated to be local.

6.2.5 Plankton

Potential impacts on plankton (phyto- and zooplankton) are related to underwater noise, suspended sediment, discharges and light.

6.2.5.1 Underwater noise

Underwater noise is a form of energy which may impact plankton, due to e.g. disruption of cells (cell lysis). Underwater noise at the TYRA project may be generated from seismic activities (airguns, multibeam and sidescan), piledriving during construction of new platforms, driving of conductors, drilling and various vessels. Table 6-11 shows typical frequency and noise levels for these activities.

Little research has been conducted in relation to impacts of underwater noise to plankton, primarily focussed on emitted energy from airguns during seismic surveys. Mortality of plankton has been observed at close range (within 5 m) of the source of the seismic gun /54//55/. A study found that close range (2 m) seismic sound emission on snow crab eggs had impacts on larval development and settlement /66/. Based on field measurements, it is expected that impact on invertebrates and planktonic larvae,behavior and physiology are expected within a few metres of noise source of 240 dB re 1 µPa /61/. In general, effects of noise are only expected to impact organisms close to (within a few metres) powerful noise sources e.g. seismic surveys and piledriving /64/ /65/.

Based on the abundance, productivity and size of planktonic populations and their high reproductive rate, plankton populations are expected to recover after disturbance. The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on plankton from underwater noise is assessed to be of negligible negative significance.

Table 6-11 Typical frequency and noise levels of activities at the TYRA project (based on appendix 1, /2//48/). n/a is not available.

Activity	Frequency	Unit	Noise level at increasing distance from source				
			1m	1-500 m	3 km	5 km	10 km
Seismic							
Airgun (2D/3D/4D seismic)	0.005-0.200 kHz	Peak-to-peak (dB re 1µPa^2)	244	n.a.	n.a.	n.a.	n.a.
	0.005-80 kHz	RMS (dB re 1µPa^2)	179-266	n.a.	167	129	n.a.
		SEL (dB re 1µPa^2)	202-216	n.a.	n.a.	n.a.	n.a.
Multibeam echosounder	70-100 kHz	RMS (dB re 1µPa^2)	225-232	n.a.	n.a.	n.a.	n.a.
Sidescan sonar	100-900 kHz	RMS (dB re 1µPa^2)	220-226	n.a.	n.a.	n.a.	n.a.
Pipelines and structures							
Piledriving*	0.03-20 kHz	Not specified (dB re 1µPa^2)	228	179.5	n.a.	n.a.	n.a
Production							
Production platform	0.01-10 kHz	RMS (dB re 1µPa^2)	162	n.a.	n.a.	n.a.	n.a.

Activity	Frequency	Unit	Noise level at increasing distance from source				
			1m	1-500 m	3 km	5 km	10 km
Drilling and well stimulation							
Driving of conductors	0.03-20 kHz	Not specified (dB re 1μPa^2)	228	179.5	n.a.	n.a.	n.a.
Drilling rig	0.002-1.2 kHz	Not specified (dB re 1μPa^2)	163	123	n.a.	n.a.	77
Transport							
Support vessel	0.01-20 kHz	RMS (dB re 1μPa^2)	122-192	120	n.a.	n.a.	n.a.
Decommisioning**							
Not available			n.a.	n.a.	n.a.	n.a.	n.a

*Pile diameter of 1,5 meter at 30 meters depth.

**Noise levels for decommissioning are not provided, as activities are not specified for the TYRA project. It is anticipated that no blasting will occur.

6.2.5.2 Suspended sediment

Suspended sediments could potentially reduce light availability to phytoplankton and affect the ingestion rate, egg production, egg-hatching success and survival rate of zooplankton. However, only small amounts of sediment are expected to be suspended for the TYRA project as part of the construction of nine new platforms and pipelines as well as from decommissioning (see section 6.2.3.1).

Many larval species use their vision for feeding and an increase turbidity may imapct larvae of species like plaice, sole, turbot and cod for prey sighting. However, larvae can live a few days without food /86//119/, and a short-term increase in suspended sediment is expected to be of negligible impact.

Pelagic fish eggs may be affected if suspended matter adheres to eggs, causing them to sink to the bottom, where there is a risk of oxygen depletion /85/. A laboratory study on herring eggs has shown that short term exposure to relatively high concentration of suspended matter do not affect the development of fish eggs /87/. Benthic eggs are associated with soft sediments, and are assessed to be less sensitive than pelagic eggs. In addition, as the regenerating capacity of plankton is large, and the TYRA project area is a small area in the central North Sea, no effect at population level is anticipated.

The sediment spread will be local, temporary and spatially distributed along new pipelines and structures during pipeline trenching and decommissioning and will mainly be limited to the lower parts of the water column. It is assessed that any impact on phytoplankton and zooplankton from suspended sediment will be negligible.

6.2.5.3 Discharges

Potential impacts on plankton from discharges are indirectly related to the impacts of different activities on the water quality, which are described in section 6.2.3.

Studies show that discharges of water based drilling chemicals may have short-term effects on phyto- and zooplankton communities /45//46//58/. The discharges of chemicals associated with production, drilling and stimulation may affect the phyto- and zooplankton communities. In general, it is expected that offshore discharges dilute rapidly and that only plankton found in the water column close to the discharge will be affected. Laboratory and field data confirms that the risk of significant biological impact is limited to 1 – 2 km from the discharges /46/. The effect of chemical discharges is expected to be minor negative, local and acute/non-persistent; therefore, the overall imparct is assessed to be of minor negative significance.

6.2.5.4 Light

Vertical migration in the water column by some phytoplankton and zooplankton species may be influenced by light from manned platforms.

Light has been reported as a fundamental factor controlling the daily vertical migration of zooplankton /60/. Plankton migrate closer to the surface on dark nights than they do on clear, moonlit nights /62/. Some species of plankton have been reported foraging in darkness to avoid predation, only to be intensively predated when illuminated by a rising full moon /63/. However, planktonic organismes are per definition carried around with the prevailing currents, and light is expected to be detectable for planktonic organism only in the vicinity of the platforms.

The potential affects are expected to be local, and may impact individuals but will not impact plankton populations in the North Sea. The overall impact on plankton from light at the TYRA project is assessed to have negligible negative significance.

6.2.5.5 Overall assessment

The overall assessment of impacts on plankton from planned activities at the TYRA project is summarised in Table 6-12.

Table 6-12 Potential impacts on plankton from planned activities at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Underwater noise	Small	Local	Short-term	Negligible negative	Medium
Suspended sediment	Small	Local	Short-term	Negligible negative	High
Discharges	Small	Local	Short-term	Minor negative	Medium
Light	Small	Local	Immediate	Negligible negative	Low

The cumulative impact to plankton is not well known. However, little geographical overlap between the various impacts is expected. Due to the high reproductive capacity of plankton it is expected that any cumulative impacts will be negligible negative.

6.2.6 Benthic communities

Potential impacts on the benthic community are related to underwater noise, physical disturbance on seabed, suspended sediment, discharges and physical presence of structures.

6.2.6.1 Underwater noise

Underwater noise may potentially impact benthic communities through e.g. behavioural and physiological effects.

Most invertebrates typically do not have delicate organs or tissues whose acoustic impedance is significantly different from water. Unlike e.g. fish with swim bladders, the general consensus regarding underwater noise effects on invertebrates and planktonic larvae under field conditions, is, that very few behavioral or physiological effects are expected unless the organisms are within a few metres of noise sources around 240 dB re 1 μPa /61/.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on benthic communities from underwater noise is assessed to be of negligible negative significance.

6.2.6.2 Physical disturbance on the seabed

Physical disturbance on the seabed may physically impact the benthic fauna. At the TYRA project, the disturbed area relates to pipelay, cables from seismic surveys and legs from the drilling rig and new platforms. During decommissioning, physical disturbance will be related to removal of the existing structures.

The placement of the spud can of the drilling rig and the installation of the new platform will result in the localised disturbance of the seabed and associated benthic fauna. Re-establishment of the benthic fauna will depend on the species present and their life cycle, but studies from the North Sea show that benthic faunal communities on a sandy seabed generally re-establish within a period of 2-3 years after disturbance /67/.

The intensity of the impact from physical disturbance on the seabed is assessed to be small with a local extent and of medium-term duration. Overall, the impact is assessed to be minor negative.

6.2.6.3 Suspended sediment

Following the installation of new platforms and pipelines, sediments will be dispersed to the water column. The impact will depend on the concentration of suspended sediments and the duration. Increased concentrations of suspended sediment in the water column may negatively affect benthic fauna by e.g. clogging of respiratory system or feeding apparatus. Smothering by re-suspended sediment as it settles may have direct mechanical effects.

Marine benthic invertebrates generally have poor if any visual ability and are unlikely to be adversely affected by suspended matter. Suspension feeders may be considered as the most sensitive to sediment suspension and sedimentation. The impact from a sand-extraction site on suspension feeders resulted in lower activities and a reduced feeding rate up to a distance of 1-1.5 km, and no long-term impact was detected /75/.

The impact of sediment resuspension on the benthic fauna is generally expected to be short term. A study of the effects of pipeline construction on benthic invertebrates showed that six months after disturbance there was no significant difference between the mean number of total individuals in the impacted site and in the reference areas /72/. Other studies have shown that benthic invertebrate communities began to re-colonise a disturbed seabed area quickly, but that it could take up to five years for the structure of the community to recover to its original composition /73/.

Due to the limited amount of dispersed sediment and sedimentation during construction of new platforms and pipelines impacts are assessed to be very local. Any measurable impacts to the benthic community are estimated to be within 10 meters from the area of activity.

The intensity of the impact from suspended sediment is assessed to be small with a local extent and short-term duration. Overall, the impact is assessed to be of minor negative significance.

6.2.6.4 Discharges

Potential impacts on the benthic communities are related to discharges which can lead to changes in water (section 6.2.2.1) and sediment quality (section 6.2.4).

Studies show that the effects of drilling discharges on the benthic fauna communities are minor and nearly always restricted to a zone within about 100 meter of the discharge of water based drilling mud and cuttings /45//46/. There is no evidence of ecologically significant bioaccumulation of metals or hydrocarbons by benthic fauna residing or deployed in cages near water based drilling mud and cuttings discharges. The lack of bioaccumulation or toxicity of drilling waste components indicates that effects of water based drilling mud cuttings piles are highly localized and will not be exported to the local food web /45//46/. Monitoring at Tyra E and Valdemar platforms in 2009 showed a weak impact to the benthic fauna from the drilling operation of the platform. The benthic fauna at the 100 m, 250 m and 750 m stations was significantly different from the benthic fauna at the reference stations. The observed significant spatial difference in benthic similarity combined with the lower number of species and abundance close to the platform compared to the reference stations may be interpreted as an impact related to platform discharges. However, the contamination of the sediment was low and sensitive species were common close to the platform /6/.

Sedimentation of water based drilling mud and cuttings on the seabed may bury some of the sessile benthic fauna. Changes in the sediment grain size and texture may render the sediment unsuitable for settling and growth of some species, while rendering the substrate more suitable for other, opportunistic species. Organic enrichment, can cause changes in the abundance, species composition and diversity of the benthic community /45/. A higher content of silt/clay and a weak smell of hydrogen sulphide in the sediment close to the platform are likely due to drilling related discharges /6/.

Discharges of water based drilling mud and cuttings in the water column will shortly increase turbidity and then settle on the seabed. Discharges have been determined to cause impacts at concentrations above 0.5 mg/l, typically restricted to a radius of less than 1 km from the discharge point /46/. Marine benthic invertebrates generally have poor if any visual ability and are unlikely to be adversely affected by suspended matter. However, smothering by settling sediment has direct mechanical effects on epifauna and infauna and may result in the modification of the substratum. Sediment may directly clog the feeding or respiratory apparatuses of suspension feeders. The impact level depends on the grain-size distribution of the settled sediments and on species-specific tolerances to increased rates of sedimentation and accumulation. Water based drilling mud and cuttings have been found to affect the benthos at a thickness of at least 3 mm or more. Such layer thicknesses will normally be confined to a distance of 100-500 m /46/. Mud and cuttings for a typical Maersk Oil well has been modelled to settle at a thickness of above 1 mm only within 200 m of the discharge (section 6.2.4).

The risk of widespread, long term impact from the operational discharges on benthic populations is presently considered low /46/. A monitoring campaign of the seabed around the Tyra E and Valdemar platforms shows that measurable impacts on the benthic community are limited to the vicinity (a few hundred meters) of the discharge point, but likely with a long-term duration /6/.

The impact is assessed to be of small intensity, local extent and long-term duration. The overall impact on benthic communities from discharges is assessed to be of minor negative significance.

6.2.6.5 Presence/removal of structures

Theplatform jacket provide a new habitat for hard substrate benthic communities that are not normally present in soft sediment environments. Structure inspection surveys of the area show that marine growth (e.g. sea anemones, seaweed, soft corals, sea squirts and sponges) are often found in the top 15-20 m below the water surface.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on benthic communities from presence of structures is assessed to be of minor negative significance to the existing fauna which .

6.2.6.6 Overall assessment

The overall assessment of impacts on benthic communities from planned activities at the TYRA project is summarised in Table 6-13.

Table 6-13 Potential impacts on the benthic communities from planned activities at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Underwater noise	Small	Local	Short-term	Negligible negative	Low
Physical disturbance on seabed	Medium	Local	Medium-term	Minor negative	High
Suspended sediment	Small	Local	Short-term	Negligible negative	High
Discharges	Small	Local	Long-term	Minor negative	High
Presence/removal of structures	Small	Local	Short-term	Minor negative	High

The cumulative impact to benthic communities is not well known in the scientific literature, but monitoring at platforms show there is some impact of all these acitivities, and thus a cumulative impact. The impact of drilling a single well is minor, while consecutive drilling of several wells in the same area is assessed to have moderate cumulative impacts.

6.2.7 Fish

Potential impacts on fish are related to underwater noise, physical disturbance on seabed, suspended sediment, discharges, light and physical presence of structures.

Note that impacts to fish eggs and larvae are assessed as part of plankton in section 6.2.5.

6.2.7.1 Underwater noise

The extent to which underwater noise may impact fish is dependent upon a number of factors including the level of noise produced at the source, the frequencies at which the sound is produced, the rate at which sound attenuates (which will vary for different frequencies and environmental conditions), the sensitivities of different species and individuals to different volumes and frequencies of noise. Noise can impact fish in several ways, including:

- Damage to non-auditory tissue
- Damage to auditory tissues (generally sensory hair cells of the ear)
- Hearing loss due to temporary threshold shift
- Masking of communication
- Behavioural effects (e.g. avoidance)

Fish behaviour in response to noise is not well understood. Sound pressure levels that may deter some species, may attract others. The fish may also freeze and stay in place, leaving it exposed to potential impact. When the fish swims away, the effects could be minimize the impact. On the other hand, it could lead to a fish swimming away from an important feeding ground, mating or spawning are This could lead to significant impact if there are long term effects /46/.

There are several sources of noise emitting from the planned activities, including drilling activities, seismic surveys, construction of new platforms (piledriving) and vessels.

Underwater noise from seismic

Noise emitted during seismic survey can have an impact either directly through harmful physiological effects or behavioral effects.

Research has shown that injuries and increased mortality can occur at distances less than 5 m from the air guns, with fish in the early stages of life being most vulnerable. The risk of injuries to individual from seismic is assessesd to be low and it is further not considered to have a significant negative impact on fish at the population level /99/. Some findings also indicated harmful effects on the sensory cells of adult fish /92/. The fish were kept in cages and the seismic vessel passed the cages along course lines running from 400-800 m distance at the beginning and up to 5-15 m from the cages. Since the experimental fish were so close to the air guns, one could discuss whether these types of injuries are representative for adult, free-swimming fish.

Behaviour of herring schools exposed to 3D seismic survey was observed. No changes were observed in swimming speed, swimming direction, or school size that could be attributed to the transmitting seismic vessel as it approached from a distance of 27 to 2 km, over a 6 h period /96/. The unexpected lack of a response to the seismic survey was interpreted as a combination of a strong motivation for feeding, a lack of suddenness of the air gun stimulus, and an increased level of habituation to the seismic shooting.

Behavioural change of fish may have implications for spawning and migration to the spawning grounds. This can change the time of the arrival of fish to the spawning areas, so that spawning conditions become less favorable. It must be emphasised that effects must be interpreted in the light of the fact that they will be unique for each species, and that the vulnerability and effect of external stimuli depend on the life stage. However, as spawning areas in the North Sea are large (section 5.8), and the change in behaviour is within a few kilometres, impact to spawning is not expected.

Seismic airguns may affect the behaviour of fish in the area close to the seismic vessel. However it is expected that seismic will not lead to long term changes to the size of fish stocks in the North Sea in general /97/.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on fish from underwater noise from seismic is assessed to be of minor negative significance.

Underwater noise from pile-driving and conductor driving

There are several examples of pile driving for wind farms resulting in the death of caged fish in the immediate vicinity of the pile driving activity in the literature. Typically, mortality is reported within a distance of 50 meters from pile driving activity /93/. Fish will most likely move away from the sound source. It is estimated that, for example, flounder and cod will respond within a distance of 500 m and 2 km, respectively /95/.

There is a substantial difference between pile driving for such a wind farm monopile and pile and conductor driving for an oil and gas installation. During installation of a platform the jacket is secured to the seabed with piles, with a diameter of up to 80 cm. The noise level form pile-driving are expected to be comparable with the driving of conductors as part of drilling. The hammering will usually be done within 2 hours for the pile used for the jacket(nine new stuctures) and 6-8 hours for conductors (130 new wells) that will be used for drilling of a new well. Conductor driving may occur either as batch or between each well.

The effects on the fish from pile-driving are assessed to be small, local and short-term. It is concluded that the overall impacts will be minor negative.Mmitigation measures such as ramp-up/slow start procedures, where the first hammer blows are at reduced impact energy allowing noise sensitive fish species to escape the immediate vicinity, impact are further reduced.

Underwater noise from other activities

Field studies have shown that some species may be disturbed by noise from passing ships, while others are not affected. Species such as cod and haddock, which often occurs in large schools around offshore platforms, do not respond to noise from passing vessels. Other species tend to move away from a passing vessel. Reaction range varies from 100 - 200 m for many typical vessels but 400 m for noisy ones /77/. The fact that the drilling rigs and offshore platforms attracts fish indicates that the noise from drilling or processing and production platform generally does not affect fish /78//79//80//80/. Observations from the platform and underwater inspections at the TYRA project also confirms the presence of fish schools.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on fish from underwater noise from other activities is assessed to be of negligible negative significance.

6.2.7.2 Physical disturbance on seabed

Potential impact to fish caused by physical disturbance of the seabed could be related to demersal fish or habitat fragmentation caused by changes to the seabed.

The physical disturbance on seabed is limited to pipelay, sediment sampling and disturbance of the seabed by the presence of cables during 4D seismic surveys and the placement of spud cans from drilling rigs or of new platforms. Pipelines are expected to be buried. The expected area is expected to be small. It is estimated that natural processes such as erosion or sediment will restore the disturbed to its original state within less than a few years.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on fish from physical disturbance is assessed to be of negligible negative significance.

6.2.7.3 Suspended sediment

The sensitivity of fish to suspended particles varies highly between species and their life stages and depends on sediment composition, concentration and duration of exposure. High levels of suspended sediment for a short period of time may be less of a problem than a lower level that persists longer. Depending on the exposure the severity of impacts may go from behavioural effects, to sub lethal and lethal effects.

Both laboratory and field investigations have showed that herring and smelt began to flee areas with fine-grained suspended sediment when the concentration reached approximately 10 mg/l and 20 mg/l, respectively /82/. Flatfish are especially tolerant to relatively high concentrations of suspended sediment. Studies of plaice with concentrations of 3,000 mg/l showed no increased lethality during a 14-day period /83/.

Many species use their vision for feeding, and the feeding activity of herring fry is shown to be affected by concentrations of suspended matter of 20 mg/l /85/. The most likely effects due to suspended material will be avoidance reactions or fish species fleeing an area during construction activities. These avoidance reactions are temporary and will have no long-term impact on fish and fish stocks.

Based on the limited amouts of sediment dispersed during pipelay and other activities at the TYRA project, any impacts would be limited to the vicinity of the disturbed seabed sediment. Food sources living in the seabed e.g. polychaetes will become exposed during pipelay/trenching, and fish that are not affected by noise and higher turbidity are likely to be attracted to the construction site /88//89//90/.

The sensitivity of fish in relation to sediment spreading in the water column is assessed to be low. The overall effects on fish from increased turbidity are assessed to be small, local and short-term. It is concluded that the overall impacts on fish and fish stocks from sediment spreading will be minor negative.

6.2.7.4 Discharges

Potential impacts on fish from disharges are related to a number of discharges, which may change the water quality (section 6.2.2.1).

Calculation of the risk of impact from the discharged produced water at the TYRA project suggests that an impact to the water column may occur up to 14 km from the combined discharges at the Tyra East and West platforms /42/. However, a recent review of environmental impacts of produced water and drilling waste discharges based on monitoring from the Norwegian offshore petroleum industry suggests that the effects of discharges are local, and in general confined to within 1-2 km from an outlet both in the waters and on the seabed, and that the risk of widespread impact from the operational discharges is low /46/.

Studies have showed that compounds present in produced water have a potential to exert endocrine effects in fish. The experimental exposure levels studied cover a range of produced water concentrations that are typically found in close proximity to the discharge points. They might therefore elicit effects on fish standing close to platforms. However, it is concluded that widespread and long lasting effects of produced water on the population level on fish are unlikely /46/.

Modelling results shows that drilling mud generally settles on the seabed within a distance of 12 km downstream of the discharge point, with the majority settling within a few km. Drill cuttings settle within a distance of 200 m (section 6.2.4). Several field studies that have measured the concentration of suspended solids in plumes of drilling mud and cuttings at different distances from the drill rigs have confirmed this pattern. The measurements have shown that the concentration of suspended drill cuttings and mud in the water column drops very quickly due to sedimentation and dilution of the material /45//46/. A monitoring campaign of the seabed around the Tyra East platform shows that measurable impacts on contaminants in the sediment are limited to the vicinity of the discharge point /6/, and any impacts on fish are considered to fall within this range.

Based on the modelling results and the type of chemicals discharged, the intensity of the impact from discharges is assessed to be small with a local extent and of a medium-term duration. Overall, the impact is assessed to be of minor negative significance.

6.2.7.5 Light

Though saftely lights are present at all satellite platforms and vessels, only manned platforms Tyra East and West are illuminated. Platforms may be providing an enhanced foraging environment for larval, juvenile and adult fishes by providing sufficient light to locate and capture prey, as well as by concentrating positively phototaxic prey taxa. For juvenile fish there is probably a trade-off between living and foraging in an artificially illuminated nocturnal environment. The increased illumination likely allows them to feed on zooplankton that have concentrated within the light field near the surface; however, the same light may make them more vulnerable to predators.

The potential disturbance to fish of light emissions from rigs, platforms and vessels is expected to be local, extending 90-100 m from the source /98/. As such, any impacts on fish arising from light emissions are considered to be minor and localised to a small proportion of the population. The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on fish from light at the TYRA project is assessed to be of negligible negative significance.

6.2.7.6 Presence/removal of structures

The introduction of a hard substrate into the water column, provide a surface that can be colonised by species that are not normally present in soft sediment environments. Structure and pipeline inspection surveys of the area show that no macrophytes are found on the seafloor and that marine growth (e.g. sea anemones, seaweed, soft corals, sea squirts and sponges) is found on the existing structures in the top 15-20 m.

The artificial reef introduced by the existing and new jacket or the area covered by rock dumping provide a new habitat for fish to find hiding places and food areas /148/. Reef fish such as e.g. goldsinny wrasse, corkwing wrasse and lumpsucker will especially profit from the new habitat. The fish are attracted to the boulders with their variety of habitats which creates a wealth of hiding places where e.g. small fish and fry can hide from predators. But also cod and whiting are attracted by the often larger food supply offered by heterogeneous structures such as boulder reefs /149/.

The impact is assessed to be of small intensity, local extent and short-term duration as all structures are removed during decommissioning. The overall impact on fish from presence of structures is assessed to be of negligible negative significance to species which are associated to sand sediment. However, for some fish species a positive impact is expected due to a local reef effect.

6.2.7.7 Overall assessment

The overall assessment of impacts on fish from planned activities at the TYRA project is summarised in Table 6-14.

Table 6-14 Potential impacts on fish from planned activities at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Underwater noise	Small	Local	Short-term	Minor negative	Low
Physical disturbance on seabed	Small	Local	Short-term	Negligible negative	Low
Suspended sediment	Small	Local	Short-term	Minor negative	Low
Discharges	Small	Local	Medium-term	Minor negative	High
Light	Small	Local	Short-term	Negligible negative	Low
Presence/removal of structures	Small	Local	Short-term	Negligible negative/positive	Low

The cumulative impact to fish is not well known. The presence of fish communities around oil and gas platform at the TYRA project, in the North Sea indicate that any impact is minor. However, little geographical overlap is expected, and it is expected that cumulative impacts will be minor.

6.2.8 Marine mammals

Potential impacts on marine mammals are related to underwater noise, physical disturbance, discharges, lights and presence of vessels and platforms.

All species of whales are listed in the habitats directive appendix IV, and special protective measures apply regarding deliberate capture or killing of individuals of these species in the wild; and deterioration or destruction of breeding sites or resting places. The TYRA project area is not a known breeding site for whales, and no deliberate capture or killing is foreseen.

6.2.8.1 Underwater noise

Hearing is the primary sense for many marine mammals for detecting prey, predators, communication and navigation in the environment. Underwater noise introduced into the environment has the potential to impact marine mammals.

Marine mammals are usually defined per functional hearing groups, based on their auditory bandwidth /41/. The hearing groups and auditory bandwidth of mammals in the North Sea are shown in Table 6-15.

Table 6-15 Functional hearing groups and auditory bandwidth for typical species found at the TYRA project area /41/.

Species in the North Sea	Functional hearing group	Auditory bandwidth
Seals (pinnipeds)		
Grey seal, harbour seal	Pinnipeds in water	75 Hz to 22 kHz
Whales (cetaceans)		
Harbour porpoise	High frequency	200 Hz to 180 kHz
White beaked dolphin	Mid-frequency	150 Hz to 160 kHz
Minke whale	Low-frequency	7 Hz to 22 kHz

The effect of underwater noise on marine mammals can generally be divided into four broad categories that largely depend on the individual's proximity to the sound source: Detection, masking, behavioural changes and physical damages /41/. The limits of each zone of impact are not distinct, and there is a large overlap between the zones.

- Detection is where the animals can hear the noise. Detection ranges depend on background noise levels as well as species specific audible threshold profiles /41/.
- Masking is where the noise conceals other sounds, e.g. communication between individuals. The impact to e.g. communication is not well understood /41/.
- 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 /41/.
- Physical damage to marine mammals relate to damage to the hearing apparatus. Physical damages to the hearing apparatus 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 is an important factor for the degree of hearing loss, as is the frequency, the exposure duration, and the length of the recovery time /41/.

In connection with the development of offshore wind in Denmark, an expert working group for marine mammals and underwater noise have recommended thresholds for permanent hearing loss (PTS), temporary hearing loss (TTS) as well as behavioural changes for seals and harbour porpoise in Danish waters /138/. Threshold values are shown in Table 6-16. Threshold values for inflicting impact have been determined from an assessment of available data from the scientific literature, based on laboratory studies of animals. The working group was not able to recommend a threshold value for behavioural effects on seal, as there is very limited evidence on how and when seals react to underwater noise.

Table 6-16 Threshold values for permanent threshold shift (PTS), temporary threshold shift (TTS) and behavioural effects related to pile driving as recommended by a Danish expert working group /138/. All levels are unweighted SEL. (- indicate that no threshold is available)

Species	Behavioural response (dB re 1 µPa SEL)	TTS (dB re 1 µPa SEL cum)	PTS (dB re 1 µPa SEL cum)
Grey seal and harbour seal	-	176	200
Harbour porpoise	140 (single strike)	≥164	≥183

A recent review concluded that very few data are available for assessment of impact on other species relevant for Danish waters, primarily white-beaked dolphin and minke whale /142/. Until further data are available, TTS thresholds from bottlenose dolphins are the best available data. These studies have shown TTS induced at sound exposure levels in the range 190-210 dB re 1 $\mu Pa^2 s$, depending on stimulus frequency and duration. No firm data is available to base recommendations regarding behavioural reactions for both species.

The highest noise levels in the North Sea is caused by pile driving associated with selected structures, in particular wind farms. The possible impacts of noise on the North Sea harbour porpoise population was recently evaluated by modelling the porpoise population sizes and distributions in relation to different pile-driving scenarios. Although the results should be considered preliminary, the patterns generated by the current version of the model did not suggest long-lasting effects of wind farm pile-driving noise on the average porpoise population size and dynamics in the North Sea /153/.

There is a substantial difference between pile driving for a wind farm monopile and for an oil and gas installation. While monopiles for wind farms may be 2 m I diameter, the OG piles may have a diameter of up to 80 cm. The noise level form pile-driving are expected to be comparable with the driving of conductors as part of drilling. The hammering will usually be done within 2 hours for the pile used for the jacket(nine new stuctures) and 6-8 hours for conductors (130 new wells) that will be used for drilling of a new well. Conductor driving may occur either as batch or between each well.

Underwater noise from seismic

The planned seismic data acquisition in the TYRA project includes a 4D seismic survey with airguns (an area of a few hundred km^2, with a duration of few months), borehole seismic surveys with airguns (with a duration of some days) and shallow geophysical surveys with small airguns and electrically generated sources, side scan sonar, single and multi-beam echo sounder (typical area of 1 km^2, with a duration of around 1 week). Typical noise levels and frequencies for the planned activities at the TYRA project are presented in Table 6-11 (section 6.2.5).

The underwater noise levels generated during seismic activities at the TYRA project can potentially be above the threshold values established for PTS, TTS and behavioural impacts. The largest noise levels are generated by the sources used for 3D, 4D and other marine seismic surveys.

An impact assessment was undertaken for a similar 4D marine seismic survey in the area /144/. This concluded that:

- The probability of the survey vessel encountering any marine mammals and other marine species is small.
- Impacts on the marine species, if any, will take place at or within 30 metres from the airgun. It was assessed that no marine animals would be exposed to sound levels which could cause PTS, and that only TTS and behavioural impacts would occur.

At the TYRA project, the extent of the impact will depend on the final set-up for the seismic survey. The 2012 impact assessment concluded that the effects of a seismic survey was local. As the source level is higher, the potential area where PTS, TTS or behavioural impacts may occur is assessed to be larger. A study of harbour porpoise during a 2D seismic survey in the Moray Firth found that animals showed behavioural response within 5-10 km /151/, while an assessment in the central North Sea found behavioural response to a distance of 20 km /2/. Overall, the impacts on marine mammals may be local (PTS, TTS) or regional (behavioural).

Both PTS, TTS and behavioural impacts are considered of small intensity as there will be partial impacts on individuals within the affected area. The TYRA project area is not of particular importance to harbour porpoise, and few individuals are observed, and it is assessed that the marine mammal populations in the North Sea will not decline significantly due to seismic activities at the TYRA project.

Permanent threshold shift (PTS) is considered a potential impact with a long-term duration as the impact is permanent to the affected individuals, and will persist. Temporary threshold shift (TTS) and behavioural impacts are generally considered potential impacts with a short-term duration, as the impact is not permanent. A study of harbour porpoise during a 2D seismic survey in the Moray Firth found that animals showed behavioural response, and were typically detected again within a few hours. Habituation to the underwater noise was also observed /151/. Overall, the potential impacts of seismic activities to marine mammals are considered of medium-term (TTS and behavioral) to long-term (PTS) duration.

The impact is assessed to be of small intensity, local or regional extent and medium to long-term duration. The overall impact on marine mammals from underwater noise from seismic is assessed to be of moderate negative significance.

If mitigating measures (section 8.1) are implemented such as soft start, the impact to marine mammals from seismic surveys can be alleviated.

Underwater noise from drilling and pile driving

Underwater noise is primarily associated with ramming of conductors, with a duration of approximately 6-8 hours, and ramming of piles for new structures. The planned drilling activities are associated with the drilling of up to 130 wells, and nine new platforms.

The impact assessment for drilling activities at the TYRA project is largely based on /140/, where underwater sound monitoring was performed for background levels, drilling operations and conductor ramming. Based on the monitoring results, potential impacts on marine mammals were assessed:

- Underwater drilling sound: The underwater noise from the drilling rig were masked by background sound within 500 -1000 meters from the rig. It was concluded that no harmful effects (threshold shifts or behavioural response) on marine mammals could be expected.
- Ramming of conductors: The noise levels where there is a risk of causing hearing damage to marine mammals is restricted to an area close to the drilling rig or circumstances of prolonged exposure to continuous sounds, which is very unlikely. However, behavioural effects are most likely to be found within a few kilometres from the rig, and permanent exclusions are not expected.

For drilling and ramming of conductors, the extent of the impact is expected to be local /140/, of small intensity and with a short-term duration. Based on this above, the overall impact caused by noise from drilling and construction activities is assessed to be of minor negative significance.

If mitigating measures (section 8.1) are implemented such as soft start, the impact to marine mammals from seismic surveys can be alleviated.

Underwater noise from production, vessels and associated activities
Noise will also be present from production and associated activities, and from vessels in the area, with typical noise levels and frequencies presented in in Table 6-11 (section 6.2.5). Vessels such as barges and supply ships produce noise with energy content primarily below 1 kHz, as do the rigs and platforms. The marine mammals in the area (harbour porpoise, mid-frequency cetaceans, harbour seals and grey seals) are more sensitive to noise at higher frequencies. Some of the most trafficked areas in Danish waters are also areas with a very high abundance of harbour porpoises /120/. Year-round presence of marine mammals observed at the Maersk Oil platforms show that the animals make a trade-off between the noise levels and likely higher prey abundance /139/. Any displacements of harbour porpoises due to this type of noise are expected to be short term, and over relatively short distances.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on marine mammals from underwater noise from pproduction and vessels is assessed to be of minor negative significance.

6.2.8.2 Discharges

The main discharges are related to the production at Tyra East and West and drilling activities at Tyra South East, Svend, Roar, Valdemar B and Valdemar A, and nine potential new wellhead platforms. Conservative estimates suggest that there could be an risk to some species up to a maximum of 14 km from the production discharges and up to a maximum of 7 km from the drilling discharges (section 6.2.2.1). Any potential impacts on marine mammals are thus confined to the local environment near the platforms, drilling rigs and vessels. The risk of bioaccumulation will be species-specific and depend on the type of prey. Bioaccumulation is not expected from the chemical expected to be used (section 8.1.3).

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on marine mammals from discharges is assessed to be of minor negative significance.

6.2.8.3 Light

Though saftely lights are present at all platforms and vessels only manned platform i.e. Tyra East and Tyra West platforms are fully illuminated. Navigational and deck working lights used to illuminate working areas, are sources of artificial light into the environment. Light may locally attract plankton and fish (section 6.2.5 and 6.2.7), serving as prey for marine mammals.

A recent study at the Dan platform /139/ 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. 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.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on marine mammals from light is assessed to be of negligible negative significance.

6.2.8.4 Presence/removal of structures and vessels

Presence of structures and vessels may contribute to the animals' habituation to human activities, and could potentially increase the risk of e.g. collisions. Marine mammal responses to vessels often include changes in general activity (e.g., from resting or feeding, to active avoidance), changes in surfacing-respiration-dive cycles, and changes in speed and direction of movement. Behavioural reactions tend to be reduced when animals are actively involved in a specific activity such as feeding or socialising /122/.

In addition to the existing structures at the TYRA project, nine new platforms are planned, with connecting with pipelines. Year-round presence of marine mammals observed at the Maersk Oil platforms /139/ show that the animals are not deterred from the platforms.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on marine mammals from presence of vessels is assessed to be of negligible negative significance.

Removal of structures will lead to underwater noise. Once the structures are decommissioned, no impact to marine mammals is foreseen.

6.2.8.5 Overall assessment

The overall assessment of impacts on marine mammals from planned activities at the TYRA project is summarised in Table 6-17.

Table 6-17 Potential impacts on marine mammals from planned activities at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Underwater noise from seismic	Small	Local or regional	Medium-term Long-term	Moderate negative	Medium
Underwater noise from drilling	Small	Local	Short-term	Minor negative	Medium
Underwater noise from production, vessels etc	Small	Local	Medium-term	Minor negative	Medium
Discharges	Small	Local	Medium-term	Minor negative	High
Light	Small	Local	Short-term	Negligible negative	High
Presence/removal of structures and vessels	Small	Local	Short-term	Negligible negative	High

The cumulative impact to marine mammals is not well known. However, little geographical overlap is expected between the activities (section 6.2.2.1 and 6.2.3), and it is expected that cumulative impacts will be minor. The current data from a long term marine mammals monitoring program around several of Maersk Oil platforms suggest that there must be a trade-off between the potential disturbance associated with the current offshore activities and the additional foraging ground provided by the presence of the platforms /139/.

6.2.9 Seabirds

Seabirds may potentially be impacted by noise, discharges and light.

6.2.9.1 Underwater noise

Noise may negatively affect the seabirds as physical damage or behavioural response.

Very little is known about underwater hearing in diving seabirds and information on effects from underwater sound on birds are sparse, but observations from seismic vessels in the Irish Sea did not reveal any behavioural response of seabirds to seismic survey activities /146/. Birds diving a few meters to an air gun array, may potentially suffer damage to the auditory system. However, birds have the ability to regenerate the sensory cells in the inner ear and a possible hearing impairment, would thus be temporary.

Due to the highly mobile nature of birds, they are generally not considered to be sensitive to noise from surveys /147/.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on seabirds from noise is assessed to be of negligible negative significance.

6.2.9.2 Discharges

Discharges have been described in section 6.2.2.1 and are assessed to have a minor negative impact on water quality.

Seabirds may be impacted if they come into contact with the discharges. The impact can include both direct impacts (contact) and indirect impacts (digestion of contaminated organisms), and will depend on the oil or chemicals encountered. Any potential impacts are thus confined to the local environment near the point of discharge. Bioaccumulation is not expected from the chemical expected to be used (section 8.1.3).

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on seabirds from discharges is assessed to be of minor negative significance.

6.2.9.3 Light

Though saftely lights are present at all platforms and vessels only manned platforms Tyra East and West are fully illuminated. Light and illumination may attract seabirds when it is dark or under certain weather conditions.. There is observations at Maersk Oil showing that the platforms may function as a resting place for seabirds, and rare observations of fatalities. The potential attraction is related to individuals, and is not assessed to have an effect on the North Sea population.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on seabirds from light is assessed to be of negligible negative significance.

6.2.9.4 Overall assessment

The overall assessment of impacts on seeabirds from planned activities at the TYRA project is summarised in Table 6-18.

Table 6-18 Potential impacts on seabirds from planned activities at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Underwater noise	Small	Local	Short-term	Negligible negative	High
Discharges	Small	Local	Short-term	Minor negative	Medium
Light	Small	Local	Short-term	Negligible negative	High

6.3 Assessment of potential social impacts

Impact assessment for planned activities for each relevant social receptor is presented in the following sections.

6.3.1 Cultural heritage

Potential impacts on cultural heritage relate to physical disturbance.

National authorities have laws and procedures to avoid impacts on cultural heritage from construction projects. Knowledge of cultural heritage in the North Sea is scarce, and surveys are performed prior to construction activities.

6.3.1.1 Physical disturbance

Prior to drilling or construction, a site survey will be undertaken to investigate whether any cultural heritage objects are present in the area. In case of a find proper actions needs to be taken, in order to assess the found object(s) and for proper handling. This includes involving The Danish Agency for Culture which is the responsible authority for cultural heritage in Denmark. Wrecks that are more than 100 years are protected by the museum law.

The impact from physical disturbance on cultural heritage is assessed to be of no significance.

6.3.1.2 Overall assessment

The overall assessment for impacts on cultural heritage from planned activities is summarised in Table 6-19.

Table 6-19 Potential impacts on cultural heritage from planned activities at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Physical disturbance	-	-	-	None	High

6.3.2 Protected areas

Potential impacts on protected areas relate to discharges.

The Natura 2000 sites are assessed in a separate screening (section 10). Other protected areas include nature reserves along the west coast of Jutland, and the UNESCO reserve Wadden Sea.

6.3.2.1 Discharges

As the distance between the TYRA project and the Wadden Sea is more than 100 km, and the distance to the nature reserves along the west coast are more than 200 km, no impacts are anticipated from planned activities.

6.3.2.2 Overall assessment

The overall assessment of impacts on protected areas (excluding Natura 2000) from planned activities at the TYRA project is summarised in Table 6-20.

Table 6-20 Potential impacts on protected areas (excluding Natura 2000) from planned activities at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Discharges	-	-	-	None	High

6.3.3 Marine spatial use

Potential impacts on marine spatial use are related to restricted zones. Note that impacts on fishery is addressed separately.

6.3.3.1 Restricted zones

A safety exclusion zone of 500 m surrounds the platforms i.e. no unauthorised vessels permitted), while a safety zone of 200 m is placed along each side of pipelines where no anchoring and no trawling are authorised..

For the TYRA project, nine new platforms could be expected, and the new safety exclusion zones could be extended up to approximately 7 km^2, and 42 km^2 where anchoring or trawling is restricted. Survey and drilling activities may pose a limited temporary restriction during the short period (days-months) the activities occurs.

Once the TYRA project is decommisioned, the structures will be removed. However, as buried pipelines are left in place, there may still be limitations for use of the seabed.

The impact is assessed to be of small intensity, local extent and short-term (survey or drilling) or long-term (platform safety zones) duration. The overall impact on marine spatial use from restricted zones is assessed to be of minor negative significance.

6.3.3.2 Overall assessment

The overall assessment of impacts on marine spatial use from planned activities at the TYRA project is summarised in Table 6-21.

Table 6-21 Potential impacts on marine spatial use from planned activities at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Restricted zones	Small	Local	Short-term long-term	Minor negative	High

6.3.4 Fishery

Potential impacts on fishery are related to occupation of seabed, restrictions and an indirect impact in case the target fish species are affected.

6.3.4.1 Physical disturbance on seabed

For the TYRA project, nine new platforms and 105 km of pipeline are planned. In addition, physical disturbance to seabed is related to site survey and temporary placement of drilling rig legs on the seabed.

The disturbance is expected near new and existing structures which are or will be covered by a restriction zone for fishery. Overall, it is assessed that the physical disturbance will have no impacts on fishery.

6.3.4.2 Restricted zones

Temporary restricted zones may be imposed during survey and drilling activities. Extension of the restricted zone may pose a temporary restriction to fishery during the short period (days-months) the activities occur.

The landed catch for fishery in the area IVB (280,000 km^2), where the TYRA project area is shown in section 5.14. The total area of the new permanent exclusion zone is expected to be up to 7 km^2 around the new platforms and the total area of the new restricted zone is expected to be approximately 42 km^2 for new pipelines (6.3.3) and These areas are small compared to the total fishing area (<0,003% and <0.02%, respectively)

The impact is assessed to be of small intensity, local extent and short-term (survey or drilling) or long-term (platform safety zones) duration. The overall impact on fishery from restricted zones is assessed to be of minor negative significance.

6.3.4.3 Changes to target fish

Potential impacts on fishery could e.g. include seismic surveys resulting in target fish temporarily moving away from the sound source, potentially causing a localized reduction in fish catch in close proximity to the seismic source. Impacts on fish have been assessed in section 6.2.7 to be negligible - minor negative. The impact is thus considered of small intensity, local extent and short-long term duration. The overall impact on fishery from changes to target species is assessed to be of negligible negative significance.

6.3.4.4 Overall assessment

The overall assessment of impacts on fishery from planned activities at the TYRA project is summarised in Table 6-22.

Table 6-22 Potential impacts on fishery from planned activities at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Physical disturbance on seabed	None	-	-	None	High
Restricted zones	Small	Local	Short-term Long-term	Minor negative	High
Changes to target species	None	-	-	Negligible negative	High

6.3.5 Tourism

Potential impacts on tourism relate to restriction zones at the TYRA project.

6.3.5.1 Restricted zones

The planned activities at the TYRA project take place offshore, at a distance of 200 km from shore. Tourism is related to the nearshore (and onshore) areas, and no impacts of restricted zones on tourism are expected.

6.3.5.2 Overall assessment

The overall assessment of impacts on tourism from planned activities at the TYRA project is summarised in Table 6-23.

Table 6-23 Potential impacts on tourism from planned activities at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Restricted zones	None	-	-	None	High

6.3.6 Employment and tax revenue

Potential impacts on employment and tax revenue relate to employment at the TYRA project.

6.3.6.1 Employment

The future developments of Maersk oils activities in the TYRA project includes seismic surveys, maintenance of pipelines and structures, drilling of up to 130 new wells, establishment of up to 9 new platforms, as well as production at the existing facilities at the TYRA project. All these activities will contribute positively to the employment.

The offshore oil and gas production is important to Danish economy, as thousands of people are employed in the offshore industry (section 3.4.1 and 5).

The impact is assessed to be of medium intensity, from local to national extent and medium-term duration. The overall impact on employment from activities at the TYRA project is assessed to be of positive significance.

6.3.6.2 Tax revenue

The tax revenue from the TYRA project has not been quantified, but the tax revenue to the state of Denmark from oil and gas activities is significant. The state's total revenue is estimated to range from DKK 20 to DKK 25 billion per year for the period from 2014 to 2018 (section 3.4.1 and 5).

The impact is assessed to be of medium intensity, from local to national extent and medium-term duration. The overall impact on tax revenue from activities at the TYRA project is assessed to be of positive significance.

6.3.6.3 Overall assessment

The overall assessment of impacts on employment and tax revenue from planned activities at the TYRA project is summarised in Table 6-24.

Table 6-24 Potential impacts on employment from planned activities at the TYRA project.

Impact mechanism	Intensity	Extent	Duration	Overall significance	Level of confidence
Employment	Medium	Local/national	Medium term	Positive	Medium
Tax revenue	Medium	Local/national	Medium term	Positive	Medium

6.3.7 Oil and gas dependency

6.3.7.1 Dependency

As part of a long-term Danish energy strategy, the oil and gas production is considered instrumental in maintaining high security of supply. Denmark is expected to continue being a net exporter of natural gas up to and including 2025 and Maersk Oil has a license to operate until 2042 (section 3.4.1 and 5).

If no production is undertaken by Maersk Oil for the TYRA project in the North Sea, there will be no contribution to the Danish economy or security of supply from the TYRA project.

The impact is assessed to be of medium intensity, local or national extent and medium-term duration. The overall impact on dependency from activities at the TYRA project is assessed to be of positive significance.

6.3.7.2 Overall assessment

The overall assessment of impacts on oil and gas dependency from planned activities at the TYRA project is summarised in Table 6-24.

Table 6-25 Potential impacts on employment from planned activities at the TYRA project.

Impact mechanism	Intensity	Extent	Duration	Overall significance	Level of confidence
Oil and gas dependency	Medium	Local/national	Medium term	Positive	Medium

6.4 Summary

The potential impacts on environmental and social receptors from planned activities at the TYRA project are summarised in Table 6-26. The impact with the largest overall significance is provided for each receptor.

Table 6-26 Summary of potential impacts on environmental and social receptors from planned activities at the TYRA project. The impact with the largest overall significance is provided for each receptor.

Receptor	Worst case potential impact
Climate and air quality	Moderate negative
Hydrography	Minor negative
Water quality	Minor negative
Sediment type and quality	Minor negative
Plankton	Minor negative
Benthic communities	Minor negative
Fish	Minor negative
Marine mammals	Moderate negative
Seabirds	Minor negative
Cultural heritage	None
Protected areas (excluding Natura 2000)	None
Marine spatial use	Minor negative
Fishery	Minor negative
Tourism	None
Employment and tax revenue	Positive
Oil and gas dependency	Positive

7. IMPACT ASSESSMENT: ACCIDENTAL EVENTS

7.1 Impact mechanisms and relevant receptors

7.1.1 Potential impact mechanisms

Potential impact mechanisms associated to the accidental events at the TYRA project are screened based on the project description (section 3) and the technical sections (appendix 1).

Potential impact mechanisms include:

- Minor accidental events (gas release, spill of chemical, diesel or oil)
- Major accidental events (oil spill or gas release)

The source of the potential impact mechanisms is provided in Table 7-1.

Table 7-1 Sources of potential impact mechanisms for the TYRA project. "X" marks relevance, while "0" marks no relevance.

Potential impact mechanism	Sesimic	Pipelines and structures	Production	Drilling	Well stimulation	Transport	Decommissioning
Minor accidental events (gas, chemical, diesel or oil)	X	X	X	X	X	X	X
Major accidental events (oil or gas)	0	0	X	X	X	0	0

7.1.2 Relevant receptors (environmental and social)

The environmental and social receptors described in the baseline are listed below.

- Environmental receptors: Climate and air quality, hydrographic conditions, water quality, sediment type and quality, plankton, benthic communities (flora and fauna), fish, marine mammals, seabirds.
- Social receptors: Cultural heritage, protected areas, marine spatial use, fishery, tourism, employment, tax revenue, oil and gas dependency.

The relevant receptors have been assessed based on the project description (section 3) and the potential impact mechanisms (section 7.1). Relevant receptors are summarized in Table 7-2.

Table 7-2 Relevant receptors for the impact assessment of accidental events for the TYRA project. "X" marks relevance, while "0" marks no relevance.

Potential impact mechanism – accidental events	Environmental Receptors									Social Receptors							
	Climate and air quality	Hydrographic conditions	Water quality	Sediment type and quality	Plankton	Benthic communities	Fish	Marine mammals	Seabirds	Cultural heritage	Protected areas	Marine spatial use	Fishery	Tourism	Employment	Tax revenue	OandG dependency
Gas release	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chemical spill*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil spill	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0

*a worst case chemical spill is very local, and not assessed further.

7.1.3 Marine strategy frameworks directive - descriptors

The list of receptors and impact mechanisms described in the ESIS can be directly related to the descriptors set within the Marine Strategy Framework Directive (MSFD; section 2.1.5). The MSFD outlines 11 descriptors used to assess the good environmental status of the marine environment (see presentation of descriptors in section 6.1.3).

The receptors identified in the ESIS are related to the MSFD status indicators hydrography (D7), harbour porpoise and benthic communities (D1, D6). The impact mechanisms for accidental events in the ESIS are related to the MSFD pressure indicators discharges (D6, D8, D9). Each impact mechanism is further assessed for the relevant receptors in the following sections 7.2 and 7.3.

7.1.4 Minor accidental events

A minor accidental event is a spill where the spilled volume is finite.

Minor spill could be chemical or diesel, and could occur following e.g. vessel collision, pipeline leakage or rupture of a chemical container. Statistical analysis shows that collisions between vessels, platforms, riser etc. are very unlikely, typically in the range of 1.4 10^{-7} to 6.5 10^{-4} per year.
Minor gas release of several m^3 may also occur during venting.

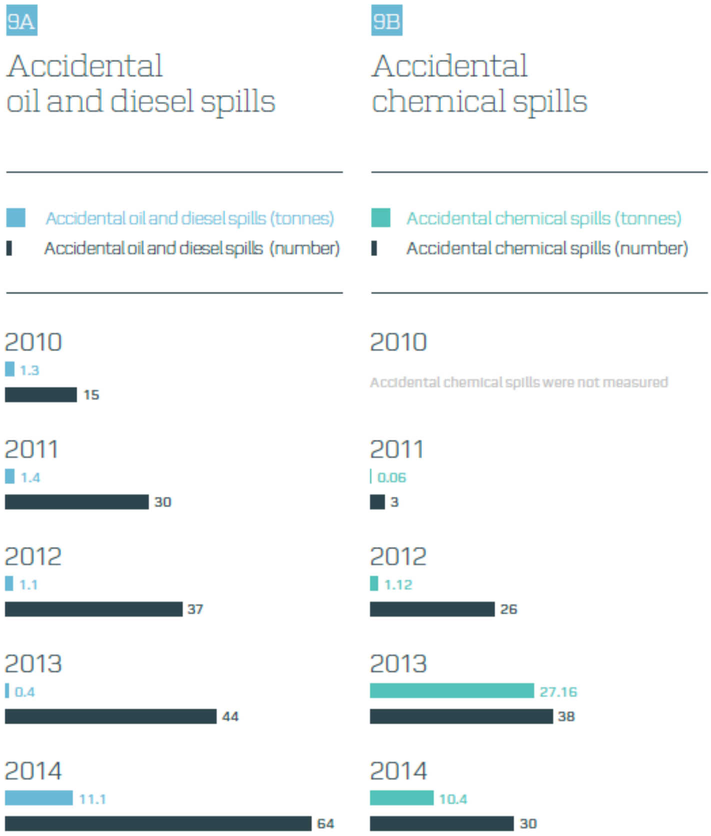


Figure 7-1 Minor accidental oil, diesel and chemical spills from Maersk Oil platforms in the North Sea /161/.

Figure 7-1 presents an overview of the accidental spills over Maersk oil facilities from the period 2010 to 2014. The number of yearly reported spills ranged from 15 to 94 from 2010-2014 and on average were less than 100 litres. During 2014, there were two large diesel spills at Harald and on an accommodation rig which contributed to an increase in the volume of oil and diesel spill. In 2013 and 2014, methanol spills at Tyra and Harald contributed to more than three quarter of the total volume of chemical spills during those years. Methanol is classified as a green chemical (see section 8.1.3). Actions has been taken to eliminate the risk of such spills occurring again: replacing parts of a pump and reinforcing the need to take the utmost care when bunkering diesel. Since 2011, all accidental discharges of oil and chemicals, regardless of volume, are reported. During 2014, the company introduced a more systematic way of reporting spills which may partly contribute to the observed increase in the number of spills being reported.

7.1.4.1 Minor chemical spill (rupture of chemical contatiner)

A chemical spill was modelled for biocide at the DONG operated Hejre platform /43/. The spill was defined for loss of biocide from a container, which was considered worst case regarding potential impact. The modelled spill was for 4,500 l of biocide to the sea, which corresponds to the volume of a typical chemical container. Results showed that the distance, to which impacts may occur (PEC/PNEC ratio of 1), was 500 m /43/. A minor chemical spill is thus confined, with impacts within 500 m. Due to the short distance where potential impacts may occur, a minor chemical spill is not assessed further.

7.1.4.2 Minor oil spill (vessel collision)

A diesel spill following a vessel collision has been modelled for a spill of marine diesel volume corresponding to a typical tank size of 1,000 m^3 during 1 hour, corresponding to the volume of the vessels tank /5//25/. The modelling results show that no shoreline impact would occur, and impacts are only expected in the local area. The results further show that most of the oil would evaporate or emulsify into the water column after 7 days, and by day 20 all of the released oil is no longer mobile; it has evaporated or biodegraded /5//25/.

7.1.4.3 Minor oil spill (full pipeline rupture)

A full rupture of a pipeline at the TYRA project in a worst case scenario is a rupture of pipeline from Tyra East to Gorm E. Emergency valves will automatically close to isolate the pipeline, and the expected maximum volume from a ruptures pipeline is a spill of 10,000 stbo crude oil.

A full bore pipeline rupture has been modelled for a spill of 10,000 stbo over 1 hour at the TYE to Gorm midpoint /152/. The results show that the oil will spread locally (Figure 7-2) , and that it is unlikely that the oil will cross a maritime border. The results show no risk of any shoreline being impacted by oil.

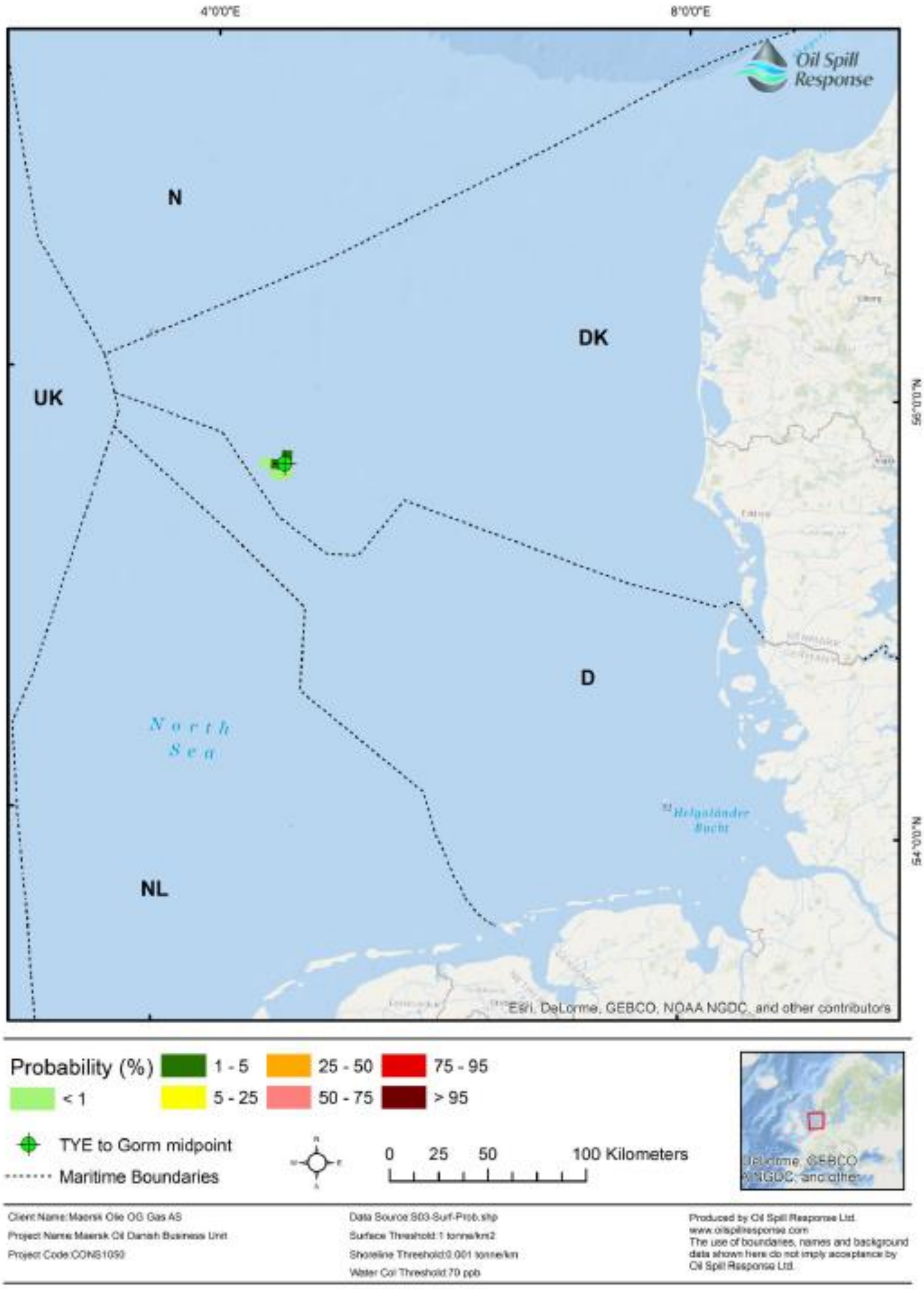


Figure 7-2 Probability that a surface a 1 km cell could be impacted by oil in case of full pipeline rupture /152/.

7.1.5 Major accidental events

A major spill results from an uncontrolled loss of a large volume of oil which often require intervention to be stopped. The main source of major spill is related to blow out events. Blow out events are highly unlikely and may occur during the drilling and completion phase or any operational phase of a well. Well blowout and well release frequencies are in the range (lowest frequency blow out – highest frequency well release) 7.5×10^{-6} to 3.3×10^{-4} per year in maintenance and operation. For development wells, the the frequencies are in the range 3.8×10^{-5} to 6.6×10^{-3} per well. As most reservoirs contains a mixture of oil and gas, the blow out may results in an oil spill and a gas release. Gas will ultimately be dispersed into the atmosphere, whereas the fate of the oil is more difficult to predict.

When the oil is spilled it goes through physical processes such as evaporation, spreading, dispersion in the water column and sedimentation to the seafloor. Eventually, the oil remaining in the sea will be eliminated from the marine environment through biodegradation. The rate and importance of these processes will depend on the type and quantity of the oil as well as the prevailing weather and hydrodynamic conditions. Models are used to predict the fate of oil spills and assess the potential impact on relevant environmental and social receptors.

Oils are classified following the ITOPF classification to allow a prediction of their likely behaviour /154/. Group 1 oils (API>45) tend to dissipate completely through evaporation, whereas group 2 (API: 35-45) and group 3 (API: 17.5-35) can loose up to 40% volume through evaporation but tend to form emulsion. Group 4 oils (API< 17.5) are highly viscous and do not tend to evaporate and disperse. Group 4 is the most persistent oil type. For the TYRA project, the oil is diverse, with a relatively light oil with an API of 60 at Tyra East and Roar, 52 at Tyra West, 47 at Tyra South East (Group 1), intermediate API of 42 at Valdemar (Group 2) and 29 at Svend (Group 3).

The maximum expected initial blow out flow rates from existing producing wells at the TYRA project are 8,330 stbo/d (1,300 m^3/d) for Tyra South East, 2,400 (380 m^3/d) for Tyra West, 32,340 stbo/d(5,100 m^3/d) for Roar, 4,200 stbo/d (660 m^3/d) for Svend and 5,415 stbo/d(850 m^3/d) for Tyra East /162/.

The oil spill model was done using the Oil Spill Contingency and Response (OSCAR) model. OSCAR is a 3D modelling tool developed by SINTEF, able to predict the movement and fate of oil both on the surface and throughout the water column /5//25//26//27/. The model simulated more than 150 trajectories under a wide range of weather and hydrodynamic conditions representative of the TYRA area. The output of the model are statistical maps based on the simulations that defines the areas most at risk to be impacted by an oil spill. Modelling is performed on the non-ignited spill without any oil spill response (e.g. mechanical recovery; section 8 and 9).

Three models were used to investigate the possible fate of an ITOPF Group1 (Xana-1X), ITOPF Group 2 (Siah NE-1X) and ITOPF group 3 (Svend) oil spill occuring at one of the wells for the TYRA existing or new development project. An oil spill from the TYRA project will be ITOPF Group 2. The modelled exploration scenarios correspond to a continuous release for 16 days with a flow rate of 8,534 stbo/d for ITOPF Group 3 oil (Xana-1X) and 40,432 stbo/d for ITOPF Group 2 oil (Siah NE-1X) respectively, and 4,200 stbo/d for ITOPF Group 1 (Svend). The duration of the modelled blowouts is based on the fact that most exploration wells such as Xana-1X and Siah NE-1X would collapse within a duration of 16 days /156/. The casing of a production well is designed to prevent the collapse of the well and a relief well may be necessary to stop the blow out. Such intervention may require about 90 days. Nevertheless, the total volume of the oil spill modelled for Siah NE-1X and Xana-1X (high flow rate and short duration) are higher or equivalent to the maximum volume that could be expected from a producing well over a longer time. Furthermore, it is expected that a high release rate over a short period would be a worse case than a lower rate (for a production scenario) over a longer period. Thus, the results for Siah NE-1X and Xana-1X can be used as representative of a worst credible well blow-out case at the TYRA project.

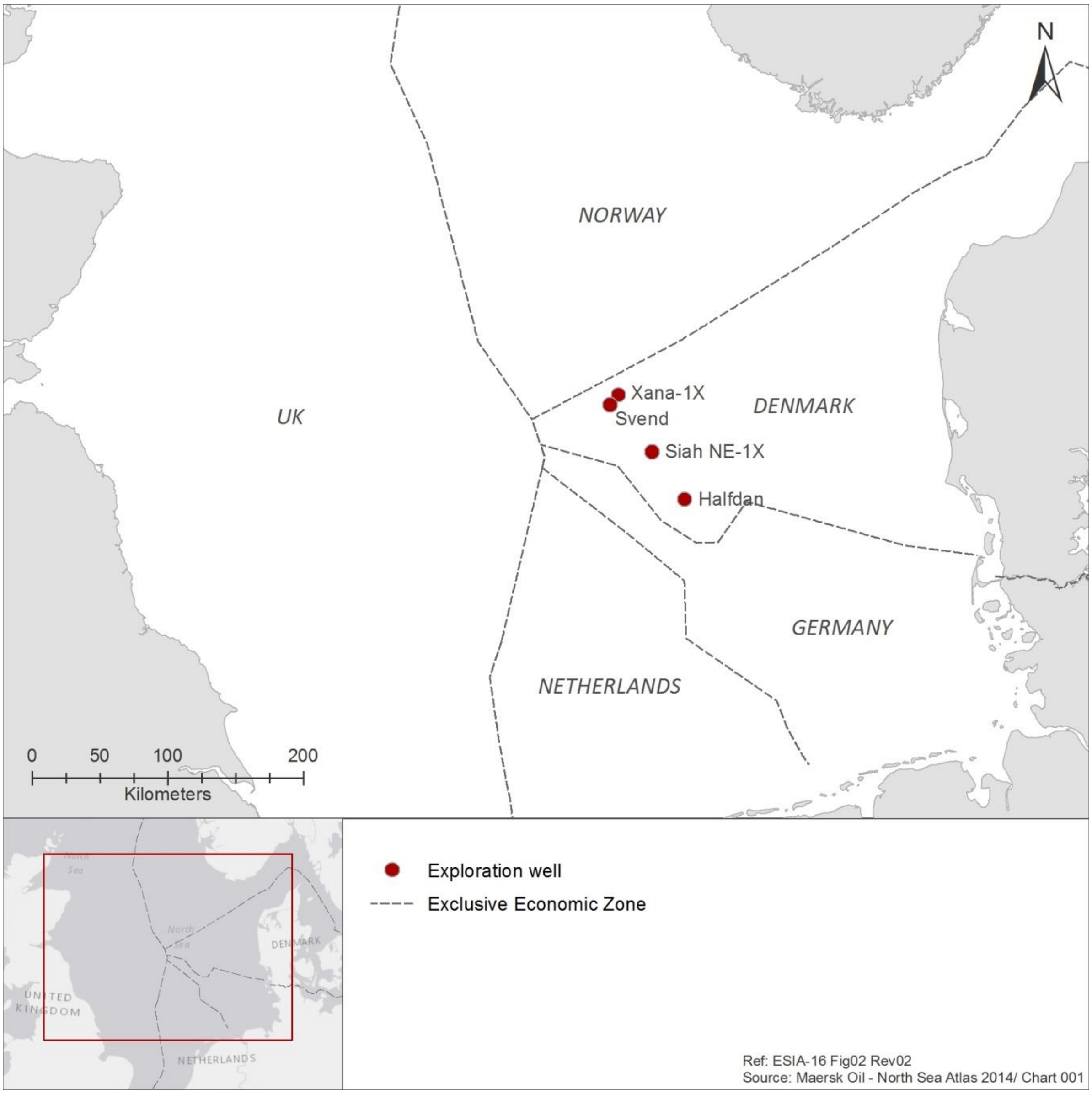


Figure 7-3 Location of four Maersk Oil wells, for which oil spill modelling has been undertaken. Siah NE-1X, Xana-1X and Svend are considered representative for the TYRA project.

The oil spill modelling was used to determine how quickly the oil would reach shoreline and which countries could be affected. It is also used to determine the different oil spill fate and the relevant receptors at the TYRA project. The results are also used to assist in the development of an adapted oil spill response plan (section 9.4).

The trajectory resulting in the most oil onshore is extracted to illustrate the potential fate of an oil spill at the TYRA project in more details /152/. The model results are summarized in Table 7-3.

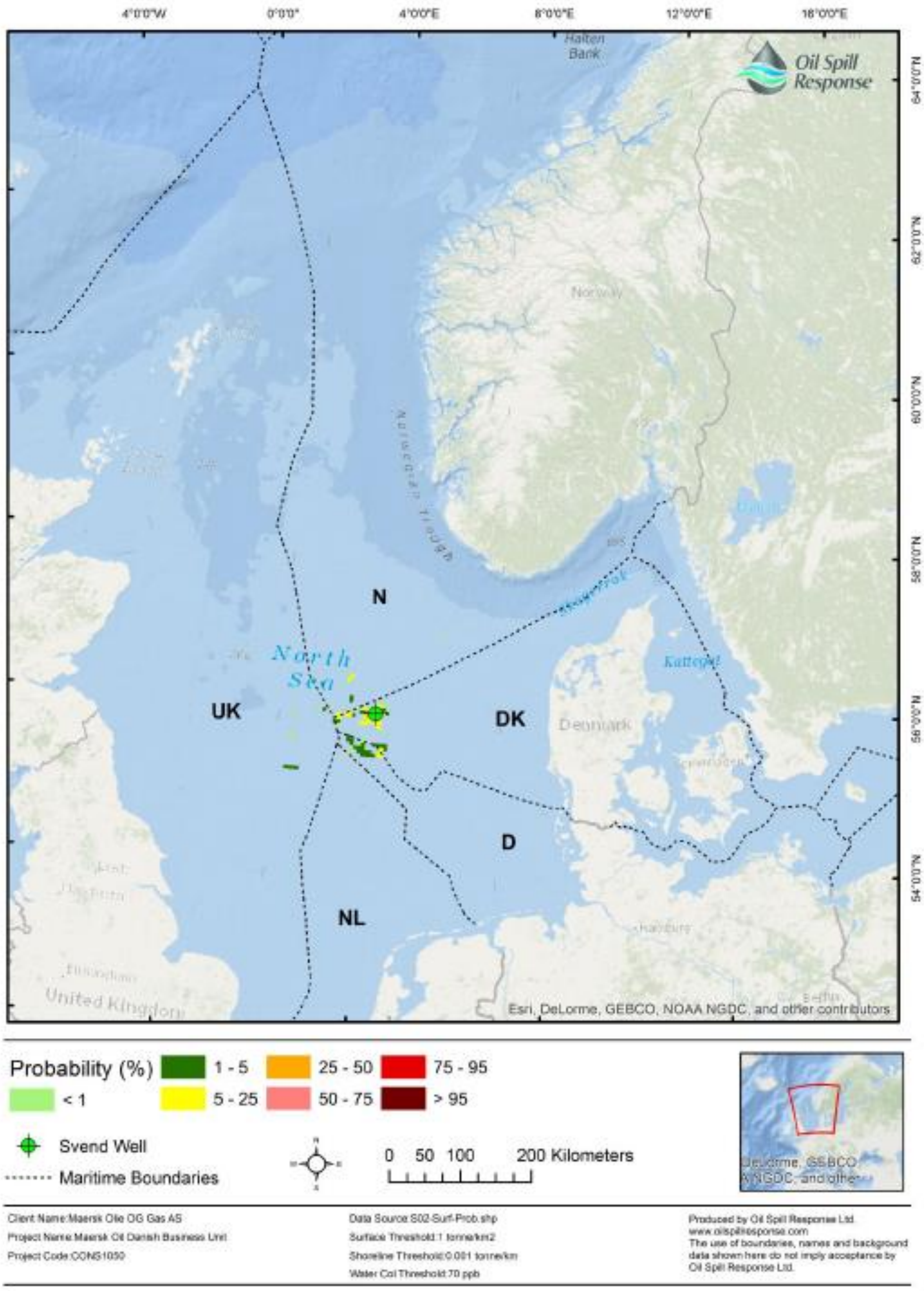
Table 7-3 Results from the worst credible case scenarios for a well blowout at the TYRA project: Svend, Siah NE-1X and Xana 1X /152//5//25//26//27/. Note that the modelling is performed without any oil recovery.

Parameter	Svend	Siah NE-1X Scenario 1	Siah NE-1X Scenario 2	Xana 1X
Model set-up				
Time of year	All year	June-November	December-May	March-September
Release rate	4,200 stbo/d	40,432 stbo/d	40,432 stbo/d	8,534 stbo/d
Release period	90 days	16 days	16 days	16 days
Total mass spilled	53,400 MT (378,000 stbo)	90,004 MT (646,912 stbo)	90,004 MT (646,912 stbo)	19,016 MT (136,544 stbo)
Model run	118 days	44 days	44 days	44 days
ITOPF (API)	3 (API of 17.5-35)	2 (API of 35 - 45)	2 (API of 35 - 45)	1 (API of > 45)
Probability of reaching shore				
% of simulations reaching shore	98 %	100 %	96 %	21 %
Minimum arrival time to shore (days)				
Denmark	10 days	14 days	15 days	14 days
Sweden	60 days	n/a	n/a	n/a
Germany	17 days	n/a	n/a	n/a
Norway	71 days	37 days	37 days	24 days
UK	n/a	n/a	n/a	n/a
Fate of oil at end of simulation (MT/%)[1]				
Onshore	400 MT (<1 %)	10,450 MT (12%)	11,600 MT (13%)	<0.2 MT (<0.5%)
Surface	17 MT (<0.1 %)	14 MT (<1%)	15 MT (<1%)	<0.1 MT (<0.5%)
Water column	1,150 MT (2 %)	370 MT (<1%)	730 MT (<1%)	30 MT (<0.5%)
Evaporated	21,500 MT (40 %)	37,700 MT (39%)	35,400 MT (39%)	2,500 MT (13%)
Sedimentation	25,500 MT (48 %)	26,000 MT (29%)	26,900 MT (30%)	8,400 MT (44%)
Biodegraded	4,850 MT (9 %)	15,470 MT (17%)	15,359 MT (17%)	8,100 MT (42 %)

7.1.5.1 Svend spill (type 3) modelling

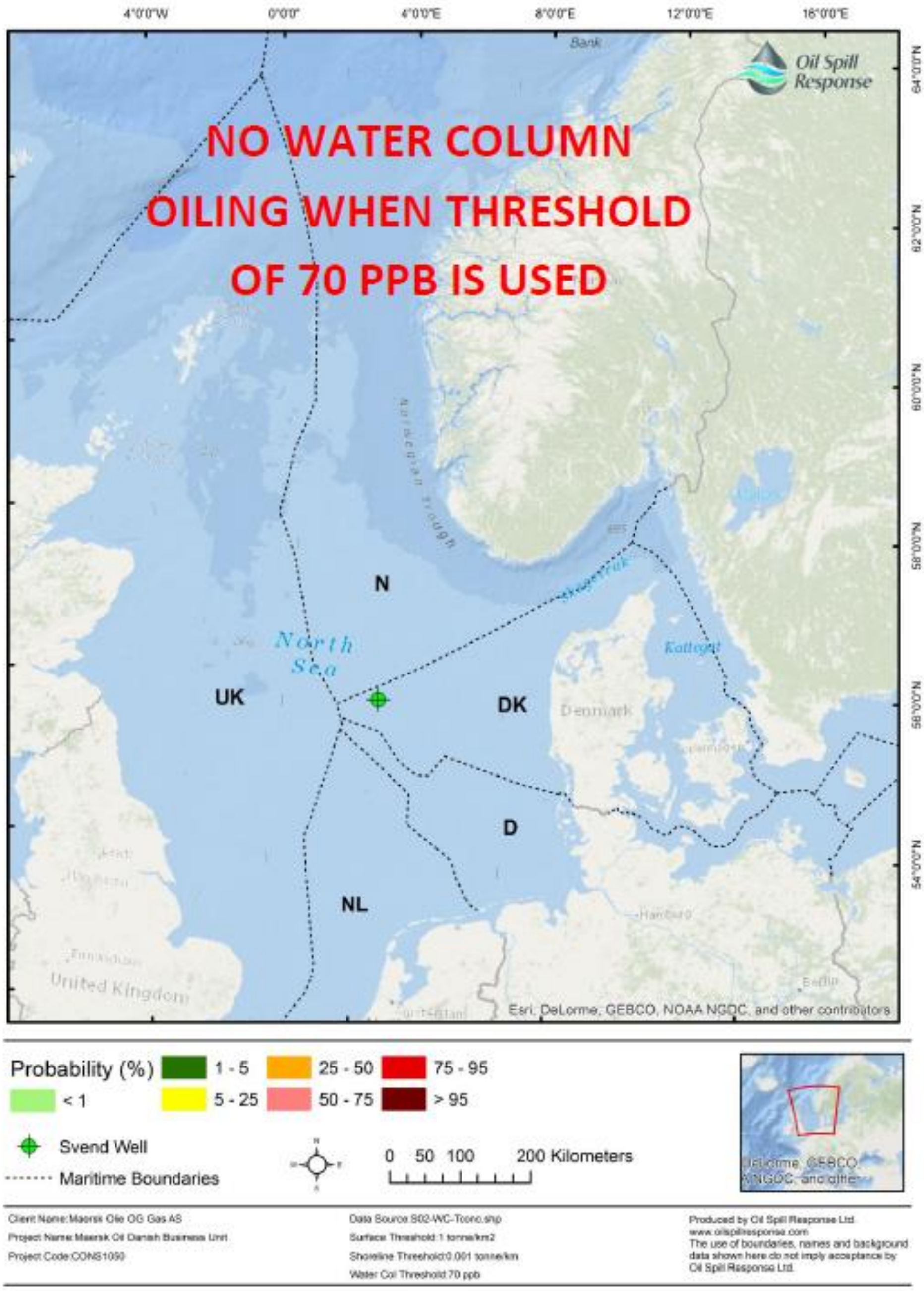
Selected results of the spill modelling for Svend are presented in the following /152/:

- Figure 7-4: Danish, German, UK and Norwegian surface waters could be impacted.
- Figure 7-5: No water column oiling is seen when a threshold of 70 ppb is applied.
- Figure 7-6: Danish, Swedish and Norwegian shorelines are most likely to be affected. The UK shoreline could also be affected.



Scenario	Threshold
S02	Thickness: 1 tonne / km^2

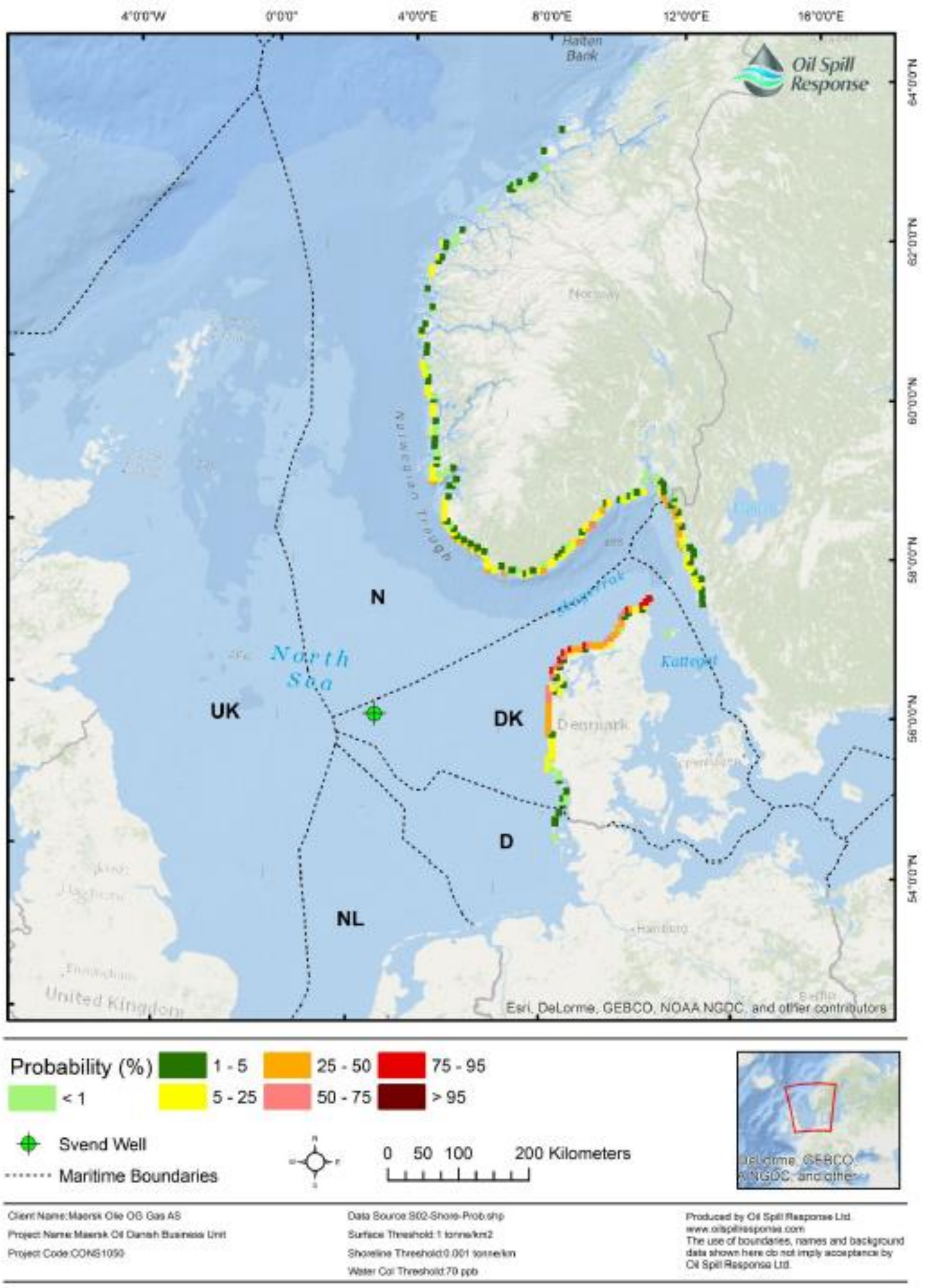
Figure 7-4 Probability that a surface cell could be impacted in a surface blowout at Svend well /152/. Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 159 independently simulated trajectories.



Scenario	Threshold
S02	Concentration: 70 ppb

Figure 7-5 Probability that a water column cell could be impacted in a surface blowout at Svend well /152/.

Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 159 independently simulated trajectories.



Scenario	Threshold
S02	Thickness: 0.001 tonnes/km

Figure 7-6 Probability that a shoreline cell could be impacted in a surface blowout at Svend well /152/.

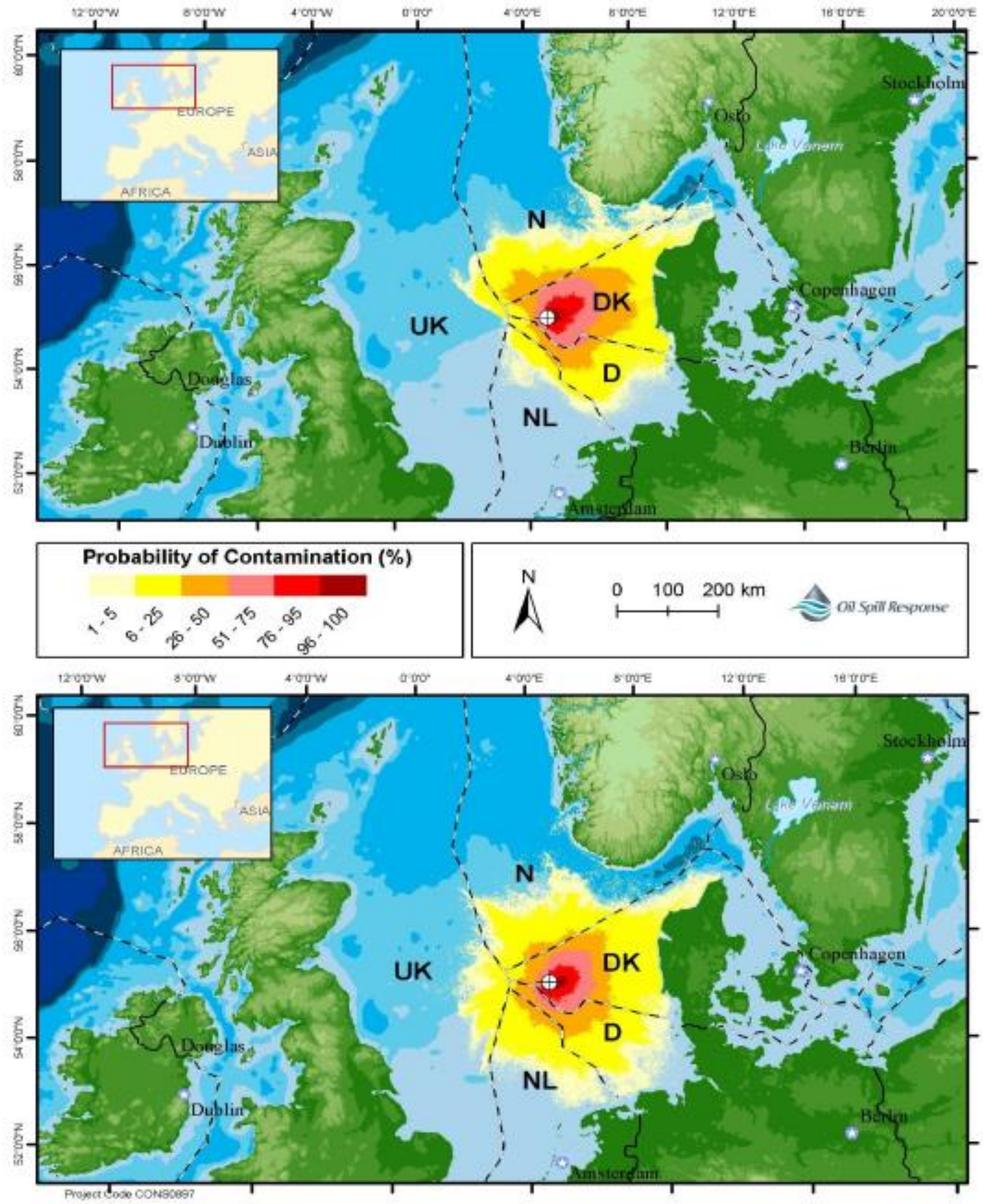
Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 159 independently simulated trajectories.

7.1.5.2 Siah NE-1X spill (type 2) modelling

Selected results of the spill modelling for Siah NE-1X are presented in the following /5//25/:

- Figure 7-7. Norwegian, German and Dutch surface waters have up to 50 % risk of being oiled under these scenarios, while UK waters have at least a 6% risk of oiling. Danish waters (where the release site is located) have a 100 % risk of oiling.
- Figure 7-8. Norwegian, German, UK and Dutch surface waters have up to 25 % risk of being oiled in these scenarios. Danish waters (where the release site is located) have a 100% risk of oiling.
- Figure 7-9. Danish, Norwegian, German and Dutch shorelines could be affected during Scenario 1. The UK shoreline could also be affected during Scenario 2. The Danish shoreline is the most likely to be affected in both scenarios.
- Figure 7-10. In both scenarios, the total concentration of oil in water is generally less than 150 ppb, but could reach up to 300 ppb in Norwegian, Danish, German, Dutch and UK waters.

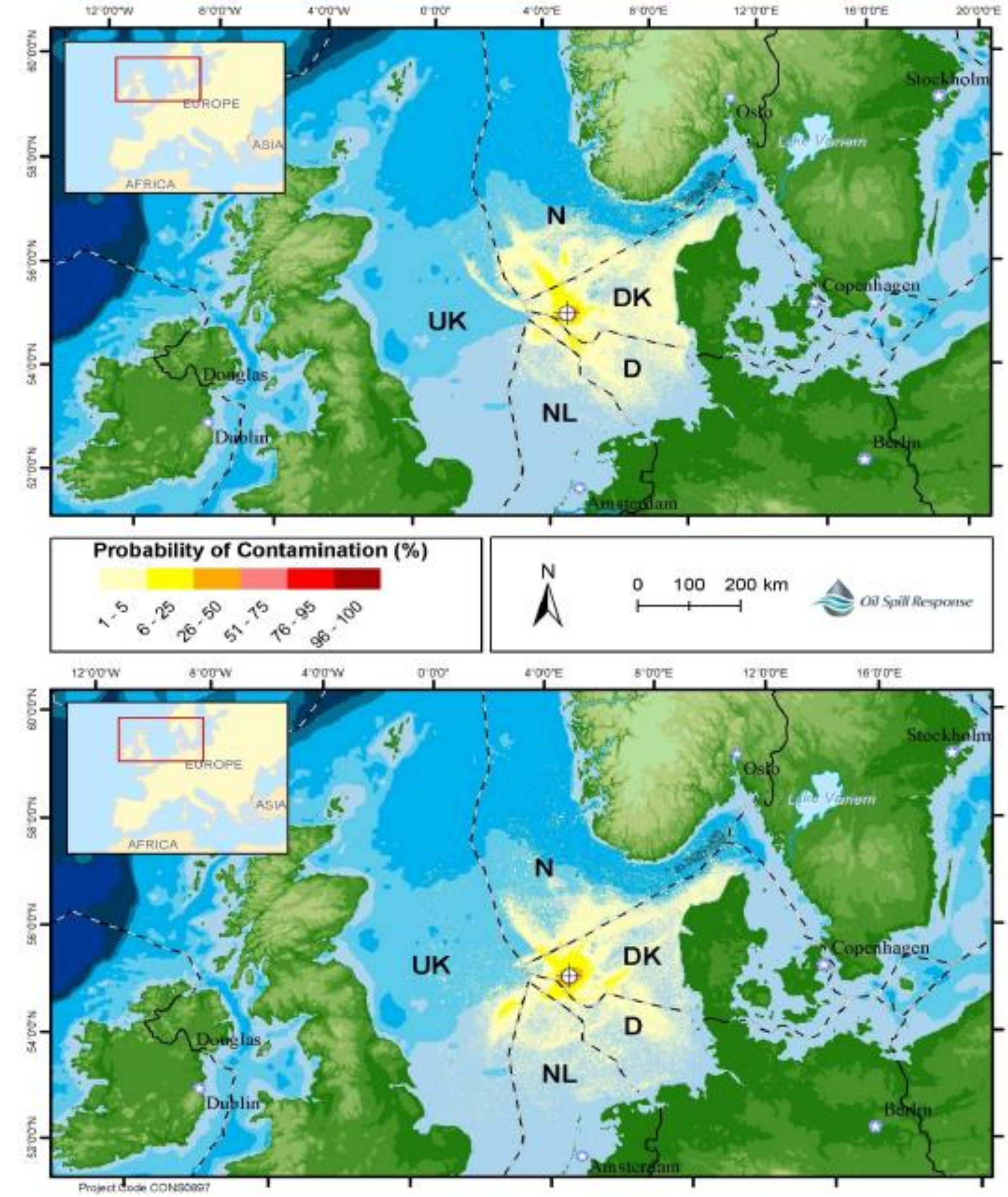
For the TYRA project, oil type 2 is found at Valdemar, with an API of 42.



Scenarios	Threshold
S01 (Jun-Nov), S02(Dec-May)	Thickness: 1 tonne / km^2

Figure 7-7 Probability that a surface a 1 km^2 cell could be impacted in Scenario 1 (sub-surface blowout between June and November, upper plot) and Scenario 2 (sub-surface blowout between December and May, lower plot) /5//25/.

Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 168/167 independently simulated trajectories.



Scenarios	Threshold
S01 (Jun-Nov), S02(Dec-May)	Total Concentration: 70 ppb

Figure 7-8 Probability that a water column cell could be impacted in Scenario 1 (sub-surface blowout between June and November, upper plot) and Scenario 2 (sub-surface blowout between December and May, lower plot) /5//25/.

Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 168/167 independently simulated trajectories.

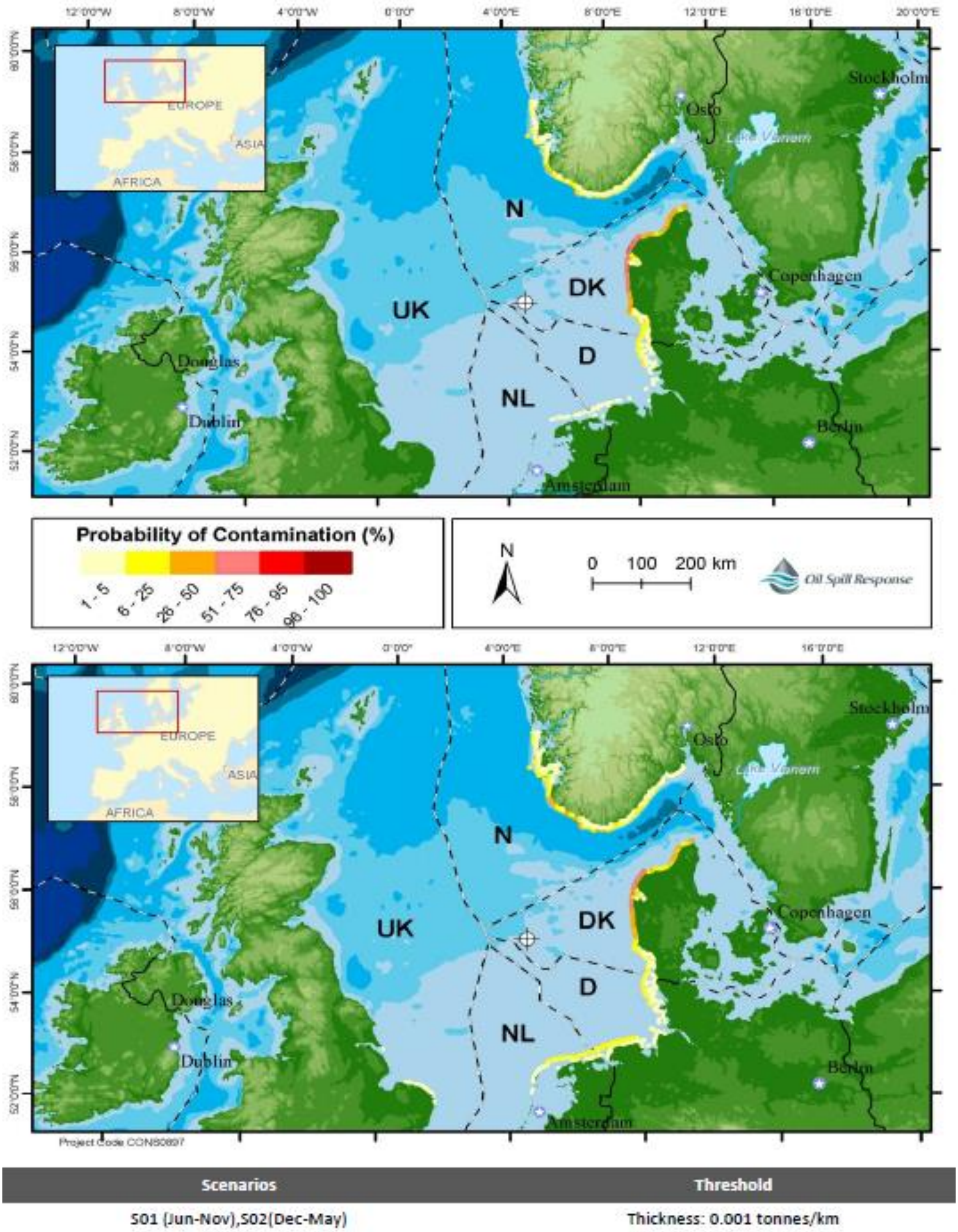
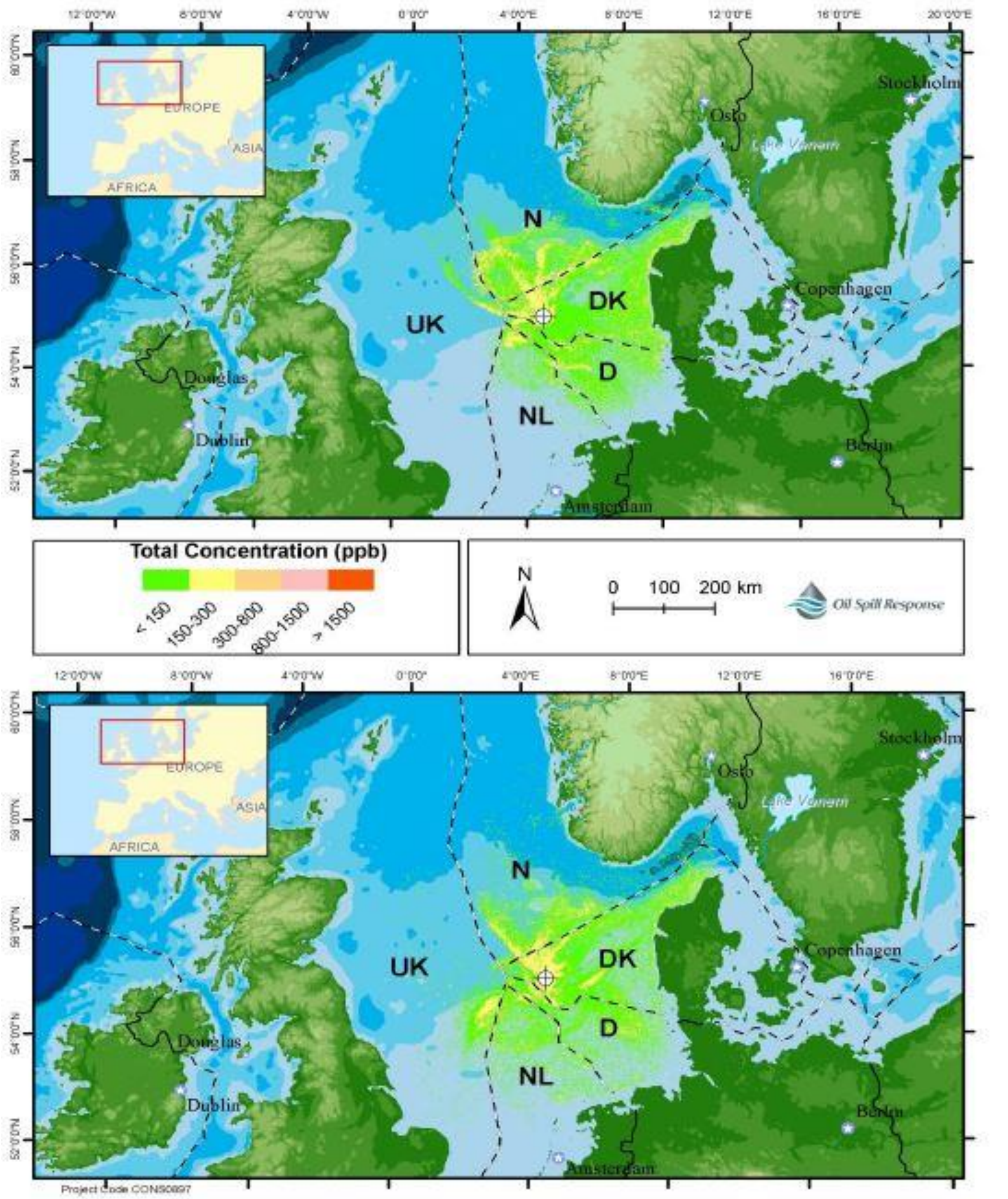


Figure 7-9 Probability that a shoreline cell could be impacted in Scenario 1 (sub-surface blowout between June and November, upper plot) and Scenario 2 (sub-surface blowout between December and May, lower plot) /5//25/.

Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 168/167 independently simulated trajectories.



Scenarios	Threshold
S01 (Jun-Nov), S02(Dec-May)	Total Concentration: 70 ppb

Figure 7-10 Maximum time-averaged total oil concentration for the two scenarios. Upper plot: June-November, Lower plot: December May /5/. Note that the images does not show actual footprint of an oil spill but a statistical picture based on 168/167 independently simulated trajectories.

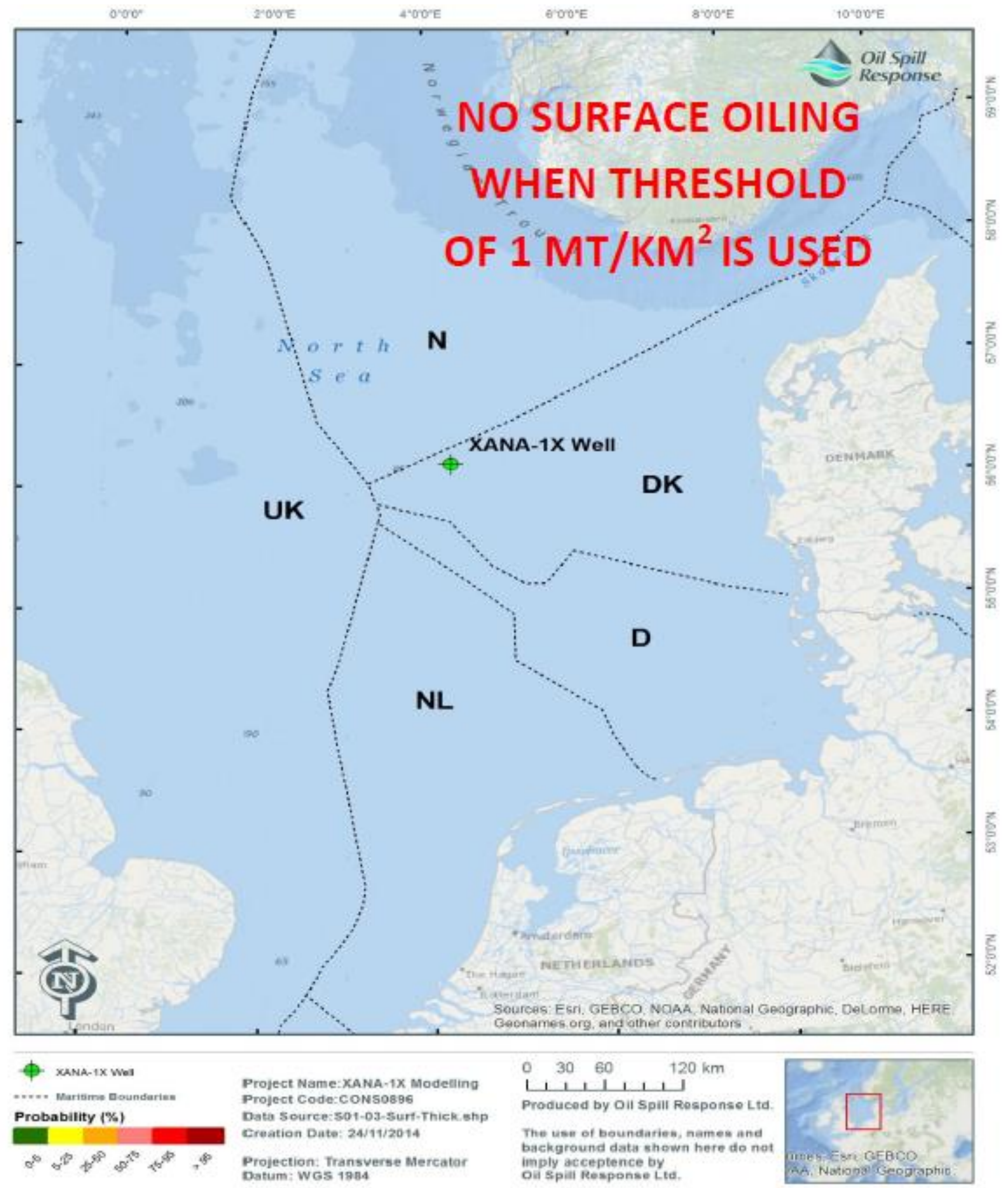
Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 168/167 independently simulated trajectories.

7.1.5.3 Xana 1X spill (type 1 oil) modelling

One scenario has been modelled for a major oil spill at Xana. Selected results of the spill modelling for Xana 1X are presented in the following /26//27/:

- Figure 7-11: No surface oiling is probable anywhere, when threshold of 1 MT/km^2 is applied.
- Figure 7-12: Other than Denmark, Norway is the only country where the water column could be impacted by a spill.
- Figure 7-13: Only Danish and Norwegian shorelines could be affected in case of a spill.
- Figure 7-14: Concentrations can be over 1,500 ppb around the release site. The oil concentration decreases further away from the site. If Norwegian waters experience oiling, it is expected the concentrations will be less than 300 ppb.

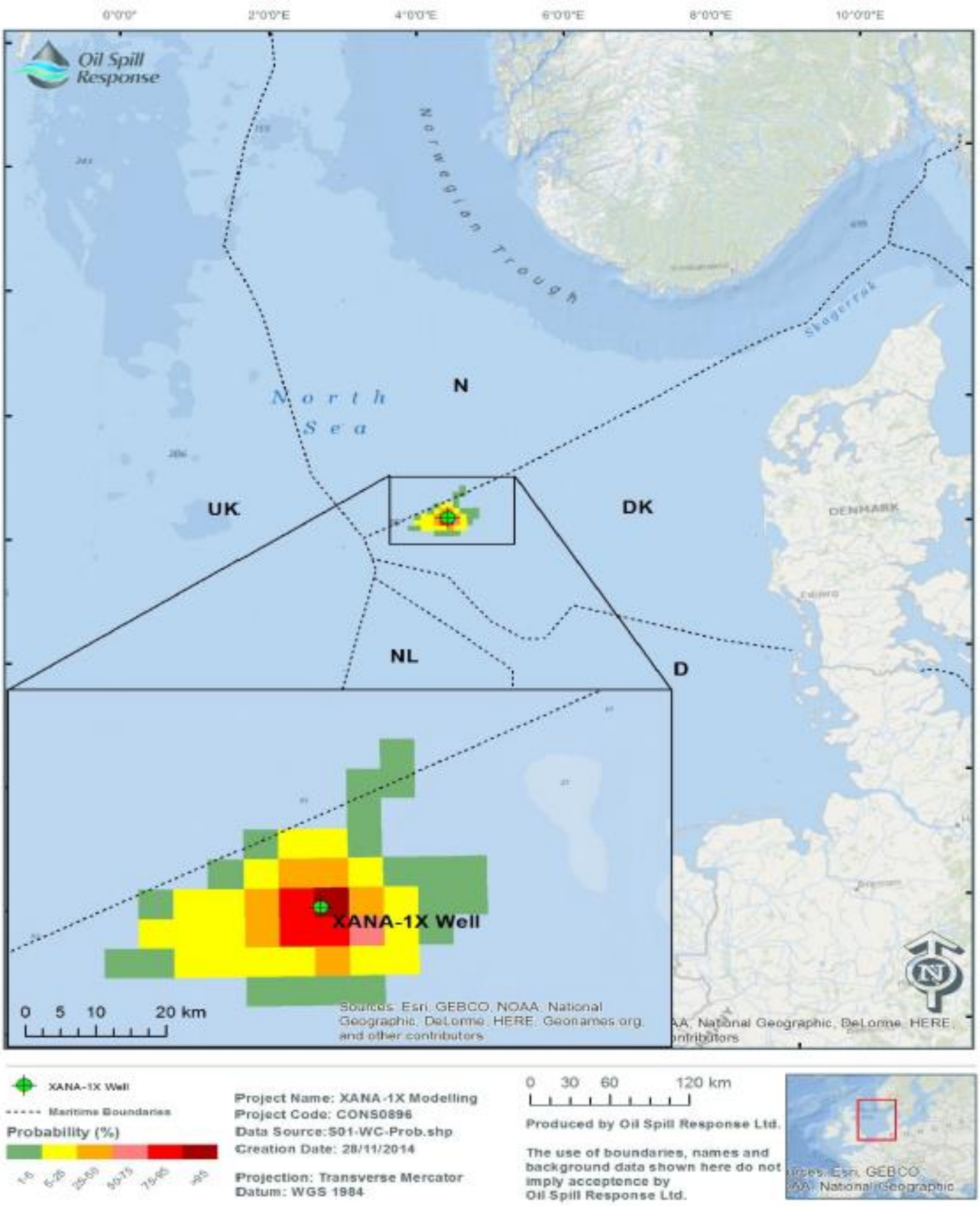
For the TYRA project, type 1 oil is found at Tyra East and Roar (API of 60), at Tyra West (API of 52) and at Tyra South East (API of 47).



Scenarios	Threshold
S01 (March-September)	Thickness: 1 tonne / km^2

Figure 7-11 Probability that a surface a 1km cell could be impacted. Note than no surface oiling is probable, when threshold of 1 MT/km^2 is applied /26//27/.

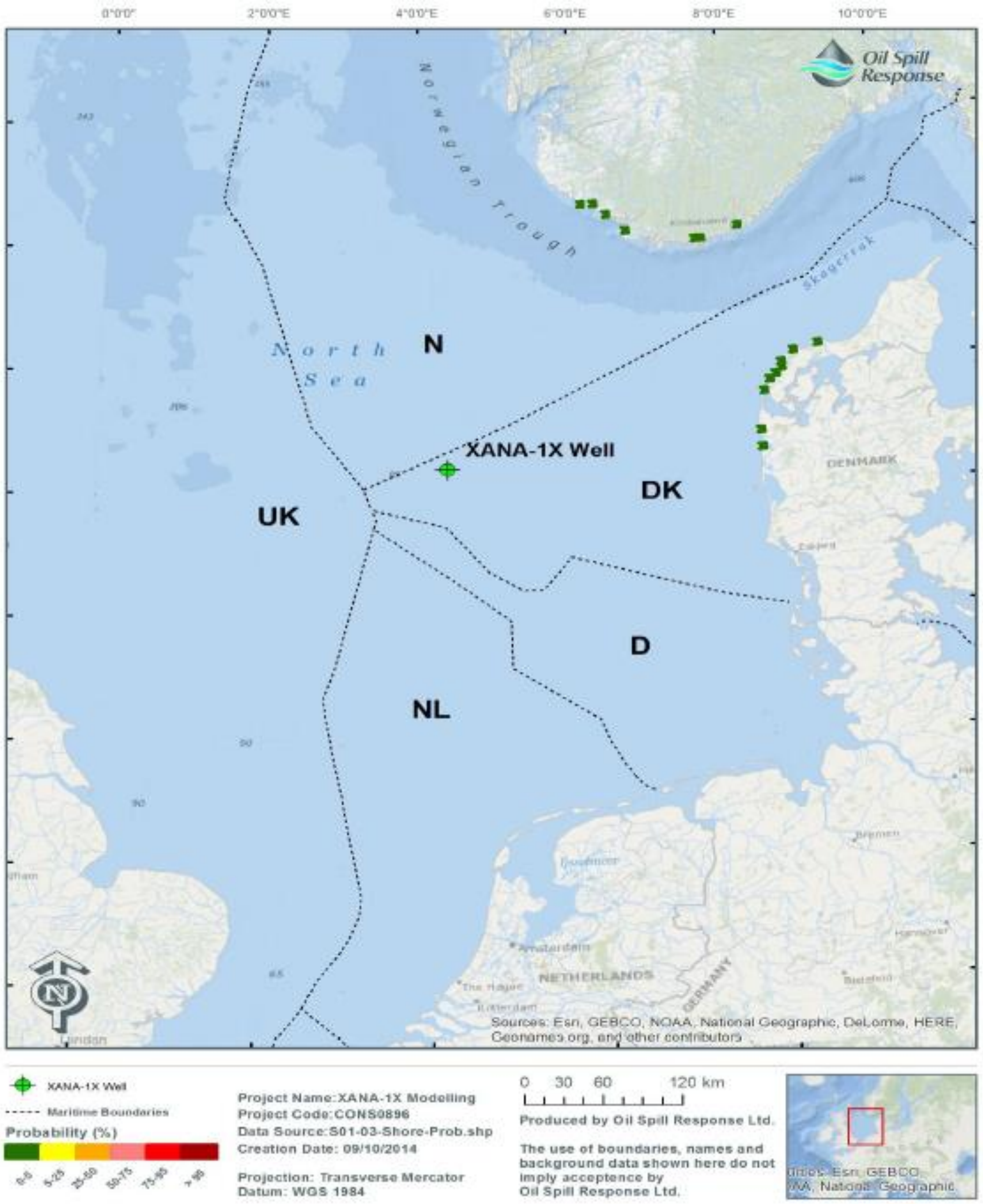
Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 400 independently simulated trajectories.



Scenarios	Threshold
S01 (March-September)	Concentration: 70 ppb

Figure 7-12 Probability that a water column grid cell could be impacted /26//27/.

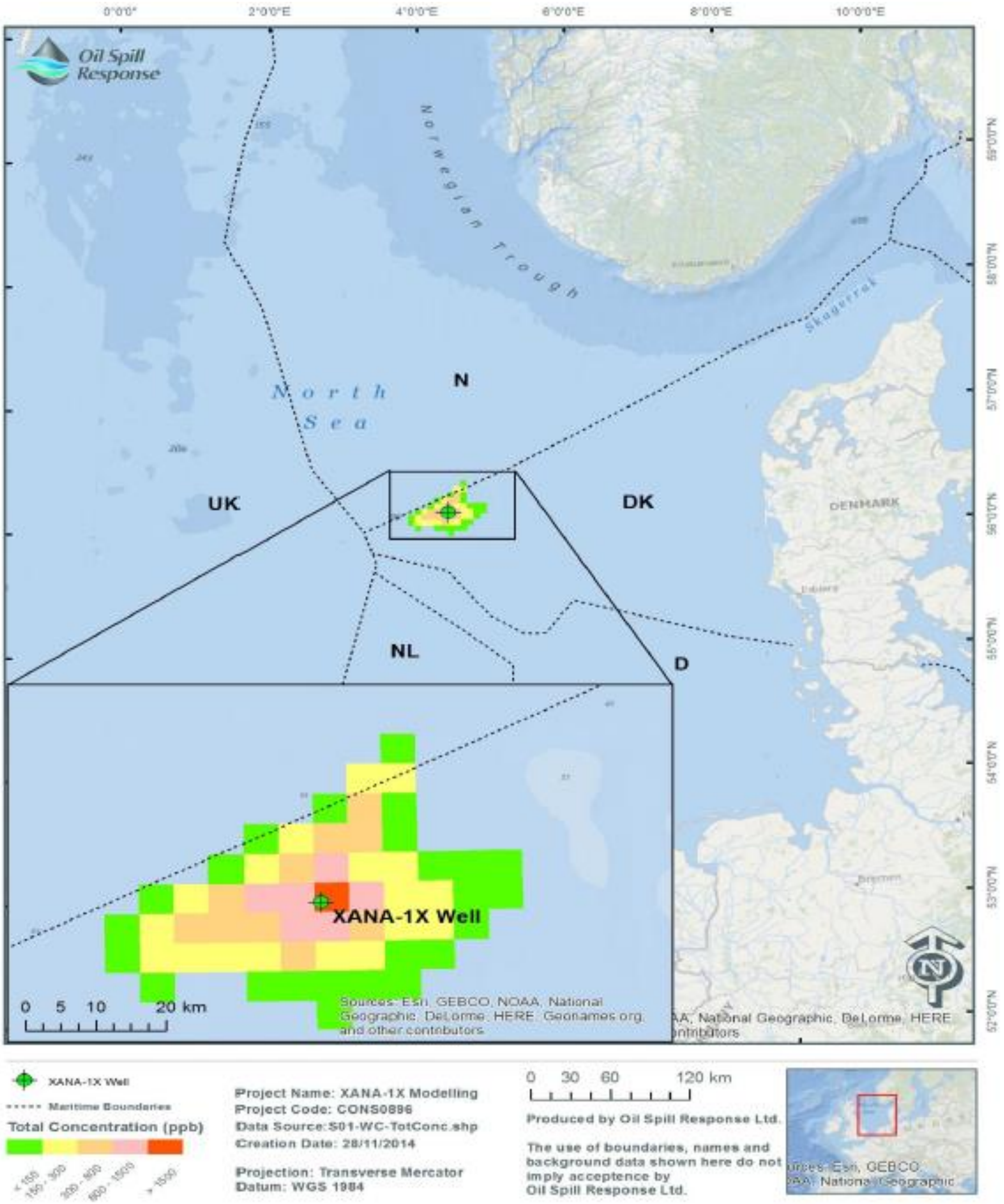
Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 400 independently simulated trajectories.



Scenarios	Threshold
S01 (March-September)	Thickness: 0.001 tonnes/km

Figure 7-13 Probability of shoreline grid cells being impacted by oil /26//27/.

Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 400 independently simulated trajectories.



Scenarios	Threshold
S01 (March-September)	Concentration: 70 ppb

Figure 7-14 Maximum time-averaged total oil concentration in water column cells /26//27/.

Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 400 independently simulated trajectories.

7.2 Assessment of potential environmental impacts

Impact assessment for the relevant environmental receptors is presented in this section for accidental events. The assessment is based on modelling data to evaluate the extent, while literature data is applied to assess the intensity and duration of impact.

7.2.1 Climate and air quality

Potential impacts on climate and air quality from accidental events are related to gas release.

7.2.1.1 Major gas release

The gas release in case of a major leak is primarily composed of methane CH_4 or CO_2 if the gas is ignited. In case of an uncontrolled gas release, gas will be released to the atmosphere. CH_4 or CO_2 are greenhouse gas and a major gas release will contribute to the global pool of greenhouse gas (see section 6.2.1).

The impact to climate and air quality from a uncontrolled gas release at the TYRA project is assessed to be of medium intensity, with a transboundary extent and a long-term duration. The overall significance of the impact is assessed to be moderate negative.

7.2.1.2 Overall assessment

The potential impacts are summarised in Table 7-4.

Table 7-4 Potential impacts on climate and air quality related to accidental events at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Major gas release	Medium	Transboundary	Long-term	Moderate negative	Low

7.2.2 Water quality

Potential impact mechanisms to water quality from accidental spill are related to minor and major oil spill.

7.2.2.1 Minor oil spill

Modelling results for a marine diesel spill from a vessel show that after 20 days all of the released oil is no longer mobile; it has evaporated or biodegraded (section 7.1.4). Modelling results for a pipeline rupture show that the dispersion is local near the rupture.

The physical presence of a large oil slick will cause considerable changes to physical and chemical parameters of marine water quality, such as reduced light or oxygen levels. In addition, the increased concentration of oil substances (THC, PAH etc) will alter the water quality.

Based on the modelling results the extent of the impact on the water quality is assessed to be local. The intensity is considered small with a short-term duration, as the oil will evaporate, settle or biodegrade. Overall, the impact on the water quality from a minor oil spill will be of minor negative significance.

7.2.2.2 Major oil spill

Based on the modelling of a major oil spill (section 7.1.5) oil components concentrations can be over 1500 ppb around the release site, while concentrations are generally below 150 ppb in the water column. At the end of the model simulation, most of the oil has either drifted onshore, evaporated, sedimented or is biodegraded (section 7.1.5).

The physical presence of a large oil slick will cause considerable changes to physical and chemical parameters of marine water quality, such as reduced light or oxygen levels. In addition, the increased concentration of oil substances (THC, PAH etc) will alter the water quality. The extent of the impact depends to a large extent on the prevailing meteorological conditions.

Based on the modelling results the impact is assessed to be of medium intensity, transboundary extent and a medium duration. Overall, the impact on water quality from a major oil spill will be of moderate negative significance.

7.2.2.3 Overall assessment

The potential impacts are summarised in Table 7-5.

Table 7-5 Potential impacts on water quality related to accidental events at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor oil spill	Small	Regional	Short-term	Minor negative	Medium
Major oil spill	Medium	Transboundary	Medium-term	Moderate negative	Medium

7.2.3 Sediment type and quality

Potential impact mechanisms to sediment type and quality are related to minor and major oil spill.

7.2.3.1 Minor oil spill

Modelling results for a marine diesel spill from a vessel show that after 20 days all of the released oil is no longer mobile; it has evaporated or biodegraded (section 7.1.4).

Based on the modelling results the intensity of the impact is assessed to be small with a potential regional extent and a short-term duration. Overall, the impact on sediment type and quality from a minor oil spill will be of minor negative significance.

7.2.3.2 Major spill

Based on the modelling of a major oil spill, significant impacts on the sediment type and quality may occur. Modelling of five different scenarios (section 7.1.5) shows that between 29-55 % of the oil will end up on the seabed, corresponding to up to approximately 159,000 MT over a large area in the North Sea. The rest will either drift onshore, evaporate or biodegrade.

Full recovery will require degradation or burial of contaminants in combination with naturally slow successional processes. Oil degradation in the marine environment is limited by temperature, nutrient availability (especially nitrogen and phosphorous), biodegradability of the petroleum hydrocarbons, presence of organic carbon, and the presence of microorganisms with oil degrading enzymes /123//124/.

Based on the modelling results the intensity of the impact from a major oil spill is assessed to be medium with a transboundary extent and a medium duration. Overall, the impact on the sediment type and quality will be of moderate negative significance.

7.2.3.3 Overall assessment

The potential impacts are summarised in Table 7-6.

Table 7-6 Potential impacts on sediment type and quality related to accidental events at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor oil spill	Small	Regional	Short-term	Minor negative	Medium
Major oil spill	Medium	Transboundary	Medium-term	Moderate negative	Medium

7.2.4 Plankton

Potential impact mechanisms to plankton are related to minor and major oil spill.

7.2.4.1 Minor oil spill

Based on the assessed impact to the water quality (section 7.2.2) a minor oil spill is assested to have a limited impact on plankton community. Though planktonic organisms may be affeced, the high reproductive potential of plankton is considered able to compensate.

The intensity of the impact is assessed to be small with a local extent and a short-term duration. Overall, the impact on plankton is assessed to be of minor negative significance.

7.2.4.2 Major oil spill

Laboratory toxicity studies have demonstrated great variation amongst planktonic organisms in response to the effects of spilled oil, with phytoplankton generally considered less sensitive than zooplankton /125/.

Tests in containers of naturally occurring algae and water soluble fraction of North Sea oil concentrations of 0.1 mg/l (=100 ppb) showed no significant effects on the total primary production /126/. Toxic effects including decreases in growth rate and inhibition of photosynthesis have been observed in phytoplankton exposed to water soluble fractions of oil concentrations ranging from 1,000 ppb to 10,000 ppb /127/.

Acute lethal effects to zooplankton have been observed from contact with water soluble fractions in concentrations greater than 200 ppb /125/. Sub-lethal effects to zooplankton, including physiological, biochemical and behavioural effects have been observed at one-tenth of lethal concentrations /125/. However, such laboratory toxicity studies have been shown to be of little relevance for predicting long-term effects on natural populations. Such studies are typically short-term and use robust, easily handled species not representative of the wide variety of planktonic organisms that exist naturally. Although such experiments demonstrate oil spill effects to plankton, field observations have typically showed minimal or transient effects /125/.

There are no examples of long-term effects on plankton stocks after oil spills. This is due to plankton reproductive capacity and the water circulation bringing new plankton from outside the affected area /128//129/. Plankton populations are thus not particularly vulnerable to oil spill, and may compensate for any impact through a high reproductive potential.

Based on the assessed impact to the water quality (section 7.2.2.2) the duaration of the impact on plankton is short-term. The intensity of the impact is assessed to be medium with an transboundary extent and a short-term duration. Overall, the impact of major oil spill on the plankton community will be of minor negative significance.

7.2.4.3 Overall assessment

The potential impacts are summarised in Table 7-7.

Table 7-7 Potential impacts on plankton related to accidental events at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor oil spill	Small	Local	Short-term	Minor negative	Medium
Major oil spill	Small	Transboundary	Short-term	Minor negative	Medium

7.2.5 Benthic communities

Potential impact mechanisms on the benthic communities are related to minor and major oil spill.

7.2.5.1 Minor oil spill

Based on the assessed impact to the sediment type and quality (section 7.2.3) any significant impacts on the benthic communities are estimated to be limited. The intensity of the impact is assessed to be none/small with a regional extent and a medium-term duration. Overall, the impact on sediment type and quality from a minor oil spill will be of minor negative significance.

7.2.5.2 Major oil spill

Lethal and sub-lethal effects to the benthos may include mortality, alterations in recruitment, growth and reproduction, as well as changes in community structure, including species richness. Nonselective deposit feeders such as polychaetes and nematodes have demonstrated resilience to the adverse effects of spilled oil /130/. Conversely, the density of crustaceans such as amphipods and copepods would be expected to decline due to their known sensitivity to the effects of oil /130/.

The biological effects of oil on the seabed and benthos depend largely on the fate of the spilled oil and the additive toxicity of aromatic hydrocarbons.

Model calculations show that upto half of the oil will end at the seafloor, i.e. a large mass over a large area (section 7.1.5). It cannot be excluded that oil components could affect bottom fauna to some extent in the affected area. Recovery of soft-bottom benthos after previous shallow-water oil spills has been documented to take years to decades /123//124/.

The intensity of the impact is assessed to be medium with an transboundary extent and a medium-term duration. In conclusion, the overall impact on the benthic comunity from a major oil spill will be of major negative significance.

7.2.5.3 Overall assessment

The potential impacts are summarised in Table 7-8.

Table 7-8 Potential impacts on benthic communities related to accidental events at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor oil spill	None/Small	Regional	Medium-term	Minor negative	Medium
Major oil spill	Medium	Transboundary	Long-term	Major negative	Medium

7.2.6 Fish

Potential impact mechanisms on fish are related to minor and major oil spill. Note that eggs and larvae are assessed as part of plankton.

7.2.6.1 Minor oil spill

Based on the assessed impact to the water quality (section 7.2.2) and the sediment type and quality (section 7.2.3) a minor oil spill is assested to have a limited impact on the fish communities. The impact of a minor oil spill is confined to impacts on individuals, and not populations The intensity of the impact is assessed to be small with a regional extent and a short/medium-term duration. Overall, the impact on fish from a minor oil spill is assessed to be of minor negative significance.

7.2.6.2 Major oil spill

Although laboratory studies have shown a range of lethal and sub-lethal effects of oil on fish /131/ the hydrocarbon concentrations at which these have occurred have generally been considerably higher than those occurring during oil spills /125/. Fish appear to be more sensitive to short-term acute toxicity from the lighter aromatic components which is probably because they possess the enzymes necessary to metabolise sub-lethal concentrations of hydrocarbons /125//131/.

Laboratory studies have shown that adult fish are able to detect oil in water at very low concentrations, and large numbers of dead fish have rarely been reported after oil spills /132/ /133/. This suggests that juvenile and adult fish are capable of avoiding water contaminated with high concentrations of oil.

Fish are most susceptible to the effects of spilled oil in their early life stages, particularly during egg and planktonic larval stages, which can become entrained in spilled oil. Contact with oil droplets can mechanically damage feeding and breathing apparatus of embryos and larvae /134/. The toxic compounds of oil in water can result in genetic damage, physical deformities and altered developmental timing for larvae and eggs exposed to even low concentrations over prolonged timeframes (days to weeks) /134/. More subtle, chronic effects on the life history of fish as a result of exposure of early life stages to oil include disruption of complex behaviours such as predator avoidance, reproductive and social behaviour /132/. Prolonged exposure of eggs and larvae to weathered concentrations of oil in water has also been shown to cause immunosuppression and allows expression of viral diseases /132/. However, the effect of an oil spill on a population of fish in an area with fish larvae and/or eggs, and the extent to which any of the adverse impacts may occur, depends greatly on prevailing oceanographic and ecological conditions at the time of the spill and its contact with fish eggs or larvae.

Concentrations of 100 ppb THC (total hydrocarbons) has been found to cause acute death of fish eggs and larvae /135/. According to the model results there is a risk thsat concentrations of 70-150 ppb in the water column can be found out to a distance of a 200-300 km. At this concentration, the eggs and larvae of fish are likely to be affected.

Based on the modelling results, and the above information, the impact is assessed to be of medium intensity with an transboundary extent and a short to medium-term duration. Overall, the impact on the fish community from a major oil spill will be of major negative significance.

7.2.6.3 Overall assessment

The potential impacts on fish are summarised in Table 7-9.

Table 7-9 Potential impacts on fish related to accidental events at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor oil spill	Small	Regional	Short/medium-term	Minor negative	Medium
Major oil spill	Medium	Transboundary	Short/medium-term	Major negative	Medium

7.2.7 Marine mammals

Potential impact mechanisms to marine mammals are related to minor and major oil spill.

7.2.7.1 Minor oil spill

Oil spill spill from collisions or pipeline rupture may impact marine mammals which come into contact with the spill. Marine mammals generally avoid oil slicks, but impacts on individuals may occur through ingestion, inhalation or consumption of contaminated organisms. The extent of a minor oil spill is local (section 7.1.4). The intensity of the impacts is assessed to be small with a short-term duration. The overall impacts on marine mammals at the TYRA project is assessed to be of minor negative significance.

7.2.7.2 Major oil spill

A major oil spill may impact marine mammals which come into contact with the spill. Impacts are related to direct contact with the oil, where smothering of seals may occur leading to inflammation, infection, suffocation, hypothermia and reduced buoyancy /25/. Whales and dolphins do not have hair, and are not susceptible to smothering. Both whales and seals may accumulate toxins through ingestion (which can lead to digestive complications), inhalation (which can lead to respiratory damage, paralysis, death) or consumption of contaminated marine organisms.

The sensitive months for marine mammals in relation to a major oil spill have been determined based on the months where the species are present the North Sea /25/. Grey seal, harbour seal and harbour porpoise are sensitive year-round, while minke whale and white-beaked dolping are sensitive in summar (May-September).

Modelling results show that oil may impact both Danish, Swedish, German, Dutch, UK or Norwegian sectors of the North Sea, and the extent is thus considered transboundary. The intensity of the impact is considered to be large, as there may be an impact to the individuals, and also to populations.

Seals can also lose their shoreline habitat if oil washes up on their haul-out sites. Oil spill modelling has identified Denmark, Sweden and Norway as most vulnerable to oil beaching, although Germany, UK and the Netherlands could also be affected.

The intensity of the impact from a major oil spill is large, and may affect the ecosystem structure of marine mammals in the North Sea. The duration of the impact is long-term, and the overall impact on marine mammals from a major oil spill is assessed to be of major negative significance.

7.2.7.3 Overall assessment

The potential impacts are summarised in Table 7-10.

Table 7-10 Potential impacts on marine mammals related to accidental events at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor oil spill	Small	Local	Short-tem	Minor negative	Medium
Major oil spill	Large	Transboundary	Long-term	Major negative	High

7.2.8 Seabirds

Potential impact mechanisms to seabirds are related to minor or major oil spill.

7.2.8.1 Minor oil spill

A minor oil spill may impact seabirds, if they come into contact with the oil (see description of vulnerability below). The extent of a minor oil spill is considered local, and of medium-term duration. The intensity if considered small, as the impact of a minor oil spill will affect individuals and not populations. The overall impact on seabirds from a minor oil spill is assessed to be of moderate negative significance.

7.2.8.2 Major oil spill

Seabirds are vulnerable to oil spills in the marine environment. Oil may impact the insulating and water-resistant properties and affecting the buoyancy of the plumage causing the bird to suffer from hypothermia, starvation or in severe case drowning. In addition, birds may get intoxicated from ingestion or inhalation of fuels when they are cleaning their plumages or are feeding on contaminated food. Intoxication may cause irritation of the digestive organs, damages to liver, kidneys and salt glands and leading to anaemia. The intensity of the impacts is therefore assessed to be large /25/.

Birds tend to nest in late spring and summer, which means juveniles are most vulnerable to oil spills in the spring and summer months, although adults of many species may be found in the North Sea all year. The window of vulnerability for migratory birds depends on whether they summer or winter along the North Sea coasts.

A major oil spill is assessed to have a transboundary extent and long-term duration. The overall impact on seabirds from a major oil spill is assessed to be of major negative significance.

7.2.8.3 Overall assessment

The potential impacts are summarised in Table 7-11.

Table 7-11 Potential impacts on seabirds related to accidental events at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor oil spill	Large	Local-Regional	Medium-term	Moderate negative	Medium
Major oil spill	Large	Transboundary	Long-term	Major negative	High

7.3 Assessment of potential social impacts

Impact assessment for the relevant social receptors is presented in this section for accidental events. The assessment is based on modelling data to evaluate the extent, while literature data is applied to assess the intensity and duration of impact.

7.3.1 Cultural heritage

Potential impacts on cultural heritage are related to oil spill.

Cultural heritage as wrecks or submerged settlements can be impacted by smothering of oil in connection with minor or major oil spills.

The impact will depend on the type of cultural heritage, and the type of oil spilled. The intensity of potential impacts is assessed to be medium, with a transboundary extent and medium-term duration. The overall impact on cultural heritage from oil spill at the TYRA project is assessed to be moderate negative.

7.3.1.1 Overall assessment

The potential impacts are summarised in Table 7-12.

Table 7-12 Potential impacts on cultural heritage related to accidental events at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor or major oil spill	Medium	National	Medium-term	Moderate negative	Low

7.3.2 Protected areas

Potential impact mechanisms are related to minor or major spill. Potential impacts on protected areas concerns nature reserves along the west coast of Jutland, and the UNESCO reserve Wadden Sea.

7.3.2.1 Minor oil spill

A chemical spill and an oil spill following vessel collision or pipeline rupture are all events which are considered of local extent, based on the presented modelling (section 7.1). As the TYRA project is located offshore (200 km from shore), minor oil spills are assessed to have no impact on protected areas.

7.3.2.2 Major oil spill

Major oil spill has been modelled (section 7.1). The potentially impacted area include the Wadden Sea and the nature reserves along the west coast of Jutland. As a precautionary approach, the intensity of the impacts is assessed to be large, with transboundary extent and long-term duration. The overall significance of impacts on protected areas from major oil spill is assessed to be major negative.

7.3.2.3 Overall assessment

The potential impacts are summarised in Table 7-13.

Table 7-13 Potential impacts on protected areas related to accidental events at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor oil spill	None	Local	Short-term	Negligible negative	High
Major oil spill	Large	Transboundary	Long-term	Major negative	Medium

7.3.3 Marine spatial use

Potential impact mechanisms are related to minor and major oil spill and major gas release.

7.3.3.1 Minor spill

Minor oil spill from e.g. collisions will impact ship traffic in terms of risk of fire, contamination of vessels and restriction areas, where emergency handling is taken place. The intensity of the impacts is assessed to be small, with national extent and short-term duration. The overall significance of impacts on ship traffic from minor oil spill is assessed to be minor negative.

7.3.3.2 Major oil spill

A major oil spill is assessed to impact ship traffic as risk of fire and contamination of vessels and as restriction areas where ship traffic is prohibited due to emergency handling. The impact will have a medium intensity with transboundary extent and medium-term duration. The overall significance of impacts on ship traffic from minor oil spill is assessed to be moderate negative.

7.3.3.3 Major gas release

An uncontrolled gas release will likely impact the ship traffic indirectly as spatial restrictions in connection with safety distance to blow out point and danger of fire. The impact is assessed to be of medium intensity, transboundary extent and short term. The overall significance of impacts on ship traffic from major gas release at the TYRA project is assessed to be minor negative.

7.3.3.4 Overall assessment

The overall assessment of impacts on ship traffic from accidental events at the TYRA project is summarised in Table 7-14.

Table 7-14 Potential impacts on marine spatial use related to accidental events at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor oil spill	Small	National	Short-term	Minor negative	Medium
Major oil spill	Medium	Transboundary	Medium-term	Moderate negative	Medium
Major gas release	Medium	Transboundary	Short-term	Minor negative	Medium

7.3.4 Fishery

Potential impact mechanisms related to oil spill and gas release.

7.3.4.1 Major gas release

An uncontrolled gas release will likely impact the ship traffic indirectly as spatial restrictions in connection with safety distance to blow out point and danger of fire. The impact is assessed to be of medium intensity, transboundary extent and short term. The overall significance of impacts on fishery from gas release at the TYRA project is assessed to be minor negative.

7.3.4.2 Major oil spill

A major oil spill may impact fishery in terms of risk of contamination of vessels and gear and target species and restriction areas, where emergency handling is taking place. The intensity of the impacts is assessed to be medium, with regional extent and short-term duration. The overall significance of impacts on fishery from major oil spill is assessed to be minor negative.

Physical effects to target species for fishery may have other consequences for fishery. As impacts on fish and marine invertebrates from an oil spill are expected to be major negative, it is assessed that impacts on fisheries will also occur. Further impacts on fisheries may arise due to market perceptions of poor product quality (no buyers or reduced prices, etc.). A major oil spill in the North Sea may significantly decreased buyers interest in fish and shellfish from the area. This can lead to loss of business and affect local economy. Perceptions are difficult to predict, since the actual (physical) impacts of the spill might have little to do with these perceptions. As a precautionary approach, the intensity of the impacts is assessed to be large, with transboundary extent and long-term duration. The overall significance of impacts on fishery from major oil spill from is assessed to be major.

7.3.4.3 Overall assessment

The potential impacts are summarised in Table 7-15.

Table 7-15 Potential impacts on fisheries related to accidental events at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Gas release	Medium	Transboundary	Short-term	Minor negative	Medium
Major oil spill Impacts on target species	Medium	Transboundary	Medium-term	Major negative	Low
Major oil spill Perception/reputation	Large	Transboundary	Long-term	Major negative	Low

7.3.5 Tourism

Potential impact mechanisms for tourism are related to major oil spill.

7.3.5.1 Major oil spill

Impacts on tourism from accidental events include oil contamination on the beaches of the west coast of Jutland and impacts on the Wadden Sea national parks and possible also the southern coast of Norway.

The oil spill modelling show, that Danish, Norwegian, German, Dutch and UK shorelines could be affected by oil, though the Danish shoreline is most likely to be affected. The reputation of this can stop tourists from returning for years and give loss of business and affect local economy. An oil spill can thus result in long term effects on tourist attraction.

The intensity of the impacts is assessed to be large, with transboundary extent and long-term duration. The overall significance of impacts on tourism from a major oil spill at the TYRA project is assessed to be major negative.

7.3.5.2 Overall assessment

The potential impacts are summarised in Table 7-16.

Table 7-16 Potential impacts on tourism related to accidental events at the TYRA project.

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Major oil spill	Large	Transboundary	Long-term	Major negative	Medium

7.4 Summary

The potential impacts on environmental and social receptors from accidental events at the TYRA project are summarised in Table 6-26. The impact with the largest overall significance is provided for each receptor.

Table 7-17 Summary of potential impacts on environmental and social receptors for accidental events at the TYRA project. The impact with the largest overall significance is provided for each receptor.

Receptor	Worst case potential impact
Climate and air quality	Moderate negative
Water quality	Moderate negative
Sediment type and quality	Moderate negative
Plankton	Minor negative
Benthic communities	Major negative
Fish	Major negative
Marine mammals	Major negative
Seabirds	Major negative
Cultural heritage	Moderate negative
Protected areas	Major negative
Marine spatial use	Moderate negative
Fishery	Major negative
Tourism	Major negative

8. MITIGATING MEASURES

Maersk Oil have identified several mitigating measures for planned activities and accidental events with a risk environmental or social impacts receptors. The mitigating measures are in place to eliminate or reduce the risk as low as reasonably practicable (ALARP). In addition to the risk mitigating measures, several monitoring campaigns are conduted around Maersk Oil platforms (section 9.5).

8.1 Mitigating risks from planned activities

8.1.1 Measures to reduce emissions

Maersk Oil has implemented a structured energy efficiency process and conduct a comprehensive review to identify ways to improve energy efficiency offshore. The production has become more energy efficient over the years, and in 2013 the energy management at Maersk Oil was ISO-14001certified. Annual audits of performance and environmental action plans are part of this. The system is to be certified every three years.

8.1.2 Underwater noise mitigating measures

The risks of underwater noise on marine mammals in geophysical acquisition and construction projects are mitigated by:

- Planning and efficient execution of the geophysical data acquisition and construction projects to minimise te duration of the operations.
- Monitoring the presence of marine mammals before the onset of noise creating activities, and throughout the geophysical data acquisition or construction.
- In areas where impacts on marine mammals are anticipated, best available technology will be assessed.
- An exclusion zone is implemented and operations will be delayed when the presence of marine mammal is detected before start-up of the operations.
- Soft-start procedures, also called ramp-up, should be used in areas of known marine mammal activity. This involves a gradual increase in sound signal level to full operational levels.

8.1.3 Discharge mitigating measures

Maersk Oil uses chemicals in its operations, and is constantly examining the use and discharge of chemicals. Before any chemicals can be permitted for use and discharge offshore, an application must be submitted to the Danish authorities. Part of the application is an environmental classification of each chemical carried out in accordance with the OSPAR Recommendation 2010/4 on a harmonised pre-screening scheme for offshore chemicals. The classification applies a colour coding system used by Maersk Oil based on the criteria outlined in OSPAR, 2010 /44/:

- **Black**: Black chemicals contain one or more components registered in OSPAR's 'List of Chemicals for Priority Action'. The use of black chemicals is prohibited except in special circumstances. Maersk Oil has not used them since 2005 but has dispensation in 2015 to use black pipe dope in part of the casing in the drilling of a high-pressure, high temperature exploration well.
- **Red**: These are environmentally hazardous and contain one or more components that, for example, accumulate in living organisms or degrade slowly. OSPAR recommendation is that the discharge of these chemicals must end by 1 January 2017. Since 2008, Maersk Oil has been phasing out red chemicals, using them only if safety, technological and environmental arguments require use. Discharges have decreased sharply since 2010.
- **Green**: These contain environmentally acceptable components recorded on OSPAR's PLONOR list that 'pose little or no risk' to the environment.
- **Yellow**: These are chemicals not covered by the other classifications and can normally be discharged.

The risks of impact on the environment of operational discharges associated with production are mitigated through management of produced water through Risk Based Approach (RBA) in accordance with the OSPAR Guidelines and Recommendation /4/.

The RBA is used to review management options, evaluate measures and develop and implement site-specific actions to reduce environmental risks of production chemicals discharges which are not adequately controlled. Risk reduction measures may comprise some of the following:

- Technical measures, such as abatement at the source by redesign of the applied processes (water shut off in the well);
- Substitution of chemicals;
- Application of closed systems (e.g. injection of produced water);
- End-of-pipe techniques such as separation or clarification techniques to treat produced water prior to discharge, and;
- Organisational measures such as management systems in place (training, instructions, procedures and reporting).

An important tool within the RBA is the use of hydrodynamic models to predict the dispersion of the produced water outflow with a substance based approach /155/. This allows to identify the most important contributors to the risk and evaluate chemical substitution options while ensuring the application of BAT/BEP.

8.2 Mitigating risks from accidental events

Maersk Oil reports all accidental discharges of oil and chemicals, regardless of volume. Measures are introduced to reduce the volume and number of spillage through e.g. inspections and training. Maersk Oil follows industrial best practices for prevention of major accidents based on identification of major hazards assessed through risk assessment /136/.

Maersk Oil strives to reduce the risk of major accidents to as low as reasonably practicable (ALARP) through the identification of major hazards in risk analyses and the development of barriers (e.g. procedure, training, and design). For example, facilities are protected against collision by installing boat fenders to jackets. Processing facilities, wells and pipelines are protected against large release by safety valves. A safety zone around pipelines and platforms is implemented to prevent collisions from bottom trawling equipment or anchoring. Procedures are in place to restricted supply vessel traffic and hose handling in case of rough weather (see also Appendix 1).

The risk assessment and reduction measures are regularly updated in case of significant new knowledge or technology development.

Emergency response and contingency planning are also developed to limit the consequence in case of a major accident related to its projects. Maersk Oil's oil spill contingency plan is summarised in section 9.

9. ENVIROMENTAL STANDARDS AND PROCEDURES IN MAERSK OIL

9.1 Environmental management system

Maersk Oil operates with a ISO 14001 certified environmental management system /121/. The objectives of the environmental management system is to minimise the impact on the environment by continually improving the environmental performance.

The objective shall be achieved by:

- Maintaining a complete and effective environmental management system
- Providing timely and effective innovative actions to reduce environmental impact
- Promoting the awareness of environmental matters at all organisational levels
- Minimising environmental impact through principles of best available technology (BAT) and best environmental practice (BEP).

9.2 Environmental and social impact in project maturation

An Environmental and Social Impact Assessment standard /160/ that lays out the process for managing risk of environmental and social impacts of new large projects has recently been implemented in Maersk Oil. The standard provides a framework embedded within the Maersk Oil project maturation process which will be used from start and throughout the different development phases of future devolpment projects.

9.3 Demonstration of BAT/BEP

The OSPAR Convention of 1992 requires contracting parties to apply best available techniques (BAT) and best environmental practice (BEP) including, where appropriate, clean technology, in their efforts to prevent and eliminate marine pollution.

As defined the OSPAR convention BAT *means the latest stage of development (state of the art) of processes, of facilities or of methods of operation which indicate the practical suitability of a particular measure for limiting discharges, emissions and waste*. BEP is defined as *the application of the most appropriate combination of environmental control measures and strategies*.

It follows that BAT and BEP for a particular source will change with time in the light of technological advances, economic and social factors, as well as changes in scientific knowledge and understanding.

BAT has also been implemented in the EU IPCC directive 96/61/EC, and the IE directive (2010/75/EU). The Danish Law on Environmental Protection of the Sea refers to BATand BEP (§3). The BAT principle is illustrated in Figure 9-1

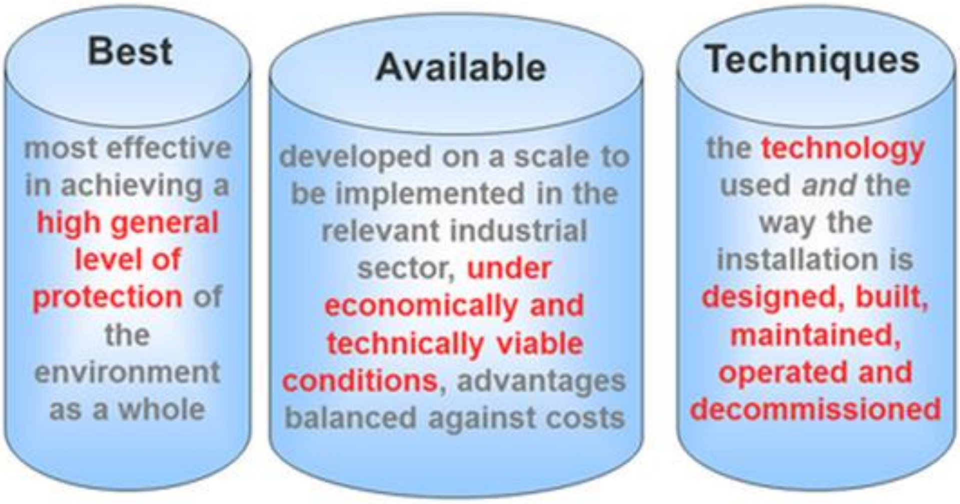


Figure 9-1 Illustration of best available technique /157/.

It is a Maersk Oil objective to implement the principles of BAT and BEP in an effort to minimize the potential environmental impacts of activities in the North Sea. This entails that environmental concerns are adressed and encompassed in the planning phase. The BAT/BEP principle has been used in the design and operation of the installations and process equipment of Maersk Oil as well as for the selection of materials and substances.

Examples of how Maersk Oil applies BAT and BEP include measures to:

- Improving energy efficiency
- Monitoring and minimising emissions
- Optimising the use and discharge of chemicals
- Supporting the development of chemicals with less environmental impact
- Use of efficient equipment during well test
- Continuous review and assessment of projects and applied equipment

For example, Maersk Oil use several technologies such as hydrocyclones, induced gas flotation units, compact flotation units for treatment of produced water, which are included in the OSPAR background document concerning techniques for the management of produced water from offshore installations, an overview from 2002 of BAT for handling of produced water.

9.4 Oil spill contingency plan

Maersk Oil's emergency preparedness in connection with serious incidents offshore on and around Maersk Oil's installations and in Danish concession areas held by A.P. Møller-Mærsk is centred around and coordinated by permanently established emergency committees.

Maersk Oil has developed an oil spill contingency plan /121/, which describes how to combat possible oil spills. Oil spill scenarios up to and including the worst credible case discharge scenario for Maersk Oil facilities and wells have been considered to ensure an appropriate tiered capability is established.

- Tier 1: e.g. small operational spills
  - Mobilise oil spill monitoring/surveillance vessel.
  - Oil spill drift modelling.
  - Use in-field vessel with boom/250 m^3 per hour skimmer equipment mobilised within 8 hours.

- Tier 2: medium spill volume
  - Tier 1 measures.
  - Use of additional resources (boom, several 200 m^3 per hour skimmer and transfer pump/hoses) mobilised from Esbjerg or from the Danish National stockpile within 20 hours to handle more tha 1,500 tons per day.
  - Waste removal is done by dedicated tanker.

- Tier 3: e.g. blow out
  - Tier 2 measures.
  - Mobilise additional vessel with 1200 m boom, skimmer and transfer pump/hoses within 30 hour. Mobilise trained personnel and additional equipment from Oil Spill Response Ltd (OSRL).
  - Waste removal is done by dedicated tanker.
  - Mobilise relief well contractor.
  - Consult NGOs regarding wildlife response.

Maersk Oil has access to oil spill equipment offshore and in Esbjerg that can be mobilised to an oil spill location immediately. If necessary, additional equipment will be mobilised from the Danish stock pile and OSRL. Maersk Oil is a participant member of OSRL and has access to their world-wide pool of personnel and equipment. OSRL's main equipment stockpile in Europe is based in Southampton in the UK but additional equipment is also available in Stavanger.

The use of dispersant chemicals to increase oil dispersion, dilution and natural breakdown will be evaluated when relevant. The use of dispersant chemicals is regulated and dispersant may only be used after approval by DEPA.

Regular emergency exercises (oil spills) are carried out as a minimum every three years to train and motivate personnel, test the equipment and to ensure plans as described are effective. Relevant authorities participate in the exercise.

9.5 Ongoing monitoring

Maersk Oil has flowmeters that continuously measures the volume of discharged produced water, and water samples are regularly obtained for analysis of oil and chemical content. The nature, type and quantities chemical used and chemicals and oil discharged to sea are reported to the Environmental Agency.

Monitoring of sediment quality and benthic fauna is undertaken at regular intervals around Maersk Oil platforms /6/.

- The physical and chemical analyses included grain size analysis, dry matter (DM), loss on ignition (LOI), total organic carbon (TOC), metals (barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), zinc (Zn), mercury (Hg) and aluminium (Al)), Total hydrocarbons (THC), Polycyclic aromatic hydrocarbons (PAH) and oil specific group of alkylated aromatic hydrocarbons (NPD).
- Samples obtained for identification and quantification of the benthic fauna

In addition, Maersk Oil monitors underwater noise and marine mammals through passive acoustic monitoring and an offshore sighting program in which offshore staff reports sightings of marine mammals near platforms.

Figure 9-2 Acoustic monitoring of marine mammals (Photo: Aarhus University, DCE).

10. NATURA 2000 SCREENING

10.1 Introduction

The Natura 2000 network comprises:

- Habitats Directive Sites (Sites of Community Importance and Special Areas of Conservation) designated by Member States for the conservation of habitat types and animal and plant species listed in the Habitats Directive
- Bird Directive Sites (Special Protection Areas) for the conservation of bird species listed in the Birds Directive as well as migratory birds

This section constitutes the Natura 2000 screening in accordance with the EC habits Directive and Order 408/2007, § 7.

10.2 Designated species and habitats

The designated Natura 2000 sites are shown in Figure 10-1.

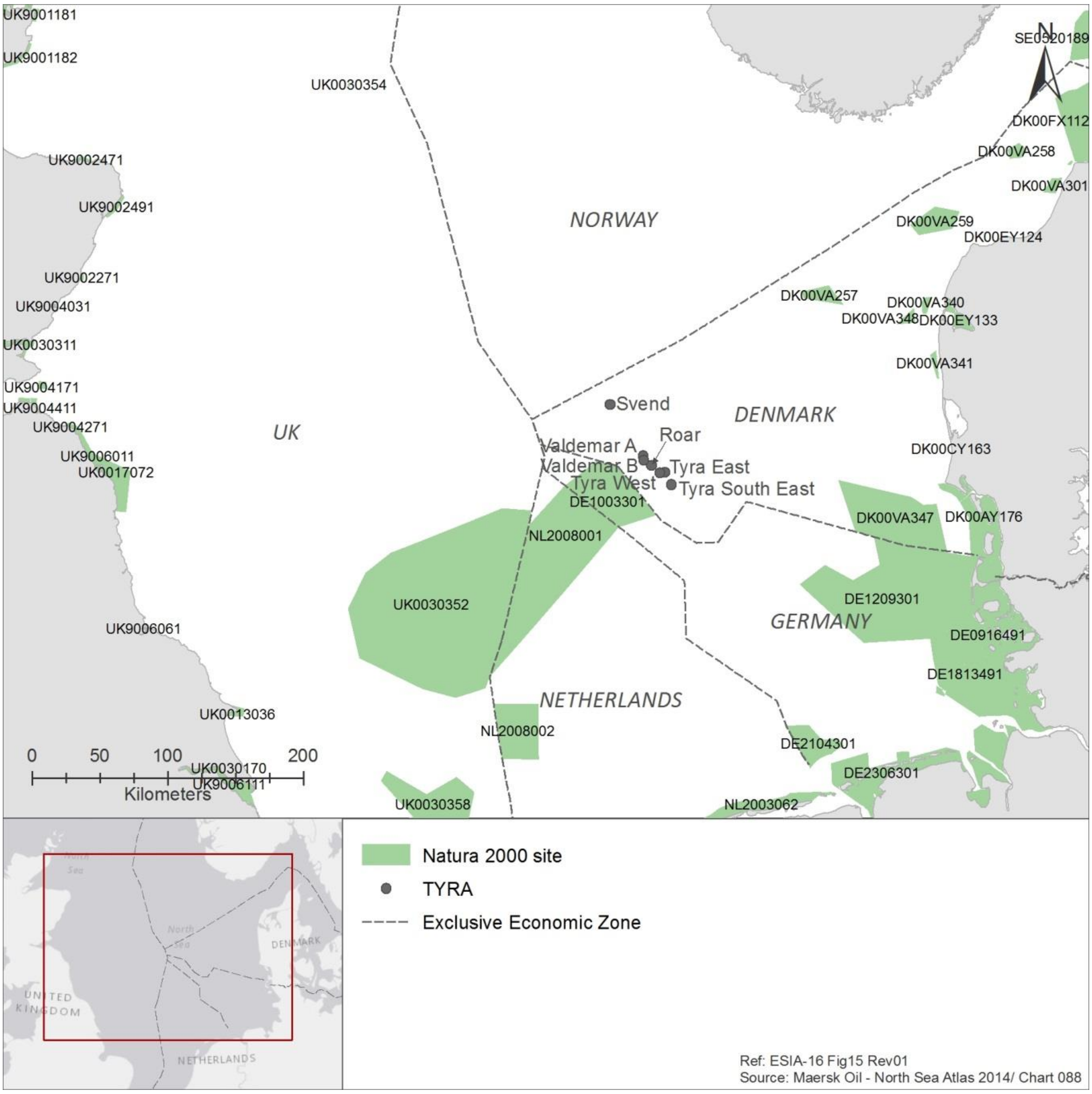


Figure 10-1 Natura 2000 sites in the North Sea.

Natura 2000 sites in the central North Sea are detailed in Table 10-1.

Table 10-1 Natura 2000 sites in the central North Sea.

Natura 2000 Site code	**Name**	**Designated marine species and habitattypes**
UK0030352	Dogger Bank	• 1110 Sandbanks which are slightly covered by sea water all the time • 1351 *Phocoena phocoena* • 1364 *Halichoerus grypus* • 1365 *Phoca vitulina*
NL2008002	Klaverbank	• 1170 Reefs • 1351 *Phocoena phocoena* • 1364 *Halichoerus grypus* • 1365 *Phoca vitulina*
NL2008001	Doggersbank	• 1110 Sandbanks which are slightly covered by sea water all the time • 1351 *Phocoena phocoena* • 1364 *Halichoerus grypus* • 1365 *Phoca vitulina*
DE1003301	Doggerbank	• 1110 Sandbanks which are slightly covered by seawater all the time • 1351 *Phocoena phocoena* • 1365 *Phoca vitulina* • *Fulmarus glacialis, Larus fuscus, Morus bassanus, Rissa tridactyla, Uria aalge*
DE1209301	Sylter Außenriff	• 1110 Sandbanks which are slightly covered by sea water all the time • 1170 Reefs • 1351 *Phocoena phocoena* • 1364 *Halichoerus grypus* • 1365 *Phoca vitulina* • 1103 *Alosa fallax* • *Gavia arctica, Gavia stellata, Lampetra fluviatilis, Larus canus, Larus fuscus, Larus marinus, Larus minutus, Morus bassanus, Rissa tridactyla, Sterna hirundo, Sterna paradisaea, Sterna sandvicensis, Uria aalge*
DK00VA347	Sydlige Nordsø	• 1110 Sandbanks which are slightly covered by sea water all the time • 1351 *Phocoena phocoena* • 1364 *Halichoerus grypus* • 1365 *Phoca vitulina* • *Gavia stellata, Gavia arctica, Larus minutus, Sula bassana, Somateria mollissima, Melanitta nigra, Stercorarius skua, Uria alge, Alca torda, Alle alle*
DK00VA257	Jyske Rev	• 1170 Reefs • 1351 *Phocoena phocoena*

10.3 Screening

The screening is carried out to identify all those elements of the project or plan, alone or in combination with other projects or plans, that may have significant impacts on the Natura 2000 site.

No activities associated with the TYRA project are planned to occur within the designated Natura 2000 sites. The distance from the TYRA project to the nearest Natura 2000 site is 18 km.

Planned activities at the TYRA project have been assessed in section 6. Potential impacts on Natura 2000 sites include underwater noise and discharges.

10.3.1 Underwater noise

A number of activities at TYRA may generate underwater noise, including seismic surveys, drilling, and presence of production platforms and vessels. There is no geographical overlap between the TYRA area and Natura 2000 sites, but underwater noise from seismic and ramming of conductors may propagate. However, based on the distance from the TYRA project to the nearest Natura 2000 site (18 km), it is assessed that underwater noise will not have significant environmental effects on the conservation objectives of the habitat types or species in the Natura 2000 sites

10.3.2 Discharges

The main discharges are related to production and drilling, though other minor negative discharges may also occur (e.g. from vessels).

- Discharges of water based mud and cuttings during planned drilling activities is expected to occur from a drilling rig (at the existing and new wellhead platforms). The distance to which impacts on pelagic environment may occur has previously been modelled for a typical well, and is up to 7 km from the discharge (section 6). The area where impacts may occur will depend on the currents, and will likely follow the prevailing northward currents. The distance to which impacts on sediment quality has also been modelled, and is assssed to be within a few hundred meters for the drilling rig (section 6.2.4). The distance from the point of discharge (Tyra East and West) to the nearest Natura 2000 site it approximately 18 km. Based on the distance, it is therefore assessed that production activities will not have significant environmental effects on the conservation objectives of the habitat types or species in the Natura 2000 sites.
- Discharges from production are expected to continue until 2042, and will occur at Tyra East and West. The distance to which impacts on the pelagic environment may occur has been modelled, and is up to 14 km from the point of discharge (section 6). The area where impacts may occur will depend on the currents, and will likely follow the prevailing northward currents. The distance from the point of discharge (Tyra East and West) to the nearest Natura 2000 site is 18 km. Based on the distance, it is therefore assessed that production activities will not have significant environmental effects on the conservation objectives of the habitat types or species in the Natura 2000 sites.

10.4 Conclusion

It is assessed that planned activities at the TYRA project will not have significant environmental impacts on the conservation objectives of the habitat types or species in the Natura 2000 sites.

11. TRANSBOUNDARY IMPACTS

11.1 Introduction

The TYRA project refers to the Tyra East and West platforms and its satellite platforms Tyra South East, Valdemar (A and B), Roar and Svend. An environmental and social impact assessment (EISA-16) is undertaken for the remaining lifetime of the ongoing projects, and the entire life time from exploration to decommissioning for planned projects. The ESIA-16 shall replace the EIA conducted in 2010 "Environmental impact assessment from additional oil and gas activities in the North Sea, July 2011" which is valid for the period 1st January 2010 to 31st December 2015.

Notifications for the TYRA project were forwarded to the relevant authorities in accordance with article 3.1 of the Espoo convention.

In this section, a summary of the TYRA project and its likely significant transboundary impacts is provided. The section is focused on providing sufficient information to facilitate the identification of possible transboundary impacts. The rationale and support for the attributed level of significance and spatial extent can be found in detail in the relevant sections of the ESIS (section 6 and 7).

11.2 ESPOO convention

The ESPOO convention states that the concerned parties likely to be affected by transboundary adverse significant impacts are to be informed of and provided with possibilities for making comments or objections on the proposed activity.

The TYRA project can be found as item 15 (offshore hydrocarbon production) on the list of activities in appendix I to the convention, that are likely to cause a significant adverse transboundary impact.

11.3 The TYRA project

11.3.1 Existing production and processing facilities

The TYRA project refers to the Tyra East and West platforms and its satellite platforms Tyra South East, Valdemar (A and B), Roar and Svend. Production was initiated at Tyra in 1984, then later Tyra South East (2002), Valdemar (1993), Roar (1996) and Svend (1996). The total production peaked in 2005 and has been on a natural decline since. Maersk Oil has the license to explore for and produce oil and gas was extended until 8 July 2042.

Tyra East and West are primarily an oil and gas producing and processing platforms that receives, processes and sends to shore the entire gas production. Treated produced water is discharged to sea at Tyra East and West

Valdemar (A and B) consist of three unmanned wellhead platform, while Tyra South East, Roar and Svend each comprise one unmanned wellhead platform.

The processing facilities include hydrocarbon processing equipment (oil stabilisation, gas processing and processing of production water), auxiliary safety systems such as an emergency shutdown system, emergency blow-down system, fire and gas detection system, firewater system, etc.

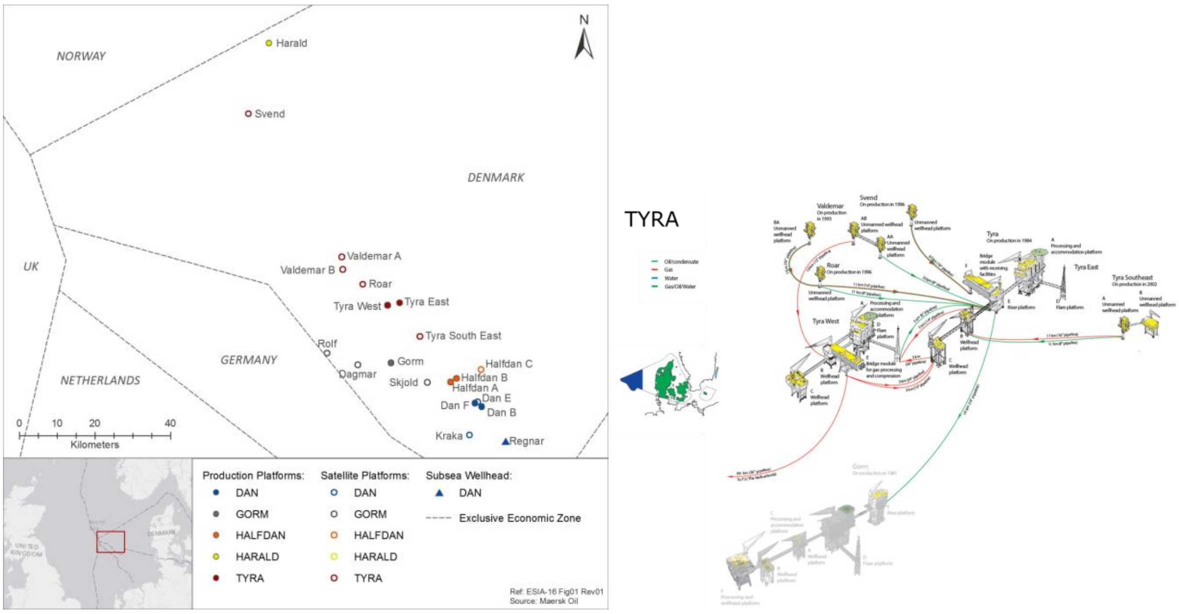


Figure 11-1 Maersk Oil North Sea projects TYRA, HARALD, DAN, GORM and HALFDAN.

11.3.2 Planned development activities

The following main activities are planned to continue and optimise the production for the TYRA project and potentially access new hydrocarbon resources:

- Seismic investigations provide information to interpret the geological structure of the subsurface and to identify the location and volume of remaining and potential new hydrocarbon reserves. Seismic data is also acquired as part of drilling hazard site surveys to map and identify potential hazards to the installation of drilling rigs and to the drilling operation. Seismic data are also acquired as part of seabed and shallow geophysical surveys to map seabed and shallow soil conditions for the design and installation of pipelines, platforms and other structures.
- New structures and pipelines are expected as a consequence of development projects planned within the remaining lifetime of the facilities Establishement of up to 9 new wellhead platforms, with connecting pipelines.
- Drilling of up to 24 wells in free well slots and 106 wells at the new structures may be done under the TYRA project. Slot recovery or redrilling from existing wells is not expected. Drilling is performed from a drilling rig, which is placed on the seabed. Different types of drilling mud will be used based on the well and reservoir properties. Water-based mud and cuttings will be discharged to the sea, whereas oil-based mud and cuttings will be brought onshore to be dried and incinerated.
- Well stimulation will be performed to facilitate hydrocarbon extraction (for a production well) or water injection (for an injection well).
- Decommissioning will be done in accordance with technical capabilities, industry experience, relevant international conventions and under the legal frameworks at the time of decommissioning.

11.3.3 Accidental events

As part of the production, accidental spills of oil, gas or chemical may occur. There is a risk of accidents that could lead to a major significant environmental and social impacts, such as vessels collisions or a well blow out. The risk of a well blowout is very unlikely.

11.3.4 Alternatives

Project alternative

The 0 alternative (zero alternative) is a projection of the anticipated future development without project realization, and describes the potential result if nothing is done. For the TYRA project, this would mean that the production would cease. If no production is undertaken by Maersk Oil for the TYRA project area in the North Sea, there will be no contribution from the TYRA project to the Danish economy or security of hydrocarbon supply and employment.

Tehcnical alternatives

Best environmental practice for the different type of activities planned for the TYRA project (seismic, pipelines and structures, production, drilling, well stimulation, transport and decommissioning) is continuously monitored and applied when feasible.

Alternative location

The TYRA project is a continuation of production and activities at existing facilities. As such, there is no alternative location for the project.

11.4 Identified impacts – planned activities

Potential impacts to environmental and social receptors during planned activities at the TYRA project have been assessed in section 6. A summary of the potential worst case impacts is presented in Table 11-1.

Table 11-1 Summary of potential impacts on environmental and social receptors from planned activities at the TYRA project. The impact with the largest overall significance is provided for each receptor (without mitigating measures).

Receptor	Worst case potential impact	
	Extent	Overall significance of impact
Climate and air quality	Transboundary	Moderate negative
Hydrography	Local	Minor negative
Water quality	Local	Minor negative
Sediment type and quality	Local	Minor negative
Plankton	Local	Minor negative
Benthic communities	Local	Minor negative
Fish	Local	Minor negative
Marine mammals	Local or regional	Moderate negative
Seabirds	Local	Minor negative
Cultural heritage	None	None
Protected areas (UNESCO, nature reserve)	None	None
Natura 2000	No significant environmental effects	
Marine spatial use	Local	Negligible negative
Fishery	Local	Negligible negative
Tourism	None	None
Employment and tax revenue	Local or national	Positive
Oil and gas dependency	Local or national	Positive

Transboundary adverse impacts have been identified for climate and air quality, where the emissions from the TYRA project may contribute to climate change and air pollution. Maersk Oil has implemented a structured energy efficiency process and conduct a comprehensive review to identify ways to improve energy efficiency offshore. The production has become more energy efficient over the years, and in 2013 the environmental management system at Maersk Oil was ISO-14001 certified.

No other significant adverse transboundary impacts have been identified for the planned activities at the TYRA project.

A Natura 2000 screening is presented for the planned activities. It is assessed that the planned activities will have no significant environmental effects on the conservation objectives of the habitat types or species in the national and international Natura 2000 sites (section 10).

11.5 Identified impacts – accidental events

Potential impacts to environmental and social receptors during accidental events from the TYRA project have been assessed in section 7. A summary of the worst case potential impacts (without mitigating measures) is presented in Table 11-2.

Table 11-2 Summary of potential impacts on environmental and social receptors for accidental events at the TYRA project. The impact with the largest overall significance is provided for each receptor (without mitigating measures).

Receptor	Worst case potential impact	
	Extent	Overall significance of impact
Climate and air quality	Transboundary	Moderate negative
Water quality	Transboundary	Moderate negative
Sediment type and quality	Transboundary	Moderate negative
Plankton	Transboundary	Minor negative
Benthic communities	Transboundary	Major negative
Fish	Transboundary	Major negative
Marine mammals	Transboundary	Major negative
Seabirds	Transboundary	Major negative
Cultural heritage	National	Moderate negative
Protected areas (UNESCO, nature reserve)	Transboundary	Major negative
Marine spatial use	Transboundary	Moderate negative
Fishery	Transboundary	Major negative
Tourism	Transboundary	Major negative

If a major oil spill occurs, there is a risk of major negative transboundary impacts. The risk of a major oil spill is very unlikely, but could potentially have significant, adverse transboundary impacts. Oil released could cross maritime boundaries with Norway, Germany, the Netherlands and the UK. The oil spill modelling identified the north and west of Denmark and south Norway as most vulnerable to oil beaching, although Germany, UK and the Netherlands could also be affected.

Maersk Oil follows industrial best practices for prevention of accidents based on identification of major hazards assessed through risk assessment. Emergency response and contingency planning are also developed to limit the consequences of a major accident related to its projects.

12. LACK OF INFORMATION AND UNCERTAINTIES

Uncertainty may be viewed as an inescapable part of assessment of impacts of plans, programmes or projects.

12.1 Project description

The project description has been based on input from Maersk Oil. The project description is based on a scenario with maximum activity, emissions and discharges.

For some activities, the location and/or timing has not been decided. This will be done as part of the preparation of the detailed planning of the activities. The ESIS is undertaken using a worst case approach, and therefore alterations to location and/or timing is assessed to be of minor influence to the assessments.

The understanding of the contribution of the TYRA project to the employment and tax revenue has not been described specifically and in details. The assessment is based on the overall DUC contribution.

12.2 Environmental and social baseline

The central North Sea is relatively well known, and the environmental and social baseline is generally considered sufficient for the ESIS.

However, a few receptors are less well understood:

- The distribution and biology of non-commercial fish species is scarce, and knowledge of spawning areas is limited.
- The variability of distribution of marine mammals within and between years is not well known, and the breeding and moulting periods and locations are not certain.
- Fishery is mapped based on the North Sea Atlas which is based onthe ICES data. However, the variability between years is not detailed for this ESIS.

12.3 Impact assessment

Impact predictions can be made using in different ways, ranging from qualitative assessment and expert judgement to quantitative techniques like modelling. Use of these quantitative techniques allows a reasonable degree of accuracy in predicting changes to the existing environmental and social conditions. However, not all of the assessed impacts are easily quantified or modelled, and expert judgement may be required.

Uncertainty has been adressed in this ESIS by presenting a level of confidence for each of the assessments in section 6 and 7. The level of confidence includes interactions between impact mechanisms and receptors, available baseline data as well as modelling (section 4).

Overall, impacts are assessed based on todays technological capabilities. Maersk Oil expects that technological development will lead to a reduction in emissions and discharges, which will reduce the impact assessed here.

12.3.1 Planned activities

The potential environmental impacts have been assessed for each receptor (e.g. plankton, employment). The impact assessment is based on empirical studies, scientific literature, modelling results as well as previous EIAs.

Previous modelling results have been applied in this ESIS, with no site-specific modelling. Similar activities have previously been assessed for the same area, and modelling has been undertaken for e.g. dispersion of drill mud and cutting, dilution of produced water as well as propagation of underwater noise. In addition, Maersk Oil prepared EIF and the PEC/PNEC calculations for each of the five projects, using the Chemical Hazard Assessment and Risk Management model (CHARM) developed by authorities and offshore industry. The calculations have some weaknessess (as reviewed in /1/), but is considered valid for the impact assessment.

The project which is assessed is at or near existing platforms, where monitoring of chemical and biological conditions have been undertaken for many years. These surveys contribute to a solid baseline, as well as an understanding of the environmental impacts.

Impacts of underwater noise is not well understood, and there is ongoing debate regarding thresholds for potential impact.

12.3.2 Accidental events

Oil spill modelling has been undertaken for a number of selected spill scenarios. However, the spill rates for blowouts are not directly comparable, but considered applicable as a worst case scenario.

12.3.3 Cumulative impacts

There is no general method for combining impacts across different geographical scales and as a result of different pressures. It is therefore generally difficult to assess the severity of the cumulative environmental impact on the ecosystem. Uncertainty and lack of knowledge about the population status of species, the range and ecological status of habitat types, and the combined impacts of environmental pressures also add to the uncertainty of assessments of cumulative impacts. Environmental monitoring can provide information on some impacts and decrease the uncertainty.

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APPENDIX 1
TECHNICAL SECTIONS