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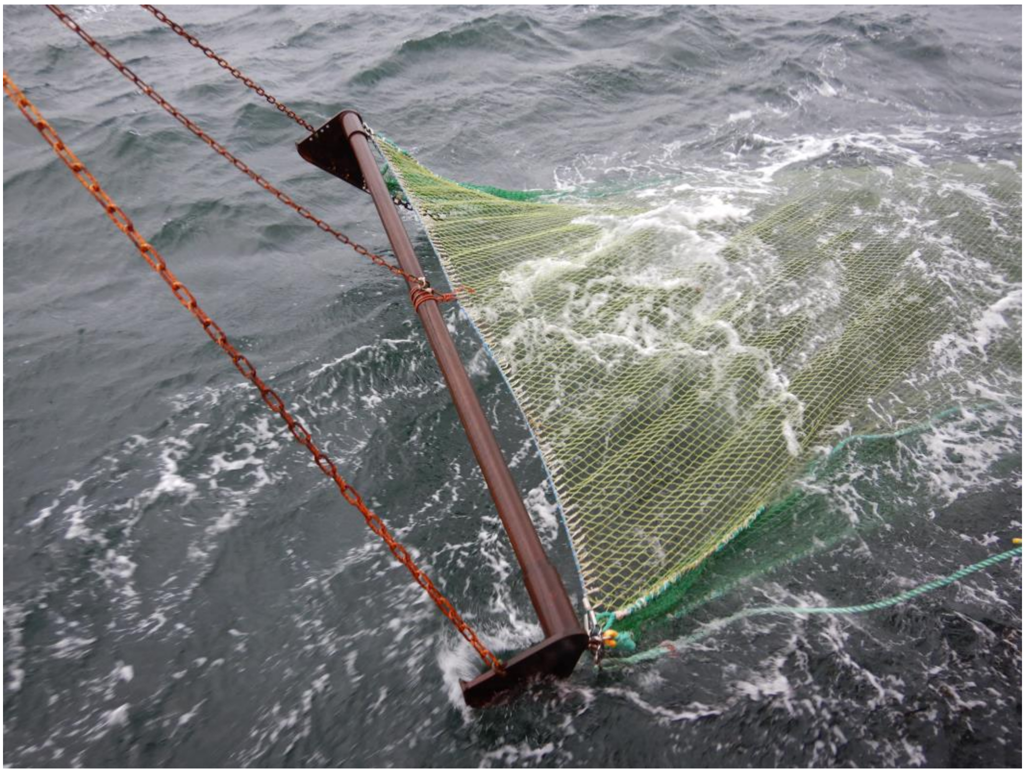
THOR OWF
TECHNICAL REPORT – FISH AND FISH POPULATIONS



THOR OWF
TECHNICAL REPORT – FISH AND FISH POPULATIONS

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TABLE OF CONTENTS

1.	**Summary**	**4**
2.	**Introduction**	**6**
2.1	Background	6
3.	**Project Plan**	**7**
3.1	Turbines	8
3.2	Foundations	8
3.3	Export cables	8
4.	**Methods And Materials**	**9**
4.1	Geophysical survey	9
4.1.1	Depth	10
4.1.2	Seabed sediment type characterization	10
4.2	Fish survey	11
4.2.1	Sampling method	12
4.2.2	Analysis of catches	13
5.	**Baseline Situation**	**15**
5.1	Description of gross area of Thor OWF	15
5.1.1	Water depth	15
5.1.2	Seabed sediment	17
5.1.3	Protected species and marine habitat types	17
5.2	Key species	19
5.2.1	Cod (*Gadus morhua* L.)	20
5.2.2	European plaice (*Pleuronectes platessa* L.)	20
5.2.3	Sole (*Solea solea* L.)	21
5.2.4	Turbot (*Psetta maxima* L.)	21
5.2.5	Dab (*Limanda limanda*)	22
5.2.6	Solenette (*Buglossidium luteum*)	22
5.2.7	Herring (*Clupea harengus*)	22
5.2.8	Sand goby (*Pomatoschistus minutus*)	22
5.2.9	Sprat (*Sprattus sprattus* L.)	23
5.2.10	Sandeel (*Ammodytes marinus* R. and *Ammodytes tobianus* L)	23
5.3	Survey data	24
5.3.1	Seasonal variation in catches	24
5.3.2	Spawning area	30
5.3.3	Size distribution and nursery area	31
5.3.4	Species diversity and evenness	34
6.	**Sensitivity analysis and potential impacts**	**37**
6.1	Potential impacts	37
6.2	Analysis of potential impacts	37
6.2.1	Suspended sediments and sedimentation	37
6.2.2	Heat development and electromagnetic fields around the cables	38
6.2.3	Underwater noise	39
6.2.4	Explosion of non-exploded ammunition	40
6.2.5	Introduction of new habitats	41
6.3	Conclusion	41
6.4	Sensitivity analysis of fish species	42
7.	**Cumulative effects**	**44**
8.	**Natura 2000**	**47**
9.	**Mitigation measures**	**48**
10.	**Knowledge gaps**	**49**
11.	**Referencer**	**50**

APPENDIX 1 – TRAWL SPECIFICATIONS SEABED SURVEY
APPENDIX 2 – BIODIVERISTY AND EVENNESS
APPENDIX 3 – ABIOTIC PARAMETERS

Abbreviation	Explanation
CC	The two cable corridor alternatives, one or both may be used
DEA	Danish Energy Agency
R2 (CC_R2)	Northern cable corridor
R3 (CC_R3)	Southern cable corridor
Thor OWF	The future Thor Offshore Wind Farm area of approximately 220 km^2
The gross area for Thor Offshore Wind Farm (OWF)	The total investigated area (440 km^2) within which the planned Thor OWF will be placed.
Gross area	Gross area of Thor Offshore Wind Farm
GA	Gross area of Thor Offshore Wind Farm
SEA	Strategic Environmental Impact Assessment
Subarea	The gross area of Thor Offshore Wind Farm has been divided into 3 subareas: GA1, GA2 and GA3
ROV	Remotely Operated Vehicle
CTDO	Conductivity-Temperature-Depth-Optical
CPUE	Catch Per Unit Effort
YOY	Young of the Year
MMT	Marin Mätteknik AB

1. SUMMARY

Introduction
As part of the Energy Agreement of June 29th, 2018 all political parties in the Danish Parliament have agreed to establish three new offshore wind farms before 2030. Thor Offshore Wind Farm (Thor OWF) is one of the three planned Offshore Wind Farms.

The plan for Thor (OWF) defines the overall framework for establishment of an offshore wind farm approx. 20 km off the coast of Thorsminde on the west coast of Denmark and includes two alternative cable corridors. One or both cable corridor alternatives may be used.

Objective
The technical report is to have a baseline for the fish density and distribution in the area and to gain information of the area's importance as spawning and nursery area. Moreover, the report is to assess the sensitivity of fish and fish populations in relation to implementation of the plan Thor OWF.

Survey method and results
The fish survey was conducted with a beam trawl in accordance with the German method StUK4, which describes the spatial and temporal distribution of fish as a baseline for offshore wind farms. The survey was conducted in a modified version with a slightly smaller trawl, which is compensated for with longer trawl hauls, so the overall area covered is identical to the area recommended in the StUK4. Two fish surveys were conducted to identify temporal variations in the fish and fish populations and identify any nursing and spawning grounds within the area. The spring survey was scheduled to coincide with the spawning time of several relevant fish species, and the autumn surveys would demonstrate the areas importance as nursery area when the new recruits of the year (Young Of the Year = YOY) have grown into small juveniles.

A total of 6424 fish were caught (spring survey: 2,752; autumn survey: 3672), representing 31 different species. During springtime, a total of 26 species were caught, and in autumn 23 species. In general, flatfish dominated the catch and comprised 74% of the catch in spring and 90% in autumn catches. The dominating flatfish species were European plaice, solenette, common dab and scaldfish, while dominating round fish included whiting and grey gurnard. The abundance of fish was highest in stations in the south western and central part of the gross Thor OWF area.

The fish survey showed that, except for a 3-4 dab, none of the fish caught in the gross area of Thor OWF were ready to spawn. Therefore, it was assessed that the gross area of Thor OWF was not utilized as an important spawning site for any of the species caught in the spring or autumn survey.

Several young individuals utilize the gross area of Thor OWF, mainly on the sandy areas in the central and southwestern parts. However, for most of the caught species (solenette, scaldfish and grey gurnard) no proper special nursery area has been documented in the scientific literature, as juveniles and adults coexist. The only species that utilize the gross area of Thor OWF as a nursery area is common dab, but the abundance of juvenile dab was low, and therefore, the area's importance as nursery for dab is expected to be low.

Sensitivity analysis
The fish species along the west coast of Jutland are adapted to living in highly exposed areas with substantial wave energy moving vast amounts of sediment on a regular basis. Therefore, the fish are robust and able to handle high concentrations of suspended sediment and sedimentation. Fish

are mobile organisms and may flee certain areas if conditions become suboptimal, and in terms of underwater noise, most fish elicit avoidance reaction when noise levels reach approximately 90 dB.

The abundance of fish was highest in the southwestern part of the gross area of Thor OWF and the lowest abundance was observed in the central part of the gross area of Thor OWF with mixed substrates. Biodiversity was lowest in the sandy areas in the southwestern part of the gross area of Thor OWF, where dredging occurs regularly. Areas where the biodiversity was high (in the central part of the gross area of Thor OWF) and in the northern part of the gross area of Thor OWF where the density of stone reefs were high, is assessed to be most sensitive to the planned Thor OWF. However, regardless of location, the fish and fish populations in the gross area of Thor OWF are robust and able to handle the disturbances caused by the construction and operation of an OWF.

Assessment of potential impacts
The largest impacts on fish and fish populations from the construction and operation of Thor OWF is expected to occur from the increased concentration of suspended sediment when deploying the cables – depending on the method and increased underwater noise from piling of turbines.

Regardless of location of the Thor OWF, the potential impacts on fish and fish populations are assessed as none to minor.

Mitigating measures
No mitigation measures are deemed necessary since no significant impacts are expected from the project plan of Thor offshore wind farm on the fish and fish populations. However, it is recommended to consider avoiding constructing the Thor OWF on the hard bottom habitats and boulder reefs, as this habitat type is less abundant in the area and has a higher biodiversity compared to the sandy and/or muddy areas. It may also be considered to reduce the total area for cable corridors in order to minimize the expected impact from suspended sediment and thereby perhaps also reduce the longevity of the construction period.

Conclusion
The conclusion is that no matter where the turbines are placed within the gross area of Thor OWF, the impacts on the fish and fish populations will be only minor.

The largest impacts on fish and fish populations from the construction and operation of Thor OWF is expected to occur from the increased concentration of suspended sediment when deploying the cables (depending on the method) and increased underwater noise from piling of turbines.
The highest abundance of fish was observed in the southwestern part of the gross area of Thor OWF and lowest in the southwestern part of the central gross area of Thor OWF with mixed substrates. Biodiversity was lowest in the sandy areas in the southwestern part of the gross area of Thor OWF. Biodiversity was highest in the central part of the gross area of Thor OWF.

2. INTRODUCTION

2.1 Background

In June 2018, the Danish Parliament signed the Danish Parliament's Energy Agreement (DEA) 2018, which, among other parts, agrees on the construction of approximately 800 MW Danish offshore wind to be grid-connected by 2024 to 2027.

Based on a screening study made by the Danish Energy Agency, it was decided, in February 2019, that the new Thor Offshore Wind Farm was to be developed in the North Sea approximately 20 km off the coast of Jutland, initially with a capacity of 800-1000 MW.

In February 2019, the Danish Energy Agency instructed Energinet to initiate site investigations, environmental and metocean studies and analysis for grid connection for this area. Therefore, Energinet is carrying out environmental surveys for the project area and a Strategic Environmental Assessment (SEA) of the plan for Thor OWF.

The purpose of this technical report is to describe and document the baseline conditions of fish and fish populations in the gross area of Thor Offshore Wind Farm and perform a sensitivity analysis in relation to the establishment of the planned Thor OWF in the area.

3. PROJECT PLAN

The plan for Thor OWF gives the overall framework for an offshore wind farm approx. 20 km from the coast off Thorsminde on the west coast of Jutland (Figure 3-1). The gross area of Thor OWF consists of a 440 km^2 triangular area. The OWF must be able to provide a minimum of 800 MW and a maximum of 1,000 MW to the national Danish power grid. The plan establishes a framework for Thor OWF with associated onshore facilities. Currently, there is no specific knowledge on the location of the offshore wind turbines within the gross area of Thor OWF nor the amount or size of turbines. However, only about half of the gross area of Thor OWF will be used.

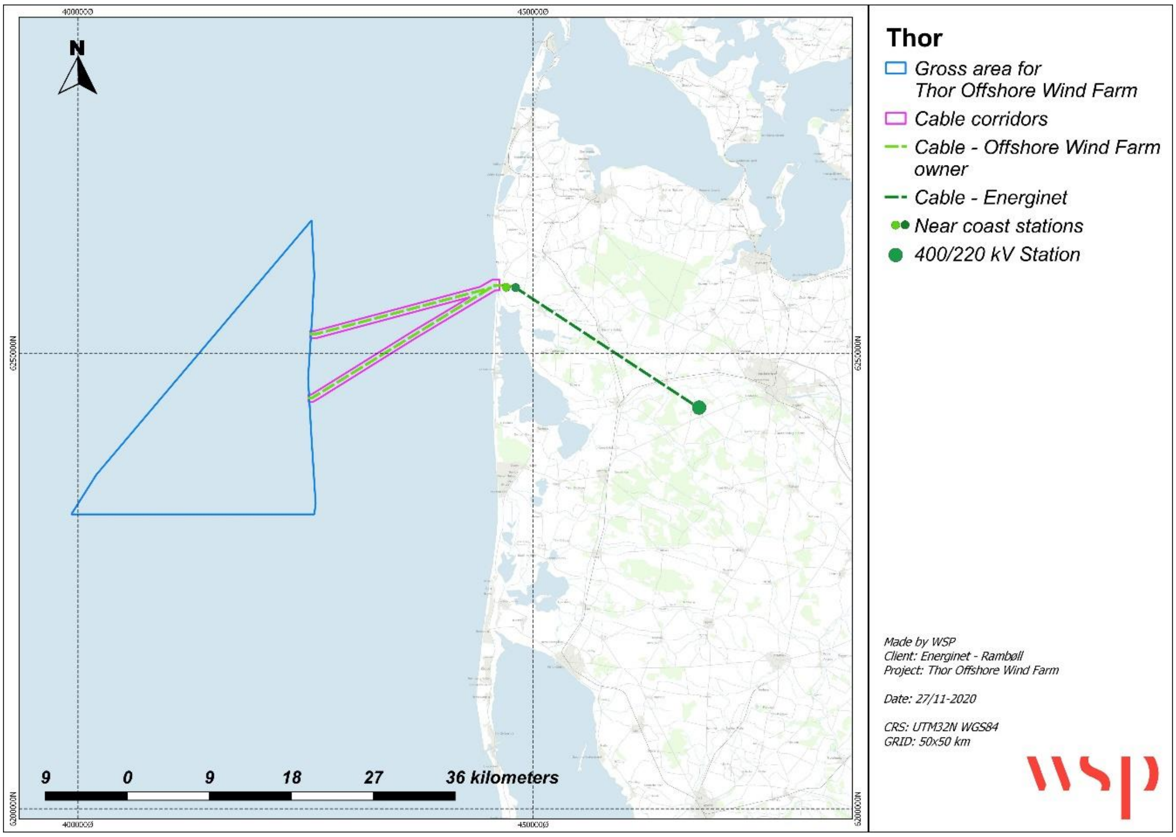


Figure 3-1. The gross area of Thor OWF. The gross area of Thor OWF is located west of Thorsminde in the North Sea. The area consists of a 440 km^2 triangular area and additional areas around two potential export cable corridors leading to one landfall on the coast north of Nissum Fjord (Energinet.dk, 2020).

The project plan includes the following elements for Thor OWF:

- the gross offshore wind farm area with wind turbines,
- the offshore substation (transformer platform),
- two cable corridors (R2 – Northern corridor) and R3 (Southern corridor) leading to one landfall on the coast north of Nissum Fjord (one or both may be used),
- a nearshore and onshore substation
- land cables to the grid connection point at Idomlund (Figure 3-1).

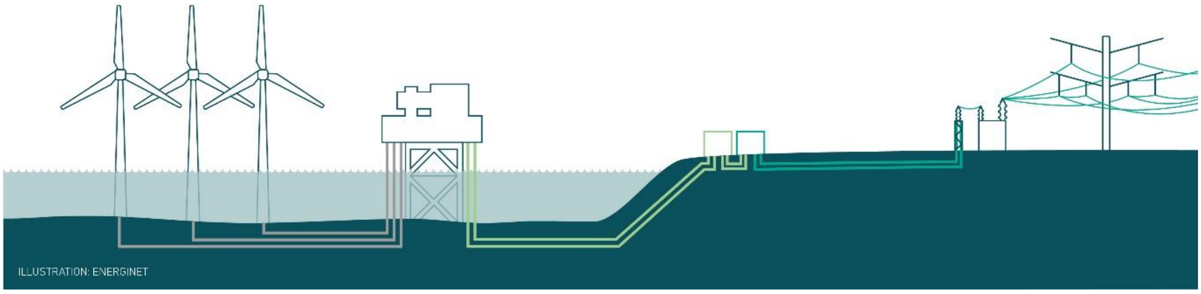


Figure 3-2. The planned Thor Offshore Wind Farm (Energinet.dk, 2020).

The project plan elements relevant for assessment of potential impacts are presented below.

3.1 Turbines

Wind turbines with a capacity in the range of 8 - 15 MW are expected. The minimum turbine capacity of 8 MW corresponds to the installation of up to 125 turbines, and that the maximum turbine capacity of 15 MW corresponds to the installation of up to 67 turbines. In order to take into account the possible technological development, the starting point for turbine sizes in this study is as listed below.

As described, the park layout and turbine design is not decided at this stage, and therefore, assessments in this study are performed on a general level taking into account various possible variations in park size, variations in turbine design and the resulting variation in the number of turbines, as well as variation in park-layout and the use of one or two cable corridors. In principle, there are endless different layouts that can lead to the final, concrete project. Therefore, the specific project, including park layout, will have to undergo an Environmental Impact Assessment (EIA) at a later stage.

3.2 Foundations

Based on the foundation methods used for ongoing offshore wind projects of up to 55 m depth, it is most likely that the offshore turbines will be based on monopiles, which are installed in the seabed by pile driving.

However, jacket or bucket foundations are included as possible alternatives. These foundation methods are generally more expensive but may come into play in special circumstances.

Possible foundation methods therefore include:

- Monopiles
- Jacket foundations
- Bucket foundations

Erosion protection/scour protection around the foundations are also a possibility. Experience from other wind farm projects along the West coast of Jutland indicates that this could potentially be done with boulders placed within a diameter of 15-20 m of the foundation (Vattenfall, 2020a; Vattenfall, 2020b).

3.3 Export cables

The export cables from the transformer platform (offshore substation) to the landfall are installed in one o both of the two alternative cable corridors (R2 or R3). The final number of cables and dimensions of export cables are not known at this point.

4. METHODS AND MATERIALS

Materials and methods used during the preparation of the technical report for fish and fish populations are presented below.

Prior to planning the fish survey, information regarding the seabed and sediment type is important since these data are used in designing the survey. Sampling with dredging fishing gear is not possible on all surfaces, so mapping of different sediment types is essential for conducting a safe and efficient fish survey. In addition, the sediment types are also an important indicator for which fish species may inhabit the area, as the various fish species have different habitat preferences. Material and methods related to the geophysical survey conducted by MMT Sweden in August to December 2019 are presented in section 4.1 – Geophysical Field Survey. Only geophysical parameters relevant to the fish fauna mapping and description are included.

Materials and methods related to the fish surveys conducted by WSP in April/September 2020 are presented in section 4.2 Fish Survey.

In the present technical report, data from various sources have been included as a supplement to the data achieved from the fish survey conducted specifically for this assessment. The supplementary data originates from commercial fisheries' logbooks, Fiskeatlas and assessment reports from nearby OWF projects.

All Danish commercial fishing vessels are obliged to keep a logbook of their catches. This is carried out either through an electronic logbook or a statement of fishing area for small vessels, which always fish in the same waters. The logbook carries information on e.g. the date, time and place of the fishing journey and of the catches in terms of species, mass and estimated value. Therefore, the logbook is an important source of information on which species can be found in the specific areas of Danish waters. Logbook data was obtained from the Danish Fisheries Agency for the three relevant ICES squares 41F7, 41F8 and 42F7 (The Danish Fisheries Agency, 2019).

This report also includes information based on Fiskeatlas. Since 2019, data on fish distribution in Danish marine waters have been gathered from a long list of historical and present sources (Fiskeatlas, 2020). For the non-coastal areas of the North Sea data primarily origin from fish surveys conducted by e.g. universities and consultant companies. The data only share information on species and number of observations – the quantity of each species is not included for the observations. The database is an important source of information on the biodiversity of fish in each Danish marine area and thereby, relevant for the present assessment.

Existing data from other relevant OWF including Vesterhav Nord and Syd as well as Horns Rev 1 has also been included in the present study (Vattenfall, 2020a; Vattenfall, 2020b) (Leonhard, et al., 2011).

4.1 Geophysical survey

Geophysical mapping was carried out in order to plan the fish survey and to predict the fish species that are expected to live in the various habitat types.

The geophysical data was collected to determine water depth, surface geology, seabed features, shallow geology and objects present in the gross area of Thor OWF. Instruments used during the geophysical survey were multibeam echo sounder, side scan sonar and sub-bottom profiler. The survey for the geophysical survey was conducted from August to December 2019 (MMT, 2020a) (MMT, 2020b).

For more details regarding the geophysical survey and results, see the Benthic Scope Report conducted by Marin Mätteknik AB (MMT) for OWF (MMT, 2020a) and CC (MMT, 2020b).

4.1.1 Depth

Water depth may determine the distribution of certain fish species. The temporal distribution of fish may also vary between seasons, with fish migrating into deeper and warmer waters during winter when coastal waters experience declining temperatures. Therefore, it is relevant to know the depth in the survey area.

Water depth was measured using a multibeam Echo Sounder system in order to provide a detailed bathymetric mapping of the entire gross area of Thor OWF and both cable corridors (MMT, 2020a).

4.1.2 Seabed sediment type characterization

Fish are attracted to the sediment types they have adapted to, and some even have essential habitats without which the fish cannot complete their life cycles. As an example, flatfish are adapted to sandy or muddy areas, where they bury into the sediment as a cryptic behavior, hiding from predators as well as prey. Other species of flatfish feed on prey buried into the sediment. So generally, flatfish are adapted to sandy areas without much structure.

In order to classify the seabed sediments, the following substrate classification method has been used to determine the roughness of the seabed sediment and the stone coverage cf. the Danish raw material order 780 of 20-06-2017 (Ministry of environment and food of Denmark, 2018). This clarification is used for implementing the seabed surface mapping. The seabed sediment classification method is based on the following seabed sediment types (substrates):

- **Type 1 – Sand and soft sediments:** Areas that consist of soft sediments as gyttja or silt, to hard sediments of sand (0.06 – 2.0 mm) and gravel fraction grain size, with a variation of bed forms (often dynamical). This type is further subdivided into 1a (gyttja or silty soft bottom sediments), 1b (hard bottom sediments of sand and gravel) and 1c (clayey sediments).
- **Type 2a – Sand, gravel and small rocks:**
- Area consisting of coarse sediment types, such as gravel, pebbles and small cobbles with varying content of sand. The sediment contains less than 1% area coverage of larger rocks (>10 cm).
- **Type 2b – Sand, gravel and small rocks and a few larger rocks (area coverage 1-10%):** Areas consisting of mixed sediment types but dominated by sand with a little content of gravel and rocks. Varying sediment content of gravel/pebble size fraction (<2 cm), small rocks of pebble and cobble grain sizes (2-10 cm) and a spread of larger rocks of cobble to boulder grain sizes with an area coverage of 1-10% (>10 cm).
- **Type 3 – Sand, gravel, small rocks and several larger rocks (coverage 10-25%):** Areas consisting of mixed sediment types dominated by sand, gravel and smaller rocks. This sediment type consists of a spread of larger rocks with an area coverage of 10-25% and can be associated with rocky reefs.

- **Type 4 – Rocky areas (reefs), consisting of many larger rocks (coverage >25%):** Dense spreading of larger rocks or rock reefs (stone reefs) with forming of cavities / rock shelters, and can have a bathymetric anomaly due to the high ground of large rocks compared to the adjacent sediment.

The substrate mapping is produced by the integration of several data sources, and in two steps:

Firstly, by the construction of a 1st generation map of seabed sediment types based on the geophysical survey (MMT, 2020a) and (MMT, 2020b). The mapping is generated by the interpretation of an already processed side scan sonar (SSS) dataset and a bathymetric dataset from a multibeam (MBES) data source. Additionally, this map is used for organizing the biological field programme, so the confirmation of all seabed sediment types is ensured.

Secondly, the construction of the 2nd generation map of seabed sediment types is generated from the integration of the biological survey data – more specific the physical results.
The 1st generation map is adjusted based on the ground truthing data related to the visual verifications (documentation by Remotely Operated Vehicle (ROV)) and the grain size analysis of the seabed sediment samples.

4.2 Fish survey

The aim of the present study is to have a baseline for the fish density and distribution in the area and to gain information of the area's importance as spawning and nursery area. For this purpose, the German method StUK4 is the ideal method as it describes the spatial and temporal distribution of fish as a baseline for offshore wind parks and other size limited areas (BSH, 2013). Furthermore, the method is ideal when determining the areas importance as nursery and spawning site for especially flatfish species, as the early life stages are more vulnerable to disturbances from OWF with the risk of increased sedimentation and underwater noise in the construction phase. The StUK4 method also ensures comparability with other fish surveys conducted in the North Sea, as the method is referenced to ICES monitoring standards in the North Sea. Due to limited vessel size and engine power, a modified smaller version of the trawl was used in the present study. The smaller trawl was compensated for with longer trawl hauls, so the overall area covered is identical to the area recommended in the StUK4. Both the ICES and the StUK4 method recommend two yearly surveys in spring and autumn, which will also be carried out in the present study.

Due to the focus on the area's importance as spawning and nursery area, supplementary analyses are added to the StUK4 methodology. The additional work includes the processing of fish gonads on board the survey vessel to estimate gonad ripeness and spawning progress. In addition to this, special emphasis is also made on length measuring more individual fish than usually to determine the length distribution of fish utilizing the project area.

Based on the geophysical survey and the mapped sediment types, a total of 20 stations were planned and sampled in the gross area of Thor OWF (see Figure 4-1). Beam trawl sampling cannot be carried out in hard bottom areas due to the risk of damage to gear and potentially also vessel and crew. Therefore, only one station was planned and sampled in the northern part of the area. Furthermore, the known nursery areas and spawning sites in the North Sea are all located offshore (Warnar, et al., 2012) (Worsøe, et al., 2002) and, therefore, the fish survey focused on the offshore area of the gross area of Thor OWF and no sampling was therefore carried out in the cable corridors.

The fish survey was conducted in the gross Thor OWF area in April (22nd to 27th) from the vessel "Cecilie" and September (25th to 30th) 2020 from the vessel "Skoven" by WSP. By conducting a spring and an autumn survey, the temporal variation of the fish community is included, as certain fish species migrate depending on their life strategy. The spring survey was scheduled to coincide with the spawning time of several relevant fish species, and the autumn surveys would demonstrate the areas importance as nursery area when the new recruits of the year (Young Of the Year = YOY) have grown into small juveniles.

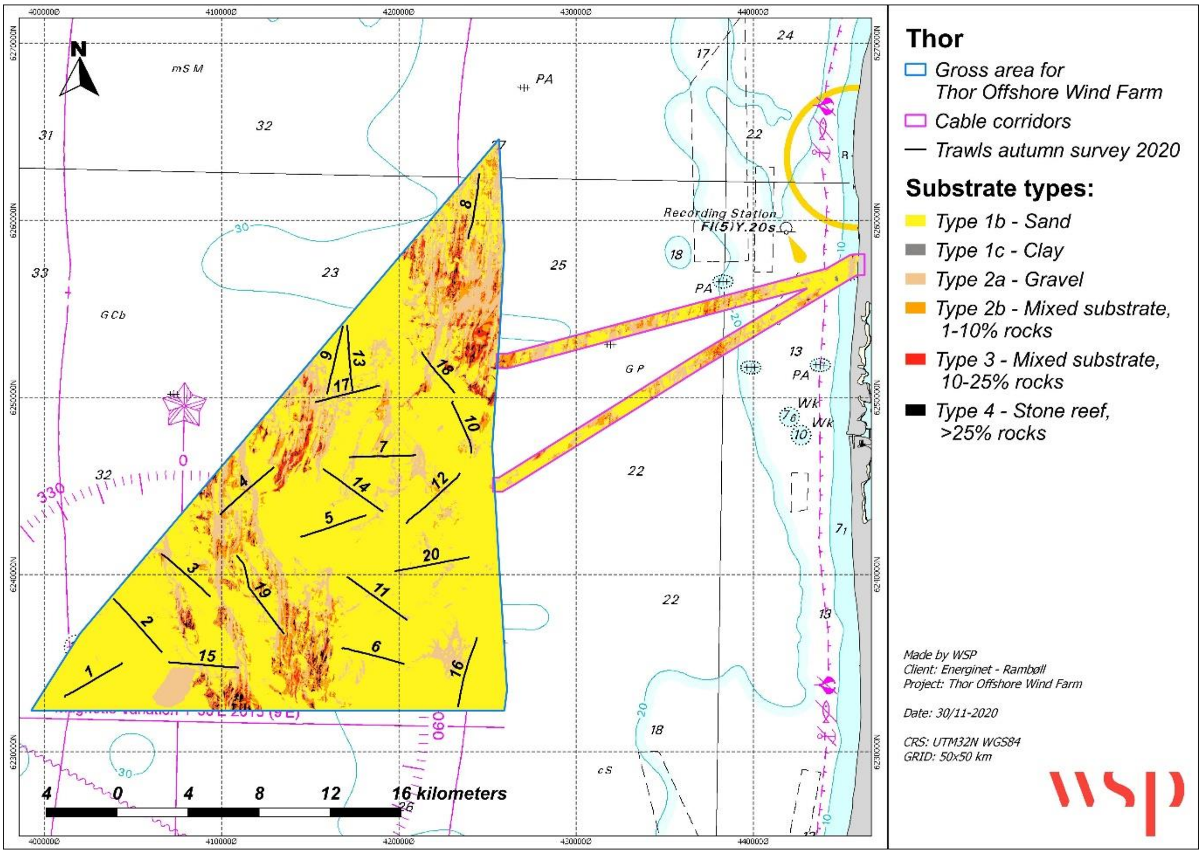


Figure 4-1: Beam trawl hauls in the gross area of Thor OWF. The hauls were placed randomly avoiding areas with high density of rocks that would damage the beam trawl.

The survey programme included the following activities at each station:

1. Beam trawl hauls for biological analysis of fish community
2. Depth and position for each start and end point of trawl hauls
3. Measurements of CTDO at surface and bottom water
4. Air temperature, wind speed and direction, intensity of clouds, and wave height

4.2.1 Sampling method

The fish survey sampling method is based on the German standard method for describing the spatial and temporal distribution of fish as a baseline for offshore wind farms, StUK4 (BSH, 2013). In the following, sampling methods for the fish survey are presented in detail.

Beam trawl hauls were carried out with a 4 m wide beam trawl – a modified and smaller beam trawl than in StUK4 to match the specific area Figure 4-2. The beam trawl had a mesh size of 20 mm.

Each haul was conducted during daylight and had a duration of approximately 30 minutes with a towing speed of 3 to 4 knots. A total of 20 trawl hauls were carried out.

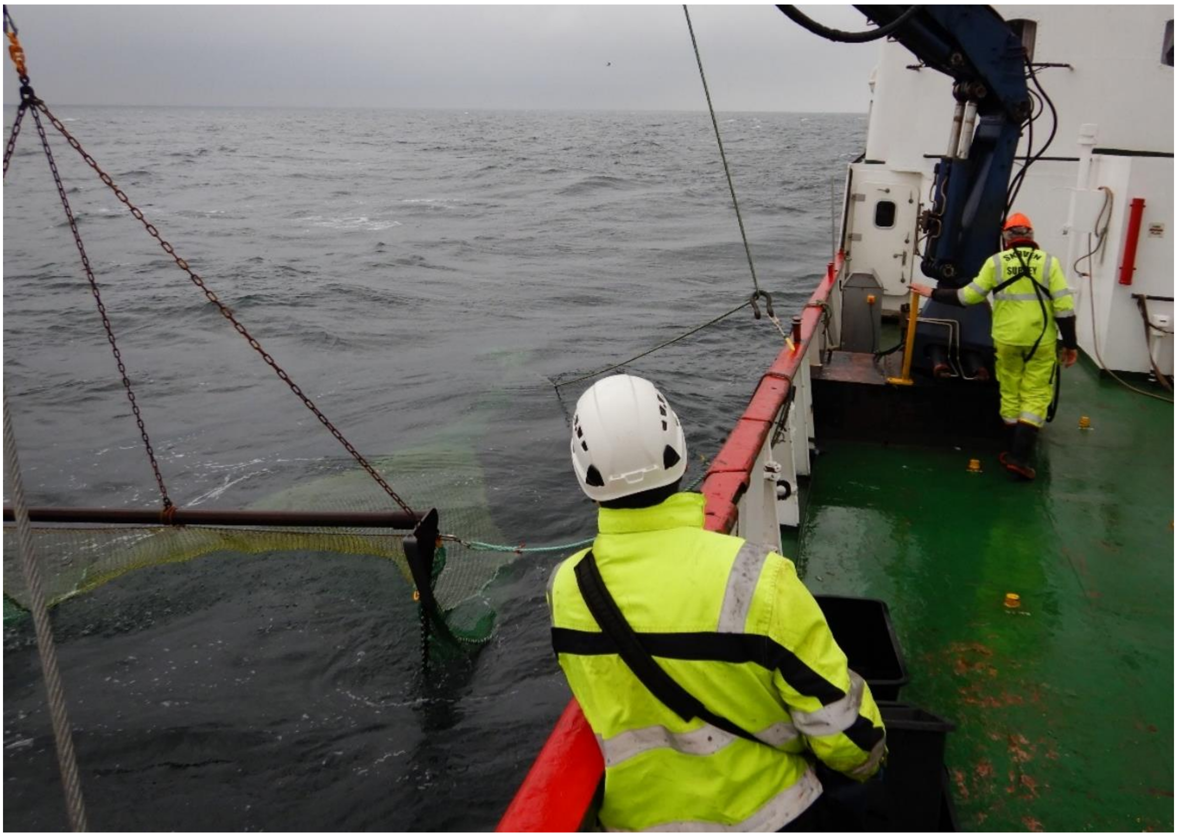


Figure 4-2 The beam trawl in action.

4.2.2 Analysis of catches

4.2.2.1 Analysis of the fish catch

All fish from the beam trawl sampling were sorted and determined to lowest possible taxonomical level (see example of catches from one station in Figure 4-3). Each fish was measured from the tip of the snout to the longest caudal fin ray (TL) to nearest lower cm and weighed to nearest lower gram. Where exceptionally large quantities of individuals of the same species were caught at the same station, the weight was given as a total for the species and not individually. Damaged fish were excluded from the measurement to avoid bias of the results.

4.2.2.2 Determination of gonad maturity stage

To determine the importance of the gross area of Thor OWF as a spawning area, the maturity stage of fish caught in the beam trawl was determined. The maturity of a fish is determined based on the visual appearance of the gonads and comparing this to a maturity index, where every stage of a fish's gonadal maturity is described. The index describes in several stages whether the fish is ripening its gonads, spawning or is "spent" (regenerating the gonads). When a fish is ripening the gonads and getting ready to spawn, they migrate to the relevant spawning site. So, if most individuals of a certain species caught in the gross area of Thor OWF are ready to spawn or are spawning, that indicates that the area is utilized as a spawning area. The gonad maturity index was determined macroscopically according to (Tomkiewicz, et al., 2002).

4.2.2.3 Size distribution

The length of all caught fish was measured to determine the size distribution of each species. By measuring the individual fish and determining the cohorts based on length-to-age literature, it is possible to determine an area's importance as a nursery area. Juvenile fish utilize nursery areas to feed and grow until they reach a size where they are less vulnerable to size-related predation. The nursery areas provide a relatively protected environments with plenty of food items such as invertebrates.

Figure 4-3 An example of the catch from a trawl haul. The catch was dominated by several species of flatfish.

4.2.2.4 Biodiversity and Evenness between species

To assess the biodiversity, the Shannon Wiener index was calculated for the catches on each station for the spring and autumn survey. The Shannon Wiener is the simplest measure of biodiversity and is a count of the number of different species in a given area. This measure is strongly dependent on sampling size and effort. The Shannon Wiener index increases as both the richness and the evenness of the infauna community increase. The values typically range between 1.5 and 4 in most ecological studies and the index is rarely greater than 4.

To assess the evenness between species, the Pielou's Evenness index was calculated for the catches of each station in spring and autumn survey. The index refers to how close in numbers each species is to the other species found at the station. The value of this index ranges between 0 and 1 - the greater the value the greater the evenness in species abundance and numbers. Please see Appendix 2 for further details on the calculations of the Shannon Wiener index and Pielou's Evenness index.

5. BASELINE SITUATION

Existing conditions in the gross area of Thor OWF for abiotic parameters as well as biological parameters are presented below. Abiotic conditions include water depth, seabed substrates and CTDO-measurements, and biological parameters includes fish fauna. Finally, an overview of the benthic habitats is presented.

Water depth and seabed sediment types are based on sampling data collected during the geophysical survey acquired in August-December 2019 by MMT Sweden AB; (MMT, 2020a) for wind farm area and (MMT, 2020b) for the cable corridors. The water depth is relevant regarding fish and fish populations as most fish species have a preferred depth range. Juvenile flatfish find shallow, sheltered areas and utilizes these areas as nursery areas until they reach a size where they are less vulnerable to size-dependent predation. During winter, several fish species are known to migrate into deeper and warmer waters and away from the coastal areas where temperatures drop in winter. Thus, the depth is relevant in terms of which species is expected to live in the area.

The sediment types are valuable information both when planning a fish survey, but also in terms of which fish species are expected to occur. Essential fish habitats are waters and substrate necessary for fish to spawn, breed, feed or grow to maturity. Flatfish are adapted to sandy or muddy areas without much structure, where they find prey and hide in the sediment, while cod depend on more complex areas with structures as nursery area.

Measurements of conductivity, temperature, depth and oxygen (CTDO) are general parameters important to ensure that sampling is carried out at normal environmental conditions and not e.g. during a period with oxygen depletion, which may cause the fish to flee and the results to be biased. The CTDO-results are listed in Appendix 3.

Existing fish data is presented along with the specific findings of the fish survey carried out in the gross area of Thor OWF. Fish data sampled during the fish survey has been compiled with data from nearby projects such as Vesterhav Nord and Vesterhav Syd (Vattenfall, 2020a; Vattenfall, 2020b) OWFs, commercial fisheries logbook data (The Danish Fisheries Agency, 2019) and data from FiskeAtlas (Fiskeatlas, 2020). The data is essential to assess the areas' importance as spawning and nursery area as existing data from the area is limited.

5.1 Description of gross area of Thor OWF

5.1.1 Water depth

Water depth ranges between -21 to -35 meters in the gross area of Thor OWF and between 0 to -30 meters in the two cable corridors as shown in the bathymetric map (Figure 5-1). The deepest water depth within the gross area of Thor OWF is found in the southwestern part, whereas the shallowest part of the area is located mainly in the eastern and south-eastern part. Within cable corridors, water depth is increasing towards the west towards the wind farm area, with the lowest water depth closest to the coast.

The bathymetry shows a dramatic steepening trend close to land on the shoreface, where the area is more dominated by sandy sediments (substrate 1b) and gravelly coarse sediments (substrate 2a) in the surf zone close to shore (Figure 5-1). The water depth conditions are very similar for CC_R2 and CC_R3.

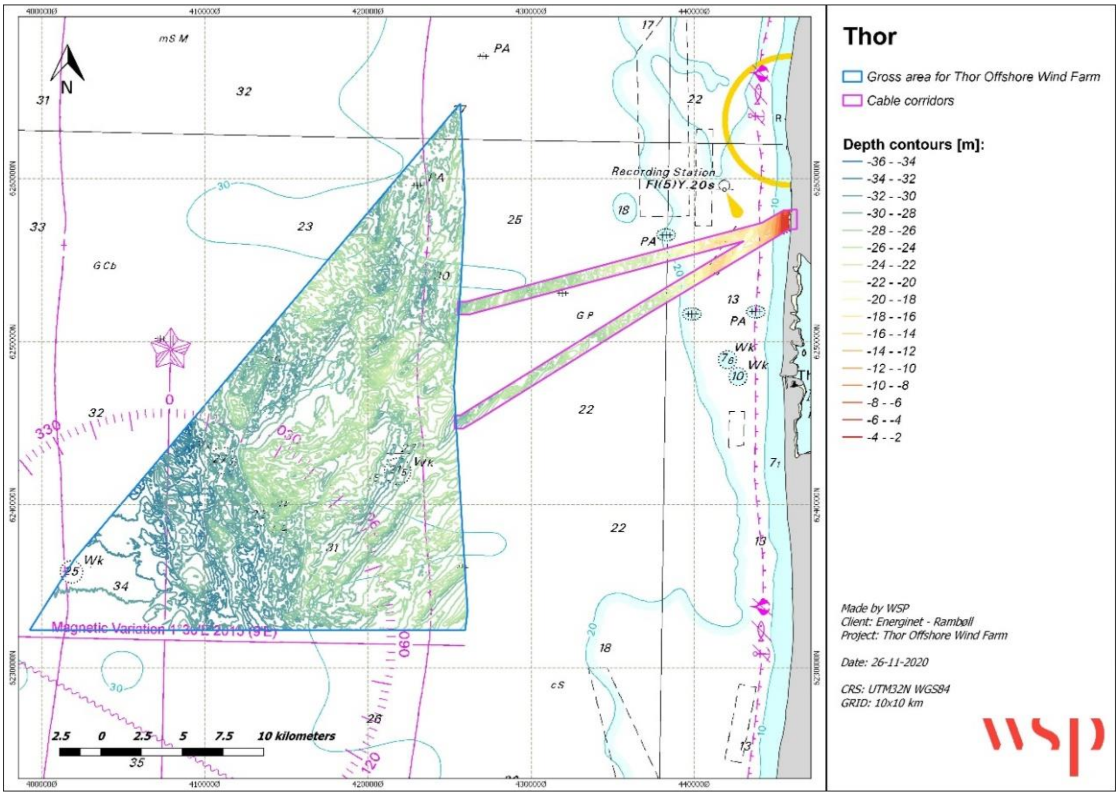


Figure 5-1 Bathymetric map of the gross area of Tor OWF and cable corridors by 2 meter interval depth contours (MMT, 2020a) for OWF and (MMT, 2020b) for CC.

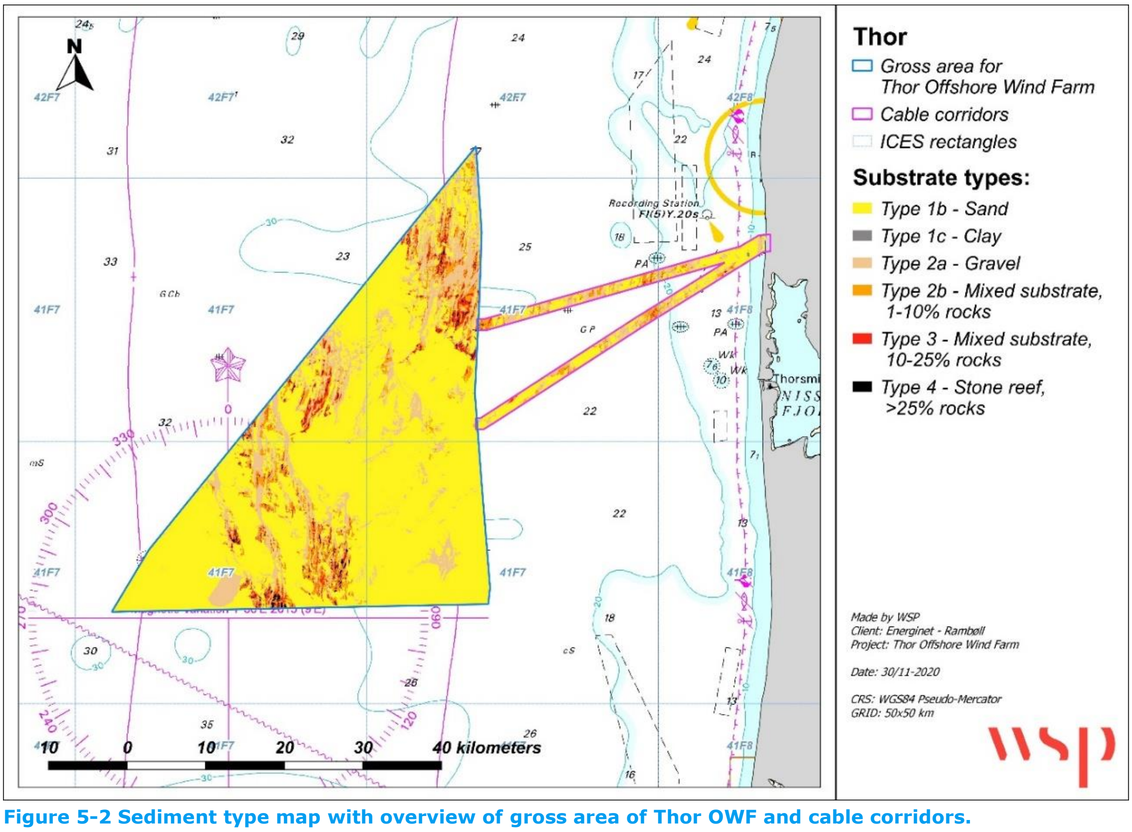


Figure 5-2 Sediment type map with overview of gross area of Thor OWF and cable corridors.

5.1.2 Seabed sediment

The seabed sediment types in the gross area of Thor OWF and cable corridors consists of a total of six different identified sediment types, i.e. cf. sediment type 1b, 1c, 2a, 2b, 3 and 4. These have been identified based on data from the geophysical survey and ground truthing data (ROV documentation and HAPS sampling) from the benthic field survey (Figure 5-2). The dominant sediment type in the gross area of Thor OWF and both cable corridors is type 1b, while the least dominant type is type 4.

5.1.3 Protected species and marine habitat types

The Habitat Directive ensures the conservation of rare, threatened or endemic plant and animal species as well as rare or characteristic habitat types. The directive holds a list of animals, plants and habitat types which the member states are obliged to protect both inside and outside of the Natura 2000 areas. The lists are the Annex II species, Annex IV species and Annex V species, where Annex II is the least restricted and Annex V the most restrictive.

The species on Annex II are attached with such strict regulations that habitats have been appointed where the species are protected, and these sites must be managed in accordance with the ecological needs of the species. Species on Annex IV are covered by a strict regime and they must be protected across their entire natural range within the EU both within and outside Natura 2000 sites. On Annex V are listed species where the member states must ensure that their exploitation of the nature areas is compatible with maintaining them in a favourable conservation status.

Annex II enfolds six different species including the sea lamprey, which is also a red listed species (Table 5-1). However, the species is not registered in the gross area of Thor OWF or the cable corridors according to Fiskeatlas (Fiskeatlas, 2020).

Species in Annex IV include Atlantic sturgeon and twaite shad. According to Fiskeatlas, the Atlantic sturgeon has been registered in the gross area of Thor OWF once (Fiskeatlas, 2020). The Fiskeatlas data only holds information on the frequency of the observations and not timing or number of individuals observed. But the observation of Atlantic sturgeon in the gross area of Thor OWF is supported by an additional 14 observations of sturgeon in the area between the gross area of Thor OWF and the coastline of Jutland (nine were positively identified as Atlantic sturgeon and the remaining five was only identified as sturgeon sp.). This unusually high number of observations of the critically endangered Atlantic sturgeon (*Acipenser sturio*) is believed to originate from reared and released Atlantic sturgeons. Attempts to restore the natural population of Atlantic sturgeons is currently taking place in German, French and Dutch rivers (Kirschbaum, et al., 2011) (Brevé, et al., 2018) and it is believed that few of the sturgeons have travelled from their release sites to Danish waters to forage (Henrik Carl & Peter Rask Møller pers. comm.).

Three fish species were included in Annex V; the river lamprey, salmon and Allis shad. However, none of these species were registered in the gross area of Thor OWF and cable corridors.

Any possible impact from the Thor OWF may affect the surrounding areas. Local Natura 2000 sites are shown in Figure 5-3 The project occupies or crosses no Natura 2000 sites directly, but one Natura 2000 site is located in the vicinity (approximately 300 m south) of the southern cable corridor (R3) and 13 km from the gross area of Thor OWF: Natura 2000 site nr. 220 (DK00VA341) *Sandbanker ud for Thorsminde*. The area is appointed for its protected habitat type: "Sandbanks which are slightly covered by sea water all the time" (DNA, 2016). Therefore, the area is not appointed due to any of the above listed protected fish species.

Table 5-1 List of marine fish species listed in the Habitats Directive Annex II, IV and X or are red listed and which are registered in the area. The sturgeon registered in the area are released specimens from German and French rivers. CR = Critically Endangered; DD = Data Deficient; LC = Least Concern; EN = Endangered. *The area is defined as the west coast of Jutland.

		Habitats Directive			Red Listed	Registered in the area*
Species	**Latin name**	**II**	**IV**	**V**		
Eel	*Anguilla anguilla*				CR	x
Sea lamprey	*Petromyzon marinus*	x			DD	x
River lamprey	*Lampetra fluviatilis*	x		x	LC	x
Atlantic sturgeon	*Acipenser sturio*	x	x			x
Atlantic salmon	*Salmo salar*	x		x	LC	x
Houting	*Coregonus oxyrhynchus*				EN	x
Twaite shad	*Alosa fallax*	x	x		LC	x
Allis shad	*Alosa alosa*	x		x		
Atlantic halibut	*Hippoglossum hippoglossus*				LC	x
Roundnose grenadier	*Coryphaenoides rupestris*				CR	

Natura 2000 area nr. 247 (DK00VA348) *Thyborøn Stenvolde* is located approximately 12 km north of the gross area of Thor OWF. All other Natura 2000 sites are more than 21 km from the gross area and cable corridors. These areas are appointed Natura 2000 sites due to the protection of twaite shad, allis shad, river and sea lamprey. These species are all anadromous, meaning that they spawn in freshwater but live most of their lives in the ocean. Twaite shad, river and sea lamprey are registered in the area but allis shad was not. Historically, allis shad has only been registered very few times in Danish waters and it is possible that the two species of shad never have spawned in Danish rivers (Krog & Carl, 2019).

Denmark is obliged to make a list of red listed species due through membership of the International Union for Conservation of Nature (IUCN). The lists may vary between countries. The Danish list was updated last in 2019 and 11 different species of fish and elasmobranchs (sharks, rays and skates) are registered as either regionally extinct, critically endangered, endangered, vulnerable or near threatened. Of them, eight are relevant for the west coast of Jutland (Table 5-1). One species, roundnose grenadier, is only listed on the red list but not on any of the EU annexes.

To summarize, only one vulnerable fish species has been registered within the gross area of Thor OWF and cable corridors; the Atlantic sturgeon has only been observed once since the first historical recordings of the Fiskeatlas. However, the Fiskeatlas does not specify whether the observation is historical or recent and the individual may be a migrated released specimen from the Rhine. Overall, the construction of the Thor OWF is not expected to impact the vulnerable fish species that Denmark is obliged to protect.

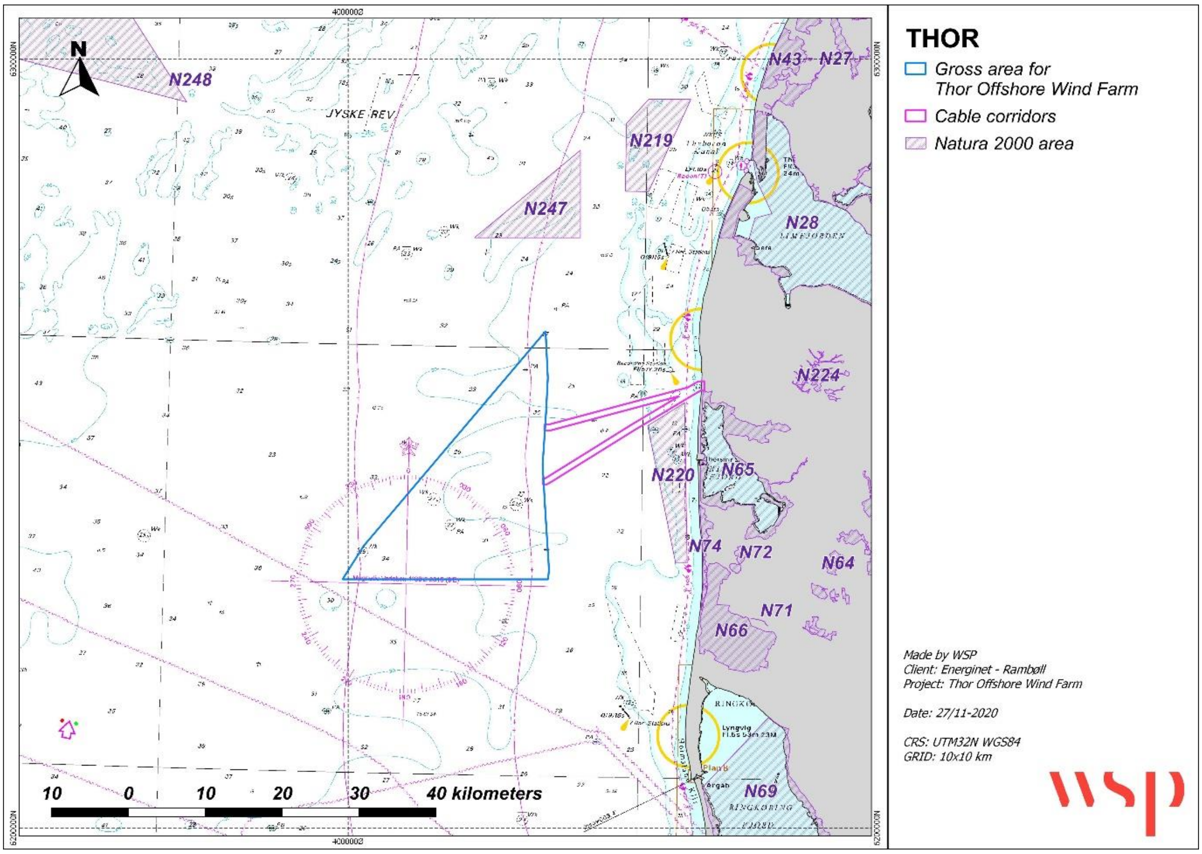


Figure 5-3. Location of the Thor offshore wind farm area, the two possible cable corridors and Natura 2000 sites in the vicinity of the OWF.

5.2 Key species

Of the estimated 200 different fish species present in the North Sea, approximately 20 species are important in the commercial fisheries in the three ICES squares that are relevant for the gross area of Thor OWF (ICES squares 41F8, 41F7 and 42F7). In the commercial fisheries, a total of 66 different fish species have been caught in the three ICES squares (The Danish Fisheries Agency, 2019).

The number of species per trawled station in Vesterhav Nord and Syd varied greatly and ranged from 0,5 to 55 fish per 1000 m^2. The species caught in Vesterhav Nord and Syd were generally common for the North Sea with the most abundant fish species being dab (*Limanda limanda*) and sand goby (*Pomatoschistus Minutus*).

A total of 37 different fish species was registered in the FiskeAtlas database within the gross area of Thor OWF and CC. Nine different species of flatfish were registered, including plaice, dab, turbot, sole, lemon sole, brill, flounder but also long rough dab (*Hippoglossoides platessoides*) and Solenette (*Buglossidium luteum*). It is hypothesized that approximately 90 different fish species frequent the gross area of Thor OWF throughout the course of a year (Henrik Carl & Peter Rask Møller pers. comm.). In the area between the gross area of Thor OWF and the west coast of Jutland the biodiversity is very high, and nearly 80 fish species have been registered here. In recent years, an unusually high number of observations of the critically endangered Atlantic sturgeon (*Acipenser sturio*) have occurred between the gross area of Thor OWF and the west coast of Jutland and the individuals are believed to originate from reared and released individuals (Henrik Carl & Peter Rask Møller pers. comm.). Please see section 5.1.3 for further details.

Fish surveys in the nearby Vesterhav Nord and Vesterhav Syd (Vattenfall, 2020a; Vattenfall, 2020b) OWFs and cable corridors conducted in 2015 showed comparable fish communities to what was found during the fish surveys in relation to Thor OWF in 2020. The number of species found in the trawl sampling in these investigations was the same as in the fish survey in this study. In the Vesterhav OWF, a few additional species were caught compared with the catches of the Thor OWF surveys; sprat, herring, common seasnail, lesser pipefish, three-spined stickleback, eelpout. The species such as pipefish, sticklebacks and eelpout suggest that vegetated areas were sampled in the Vesterhav OWF surveys, while the areas sampled in the gross area of Thor OWF were of a more sandy/muddy character. As a result of the sampled sandy substrate, additional flatfish species were caught in the gross area of Thor OWF compared to Vesterhav OWF including Norwegian topknot, scaldfish, solenette and brill.

The construction, operation and demolition of offshore wind farm and their cables will influence the fish and fish populations in different ways depending on the behavior and nature of the various fish species in the area. For a better understanding of the potential consequences for fish and fish populations, a description of ten key species of fish in the North Sea is given below.

5.2.1 Cod (*Gadus morhua* L.)

The Atlantic cod is a roundfish from the family of *Gadidae* where most species have a characteristic chin hook (Muus & Nielsen, 2006). The cod grows up to 150 cm, although individuals of this size is very rare today due to high fishing pressure. A more usual maximum size is approximately 110 cm and 15 kg. Cod lives from coastal areas to 5-600 m depth near the bottom but can also occur pelagic. The habitat range for Atlantic cod includes the North Atlantic and the Arctic (Fishbase.org, 2021). Generally, the cod spawns in January to April and the eggs drift with the water current in the pelagic. Juvenile cod utilize hard bottom areas as nursery area, where they feed on small crustaceans and the diet gradually shifts to be increasing piscivorous. Cod was caught in the gross area in the present study.

5.2.2 European plaice (*Pleuronectes platessa* L.)

The European plaice is a flatfish from the family of *Pleuronectidae.* Plaice occurs on sandy or muddy bottoms from a few meters down to about 200 m, at sea, estuaries and rarely entering freshwaters (Muus & Nielsen, 2006). The habitat range of the European plaice covers most of the European seas; from Iceland in west to the Baltic sea in the eat and north to the Norwegian and White Sea and the species southern range is south of the Iberian Peninsula (Fishbase.org, 2021). It feeds mainly on thin-shelled molluscs and polychaetes. Spawning occurs in the same way as for most flatfish in the North Sea (Figure 5-4); adult spawners meet during winter in softbottom areas in approximately 30-60 m depth and the eggs drift pelagically in the vast water masses with the current into shore where they hatch and settle in shallow softbottom sheltered areas with ample food resources known as nursery areas. As the water temperature drops over winter, the juveniles migrate into deeper water only to return to the shallows the following spring to further eat and increase in size. The older the fish grows the deeper it migrates during winter until it reaches maturity and migrates to the spawning sites. Plaice was caught in great numbers in the gross area of Thor OWF in the present study.

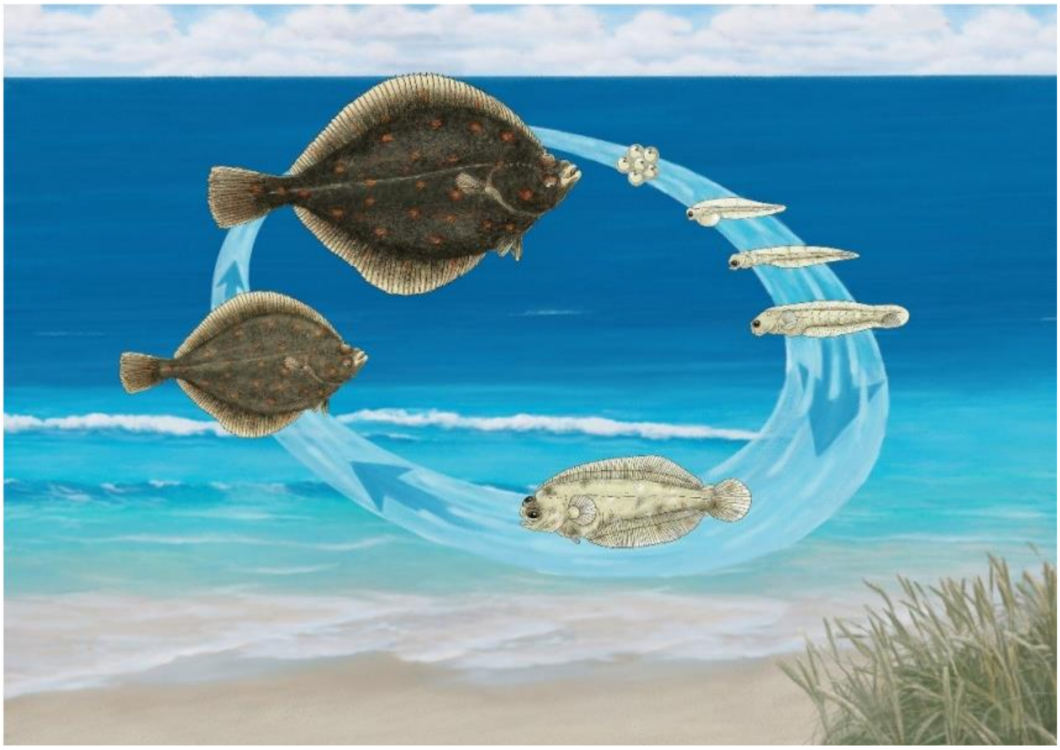


Figure 5-4 Life cycle of the European plaice and most other flatfish. The eggs hatch in the pelagic and the juveniles subsequently settle in shallow sheltered areas where they grow up. During winter the plaice migrate gradually into increasingly deeper waters until they reach maturity and migrate to the spawning sites (Source: (Støttrup, et al., 2019))

5.2.3 Sole (*Solea solea* L.)

The common sole is a flatfish belonging to the *Soleidae* family that comprises 90 species which primarily live in the tropics (Muus & Nielsen, 2006). It grows up to approximately 50 cm and lives on soft bottoms in sandy or muddy areas at up to 150 m depth. The habitat range for sole is the Eastern Atlantic: Norway in north to west Afrika in south, including the North Sea, western Baltic, the Mediterranean Sea and southwestern Black Sea (Fishbase.org, 2021). The sole is nocturnal and feeds on small invertebrates such as worms, mussels and other shellfish which it senses in the sediment with its "beard". Spawning occurs in the same way as for most flatfish in the North Sea, Kattegat and Skagerrak (Figure 5-4). The eggs and larvae drift with the current until they reach the nursery grounds in shallow sandy areas where they grow until winter where they swim to deeper and warmer waters. Sole was caught in the gross area in the present study.

5.2.4 Turbot (*Psetta maxima* L.)

Turbot is a flatfish in the Scophthalmidae family, which holds 20 species all living in the North Sea (Muus & Nielsen, 2006). The turbot is more round compared to most other flatfish, and it has spiny lumps on the upper side of the body, which makes it easily recognisable. The habitat range for turbot is the Northeast Atlantic; in the Mediterranean and along the European coasts to the Arctic Circle and in most of the Baltic Sea (Fishbase.org, 2021). The species lives on 20-70 m depth on sandy, rocky or mixed bottoms preying on crustaceans but as the turbot grows, the diet also includes fish such as small cod, other flatfish and sandeel. The maximum size of the turbot is approximately 100 cm and 25 kg, but the more usual size is no more than 50 cm for males and 70 cm for females. Spawning occurs in the same way as for most flatfish in the North Sea (Figure 5-4) and the juveniles live in shallow sandy nursery areas until winter, where they swim into deeper areas. Turbot was caught in the gross area of Thor OWF in the present study.

5.2.5 Dab (*Limanda limanda*)

The dab is a righteye flounder with a small mouth and distinctive, marked curve over the pectoral fin on the lateral line. The dab resides on sandy and soft bottom areas at depths up to 150 m (Muus & Nielsen, 2006). The habitat range of dab is the Northeast Atlantic from the Bay of Biscay to Iceland and Norway, in the Barents and White seas and in the Baltic Sea (Fishbase.org, 2021). The maximum size is up to 40 cm, weighing around 1 kg. However, the most common sizes are rarely above 30 cm. Spawning occurs in the entire North Sea area, throughout January-August. The diet consists of worms, crustaceans, bivalves and smaller fish such as gobies and young sand-eels. The dab is the most abundant species of flatfish in the North Sea and the Baltic Sea. Dab was caught in great numbers in the gross area of Thor OWF in the present study.

5.2.6 Solenette (*Buglossidium luteum*)

The solenette is a type of flatfish which has a rounded head and eyes on the right side. The species is often mistaken for juvenile sole due to the similarity. It resides on sandy bottoms, and is very common in the southern part of the North Sea and in the English Channe (Muus & Nielsen, 2006). The habitat range of solenette is the Eastern Atlantic from Iceland and Scotland southward, the North Sea and Baltic Sea, the Mediterranean Sea including Adriatic, Sea of Marmara, Bosporus (Fishbase.org, 2021). The maximum length is 13 cm, and spawning occurs around 7 cm of size, usually from March-July. The solenette feeds primarily on small, bottom dwelling invertebrates. Solenette was caught in great numbers in the gross area of Thor OWF in the present study.

5.2.7 Herring (*Clupea harengus*)

The herring is a pelagic, silvery, shoaling fish with soft fin rays. The maximum size is 40 cm and it may reach an age of 20 to 25 years (Muus & Nielsen, 2006). The habitat range for herring is the North Atlantic: in the west from Greenland and Labrador southward to southern USA. In the North it ranges The Arctic Sea and the White Sea, throughout the North Sea and Baltic Sea and south to the Bay of Biscay (Fishbase.org, 2021). This species is an important food item for many other fish. The herrings diet consists mainly of copepods, pelagic gastropods and fish larvae. The herring is a common species in the North Sea and is an important food source to e.g. cod. Herring are demersal spawners, and the eggs are attached to gravel, so the spawning sites are characterized by this sediment type (Pihl & Wennhage, 2002) (Rajasilta, et al., 1989). The North Sea herring mainly spawn in autumn (or spring depending on the population) where they migrate to the spawning sites along the English and Scottish coastline (Warnar, et al., 2012) (Worsøe, et al., 2002) (Coull, et al., 1998). The eggs and larvae drift towards east with the current and utilize the entire eastern North Sea as nursery area (Warnar, et al., 2012) (Worsøe, et al., 2002) (Coull, et al., 1998). Herring was not caught in the present study due to the benthic nature of the beam trawl.

5.2.8 Sand goby (*Pomatoschistus minutus*)

The sand goby is a small bottom living fish found in depths of 2 to 200 meters on sandy or muddy bottoms. The maximum length is approximately 17 cm (Muus & Nielsen, 2006). The habitat range for sand goby includes the Eastern Atlantic from Norway to Spain, the Mediterranean Sea and Black Sea (Fishbase.org, 2021). Spawning takes place during summer in shallow waters, where the females choose to mate with a male demonstrating good parental skills such as large nest size (Lindström, 1992). The juveniles are cared for by the parents. The sand goby is common throughout the North Sea, the Baltic Sea and the English Channel. The species is an important food subject to several piscivorous fish in the North Sea. Sand goby was caught in the gross area of Thor OWF.

5.2.9 Sprat (*Sprattus sprattus* L.)

Sprat is a pelagic round fish very similar in appearance to herring. It grows up to 16 cm and occurs in fjords and coastal areas including estuaries (Muus & Nielsen, 2006). During daytime it schools densely near the bottom while at night the fish follow the diel migration of copepods and sprat tend to spread out and swim near the surface to prey on the copepods. During summer it occurs at 5-50 m depth and in wintertime deeper at approximately 150 m depth. The habitat range for sprat is the Northeast Atlantic; From Norway and west of the British Isles, the North Sea and the Baltic Sea, the northern Mediterranean and Black Sea (Fishbase.org, 2021). Spawning time is January to July where the eggs are spawned pelagic at 10-12 m depth where they drift with the current. Sprat utilize the majority of the North Sea as spawning site except the Danish west coast, and the nursery is just as wide spread as the juveniles tend to school with the adults already from metamorphosis (Warnar, et al., 2012) (Worsøe, et al., 2002) (Coull, et al., 1998). Sprat is an important prey item for cod and several other predatory fish. Sprat was not caught in the present study due to the benthic nature of the beam trawl.

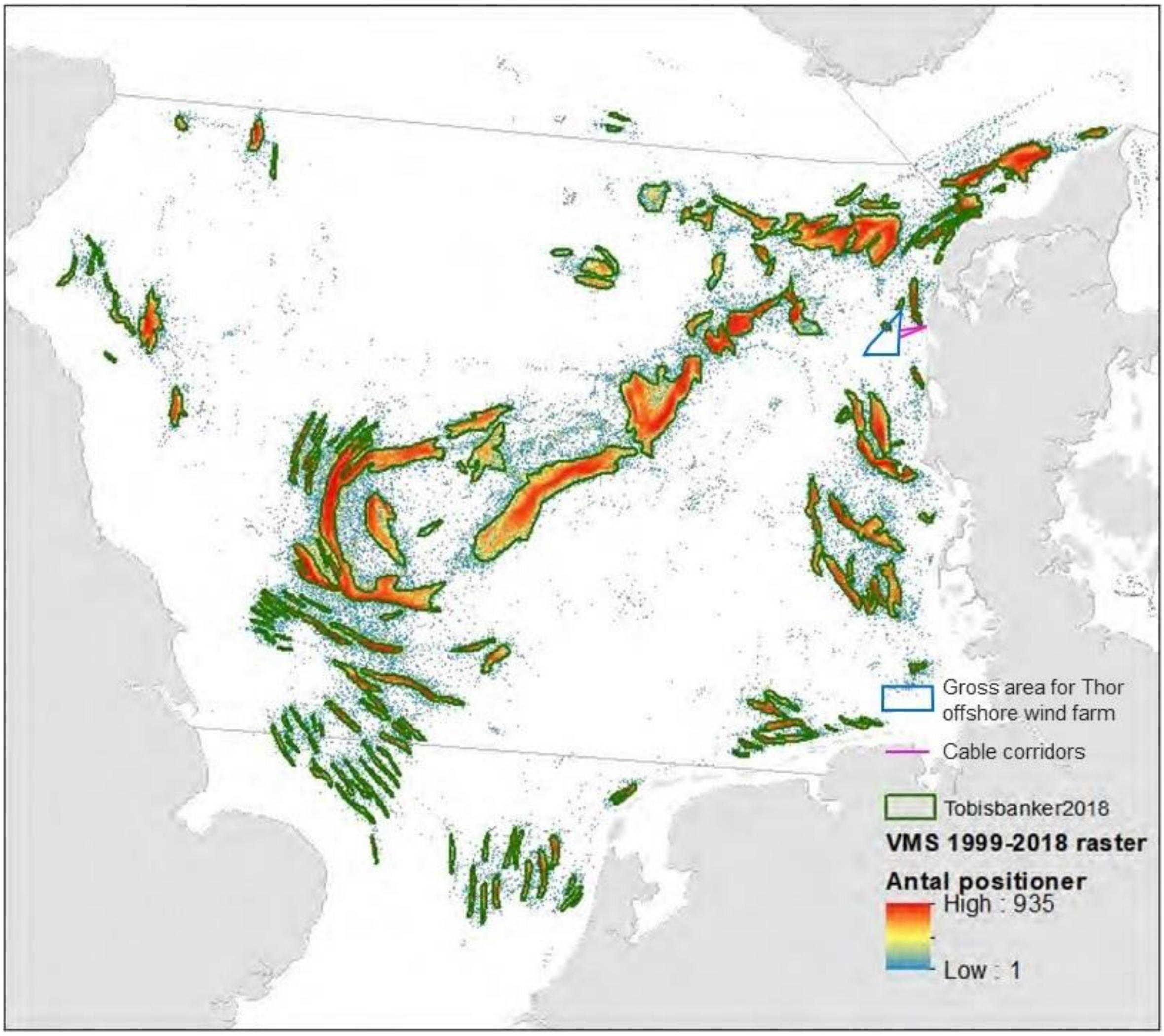


Figure 5-5 VMS positions from sandeel fisheries from 1999 to 2018, summarized in a 1*1 km grid, and including digitalised sandeel banks (Modified from (van Deurs, 2019)

5.2.10 Sandeel (*Ammodytes marinus* R. and *Ammodytes tobianus* L)

Sandeel caught in the commercial fisheries comprise of two separate species, which are usually not differentiated in the landings. The species are lesser sand-eel (*Ammodytes marinus*) and small sandeel (*Ammodytes tobianus*). The lesser sandeel is usually found further offshore compared to the small sandeel. Both species are long and slender fish of up to 20-25 cm long is a dominating fish species in the North Sea area between 10 and 150 m depth (Muus & Nielsen, 2006). The habitat range for small sandeel is the North Atlantic from Spain in south, Iceland in west, and the Baltic sea in east. The northern range is the White Sea (Fishbase.org, 2021). The habitat range for the lesser sandeel is the northeast Atlantic from Greenland, Iceland, The British Isles, the Barents Sea, the North Sea and the southern Baltic Sea (Fishbase.org, 2021). The most important habitats and fishing grounds for North Sea is illustrated in Figure 5-5. The fish spend most of the time at low light intensities (night and winter) buried in the sandy substrate. During feeding, which is correlated with the tidal current, they form massive schools in the water masses. The sandeel feeds on pelagic plankton. Spawning occurs for the lesser sandeel in the North Sea from November to February and for the small sandeel two strategies exists: spring and autumn spawning. The eggs are attached to sand and gravel. Sandeel are important prey items for cod, haddock and saithe. Sand goby was caught in the gross area of Thor OWF.

5.3 Survey data

A total of 6424 fish were caught – 2,752 in spring and 3672 in autumn, representing 31 different species. In spring, a total of 26 species were caught, and in autumn 23 species. The spring catches amounted to approximately 135 kg, and the autumn catches 116 kg – a total of 251 kg.

The catches are naturally biased towards benthic and demersal species as sampling was conducted with beam trawl which is only possible on sandy or muddy areas dominated by these species. However, since the emphasis of the report is to assess the areas of importance as spawning and nursery areas, beam trawl is ideal.

Please see the following sections for the results on nursery and spawning grounds in the gross area and cable corridors.

5.3.1 Seasonal variation in catches

The number of species caught was slightly higher in the spring survey compared to the autumn survey. The variation in abundance between stations was also greater in the spring, with a generally low abundance on all stations in autumn. The biomass pr. station was significantly greater for autumn the survey with an average of 750 g fish caught pr. 1000 m^2 compared to 433 g fish pr. 1000 m^2 in spring.

Catches in both spring and autumn were dominated by flatfish, but in spring, other species comprised approximately 25% in terms of abundance, while in autumn round fish only comprised 10% of the total catch.

5.3.1.1 Spring survey

The spring catches consisted mainly of flatfish and comprised 74% of the catch with seven other different species represented. The most abundant species in the beam trawl catches were the European plaice, solenette and common dab Table 5-2, making up 41%, 18% and 14 % of the catch, respectively. The density of fish per 1000 m^2 varied from 2 to 17 fish. In terms of weight, common dab, whiting and grey gurnard were also important species in the catch.

In the spring survey, reticulated dragonet (*Callionymus reculatus*) was caught. The species lives in warmer areas of the North Sea and has not been registered in Danish waters until 2014, where it was caught e.g. in the fish survey for OWF Vesterhav Syd and Nord (Krog, 2014) (Krog Consult & BioApp, 2015).

The catch was converted into Catch Per Unit Effort (CPUE) of 1000 m^2 to consider the different trawl lengths. Station 2 was the station with the highest abundance of fish, with 17,5 fish per 1000 m^2 Table 5-2. This was more than six times the abundance caught on station 5, where only 2,7 fish per 1000m^2 was caught. See Figure 5-6 for overview of the abundance for the varies stations.

Table 5-2 The total fish abundance in the gross area of Thor OWF area spring survey 2020. The catch has been converted to Catch Per Unit Effort (CPUE = 1000m^2).

no. / 1000 m^2	St 1	St 2	St 3	St 4	St 5	St 6	St 7	St 8	St 9	St 10	St 11	St 12	St 13	St 14	St 15	St 16	St 17	St 18	St 19	St 20	Total
American plaice														0,06						0,06	**0,1**
Atlantic mackerel										0,06											**0,1**
Brill				0,07	0,06														0,05		**0,2**
Atlantic cod				0,2					0,2			0,13	0,07				0,14	0,07	0,05		**0,8**
Common dab	3,59	3,51	0,68	0,47	0,38	0,77	0,61	0,27	0,39	0,45	0,95	0,91	0,34	0,49	1,42	1,6	1,57	1,41	0,37	1,53	**21,7**
Common dragonet	0,25	0,5	0,15	0,13			0,2	0,68	0,2	0,39	0,06	0,33	0,14	0,18	0,41	0,19	0,48	0,33		0,18	**4,8**
Common sole				0,07				0,2			0,06	0,07	0,2	0,06		0,06			0,05		**0,8**
European plaice	4,28	6,51	1,65	1,35	0,51	1,22	2,72	2,16	3,26	2,51	3,36	3,25	4,02	2,25	3,86	2,89	5,12	4,62	1,93	3,82	**61,3**
Fivebeard rockling			0,08																		**0,1**
Great sand eel				0,07				0,07			0,06									0,06	**0,3**
Greater sand eel													0,07								**0,1**
Greater weever		0,06		0,07	0,06				0,13		0,25	0,13									**0,7**
Grey gunard	1,18	1,25	0,38	0,27	0,32	1,35	0,54	0,2	0,46	0,97	1,01	0,46	0,95	0,61	0,95	0,39	0,41	0,54	0,41	0,7	**13,3**
Hooknose	0,74	1					0,07			0,13	0,06	0,07	0,07	0,06	0,2	0,13		0,13	0,14	0,06	**2,9**
Lemon sole	0,06																		0,05		**0,1**
Lesser weever									0,07												**0,1**
Raitt's sand eel										0,06											**0,1**
Reticulated dragonet				0,13					0,13	0,06	0,19			0,06	0,07		0,27				**0,9**
Sand goby	0,12									0,06	0,06	0,07		0,06		0,06	0,07				**0,5**
Scaldfish	0,19	0,63	0,3	0,2	0,13	0,06		0,07		0,19	0,32	0,26		0,12			0,2	0,2		0,12	**3,0**
Shorthorn sculpin				0,07			0,2	0,07	0,13			0,13	0,07	0,24		0,06	0,07	0,13		0,06	**1,2**
Solenette	2,11	4,01	1,35	0,34	1,21	1,86		1,55	0	1,16	2,09	0,98		2,92		3,27		1,21	0,73	2,41	**27,2**
Spotted dragonet																		0,07			**0,1**
Tub gunard						0,13			0,2			0,07	0,2					0,07	0,05	0,18	**0,9**
Whiting	0,25		0,15	0,27	0,06	0,06	0,82	0,2	0,85	2,19	0,06	1,3	0,27	0,37	0,14	0,13	1,36	0,54	0,37	0,47	**9,9**
Total	**12,8**	**17,5**	**4,7**	**3,7**	**2,7**	**5,5**	**5,2**	**5,5**	**6,0**	**8,3**	**8,6**	**8,1**	**6,4**	**7,5**	**7,0**	**8,8**	**9,7**	**9,3**	**4,2**	**9,6**	**151,0**

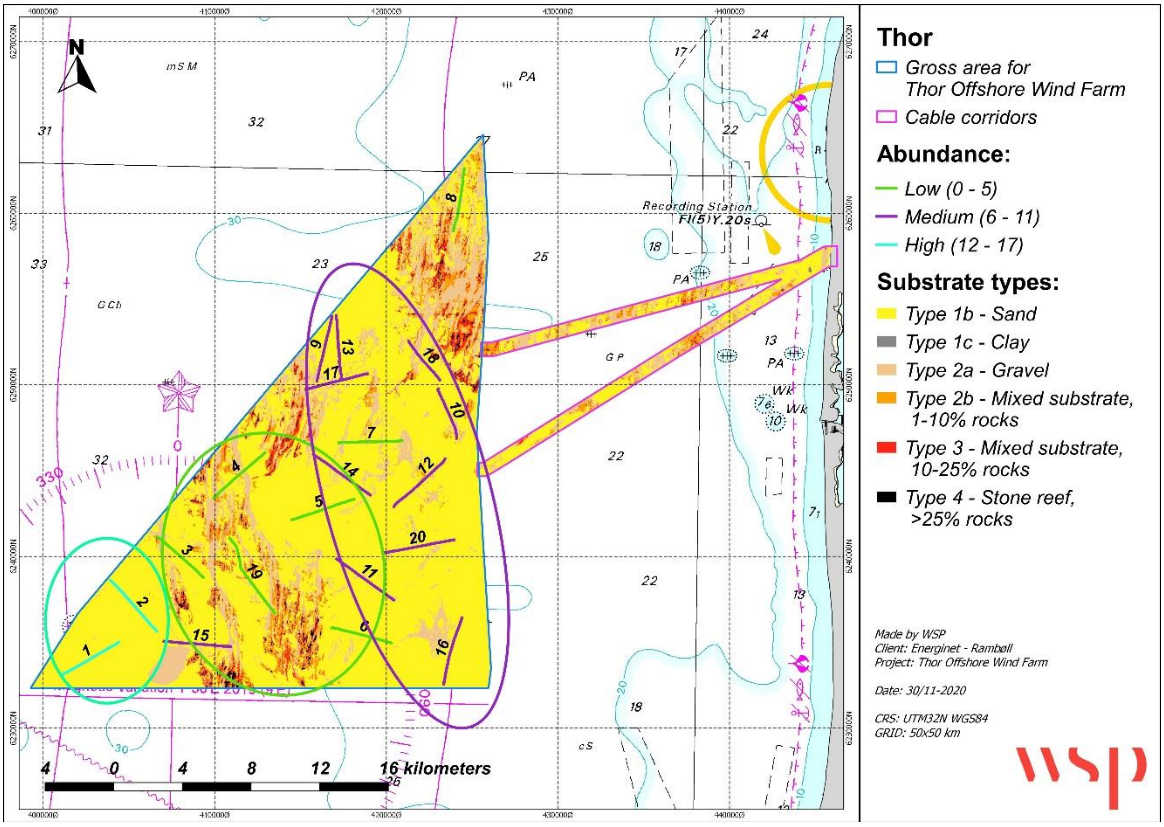


Figure 5-6 The fish abundance in CPUE 1000 m^2 for each sampled station in the spring survey. Low=0-5 fish; Medium=6-11 fish; High=12-17 fish.

Table 5-3 The total fish biomass in the gross Thor OWF area for spring survey 2020. The catch has been converted to CPUE = 1000m^2.

g / 1000 m^2	St 1	St 2	St 3	St 4	St 5	St 6	St 7	St 8	St 9	St 10	St 11	St 12	St 13	St 14	St 15	St 16	St 17	St 18	St 19	St 20	Total
American plaice														4,26						5,87	**10**
Atlantic mackerel										7,09											**7**
Brill				25,6	14,7														7,34		**48**
Atlantic cod				16,1					10,4			11,7	13,6				4,77	4,02	1,84		**63**
Common dab	161	160	63,2	66,6	54,2	65,6	49,6	33,8	55,5	40,9	65,3	67	37,5	25,6	108	121	76,7	74	28	93,4	**1447**
Common dragonet	8,05	21,3	6,02	6,73			9,51	25,7	9,14	9,67	3,8	18,2	2,73	12,8	13,6	4,49	14,3	9,37		5,87	**181**
Common sole				10,1				31,1			11,4	52,1	72,2	12,2		14,1			9,18		**212**
European plaice	305	365	170	239	32,5	120	198	236	392	170	200	208	429	123	342	162	286	439	171	291	**4877**
Fivebeard rockling			2,26																		**2**
Great sand eel				2,02				1,35			2,54									2,35	**8**
Greater sand eel													1,02								**1**
Greater weever		13,8		2,69	1,59				11,7		6,34	11,7									**48**
Grey gunard	28,5	40,1	11,3	28,2	12,8	75,8	23,1	1,35	25,5	58	63,4	24,1	47,7	10,4	23	21,8	17,1	21,4	23,9	33,5	**591**
Hooknose	7,43	21,9					1,36			1,29	0,63	1,95	2,04	1,22	4,07	2,57		2,68	3,21	1,17	**52**
Lemon sole	7,43																		1,38		**9**
Lesser weever									1,31												**1**
Raitt's sand eel										1,29											**1**
Reticulated dragonet				1,35					1,31	0,32	1,27			0,3	0,34		1,36				**6**
Sand goby	0,31									0,32	0,32	0,33		0,61		0,13	0,34				**2**
Scaldfish	0,93	8,77	7,52	5,38	3,83	1,93		0,68		2,58	5,07	5,21		3,65			2,05	4,02		2,94	**55**
Shorthorn sculpin				8,07			7,47	12,2	14,4			9,11	9,54	39,6		1,93	5,46	11,4		7,05	**126**
Solenette	59,5	105	9,02	4,04	11,5	16,7	28,5	16,2	10,4	11,6	55,8	7,81	11,6	31,1		28,2	25,9	9,37	7,34	22,3	**472**
Spotted dragonet																		0,67			**1**
Tub gunard						16,7			17			9,11	21,1					6,7	6,42	18,2	**95**
Whiting	12,4		6,02	14,8	2,55	1,29	23,1	9,46	32,6	70,9	2,54	33,8	10,9	18,9	12,2	3,21	54,6	18,1	11,9	11,7	**351**
Total	**590**	**736**	**275**	**430**	**134**	**298**	**340**	**368**	**581**	**374**	**418**	**460**	**659**	**283**	**503**	**359**	**488**	**601**	**271**	**495**	**8667**

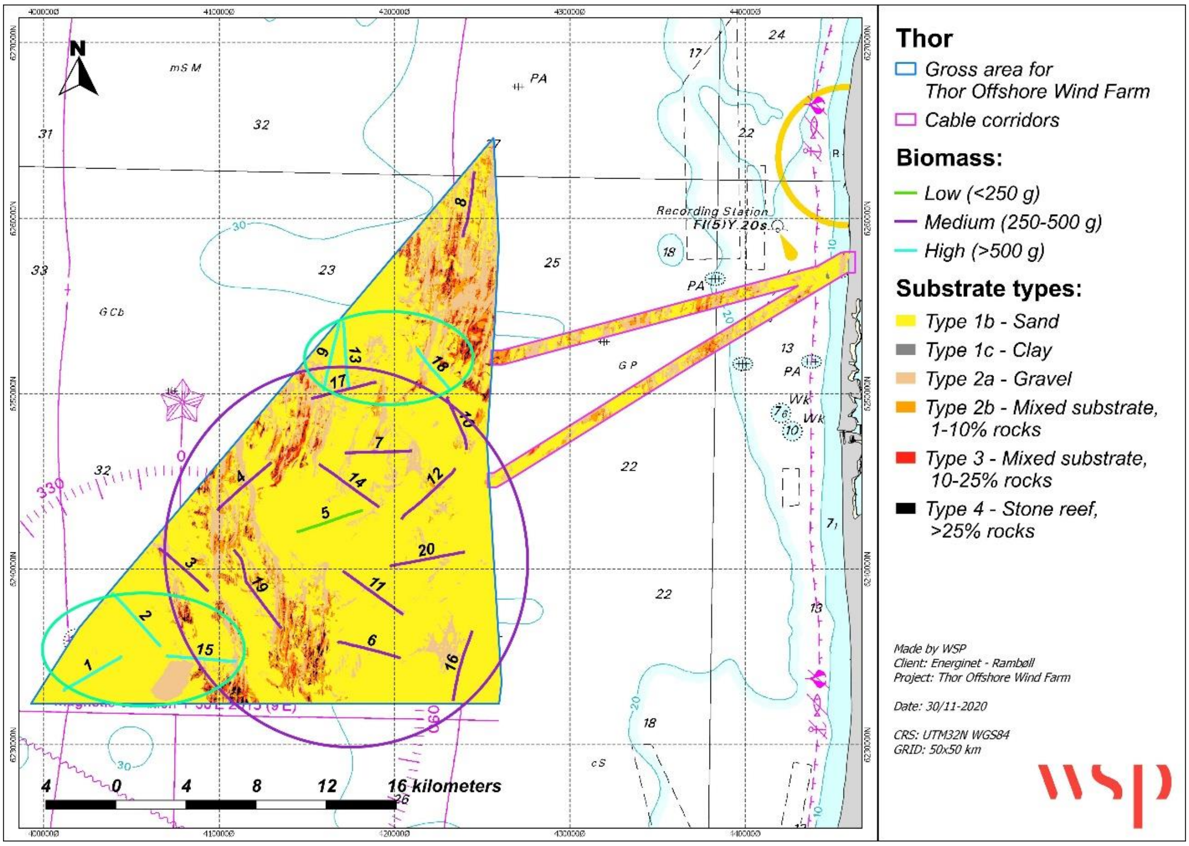


Figure 5-7 Fish biomass in CPUE 1000 m^2 for each sampled station in the spring survey. Low=<250g; Medium=250-500g; High=>500g.

The weight of the spring catch was also converted into CPUE per 1000m^2 Table 5-3. Again, station 2 in the southwestern part of the area was the station with the highest value with 736-gram fish pr. 1000m^2. Similarly, station 5 in the central part of the area was the station with the lowest value of just 134 grams of fish pr. 1000m^2. See Figure 5-7 for overview of the biomass for the varies stations.

5.3.1.2 Autumn survey

The autumn catches consisted mainly of flatfish (90%), representing 9 of the 23 fish species. The most abundant species in the beam trawl catches were solenette and plaice Table 5-2, making up 38% and 30% of the catch in terms of number, respectively. The density of fish per 1000 m^2 varied from 3 to 17 fish – very similar to the spring survey. In terms of weight European plaice comprised 61% of the total catch, while dab and solenette comprised 14% and 10 % of the total catch.

Fewer species were caught in the autumn survey (23 species) compared to the spring survey (26 species). So, most of the species caught in the autumn survey were also caught in the spring survey. However, the Norwegian topknot was only caught in the autumn survey and only two specimens. The Norwegian topknot is the smallest flatfish in European waters measuring only up to 12 cm. In addition, haddock, horse mackerel, lesser sand eel, long-spined sea-scorpion, surmullet and sand goby was only caught in the autumn survey.

Table 5-4 The total fish abundance in the gross Thor OWF area for autumn survey 2020. The catch has been converted to Catch Per Unit Effort (CPUE = 1000m²).

no. / 1000 m²	St 1	St 2	St 3	St 4	St 5	St 6	St 7	St 8	St 9	St 10	St 11	St 12	St 13	St 14	St 15	St 16	St 17	St 18	St 19	St 20	Total
Atlantic cod				0,1			0,1					0,1			0,1		0,1				1
brill			0,1			0,1		0,1		0,1							0,1		0,0		0
common dab	2,0	2,9	0,8	0,6	0,3	1,1	0,9	0,3	0,4	2,1	0,2	1,8	0,6	0,5	1,3	2,3	1,1	4,0	1,0	4,0	28
dragonet	0,3	0,3	0,5	1,1		0,1	1,5	0,7	0,1	0,6		0,2	0,3	0,4	0,4	0,4	1,6	0,3	0,5	1,3	10
European plaice	1,8	5,3	3,0	5,6	1,5	0,9	5,7	5,5	2,1	6,4	1,1	4,6	1,1	3,7	4,7	1,0	5,1	5,3	3,8	3,8	72
grey gurnard	0,1	0,1	0,3	0,3	0,1		0,1	0,1	0,1	0,3	0,1	0,2	0,1	0,3	0,1	0,2	0,1	0,1	0,0	0,1	3
haddock			0,1	0,1													0,1				0
hooknose	0,1	0,3	0,7	0,2			0,1	0,1							0,1	0,1	0,1	0,0	0,0		2
horse mackerel						0,1											0,1	0,1	0,0		0
lemon sole	0,1		0,3	0,1			0,3					0,1					0,1	0,1	0,0		1
lesser sand-eel			0,0	0,2																	0
lesser weever			0,1	0,1	0,1				0,4											0,1	1
longspined bullhead														0,1							0
Norwegian topknot				0,1								0,1									0
sand goby	0,1	0,6	0,3	0,6			0,4										0,1				2
scaldfish	1,8	1,9	1,3	0,9	1,4	0,1	1,5	0,5	0,2	0,6	0,2	0,8	0,2	1,3	2,0	0,9	1,6	0,9	1,0	0,5	20
shorthorn sculpin			0,1	0,1			0,1							0,1			0,1				0
sole			0,1	0,2		0,1	0,1	0,4	0,1		0,1	0,1		0,1			0,1	0,1	0,2	0,1	2
solenette	5,0	4,6	5,3	5,6	5,5	2,2	5,7	5,3	3,6	3,9	1,6	4,3	4,6	5,2	4,9	5,1	5,5	2,5	4,1	5,5	90
surmullet												0,1	0,1	0,1		0,1				0,1	0
tub gurnard		0,1	0,1	0,1			0,1	0,1	0,1			0,1	0,1	0,1			0,1		0,1		1
turbot			0,1	0,1				0,2			0,1		0,1						0,1		1
whiting		0,1		0,2		0,1		0,1			0,1	0,2				0,8	0,1	0,3			2
Total	**11**	**16**	**13**	**16**	**9**	**5**	**17**	**13**	**7**	**14**	**3**	**12**	**7**	**12**	**14**	**11**	**16**	**14**	**11**	**15**	**237**

The catch was converted into CPUE of 1000 m² to consider the different trawl lengths. Station 7 in the central part of the area was the station with the highest abundance of fish, with 17 fish per 1000 m² (Table 5-4). This was six times the abundance caught on station 11 where only 3 fish per 1000m² was caught. See Table 5-4 and Figure 5-8 for overview of the abundance for the varies stations.

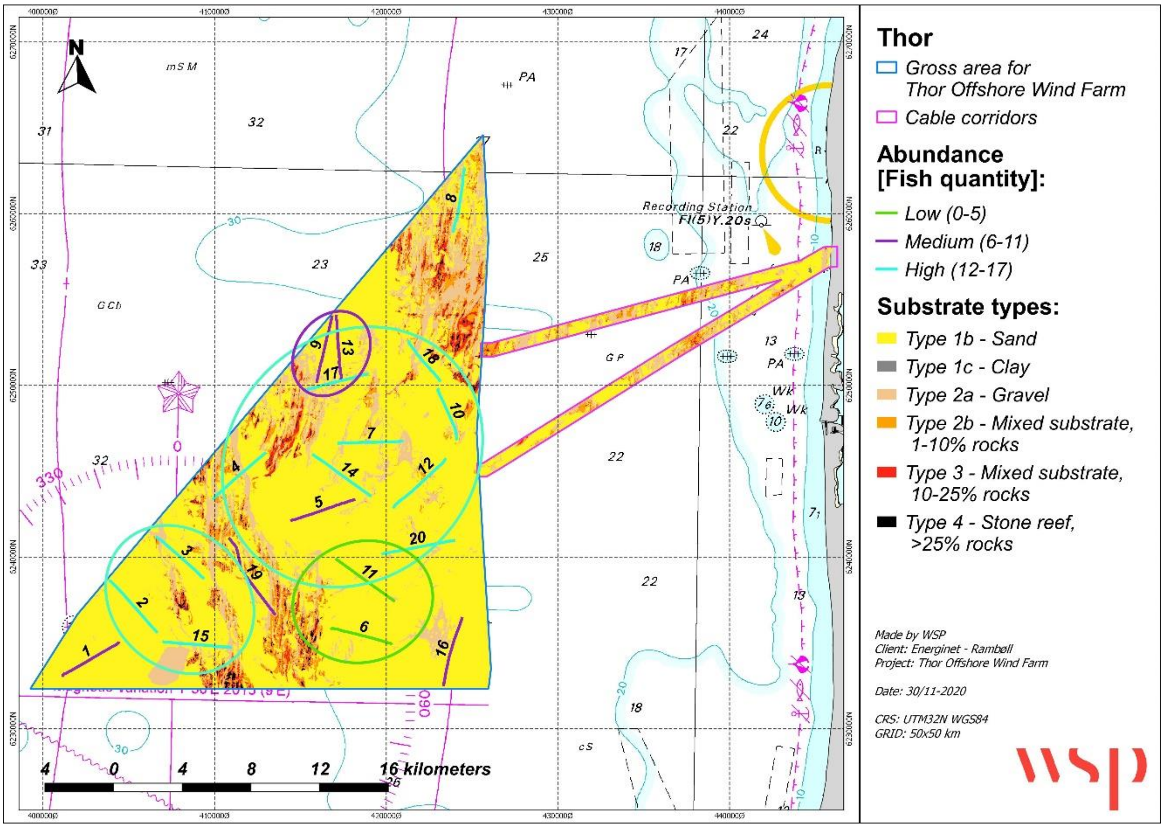


Figure 5-8 The fish abundance in CPUE 1000 m² for each sampled station in the autumn survey. Low=0-5 fish; Medium=6-11 fish; High=12-17 fish.

The weight of the autumn catch was also converted into CPUE per 1000m^2 (Table 5-5). Here, station 8 in the northern part of the area was the station with the highest value, with 1.4 kg of fish pr. 1000m^2. Station 5, 6 and 11 were the stations with the lowest biomass of just 265, 262 and 257 g fish pr. 1000m^2, respectively. See Table 5-5 and Figure 5-9 for overview of the biomass for the varies stations.

Table 5-5 The total fish weight in the gross Thor OWF area for autumn survey 2020. The catch has been converted to Catch Per Unit Effort (CPUE = 1000m^2).

g / 1000 m^2	St 1	St 2	St 3	St 4	St 5	St 6	St 7	St 8	St 9	St 10	St 11	St 12	St 13	St 14	St 15	St 16	St 17	St 18	St 19	St 20	Total
Atlantic cod				48,4			25,7					39,2			14,2		13,6				**141**
brill			22,3			21,8		73,6		29,6							25,8		18,0		**191**
common dab	74,1	150,9	48,4	68,9	36,3	126,8	76,6	37,7	54,2	156,1	35,9	186,1	89,1	43,2	86,6	121	87,1	339,1	63,3	219,6	**2.101**
dragonet	7,7	13,2	21,9	38,9		0,7	43,2	26,4	4,5	15,1		6,5	9,7	11,6	17,9	4,9	61,6	8,7	17,4	41,7	**352**
European plaice	111,2	400,1	392,2	861,3	142,9	89,6	729,3	997,0	300,9	766,3	116,6	529,6	138,2	412,3	479,2	66,0	881,7	507,6	833,0	330,1	**9.085**
grey gurnard	0,5	0,6	7,1	21,9	10,7		1,6	0,1	1,7	3,0	2,6	1,1	6,2	4,2	0,4	1,0	1,2	0,8	1,6	0,9	**67**
haddock			2,4	2,4													3,5				**8**
hooknose	1,2	7,0	11,8	4,8			1,5	5,7							0,9	4,9	1,4		1,1		**40**
horse mackerel						1,0											0,7	0,4	0,3		**2**
lemon sole	3,3		20,1	2,5			17,9					1,9					1,0	2,8	2,8		**52**
lesser sand-eel				2,4																	**2**
lesser weever			0,3	2,0	0,6				4,5											0,2	**8**
longspined bullhead														1,2							**1**
Norwegian topknot				0,3								0,4									**1**
sand goby	0,1	0,6	0,4	0,6			0,4										0,1				**2**
scaldfish	22,6	36,4	28,6	20,3	34,1	0,8	31,2	12,9	4,5	14,7	4,4	20,0	3,9	23,3	38,3	18,1	38,0	22,9	18,0	14,6	**408**
shorthorn sculpin			20,2	6,7			6,2							6,0			10,0				**49**
sole			8,5	76,5		6,1	5,5	46,9	37,9		22,9	9,0		12,7			28,6	11,8	58,2	7,2	**332**
solenette	183,3	255,1	100,5	51,7	40,7	13,2	109,5	50,3	27,9	29,6	11,0	35,8	36,5	166,5	80,2	88,5	68,4	21,0	51,3	43,3	**1.464**
surmullet												0,3	0,3	0,2		0,6				0,2	**2**
tub gurnard		13,7	9,3	11,7			19,2	38,0	14,0			9,8	28,7	37,1			22,8		14,7		**219**
turbot			153,6	31,5				79,1			62,5		35,6						39,7		**402**
whiting		1,5		29,0		2,5		0,4			1,2	9,2				12,3	5,3	6,8			**68**
Total	**404**	**879**	**848**	**1.282**	**265**	**262**	**1.068**	**1.368**	**450**	**1.014**	**257**	**849**	**348**	**718**	**718**	**318**	**1.251**	**922**	**1.119**	**658**	**14.998**

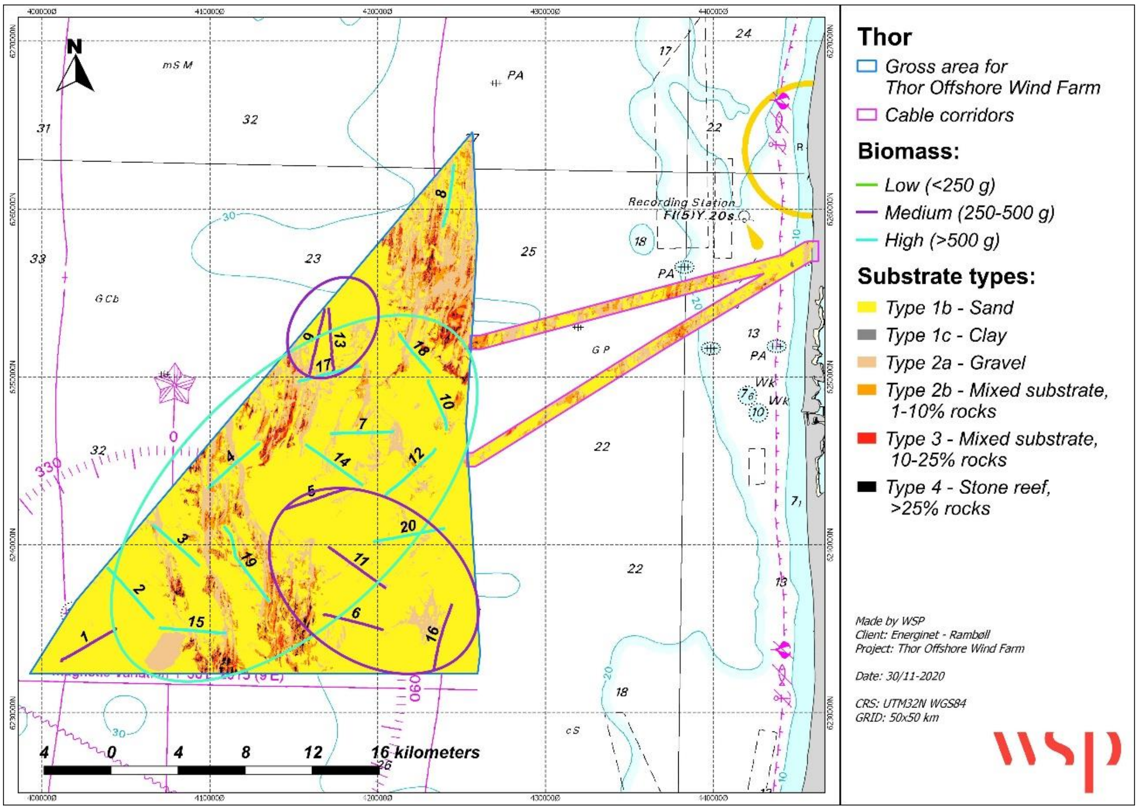


Figure 5-9 Fish biomass in CPUE 1000 m^2 for each sampled station in the autumn survey. Low=<250g; Medium=250-500g; High=>500g.

5.3.2 Spawning area

Existing literature suggests that the entire gross area of Thor OWF is a general spawning area for cod, however, not an important spawning site (Worsøe, et al., 2002). Sand-eel may potentially use the area as a spawning site based on the characteristics of the area (Coull, et al., 1998), but that is generally true for sandy areas in the North Sea. Furthermore, cod eggs are known to occur in gross area of Thor OWF during spring along with whiting fish larvae and juvenile sprat (Munk, et al., 2009) (Worsøe, et al., 2002). Sprat is known to have a widespread spawning area covering most of the North Sea except for along the Danish west coast (Worsøe, et al., 2002), (Coull, et al., 1998). Sprat utilize the Danish west coast along with most of the southern North Sea as nursery area (Worsøe, et al., 2002) (Coull, et al., 1998) (Warnar, et al., 2012).

The fish survey showed that, except for 3-4 dab, none of the fish caught in the gross area of Thor OWF were ready to spawn. For dab, most of the individuals were estimated to have premature gonads not ready for spawning. According to the literature, April is usually the month where dab begins to spawn (see Table 5-6). Therefore, if the area was important as a spawning area catches of more dab ready to spawn would have been expected. The same was the case for solenette. The European plaice caught in the gross area of Thor OWF still had premature gonads. As European plaice generally spawn from January to April, the individuals caught in the gross area of Thor OWF were most likely not sexually mature yet – the majority being smaller than 20 cm. The males become sexually mature at approximately 18-26 cm length and the females at 30-35 cm length (Muus & Nielsen, 2006). The gross area of Thor OWF was not utilized as an important spawning site for any of the species caught in the spring or autumn survey. If the area had been an important spawning site, catching fish ready for spawning in April was to be expected, as this is the month where most different fish species spawn (Table 5-6).

Table 5-6 Spawning time and behaviour for 20 common fish of the North Sea. Source (Muus & Nielsen, 2006), (Worsøe, et al., 2002), (Warnar, et al., 2012) (Whitehead, et al., 1986)

Common name	Latin name	Spawning time												Spawning behaviour
		J	F	M	A	M	J	J	A	S	O	N	D	
hooknose	*Agonus cataphractus*	x	x	x	x									Demersal spawner, pelagic larvae
lesser sand-eel	*Ammodytes marinus*	x											x	Demersal spawner, pelagic larvae
scaldfish	*Arnoglossus laterna*					x	x	x	x					Pelagic spawner
solenette	*Buglossidium luteum*			x	x	x	x	x	x					Pelagic spawner
common dragonet	*Callionymus lyra*				x	x	x	x	x					Pelagic spawner
spotted dragonet	*Callionymus maculatus*				x	x	x	x	x	x				Pelagic spawner
reticulated dragonet	*Callionymus reticulatus*				x	x	x	x	x					Pelagic spawner
tub gunard	*Chelidonichthys lucerna*				x	x	x	x	x					Pelagic spawner
lesser weever	*Echiichthys vipera*						x	x	x					Pelagic spawner
grey gunard	*Eutrigla gumardus*				x	x	x	x	x					Pelagic spawner
cod	*Gadus morhua*	x	x	x	x	x								Pelagic spawner
American plaice	*Hippoglossoides platessoides*			x	x	x								Pelagic spawner
great sandeel	*Hyperoplus lanceolatus*				x	x	x	x	x					Demersal spawner, pelagic larvae
greater sand-eel	*Hyperplus immaculatus*				x	x	x	x	x					Demersal spawner, pelagic larvae
common dab	*Limanda limanda*				x	x	x							Pelagic spawner
whiting	*Merlangius merlangus*		x	x	x	x	x							Pelagic spawner
lemon sole	*Microstomus kitt*				x	x	x	x	x					Pelagic spawner
shorthorn sculpin	*Myoxocephalus scorpius*	x	x									x	x	Demersal spawner, parental care
european plaice	*Pleuronectes platessa*	x	x	x	x								x	Pelagic spawner
sand goby	*Pomatoschistus minutus*					x	x	x	x					Demersal spawner, parental care
Atlantic mackerel	*Scomber scombrus*			x	x	x	x	x						Pelagic spawner
brill	*Scopthalmus rhombus*					x	x	x						Pelagic spawner
common sole	*Solea solea*				x	x	x							Pelagic spawner
greater weever	*Trachinus draco*						x	x	x					Pelagic spawner

5.3.3 Size distribution and nursery area

The size distribution was analysed for the five most abundant fish species for the spring and autumn survey combined – European plaice, solenette, common dab, scaldfish and grey gurnard (grey gurnard was only caught in the spring survey).

European plaice was the species demonstrating the largest size variation in the catches and sizes varied from 2 to 52 cm (only 14-51 cm in autumn catches) – see Figure 5-10. One plaice was measured to be 52 cm, which is on the border of the maximum size of a plaice, and the individual could be as old as 15 years (Muus & Nielsen, 2006). Many of the individuals measured 15-20 cm in the spring survey, and the same cohort is visible in the autumn survey now ranging from 19-23 cm. According to size-at-age literature, this cohort is approximately 2-3 years old (Muus & Nielsen, 2006). Plaice also had a small peak of individuals of 10-11 cm in the spring survey, suggesting a cohort of 1-2-year old plaice. The same cohort has grown to 16-18 cm in the autumn survey. One plaice of only 2 cm was caught in the spring survey at station 12, which is a newly settled young of the year (YOY). European plaice ≤ 10 cm were caught in the spring survey in stations 1, 2, 5, 6, 7, 10, 11, 12, 14, 16, 17, 18 and 20 – so on sandy areas in the central and south western part of the gross area of Thor OWF. Only one plaice <13 cm was caught in station 6 in the autumn survey). Plaice utilize shallow, sheltered and sandy areas as nursery areas after settling, (Poxton & Nasir, 1985) and the gross area of Thor OWF does not fit the profile for a nursery area. The most important nursery area for plaice in Danish waters is the Wadden Sea and the east coast of Jutland (Kuipers, 1977). However, the younger individuals swim to deeper areas with warmer water during wintertime, which may be the reason for the relatively large proportion of young fish in the springtime. The winter 2019-2020 was characterized by a late temperature drop, and thus, the water temperature was still low in April. In autumn, fewer smaller fish were observed, and this may be because the young fish were still foraging in shallow areas before returning to deeper waters when temperatures decrease.

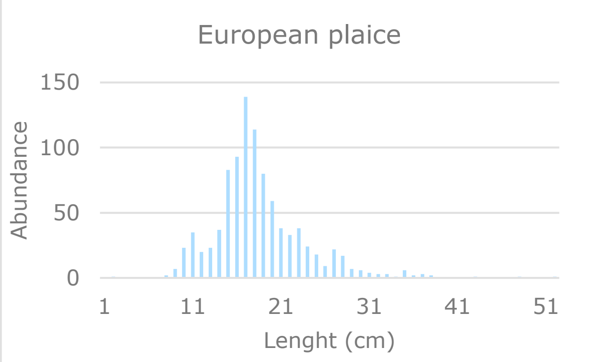
Common dab was represented in both spring and autumn catches ranging from 6-30 cm plus one individual measuring 34 cm, which is rare (Muus & Nielsen, 2006). In spring, dab had three cohorts; 10-11 cm, 15 cm and 18-22 cm which according to size-at-age literature indicates 1, 2 and 3-year olds, respectively (Muus & Nielsen, 2006). In the North Sea, the dab spawn from April to June, and, thus, no YOY were present during the spring survey (Muus & Nielsen, 2006). In autumn, these 1- and 2-year cohorts had increased in size to 14-16 cm and 19-23 cm while the peak of 3-year olds did not seem to appear in the area in autumn. Additionally, in autumn, a clear peak occurred at 6-10 cm representing YOY. The juvenile dab settle at 6-70 m depth (Muus & Nielsen, 2006), and, therefore, the gross area of Thor OWF is relevant as nursery area for this species. A total of 32 individuals ≤ 10 cm were caught in the spring survey, and 15 in the autumn survey in stations 1, 2, 6, 7, 10, 11, 12, 14, 15, 16, 17, 18, 19 and 20 – generally on the most sandy and/or muddy areas (meaning the central and southwestern part of the gross area of Thor OWF) while avoiding the more gravelly and mixed substrates in the north and north western area (station 3, 4, 8, 9, 13).

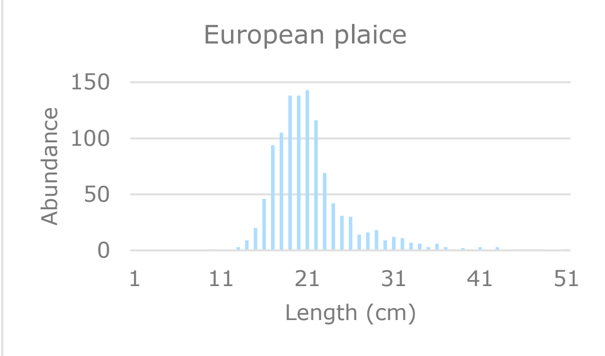
Solenette was represented by individuals with a size range of 5-12 cm both in spring and autumn survey. Compared to the other flatfish, this may seem like juveniles and therefore, it is a common mistake to confuse adult solenette with juvenile sole. However, the maximum size of solenette is approximately 12-13 cm (Muus & Nielsen, 2006). Thus, the individuals observed are adults, as the species is sexually mature at the size of 6-8 cm depending on the sex. Studies have demonstrated that for solenette there are no special nursery areas and that juveniles and adults occur in the same areas (Baltus & Van der Veer, 1995). However, in the present study, no juveniles were caught within the entire gross area of Thor OWF, and, therefore, the species does not utilize the gross area of Thor OWF as nursery area.

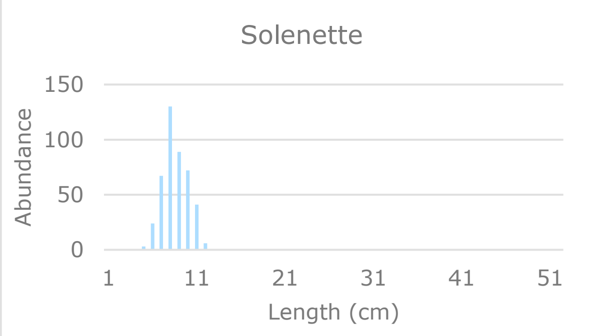
Scaldfish was caught in spring and autumn with a size range of 3-16 cm. In the North Sea the maximum size of scaldfish is 20 cm (Muus & Nielsen, 2006), and no special nursery area have been documented for this species as the distribution of juveniles and adults overlap (Baltus & Van der Veer, 1995). The flatfish larvae metamorphose and subsequently settle on the seabed at 16-30 mm length (Muus & Nielsen, 2006). So, the smallest individuals caught are thus newly settled. In the spring catches, two clear cohorts are evident – 4-7 cm and 10-15 cm. These likely represent 1-year olds and 2-3-year olds, as the species spawn in May-August (Muus & Nielsen, 2006). For the autumn catches three cohorts are evident from the data – 3-5 cm, 10 cm and 13-15 cm. The smallest group is most likely YOY spawned over summer, while the two other peaks are 2-3-year olds. In total, 5 individual scaldfish ≤ 10 cm were caught in the spring survey and 15 in the autumn survey. The juveniles were caught in stations 1, 2, 5, 7, 10, 14, 15, 16, 17 and 19 – so sandy areas in the central and south western part of the gross area of Thor OWF function as nursery areas, although larger individuals coexist.

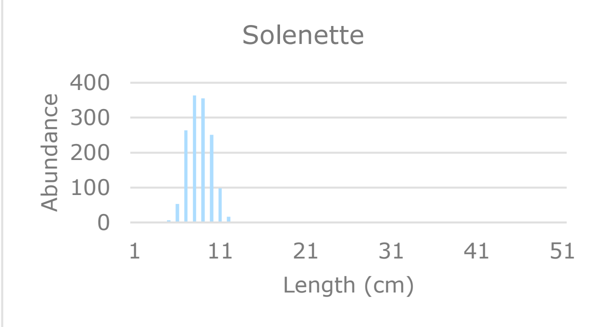
Grey gurnard was present in spring and autumn with a size range of 6-28 cm in spring catches and 7-26 cm in autumn catches. For the spring survey, the species clearly demonstrated two cohorts of approximately 10-13 cm and 17-21 cm, representing 2-year olds and 3-year olds (Muus & Nielsen, 2006). The result is less clear for the autumn survey, where only 15 individuals were caught, but a clear peak is evident at 10 cm length, which is most likely 1-year olds. Scientific evidence does not suggest any clear nursery areas (ICES, 2018). In the gross area of Thor OWF several younger cohorts co-exist. However, the data does not suggest that the species utilize the area as a nursery area.

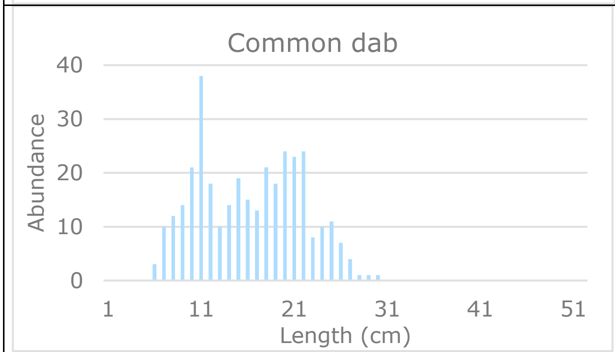
April 2020	September 2020

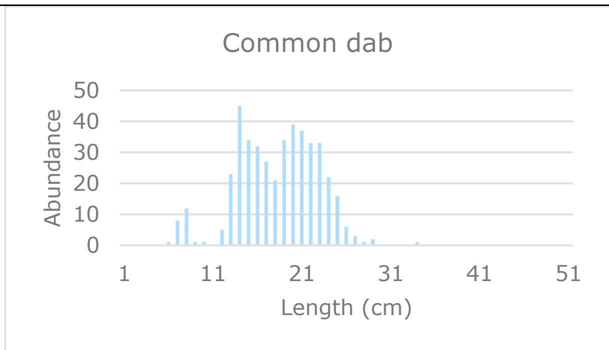


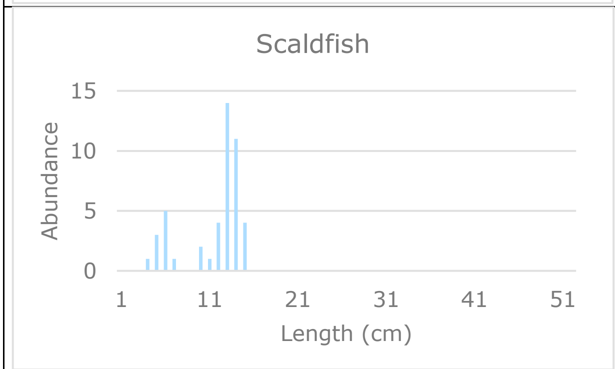


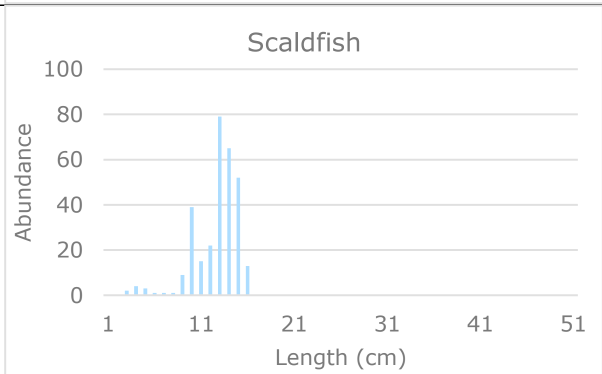












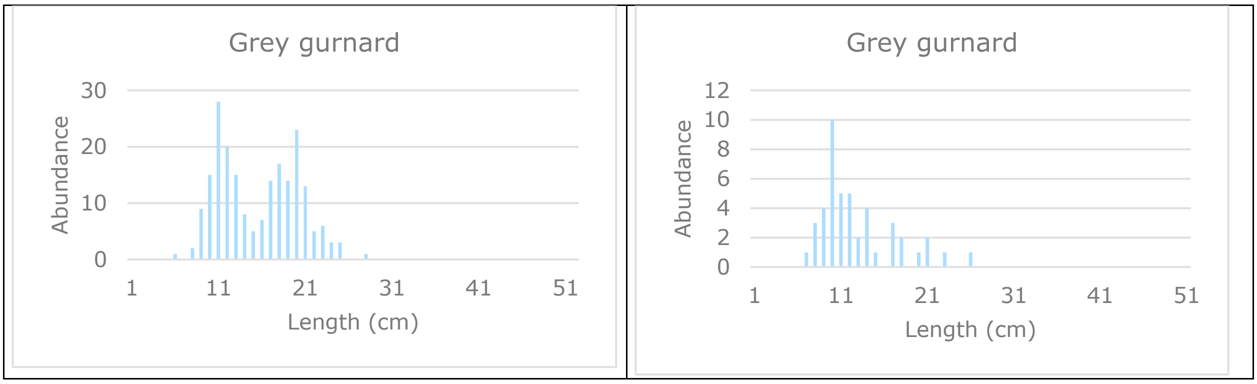


Figure 5-10 The size distribution of the five most abundant fish species in the beam trawl catches in spring and autumn 2020. Grey gurnard was only caught in the spring survey. Please note the differences in abundances between graphs.

The results presented here indicate that several young individuals utilize the gross area of Thor OWF mainly on the sandy areas in the central and southwestern parts. However, for solenette, scaldfish and grey gurnard no special nursery area has been documented in the scientific literature, as juveniles and adult coexist (Baltus & Van der Veer, 1995) (ICES, 2018). For plaice, the gross area of Thor OWF does not fit the profile as a shallow and sheltered area, and the results from this study support this. The area may be utilized by several cohorts of young plaice during winter when the fish swim to deeper and warmer waters, but it does not constitute a nursery area for plaice. Scientific literature also report the Wadden Sea as the most important nursery area for plaice in Danish Waters (Kuipers, 1977) The only species that utilize the gross area of Thor OWF as a nursery area is common dab, which settle on sandy or softbottom areas at 6-70 m depth. The dab spawns in April to June, and, thus, the nursery function is most pronounced over summer through autumn. However, the abundance of juvenile dab was low, and therefore, the area's importance as nursery for dab is expected to be low.

5.3.4 Species diversity and evenness

The number of fish species caught in the spring survey per station varied from 7 to 14 species with an average of 10 species (Table 5-7). For the autumn survey, the range was broader; 6 to 19 species with an average of 11 species. The Shannon Wiener index for the 20 sampled stations varied from 1.3 to 2.2 in the spring survey, with an average of 1,6 within the gross area of Thor OWF. For the autumn survey, the range was again lower; 1.1-1.9 with an average of 1.5. Generally, a low Shannon Wiener index indicates a low number of species and/or strong dominance of one or a few species. On the other hand, a high Shannon Wiener index indicates a high species richness with great evenness between species. The index value rarely exceeds 4, and therefore, the values found in the gross area of Thor OWF are a sign of medium to low species diversity for the fish community.

The evenness is an estimate of how even the individuals are distributed between species. If values are low, one or few species dominate the community, and if values are high, a more even distribution of individuals between species is indicated. The index values range between 0 to 1, with values near 1 indicates an even distribution of individuals between species, while values near 0 indicates a strong dominance of one or few species. The spring survey had an Evenness score of 0,5 and so did the autumn survey. This indicates that the species caught in the spring and autumn survey were equally distributed between species in the two surveys.

The Shannon Wiener index was calculated for Horns Rev 1, where the values varied from 1.07 before the construction of the OWF and from 0.65 to 1.35 after the construction (Leonhard, et al., 2011). The biodiversity within the gross area of Thor OWF was estimated to be higher than at Horns Rev 1.

Table 5-7 Number of species, Shannon Wiener (biodiversity) and evenness index for all station

	Spring			Autumn		
	No. of species	Shannon Wiener	Evenness	No. of species	Shannon Wiener	Evenness
St 1	8	1,7	0,8	9	1,5	0,7
St 2	8	1,6	1,0	10	1,6	0,8
St 3	8	1,7	0,6	16	1,9	0,4
St 4	14	2,2	0,2	19	1,8	0,3
St 5	8	1,6	0,3	6	1,1	0,8
St 6	7	1,5	0,6	9	1,5	0,3
St 7	7	1,4	0,7	16	1,7	0,6
St 8	10	1,7	0,4	12	1,5	0,5
St 9	11	1,6	0,4	9	1,4	0,4
St 10	12	1,8	0,4	7	1,4	1
St 11	13	1,7	0,3	8	1,3	0,3
St 12	14	1,9	0,4	13	1,6	0,3
St 13	11	1,4	0,3	9	1,2	0,4
St 14	13	1,7	0,3	11	1,5	0,4
St 15	7	1,3	0,7	8	1,4	0,8
St 16	10	1,5	0,4	9	1,6	0,8
St 17	10	1,5	0,6	17	1,7	0,3
St 18	12	1,7	0,5	11	1,5	0,6
St 19	11	1,7	0,2	13	1,6	0,3
St 20	12	1,7	0,4	9	1,5	0,7
Average	**10**	**1,6**	**0,5**	**11**	**1,5**	**0,5**

When the results are transferred to a map, the south western part of the area had the lowest biodiversity of the area (Figure 5-11). This is similar for both spring and autumn results. In addition, low biodiversity was also evident in the autumn survey in the south eastern part of the gross area of Thor OWF. Both areas with low fish diversity coincide with the area with the most intense trawl fishing occurring in the gross area of Thor OWF (Rambøll & Orbicon, 2020). The central part of the gross area of Thor OWF is where the biodiversity was highest for both spring and autumn survey, while the pattern was a bit less clear in the autumn survey. For both spring and autumn survey, the northern area had a medium biodiversity.

When comparing the map for fish biodiversity with infauna biomass (Rambøll & Orbicon, 2020), the areas with high infauna biomass coincide with the areas where fish biodiversity is highest. This agrees with the fact that the fish community was dominated by flatfish (90%) where most species find their food in or on the sediment.

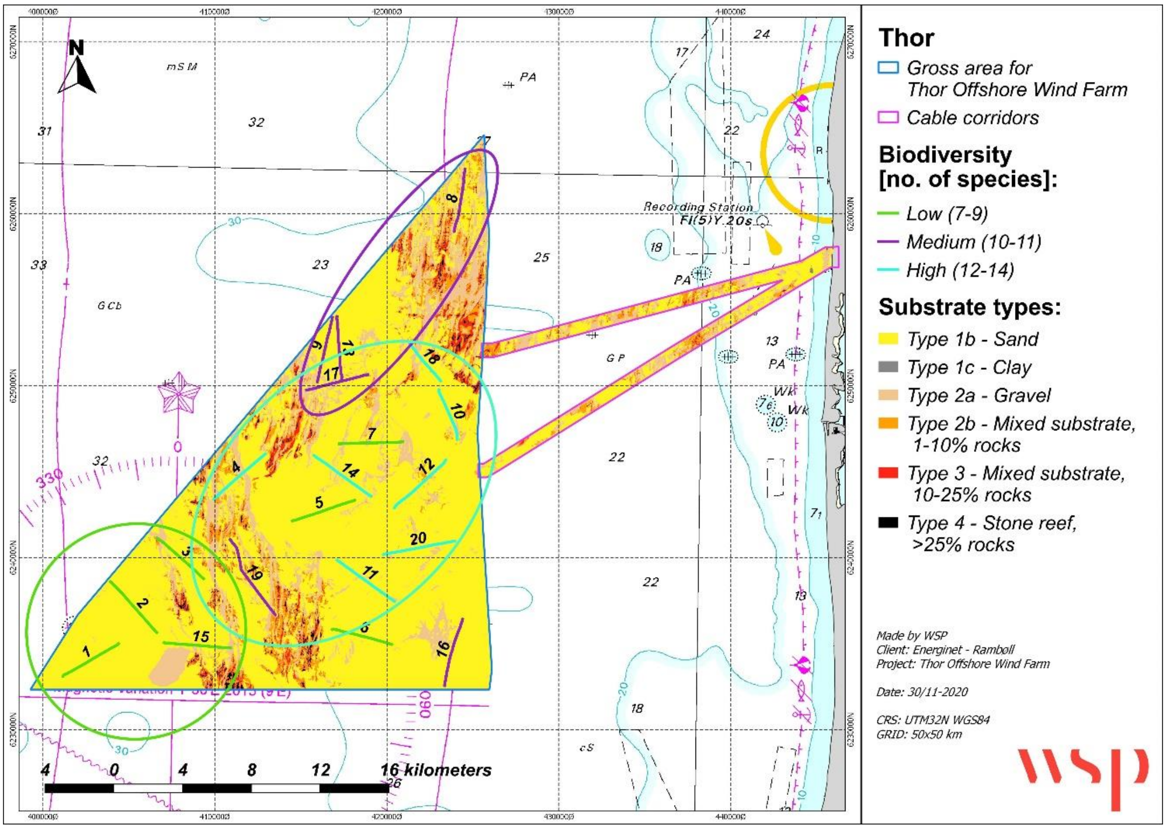


Figure 5-11 Biodiversity for the fish species sampled on each station in the spring survey (autumn survey result were similar). Low=7-9 species; Medium=10-11 species; High=12-14 species.

6. SENSITIVITY ANALYSIS AND POTENTIAL IMPACTS

In the following, potential impacts of the plan for Thor OWF on fish and fish populations are listed. A sensitivity analysis of fish and fish populations is included, and finally, potential impacts are assessed.

6.1 Potential impacts

The identification and assessment of potential impacts on fish and fish populations is carried out based on the activities defined in the plan for Thor OWF. The below can potentially cause impacts on fish and fish populations:

Temporary impacts
- Increased sediment concentrations in the water column from construction of OWF
- Sedimentation on the seabed from construction of OWF
- Underwater noise from piling of turbines
- Disturbance caused by detonation of un-exploded ordnances (UXO) in the seabed

Permanent impacts:
- Underwater noise from operation of turbines
- Introduction of new habitats and footprints
- Electromagnetic fields around cables in the seabed
- Heat development from cables in the seabed

6.2 Analysis of potential impacts

In the following, potential impacts of the plan for Thor OWF and cable corridors on fish and fish populations are assessed in further detail.

6.2.1 Suspended sediments and sedimentation

Sediment spillage results in increased suspended sediment concentrations and sediment deposition locally around the excavation and cable deployment activities. Sediment spillage in the water column is a result of installation of cables and potential digging activities for foundations.

Results from sediment modelling at Vesterhav Nord and Syd shows that increased suspended sediment and deposition from cable flushing and installment of foundations has low occurrence and is within the natural variation in suspended sediment seen along the highly dynamic West coast of Jutland (Vattenfall, 2020a; Vattenfall, 2020b). Furthermore, activities that result in sediment spillage are short-term (<2 months) and progresses spatially e.g. does not occur in the entire area at the same time at Vesterhav Nord and Syd OWFs (Vattenfall, 2020a; Vattenfall, 2020b). The sediment spillage in relation to establishment of Thor OWF is expected to be comparable to that found in the Vesterhav Syd and Nord OWFs, which are located within 13-14 km of the gross area of Thor OWF. The duration of the sediment spilling activities will most likely be longer, since the number of turbines planned for Thor OWF (67 or 125) is currently 3-6.5 times larger than for Vesterhav Nord and Syd OWFs (21-20 turbines).

The increased concentrations of suspended sediment may have a negative or even lethal impact on fish, as it reduces the efficiency of the respiratory system (Moore, 1991) (Newcombe & MacDonald, 1991) (Engell-Sørensen & Skyt, 2002). Furthermore, sediment may adhere to pelagic eggs causing the eggs to sink out to the bottom with lower oxygen levels. However, the present study indicate that the area is not an important spawning site for any of the caught species and only few juvenile dab utilized the area as nursery area. Thus, the occurrence of vulnerable fish eggs, larvae and juveniles is expected to be low in the gross area of Thor OWF. In addition, the fish fauna on the West Coast is dominated by flatfish, which have adapted to the high and varying concentrations of suspended sediment in the water column, and flatfish can survive sediment concentrations of 3,000mg/l (Engell-Sørensen & Skyt, 2002), although fish tend to flee the area at concentrations higher than 10-50mg/l (FeBEC, 2013) (Støttrup, et al., 2006). The natural concentrations are generally highest just above the seabed (Vattenfall, 2020a) (Rambøll, 2020a). The background concentrations of suspended sediment in the water column on the west coast of Jutland is estimated to be approximately 0-7mg/l, but may at times be as high as 185 mg/l (Rambøll, 2020a).

The modelled sedimentation in Vesterhav Nord and Syd OWFs is estimated to result in local depositions of a few millimeters, which is low compared to the natural sediment transport on the dynamic west coast of Jutland. During severe storms, more than 1 m of sand can be removed or applied (COWI, 2015). In addition, the sand transport along the west coast of Jutland is approximately 1.4 million m^3 per year towards south from Thorsminde and up to 1 million. m^3 per year in a northerly direction towards Thyborøn (Kystdirektoratet, 2001) (Vattenfall, 2020a).

The increased levels of sedimentation may alter the habitat and bury food subjects in the sediment, potentially reducing the food availability. However, according to the Thor OWF Technical Report on Benthic Fauna and Flora (Rambøll & Orbicon, 2020), the exposure is short and the benthic community on the west coast of Jutland is very robust and able to handle regular displacement, burial and high sediment concentrations due to the area’s dynamic nature.

Increased concentrations of suspended sediment and increased deposition due to sediment spillage from an offshore wind farm are likely to be within the span of natural variation seen along the west coast of Jutland. The fish and fish populations are assessed to be robust and have a low sensitivity. Regardless of location in the project area, the potential impact of suspended sediment and increased sedimentation is assessed as having *none to minor* impact on fish and fish populations in the area.

6.2.2 Heat development and electromagnetic fields around the cables

The electric current in the inter-array cables and export cables generates electromagnetic fields (EMF) and heat. It is assumed that the submarine cables for the establishment of Thor OWF will be designed to shield the surroundings from the electric field (E-field) that arises during the operation of the wind turbines. Due to the difference in current strengths, the field strengths over the inter array cables connecting the turbines will be significantly lower than over the export cable from the OWF to landfall (Vattenfall, 2020a). The electromagnetic field can cause increases in temperature in the sediment just around the cable. However, the risk of electromagnetic currents being higher than the background currents in Danish waters and of increased temperatures even measurable is extremely low but will depend on the final project design.

Multiple studies suggest that magnetic fields may influence fish. However, the knowledge on fish behavior near the magnetic field created from cables is still limited (Öhman, et al., 2007). Only few fish along the west coast of Jutland are expected to respond to electromagnetism. Sharks and rays find their prey by detecting electric fields surrounding their prey (Kalmijn, 1982) and may potentially be affected. European eel are also known to detect magnetic fields, and few studies have demonstrated that eel tend to swim slower but not altering their original direction when crossing OWF cables (Westerberg & Lagenfelt, 2008) (Westerberg, 1994). Furthermore, studies have shown that the vast majority of brown shrimp may demonstrate a tail flip when exposed to different frequencies of electric pulses. However, no increase in mortality or injuries has been detected (Soetaert, et al., 2015).

The fish species dominating within the gross area of Thor OWF are flatfish. Scientific investigations on impact from operating OWF have demonstrated no changes to the flatfish communities when comparing fish catches in the OWF area with reference area (Wilber, et al., 2018). Behavioral studies of flatfish allowed to move freely between areas with and without electromagnetism showed no difference in distribution compared to control test without electromagnetism (Bochert & Zettler, 2006). Only a few of the species known to respond to electromagnetism occur in the gross area of Thor OWF. Furthermore, it is expected that the level of electromagnetic current is lower than the natural occurring levels, as it has been for other comparable OWF (Vattenfall, 2020a; Vattenfall, 2020b).

The effect of heat development and electromagnetic fields around the cables is expected to have an insignificant and very local effect on fish. However, the effect is long term and may occur in the operation phase both from cables between turbines and cables connecting the OWF to the land grid. The impact is therefore assessed as none for fish and fish populations.

6.2.3 Underwater noise

Some fish species are more sensitive to underwater noise than others. Flatfish lack a swim bladder and are therefore less sensitive to noise. Species such as mackerel have a swim bladder but only a primitive hearing sense and they can hear noise. Species such as herring with a highly developed hearing are more sensitive to underwater noise compared to others. The fish species caught in the present study was dominated by flatfish with rudimentary hearing, but round fish with more developed hearing such as both mackerel and herring also live in the gross area of Thor OWF.

Almost all fish respond to noise at 90 dB and above by eliciting a strong avoidance reaction (Nedwell, et al., 2007). From 186 dB, fish experience a temporary threshold shift (TTS) in their hearing ability, reversible impairments occurs from approximately 203-2016 dB, depending on the hearing ability of the species (Popper, et al., 2014). Mortal injury occurs from 207 dB for adult fish and 210 dB for fish eggs and larvae (Popper, et al., 2014).

Several mitigating measures are taken to prevent injury to nearby marine mammals. The measures include e.g. so-called ramp-up, where the force of the hydraulic hammer is gradually increased to scare marine mammals and establishments of barriers of air bubbles to avoid noise distribution. Fish in the area also benefit from this, as they too demonstrate avoidance behaviour when exposed to high level noise (above 90 dB) (Popper, et al., 2014).

During the construction of an offshore wind farm, an increase in vessels sailing to and from the area, will temporarily increase the underwater noise levels. Most fish species are expected to sense this increase in noise. However, when taking the background levels of vessel noise and the expected short duration into consideration, the impact on the local fish populations is assessed to be very short and local with a possible migration of fish out of the area for a short period of time. The impact is assessed to be *none* for the fish and fish populations.

The largest impact from underwater noise is expected to originate from piling the turbines into the sediment. However, the precise impact of underwater noise on fish is still a topic with limited knowledge and many uncertainties. For this reason, a precautionary principle is used, and the estimated values showed in the following are conservative. See table Table 6-1 for specified noise levels and their impact on fish.

The volume of noise (dB) and frequency (Hz) created when piling the foundations of windfarm turbines into the sediment depends on the specific project. Furthermore, the transport of the noise depends on e.g. water depth and the energy of the hammer.

The results from the modelling of underwater noise from a generalized Thor OWF illustrates that the noise is of high intensity but short term (Rambøll & ITAP, 2020) (Table 6-1). The precise impact and range will depend on the precise project. The calculations depend on the Danish legislation of the topic where e.g. double big bubble curtain (DBBC) and noise mitigation screens (NMS) may be used to reduce impact on marine mammals – and fish benefit from this as well.

Table 6-1 The effect of noise at different levels on fish and fish larvae (Source: (Rambøll & ITAP, 2020)).

Organism	Effect	Type	Reference	Impact	dB	Range (km)
Fish	Reversibel impairment	Impuls	Popper et al. 2014	SELcum	203	6.641
Fish	Temporary hearing impairment	Impuls	Popper et al. 2014	SELcum	185	34.378
Fish	Mortal injury	Impuls	Andersson et al. 2016	SELcum	204	5.868
Fish larvae	Mortal injury	Impuls	Andersson et al. 2016	SELcum	207	3.975

With continuous and accumulated noise (SELcum), the hearing of fish will be impaired (Popper, et al., 2014). Irreversible injuries on internal organs both in relation to hearing and other tissue will occur for adult fish at noise levels of 204 dB and for fish larvae at 207 dB (Popper, et al., 2014) (Andersson, et al., 2016).

The exact radius where mortality or permanent and temporary hearing impairments may occur will depend on the precise project, but the initial and generalized model of underwater noise suggests mortal injury for fish at 5.868 km from the source and 3.975 km for fish larvae without any mitigating measures.

The fish in the area are expected to flee the area when noise levels increase. The underwater noise from piling of foundations is expected to be of high intensity with a geographical range of 3-34 km for mortal injury or temporary hearing impairment, respectively when no mitigating measures are used. The underwater noise is expected to be of short duration during construction, and the noise will not be continuous, but only occur during piling of turbines. The impact may be harmful for a few individual fish, but for the overall populations, no impact is expected. Therefore, the impact on fish and fish populations is assessed as *minor*.

6.2.4 Explosion of non-exploded ammunition

If unexploded ammunition in the seabed is identified when planning the construction activities, these may have to be detonated. The impulse noise when blasting may be so intense that the volume exceeds the threshold values for injury or death of fish (see previous section). It is possible that the explosion may be lethal to any fish present in the area when blasting but the overall impact on fish populations is insignificant and the structure and function of the fish populations will be unaffected. Therefore, sensitivity of fish and fish populations in the area is assessed as low and thus, the impact is assessed as none to minor for fish and fish populations regardless location of the offshore wind farm and connecting cables.

6.2.5 Introduction of new habitats

The gross area of Thor OWF consists of varying habitat types ranging from mud and sand to stones. When constructing the offshore wind farm, the natural habitat is replaced with the introduction of hard bottom habitats of steel and scour protection. The lost habitat, i.e. the footprint of the turbines, is expected to be very small (less than 1% of the project area) and insignificant compared with the size of the surrounding habitats but the exact footprint area will depend on the precise project. When introducing the foundations, most of the fish in the area will flee, and very few, if any, fish are expected to be injured or die due to the footprint of the OWF.

The turbine foundations and protection from the erosion will function as an artificial reef. Studies of other offshore wind farms in the North Sea have shown that the new substrate attracts fish species such as cod and wrasses which utilize the artificial reef for shelter from the water current, shelter from predators and feeding opportunities (Reubens, et al., 2011) (Leonhard & Pedersen, 2006). In addition, benthic structures are known to increase the biodiversity of the area, and it is well established that structures on the seabed constitute essential fish habitats for e.g. juvenile cod (Støttrup, et al., 2014) (Kristensen, et al., 2017).

It has been suggested that the introduction of hard bottom habitats in areas with vast sandy or muddy character may facilitate the spreading of nonindigenous species, which may eventually outperform the domestic species. However, given the heterogenic nature of the habitats in the gross area of Thor OWF with the presence of hard bottom habitats, the impact of nonindigenous species is expected to be insignificant.

An increase in the hardbottom area within the offshore wind farm area and cable corridor of less than 1% is permanent but will not change the fish and fish populations in the areas, since hard bottom is already a natural part of the area. Therefore, no impacts are expected on fish and fish populations, regardless of location in the OWF and cable corridors, as a result of such a small increase in hard bottom area.

6.3 Conclusion

The largest impacts on fish and fish populations from the construction and operation of Thor OWF is expected to occur from the increased concentration of suspended sediment when installing the cables and increased underwater noise from piling of turbines.

The increased concentrations of suspended sediment and increased deposition due to sediment spillage from Thor OWF are expected to be within the span of the natural variation seen along the west coast of Jutland. In addition, the fish and fish populations in the North Sea are adapted to the dynamic character of the area and are therefore robust and able to flee the area if conditions become suboptimal for a short duration. Regardless of location in the project area, the potential impact of suspended sediment and increased sedimentation is assessed as having *none to minor* impact on fish and fish populations in the area.

The fish in the area are expected to flee the area when noise levels increase above 90 dB. The underwater noise from piling of foundations is expected to be of high intensity with a geographical range of 3-34 km for mortal injury or temporary hearing impairment, respectively, when no mitigating measures are used. The underwater noise is expected to be of short duration during construction, and the noise will not be continuous, but only occur during piling of turbines. The impact may be harmful for a few individual fish, but for the overall populations, no impact is expected. Therefore, the impact on fish and fish populations is assessed as *minor*.

6.4 Sensitivity analysis of fish species

The sensitivity of the fish species is determined by the species ability to recover and re-establish themselves in an affected area, and the time this takes.

The fish species along the west coast of Jutland are adapted to living in highly exposed areas with substantial wave energy moving vast amounts of sediment on a regular basis. The fish are therefore very robust and able to handle high concentrations of suspended sediment and sedimentation. As fish are mobile organisms, they can flee certain areas if the concentrations of suspended sediment increase too much. Apart from a short and local impact from increased suspended sediment and increased sedimentation, the fish are therefore not vulnerable to the construction and operation of the Thor OWF, regardless of location.

In terms of underwater noise, most fish elicit avoidance reaction when noise levels reach approximately 90 dB (Nedwell, et al., 2007). This behaviour will ensure that only very few fish will be harmed from the underwater noise from the construction of the Thor OWF. The mitigating measures taken for marine mammals will also benefit the local fish and reduce the number of affected fish even further. The fish eggs and larvae that drift in the pelagic unable to move significantly away from the source of the noise may be hurt or killed from the noise levels. However, as no important spawning sites were demonstrated in the gross area of Thor OWF, based on the findings in this study and relevant literature, this is not expected to be of significant impact.

Most fish species reproduce through pelagic spawning, after which the eggs and larvae drift pelagically with the current until they reach a suitable nursery area. Few individuals ready for spawning were caught in the gross area of Thor OWF, indicating that the area is not an important spawning area. As the eggs and larvae drift with the current, the fish species living in the gross area of Thor OWF only comprise a small fraction of the total population living in the eastern North Sea, and, for some, including the Atlantic Ocean (Muus & Nielsen, 2006). The large population sizes, vast geographical distribution and high mobility makes the fish and fish populations in the gross area of Thor OWF very robust and able to handle local disturbances from Thor OWF, regardless of location.

The results indicate that juveniles of several species utilize the gross area of Thor OWF as nursery area mainly on the sandy areas in the central and southwestern part of the area. However, densities of juvenile fish were generally low, and existing literature point towards most fish species utilizing vast areas of the North Sea as both spawning and nursery area. This includes European plaice, cod, sole, mackerel, sand-eel, sprat and herring (Coull, et al., 1998), (Worsøe, et al., 2002), (Warnar, et al., 2012). Juvenile sprat and sand-eel even utilize the same habitats as the adults, and no separate nurseries exists (Wright, et al., 1998) (Worsøe, et al., 2002). Thus, the area is by no means an essential habitat for any of the observed species, and the similar areas around the gross area of Thor OWF are just as important – if now more so, as nursery areas for the North Sea fishes. So, in terms on sensitivity, the construction and operation will not impact the fish and fish populations significantly, regardless of location. But the sandy areas in the central and southwestern part of the gross area of Thor OWF is highlighted as the most vulnerable.

The abundance of fish pr. 1000 m^2 surveyed in the present study, have demonstrated the highest abundance in the southwestern part of the gross area of Thor OWF (Table 5-2). The lowest abundance of fish was observed in the southwestern part of the central gross area of Thor OWF with mixed substrates. However, the survey results are biased towards benthic and demersal species living on sandy bottoms where the beam trawl could sample. Biodiversity was lowest in the sandy areas in the southwestern part of the gross area of Thor OWF, where dredging occurs regularly. Areas, where the biodiversity was high (in the central part of the gross area of Thor OWF) and in the northern part of the gross area of Thor OWF where the density of stone reefs were high, is assessed to be most sensitive to the planned Thor OWF. However, the impacts from the construction of the planned Thor OWF will only result in short term impacts, and the turbines will provide additional hard bottom habitats, although the m^2 of the footprint is expected to be small compared to the natural hard bottom area in the gross area of Thor OWF. So regardless of location, the fish and fish populations in the gross area of Thor OWF are robust and able to handle the disturbances caused by the construction and operation of an OWF. Therefore, sensitivity of these species is assessed as low in the gross area of Thor OWF.

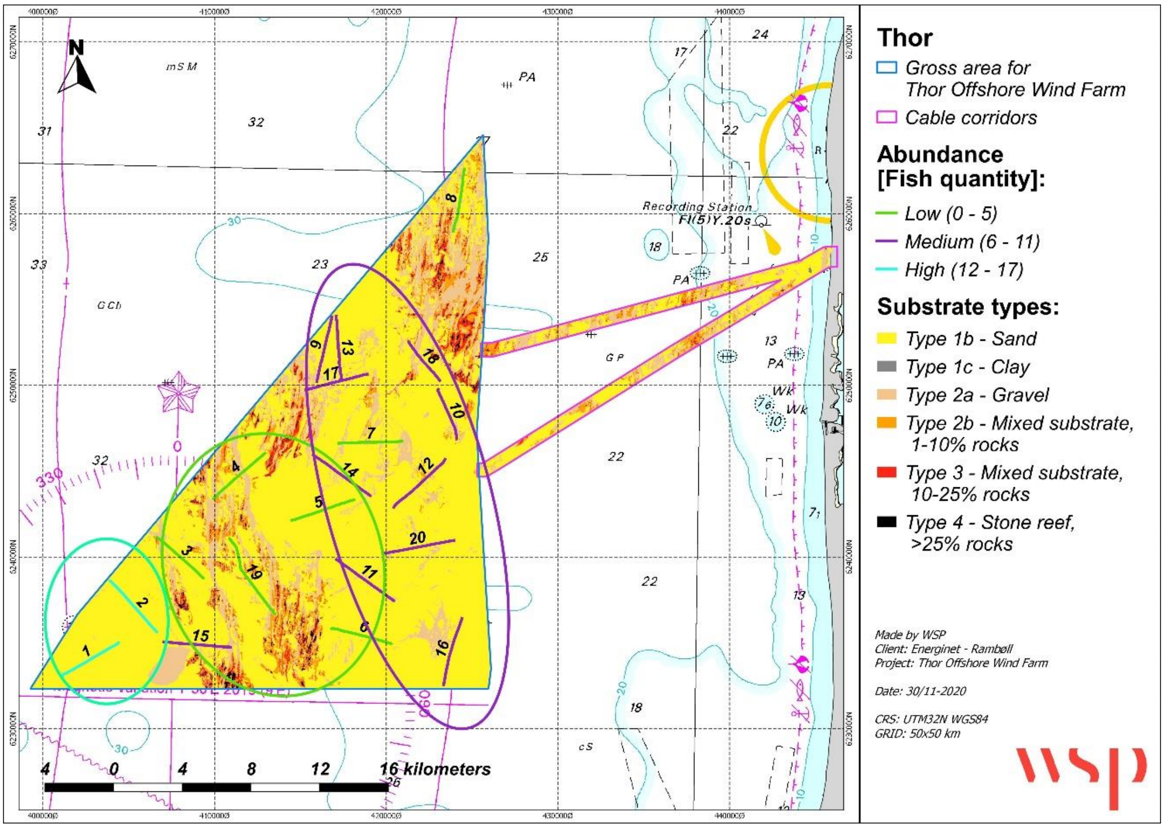


Figure 6-1 The fish abundance in CPUE 1000 m^2 for each sampled station. Low=0-5 fish; Medium=6-11 fish; High=12-17 fish.

7. CUMULATIVE EFFECTS

Cumulative effects can be the result of cumulated impacts from the plan, i.e. construction of an offshore wind farm and grid connection in the gross area of Thor OWF within the planned period of establishment, compared with other contemporary known plans, programs or specific projects in the area.

The potential cumulative effects for fish and fish populations are concentrated around sediment spillage and underwater noise in the construction phase, which originate mainly from installation of cables and establishment of foundations depending on method used. Sediment spillage in the water column causes increased suspended sediment concentrations in the water column and subsequent increased sediment deposition on the seabed and associated organisms. Underwater noise exceeding 90 dB is expected to cause avoidance behavior in fish that will flee the area.

The following projects are relevant to consider in relation to the cumulative effects for fish and fish populations (Figure 7-1):

- Vesterhav Nord Offshore Wind Farm
- Vesterhav Syd Offshore Wind Farm
- Sediment extraction site 562-AD Ferring
- Shore nourishment and beach nourishment along the West coast of Jutland
- NordLink cable

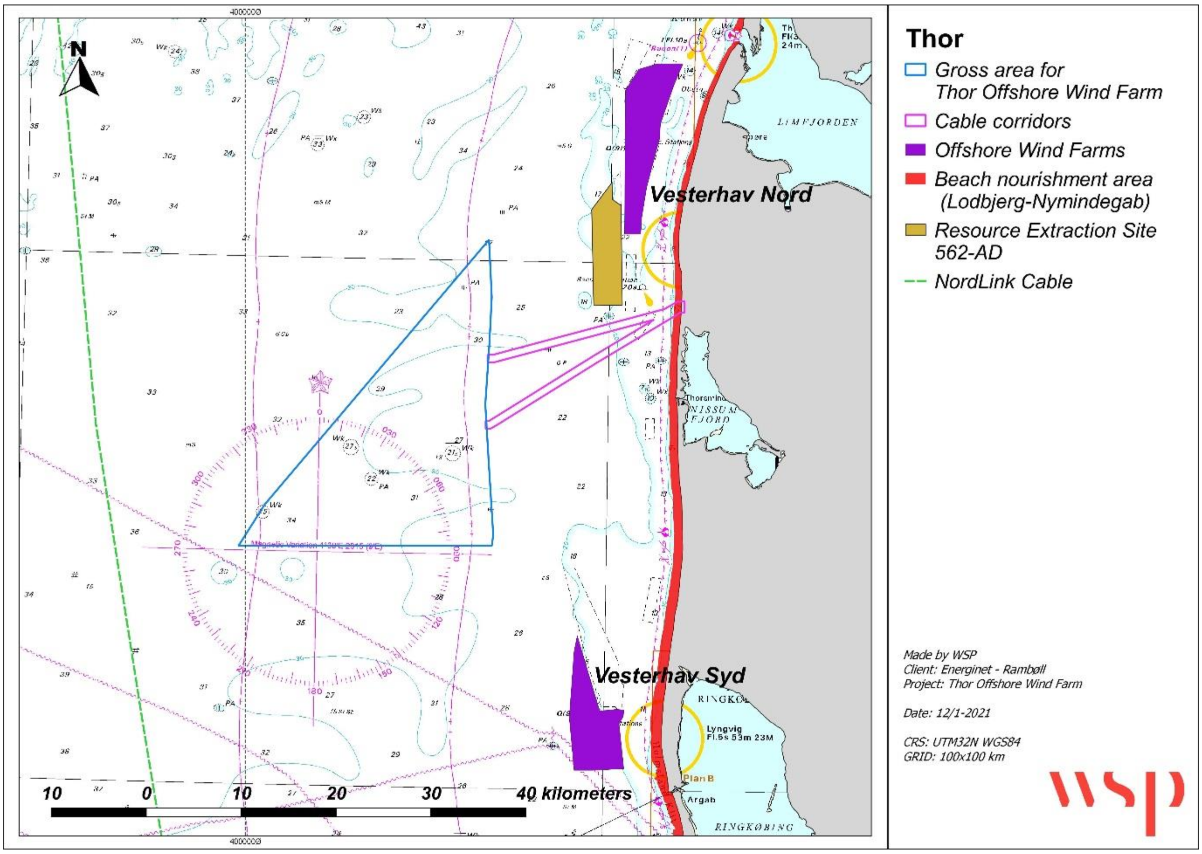


Figure 7-1 Nearby projects that may cause cumulative pressures on fish and fish populations

It is expected that construction of Thor OWF can begin in 2024 and run until 2027. It is likely that the offshore wind farm can be put into operation at an ongoing basis from 2025 and be fully developed in 2027 (Rambøll, 2020b).

The offshore wind farms Vesterhav Nord and Vesterhav Syd are expected to be constructed in 2023 with full commissioning at the end of 2023 (Rambøll, 2020b).

Along the west coast, a few sites for sediment extraction are located – primarily regarding nourishment of the beaches for coastal protection. As part of specific EIAs for these extraction sites, modelling of sediment spreading from the extraction activity has been made. These models show that sediment spreading occurs be within the extraction sites (including a 500 m protection zone). Therefore, it is assessed that the extraction sites and the construction of Thor OWF will have no cumulative impact on the fish and fish populations.

Regarding coastal feeding, there is a joint agreement for the Lodbjerg-Nymindegab section, where in the period 2020 – 2024, coastal protection can take place in the form of coastal sand nourishment in selected sections of the coast. The purpose is to ensure that the dunes on the west coast of Jutland can withstand erosion and associated dune breakthroughs during a 100-year storm event at the start of each winter season. This means that the dunes must have a minimum height and a minimum width (Rambøll, 2020b).

The NordLink is a subsea power cable between Norway and Germany for exchanging solar and wind power from Germany and hydropower from Norway, depending on the market price. The cable was completed in 2020 and the final trial operations are expected to be completed in March 2021. The nearest section of the cable is located approximately 12 km from the south western part of the gross area of Thor OWF. As the cable has already been completed, no cumulative effects are expected on the fish and fish populations.

Specification of overlapping time periods (Rambøll, 2020b)**:**

- Based on schedules for the establishment of Thor OWF in relation to the Vesterhav Nord and Vesterhav Syd, no cumulative impacts are expected, as construction of Thor OWF will not take place until 2024, after Vesterhav Nord and Vesterhav Syd is supposed to be fully commissioned.
- There can potentially be a cumulative effect in the form of sediment spillage from the construction of Thor OWF and co-occurring sediment spillage from the coastal nourishment project along the West coast of Jutland, which takes place every year and is planned in the period (2020 - 2024). The area, from where the cables of Thor are connected with the land grid, is one of the coastal sections for coastal feeding.

Results from sediment modelling at Vesterhav Nord and Syd OWFs shows that increased suspended sediment and deposition from cable flushing and instalment of foundations is low and within the large natural variation in suspended sediment seen along the highly dynamic west coast of Jutland (Vattenfall, 2020a; Vattenfall, 2020b). The sediment spillage from Thor OWF is expected to be comparable to that found in the Vesterhav Syd and Nord OWFs, which are located within 13-14 km of gross area of Thor OWF.

Since the increase in suspended sediment is likely within the natural variation in the Thor OWF and CC and the same is the case for the Vesterhav Nord and Vesterhav Syd, the cumulated effects from these two projects are also expected to be none to maximally *minor impacts*.

Coastal nourishment along sections of the coast is done within 0-8 meters depth and is expected to have potential cumulative effects only with cable deployment activities along the export cables from the gross area of Thor OWF to landfall area.

An alteration of the fish community has been observed following beach nourishment near Fjaltring/Harboøre Tange (Støttrup, et al., 2006). The abundance of dab was slightly higher shortly after the coastal nourishment event possibly due to the increased food availability in the area, i.e. dead bristle worms. Later, the abundance of plaice was significantly lower than prior to the event due to the lower abundance of live bristle worms in the area. The abundance of flatfish was generally low in the area with coastal nourishment compared to reference areas without coastal nourishment.

Sediment modelling from the EIA of coastal nourishment from Lodbjerg to Nymindegab (Rambøll, 2020a), for a normal and extreme nourishment scenario also shows increased suspended sediment and sedimentation generally within the large natural variation along the very dynamic shore of West Jutland. The fish species in the North Sea are adapted to the dynamic character of the area and are generally robust species with a wide distribution range in the North Sea and/or the Atlantic Ocean. The impact of increased suspended sediment and sedimentation from the beach nourishment is assessed as insignificant (which is lower than minor) for fish and fish populations.

Since the increase in suspended sediment is likely within the natural variation in the Thor OWF and CC and the same is the case for the beach nourishment project, the cumulated effects from these two projects are also expected to be none to maximally *minor impacts*.

8. NATURA 2000

The project occupies or crosses no Natura 2000 sites directly, but one Natura 2000 site is located approximately 300 m south of the southern cable corridor (R3) and 13 km from the gross area of Thor Offshore Wind Farm: Natura 2000 site nr. 220 (DK00VA341) *Sandbanker ud for Thorsminde*. Local Natura 2000 sites are shown in Figure 8-1.

Natura 2000 area nr. 247 (DK00VA348) *Thyborøn Stenvolde* is located approximately 12 km north of the gross area of Thor OWF designated for the habitat type 1110 Sandbanks. All other Natura 2000 sites are more than 21 km from the gross area of Thor OWF and designated for the habitat type 1170 stone reef. SPAs under the Bird directive are not present.

The planned offshore wind farm can potentially impact only the closest Natura 2000 site via sediment spillage and related increases in sediment concentration and sedimentation. The area is appointed for its habitat type (sandbanks, which are slightly covered by sea water all the time) and not for the occurrence of any vulnerable fish species. In addition, sediment modelling in the nearby Vesterhav Syd and Nord OWF showed sediment spillage resulting in increased sediment concentrations which were within the natural variation in this dynamic area off the west cost of Jutland (Vattenfall, 2020a; Vattenfall, 2020b). Therefore, significant impacts of sediment spillage are not expected from the current existing knowledge from the area.

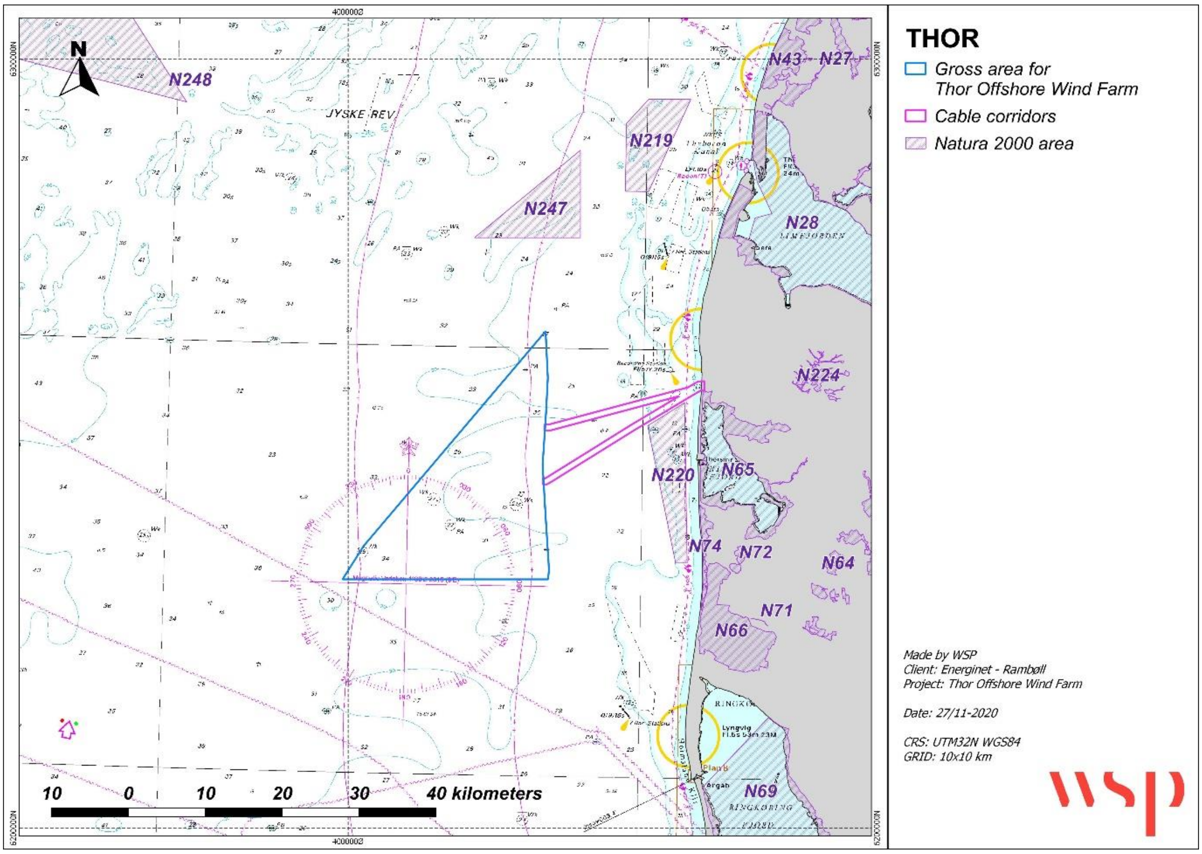


Figure 8-1. Location of the gross area of Thor Offshore Wind Farm, the two possible cable corridors (CC) and local Natura 2000 sites.

9. MITIGATION MEASURES

No mitigation measures are deemed necessary since no significant impacts are expected from the project plan of Thor offshore wind farm on the fish and fish populations. However, it is recommended to consider avoiding constructing the Thor OWF on the hard bottom habitats and boulder reefs, as this habitat type is less abundant in the area and has a higher biodiversity compared to the sandy and/or muddy areas. It may also be considered to reduce the total area for cable corridors in order to minimize the expected impact from suspended sediment and thereby perhaps also reduce the longevity of the construction period.

10. KNOWLEDGE GAPS

Existing data combined with the comprehensive field sampling of fish and biological parameters in the gross area of Thor OWF ensures a solid and sufficient base for the baseline mapping and the impact assessment of fish and fish populations.

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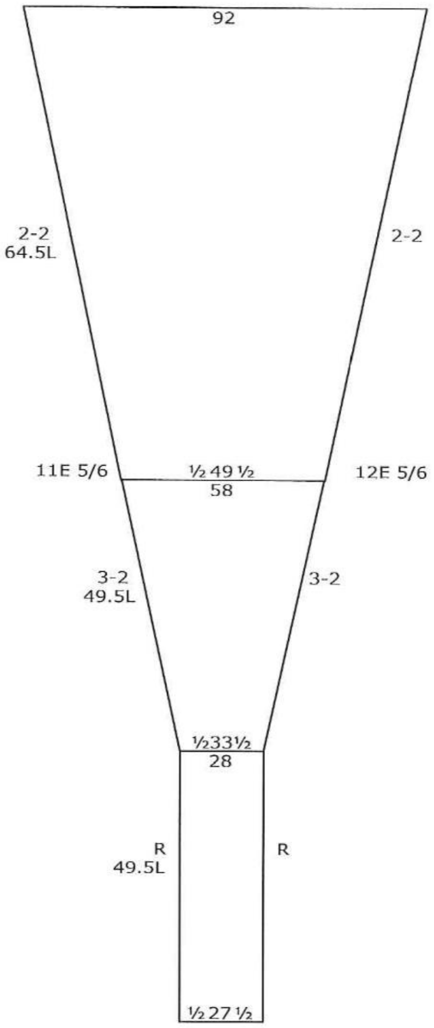
APPENDIX 1
TRAWL SPECIFICATIONS

Overpanel

masker mm	tråd	strakt længde	knuder i søm
55.0	2,5PE	7.15	4
46.0	3,2PE	4.60	4
46.0	3,2PE	4.60	4



Skovn Bomtrawl

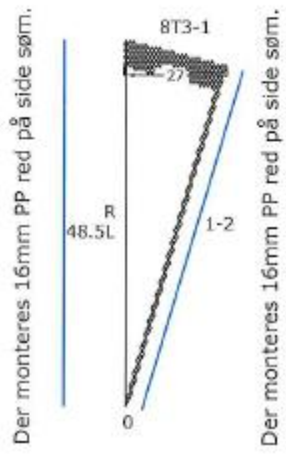
HVIDE SANDE VODBINDERI ApS
H. IVERSEN & SØN
Nordhavnskaj 21 - 6960 Hvide Sande - Telefon 97 31 10 42 - Telefax 97 31 27 60
DK-Danmark

Dwg No.	Skovn
Date	20.03.2020
Drawn	Thomas Bank Olesen.
Scale.	1 : 75

Sidepanel

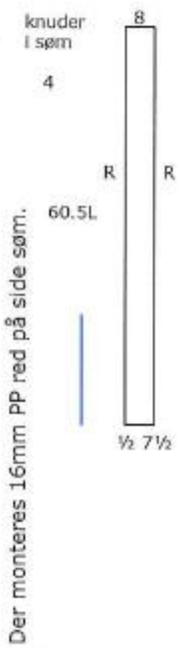
Bryst reb i 12mm Nylon reb.

masker mm	tråd	strakt længde	knuder i søm
46	3.2PE	4.50	4



Plade til Underpanel

masker mm	tråd	strakt længde	knuder i søm
46.0	3,2PE	5.61	4



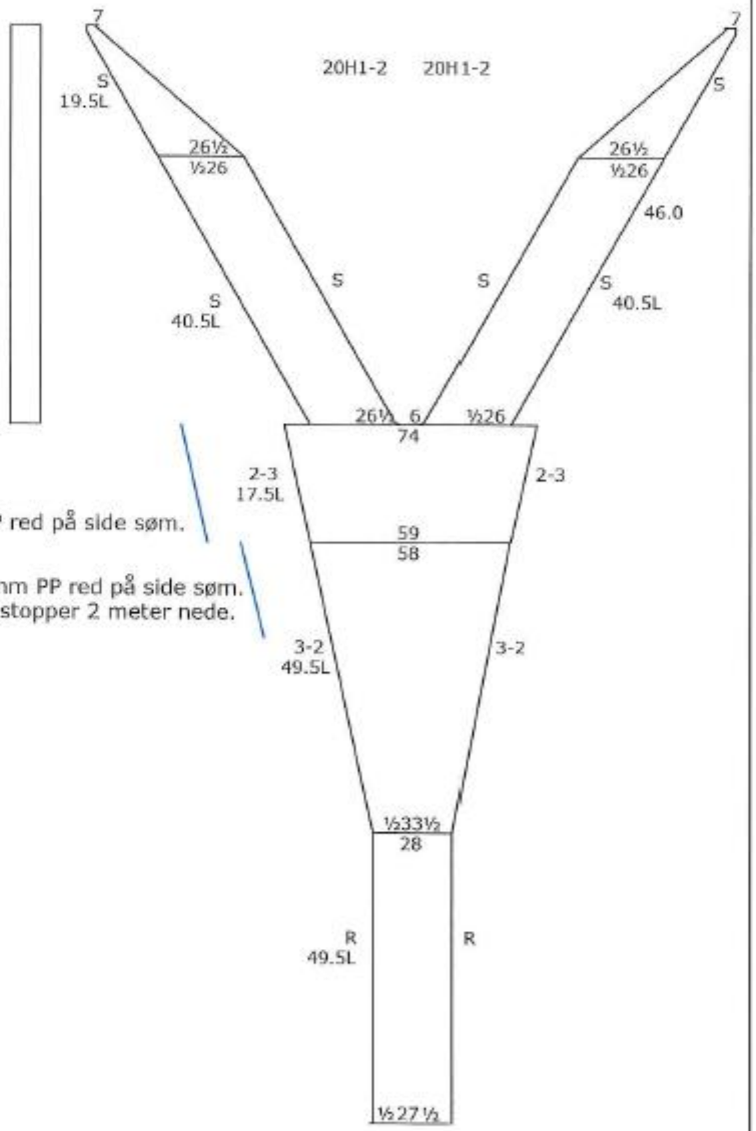
Skovn Bomtrawl

HVIDE SANDE VODBINDERI ApS
H. IVERSEN & SØN
Nordhavnskaj 21 - 6960 Hvide Sande - Telefon 97 31 10 42 - Telefax 97 31 27 60
DK-Danmark

Dwg No.	Skovn
Date	20.03.2020
Drawn	Thomas Bank Olesen.
Scale.	1 : 75

Underpanel

masker mm	tråd	strakt længde	knuder i søm
46.0	3,2PE	1.84	4
46.0	3,2PE	3.77	4
46.0	3,2PE	1.66	4
46.0	3,2PE	4.60	4
46.0	3,2PE	4.6	4



Der monteres 16mm PP red på side søm.

Der monteres 16mm PP red på side søm.
Søm forskærkere stopper 2 meter nede.

Skovn Bomtrawl

HVIDE SANDE VODBINDERI ApS
H. IVERSEN & SØN
Nordhavnskaj 21 - 6960 Hvide Sande - Telefon 97 31 10 42 - Telefax 97 31 27 60
DK-Danmark

Dwg No.	Skovn
Date	20.03.2020
Drawn	Thomas Bank Olesen.
Scale.	1 : 75

APPENDIX 2
BIODIVERISTY AND EVENNESS

11.1.1.1 Biodiversity and Evenness between species

The following analyses were performed on fish fauna data.

Species richness S is the simplest measure of biodiversity and is a count of the number of different species in a given area. This measure is strongly dependent on sampling size and effort.

Shannon-Wiener index increases as both the richness and the evenness of the infauna community increase. The fact that the index incorporates both components of biodiversity is both a strength and a weakness. A strength because it provides a simple synthetic summary, but a weakness because it makes it difficult to compare communities that differ greatly in richness. Typical values are generally between 1.5 and 4 in most ecological studies and the index is rarely greater than 4.

$$H' = -\sum_{i=1}^{R} p_i \ln p_i$$

where *R* is richness (the total number of species in the dataset) and the proportional abundance of the *i*'th type is p_i.

Pielou´s Evenness index refers to how close in numbers each species is to the other species found at the station. Mathematically, it is defined as a diversity index, a measure of biodiversity, which quantifies how equal the community is numerically. The value of this index ranges between 0 and 1 - the greater the value the greater the evenness in species abundance and numbers.

$$J' = \frac{H'}{H'_{max}}$$

H' is the number derived from the Shannon diversity index and H'_{max} is the maximum possible value of *H'* where:

$$H'_{max} = \ln S$$

APPENDIX 3
ABIOTIC PARAMETERS

CTDO – salinity, temperature, depth and oxygen
Salinity, temperature and oxygen concentration and saturation % was measured at the bottom and surface waters at 20 stations. The range of data is presented in the table below (Table 11-1). Moderate oxygen deficiency is defined as oxygen concentrations between 2-4 mg O2 l^{-1} and severe oxygen deficiency as <2 mg O2 l^{-1}. No CTDO data indicated oxygen deficiency at any stations in the OWF area.

Table 11-1 Range of oxygen (saturation %), salinity, temperature and depth at the sea floor and surface

	Oxygen (%)	Oxygen (mg/L)	Salinity (PSU)	Temperature (°C)	Depth (m)
OWF surface	106.4-108.8	12.25-12.55	32.9-33.4	8.4-8.7	0.5
OWF bottom	106.5-110.8	12.31-12.82	33.1-33.7	7.8-8.5	22-29