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THOR OWF
TECHNICAL REPORT – COMMERCIAL FISHERIES

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Prepared by	**Louise Dahl Kristensen**
Checked by	**Anna Schriver**
Approved by	**Lea Schmidt**
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Ramboll
Hannemanns Allé 53
DK-2300 Copenhagen S
Denmark

T +45 5161 1000
F +45 5161 1001
https://ramboll.com

Rambøll Danmark A/S
DK reg.no. 35128417

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APPENDIX

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 investigated area of 440 km2 which the planned Thor OWF will be placed within
Gross area	Gross area for Thor Offshore Wind Farm
EIA	Environmental Impact Assessment
GA	Gross area for Thor Offshore Wind Farm
SEA	Strategic Environmental Impact Assessment
Subarea	The gross area for Thor Offshore Wind Farm has been divided into 3 subareas: GA1, GA2 and GA3
VMS	Vessel Monitoring System
ICES	International Council for the Exploration of the Sea
CPUE	Catch Per Unit Effort

1. SUMMARY

Introduction

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

The plan for Thor Offshore Wind Farm (OWF) defines the overall framework for establishment of an offshore wind farm approx. 20 km off the coast of Thorsminde in the North Sea and includes two cable corridors. One or both cable corridor alternatives may be used. The larger investigation area, the gross Thor OWF area, is approx. 440 km^2, while the planned Thor OWF area comprises approx. 220 km^2.

Objective

This technical report documents the findings of the analysis of VMS- and logbook data for the commercial fisheries in the past decade within the gross area of Thor OWF and related ICES statistical rectangles and assesses the sensitivity of the commercial fisheries to the planned OWF.

Baseline conditions

The Danish commercial fisheries in the North Sea consists of two primary types of fisheries; the industrial fishery and the fishery, which deliver fish for human consumption. In the industrial fishery, species such as sand eel, sprat and Norway pout are processed into fishmeal and -oil, while the food fishery catches fish such as flatfish, cod and haddock for human consumption.

The most important catch in terms of weight in the three ICES statistical rectangles, 41F7, 41F8 and 42F7, was sand eel caught in the industrial fisheries. However, plaice was the most valuable species in terms of weight and estimated value in the food fisheries.

In the gross area of Thor OWF area (GA), beam trawl, bottom trawl and gillnet fishery are most intense in the south west and south east part. The smaller vessels also fish in the central part of the gross area of Thor OWF. Gillnet fishery occurs in most of the gross area of Thor OWF area except in the northern area and is more scattered in the central part of the gross area of Thor OWF. Beam trawl occurs in both proposed cable corridors (CC) near the coast of Jutland, and gillnet fishery is also extensive in both cable corridors.

Assessment of potential impacts

The potential impact on the commercial fisheries from the temporary safety zones around the turbines and the cable corridors will be local and of short duration. Therefore, the impact for the beam and bottom trawl fisheries of the temporary safety zones in the gross area of Thor OWF area is assessed to be *minor*, regardless of location. For the gillnet fishery that can deploy their gillnets almost anywhere, the impact is assessed to be *none to minor*, regardless of location. Similarly, the impact of the permanent safety zones in the cable corridors is likewise local and of short duration and the impact for the beam and bottom trawl fisheries is also assessed to be *minor*, regardless of whether one or both cable corridors are chosen for the further Thor OWF. For the gillnet fishery in the cable corridors the impact is assessed to be *minor*, regardless of whether one or both cable corridors are chosen for the future project.

The impact of the construction phase on fish is not expected to impact the overall fish populations. The fish species in the gross area of Thor OWF and cable corridors are robust and able to handle local disturbances from the Thor OWF and will flee the area, if conditions become suboptimal in terms of underwater noise and increased concentrations of suspended sediment in

the water column. Even if few individual juvenile or adult fish are injured or die during the construction of the Thor OWF, this has no impact on the overall fish populations in the North Sea. Therefore, the impact on the commercial fisheries is assessed to be *minor*.

The impact of the permanent safety zones on beam and bottom trawlers is local but of long duration (the OWF is expected to be operating for 20-30+ years) and is, for this reason, assessed to be *minor to moderate*, regardless of location. For the gillnet fishery, the impact is assessed to be *none to minor*, regardless of location. The fishing ban in the cable corridor is local but of long duration, and the impact on the beam trawl fishery is therefore assessed to be *moderate*, regardless of whether one or both cable corridors are chosen. The extensive gillnet fishery occurring in both cable corridors is not expected to be impacted by the permanent safety zones around the cable corridors. The gillnet fishery is expected to be able to carry on fishing in the cable corridor(s) for the Thor OWF. Therefore, the impact on the gillnet fishery is assessed to be *none*, regardless of whether one or both cable corridors are chosen.

In the operational phase, the largest impact on fish and fish populations is expected from electromagnetic fields around the cables between turbines and the shoreline. However, a reef effect from the structure provided from the turbines and along with the scour protection is expected. The impact on fish and fish populations from the operational phase is expected to be small and local but long term. Therefore, the impact on the commercial fisheries is assessed to be *none to minor*.

To summarize, the potential impact on the commercial fisheries is assessed to be from none to moderate. The largest impact is expected to arise from the permanent safety zones restricting the commercial fisheries.

Sensitivity analysis
The commercial fishery is most sensitive to placement of the turbines in the south-western, south-eastern and central part of the gross area of Thor OWF area, and the area least sensitive to placement of the future turbines is the northern part of the gross area of Thor OWF. With regards to the cable corridors, there is very little difference between the fishing intensity in the two areas. However, based on the interviewed fishermen, the northern CC would be the one with least conflict with the fishery. None the less, the commercial fishery is robust and able to handle the future Thor OWF and cable corridors.

Mitigation measures
To assess the possible necessity of mitigation measures, this report includes VMS data from the past ten years, which has been used as a basis for analysing potential impacts on the following fishery types:

- Bottom trawling
- Beam trawling
- Pelagic trawling
- Gillnet fishing
- Seine fishing

The potential impacts are all considered *none* to *minor* and the owner of the OWF will be required to make an agreement with the fishermen about possible compensation. Therefore, the overall impact is considered to be negligible. Based on the findings, no mitigation measures are deemed necessary.

2. INTRODUCTION

2.1 Background

In June 2018, the Danish Parliament signed the Danish Parliament's Energy Agreement 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, the Danish Energy Agency made the decision in February 2019 for the project development of an area in the North Sea approx. 20 km off the west coast of Jutland for Thor Offshore Wind Farm (OWF) 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 the commercial fisheries in the gross Thor (OWF) area and the two cable corridors and perform a sensitivity analysis in relation to the establishment of the planned Thor OWF within the area.

3. PROJECT PLAN

The plan for Thor OWF defines the overall framework for designing an offshore wind farm approx. 20 km off the coast of Thorsminde on the west coast of Jutland (Figure 3-1). The planned OWF must be able to provide a minimum 800 MW and maximum 1,000 MW to the national Danish power grid. The decision on the location for the possible OWF is based on a fine screening of possible installation areas carried out by COWI for the Danish Energy Agency in December 2018.

The plan establishes a framework for a future OWF with associated onshore facilities, but only at an overall level. Thus, there is no knowledge of the offshore wind farm's specific design, including the number, size and location of offshore wind turbines at this stage.

Figure 3-1. The gross area for the Thor offshore Wind Farm and two cable corridor alternatives. The gross area for Thor Offshore Wind Farm , which is located west of Thorsminde in the North Sea, consists of a 440 km^2 triangular area and additional areas around two alternative cable corridors leading to one landfall on the coast north of Nissum Fjord (Energinet, 2020).

The project plan includes the following elements for Thor OWF:

- the OWF 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
- and land cables to the grid connection point at Idomlund, which is east of Nissum Fjord (Figure 3-2).

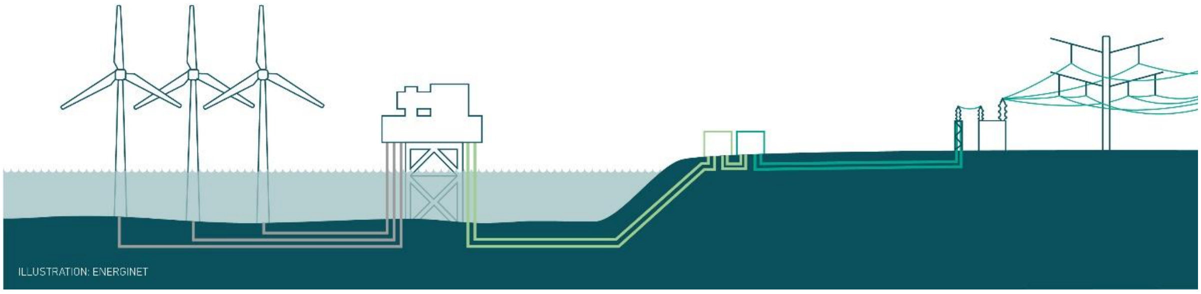

Figure 3-2. The planned Thor Offshore Wind Farm (Energinet, 2020).

The elements of the project plan that are relevant for assessing the sensitivity on the commercial fisheries are presented below.

3.1 Turbines

Wind turbines with a capacity range between 8 to 15 MW are to be expected. The minimum turbine capacity of 8 MW corresponds to the installation of up to 125 turbines, and the maximum turbine capacity of 15 MW corresponds to the installation of up to 67 turbines. To include the possible phase of technological development, the starting point for this study has been based on the turbine sizes below. The listed sizes are not final.

As described, the park layout and turbine design is not decided at this stage, and therefore, the assessment in this study is performed by including various possible variations in park size, variations in turbine design and the resulting variation in the number of wind turbines, as well as variation in park-layout. It is pointed out that there are several possible variations that the final, concrete project may end up in. For this reason, 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 general methods used for foundations in ongoing offshore wind projects of up to 55 m sea depth, it is most likely that the offshore turbines will be placed on monopiles installed in the seabed by pile driving.

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

Possible foundation methods 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 Cables

Export cables from the transformer platform (offshore substation) to landfall are installed in one of the two cable corridors R2 or R3. Dimensions are not known at this point.

4. METHODS AND MATERIALS

The extent and characteristics of the commercial fisheries in the North Sea is described through the use of detailed official fisheries statistics obtained from the Danish Fisheries Agency, along with interviews with fishermen, who actively fish in the gross area of Thor OWF area and adjacent areas. In the following section, the methods for obtaining data and analysis is described in detail.

4.1 Fisheries statistics - logbook and VMS data

All Danish commercial fishing vessels are obliged to keep a logbook of their catches (BEK 1514, 2017). 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. The estimated value is based on average landing value. Therefore, the logbook is an important source of information on which species can be found in the specific areas of Danish waters and indicates the economic importance of the area for the commercial fisheries.

Since 2002, Danish fishing vessels of more than 24 m length have been required to register their position through an electronic satellite system named the Vessel Monitoring System (VMS) (EU, 2009). In 2005, the system was expanded to also include vessels of 15 m or more, and in 2012 it became mandatory for vessels of 12 meters or more to use the VMS. The VMS data holds information on identity, position, direction and speed of the fishing vessels.

The commercial fish catches are divided into statistical rectangles according to ICES (International Council for the Exploration of the Sea) (ICES, 1977). The VMS makes it possible to locate the position and speed of each of the fishing vessels within the relevant ICES rectangle at any given time. Based on the logged sailing speed of fishing vessels during active fishing activities with different gear types (Table 4-1), it is possible to determine whether the vessel actively fish or merely sail to and from fishing grounds. In addition, the VMS-data from the present study have been sorted in to gear types,, and speed histograms have been produced to customize the analysis for the specific data used in this report (see Appendix 2). Thus, the analysis provides information on which areas are important for different gear types.

Table 4-1 The estimated speed of fishing vessels when actively fishing – see also Appendix 2

Fishing type	Speed in knots
Trawlers	1,5-4,5 knots (Hall-Spencer, et al., 2009) 0-5 knots (ICES, 2019) 2-4 knots (Prado & Dremiere, 1990)
Beam trawlers	0-5 knots (ICES, 2019) 2-7 knots (Prado & Dremiere, 1990)
Gillnetters	0-5 knots (ICES, 2019) 3-5 knots FAO 1990
Seiners	0-5 knots (ICES, 2019) 0-3 knots (Eigaard, et al., 2016)
Other gear	0-5 knots (ICES, 2019)

Utilizing the VMS data, it is possible to illustrate the frequency of fishing activity for each gear type within the gross area of Thor OWF and thereby, determine the importance of the area for the fishing fleet. However, VMS data is biased, as only larger fishing vessels (>12m) are included in the VMS data. This is compensated for with the analysis of the logbook-data, where the catches of all vessels, regardless of size, is included. In addition, the bias is reduced by implementation of the large dataset and statistical average point of view.

The gross area of Thor OWF area is situated within the fishery statistical area of the "Central North Sea" (ICES subarea IVb) (ICES, 1977) , which is further divided into ICES statistical rectangles 41F7, 41F8 and 42F7. . Each ICES square is approximately 30 x 30 nautical miles (Figure 4-1). The eastern most part of ICES square 41F8 consists mainly of land in western Jutland. When this land area is excluded from the analysis, the ICES statistical rectangles encompass 3435 km², 400 km² and 3390 km² of ocean – a total of 7225 km².

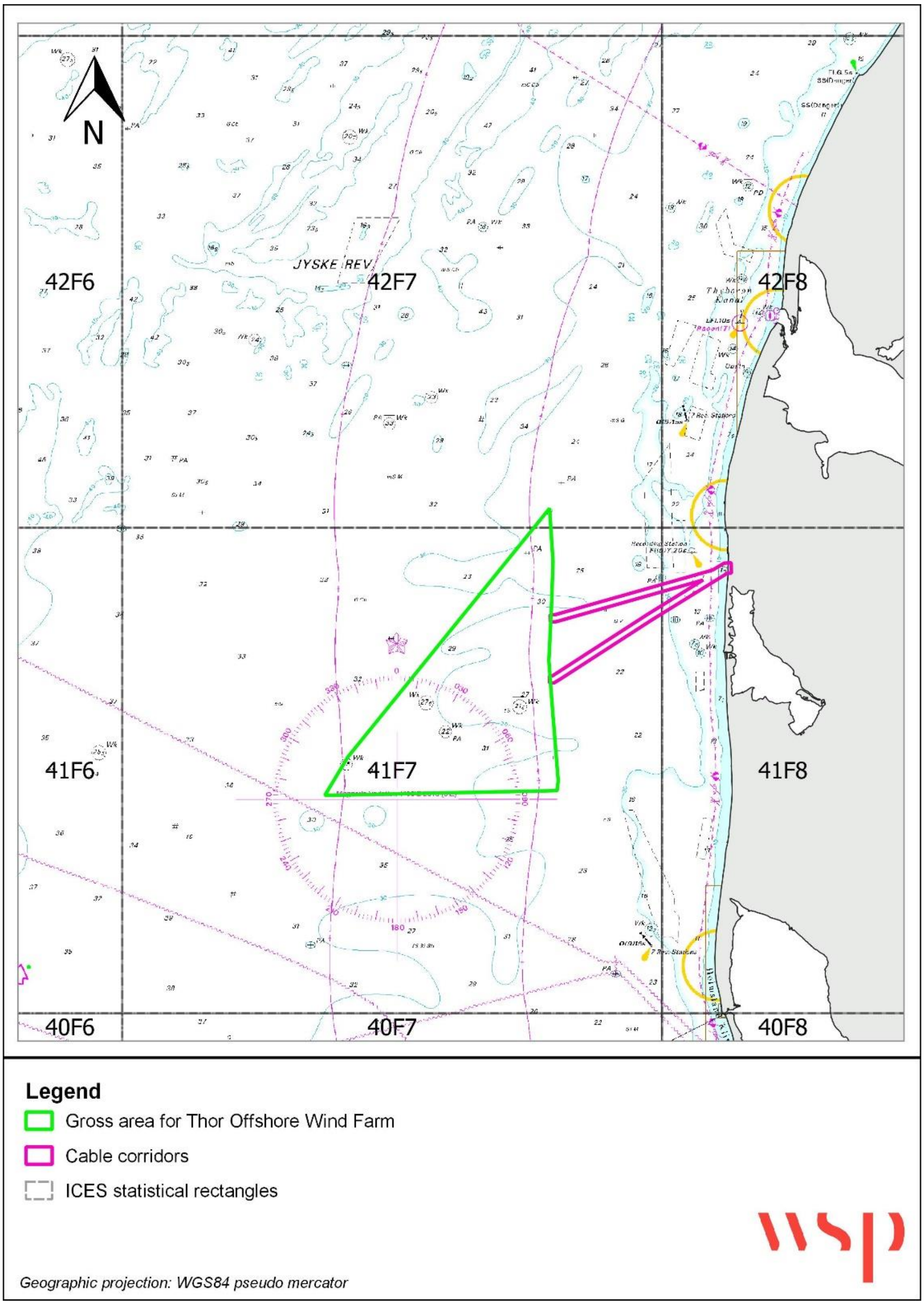

Figure 4-1 The project area and ICES rectangle 41F7, 41F8 and 42F7.

4.2 Interview of fishermen

The fishing fleet have great knowledge of the area and the distribution of the commercial fish species. This knowledge is often passed on verbally through generations of fishermen and rarely written down. Thus, the only way to include this information into the present analysis area is by interviewing the fishermen, who are actively fishing in the project area and the adjacent areas. The three main fisheries organizations in Denmark, Danish Fishermen Producers Organization (DFPO), the Danish Pelagic Producers Organization (DPPO) and the Association for Low Impact Coastal Fishing (FSK) facilitated contact to fishermen, whom actively fish in the gross area of Thor OWF and with home port in Hvide Sande, Thorsminde or Thyborøn. In total, three interviews were conducted (Appendix 1), which represent different vessel sizes and fishing gear used in the gross area of Thor OWF area; bottom trawl, beam trawl and gillnet.

Commercial fishing vessels have chart plotters onboard for navigation and plotting their fishing activities. Screen dumps from the fishermen's chart plotters have been included in the analysis of the windfarm area. The chart plotters often contain information about the fisheries in the gross area of Thor OWF area over several years demonstrating the present fishing activities as well as the tendency over time.

4.3 Description of the fishing methods

The construction, operation and demolition of offshore turbines and their cables may influence the fisheries in the area. The largest effects are expected from limitations to the maneuverability of the fishing fleet and possible impact on the fish resource. For a better understanding of the consequences for the commercial fisheries, a description of the three most important fishing types of the area is included here.

The Danish commercial fisheries in the North Sea consists of two primary types of fishery; the industrial fishery and fishery, which deliver fish for human consumption. In the industrial fishery, species such as sand eel, sprat and Norway pout are processed into fishmeal and -oil, while the food fishery catches fish such as flatfish, cod and haddock for human consumption.

4.3.1 Beam trawl

A trawl is one or more net bags dragged through the water either near or on the sea bottom (beam and bottom trawl) or through the water (pelagic) depending on the behaviour of the target species. The size of the trawl is adjusted to match the engine power of each fishing vessel; small engines can haul small trawl and vice versa for larger engines.

The original types of trawl were similar to the beam trawl, where a steel bar kept the trawl bag open at all times (Korsgaard, et al., 2007). When fishing with beam trawl (Figure 4-2), two trawls – one on each side of the fishing vessel, is dragged from the beams attached to the foremast of the vessel (Korsgaard, et al., 2007). When the vessel is fishing, the beams are lowered to almost horizontal and the beams are pulled back up when the trawls are hauled in. Beam trawl targets benthic species such as flatfish and brown shrimp.

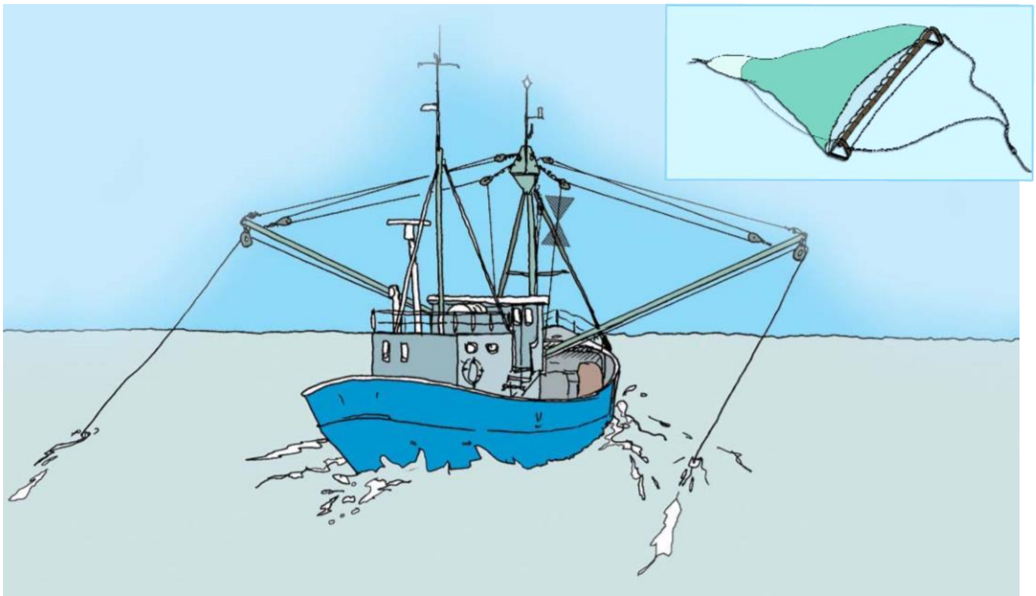

Figure 4-2 A beam trawler with trawls deployed. Top right corner: Illustration of the trawl kept open with a steel bar. From (Korsgaard, et al., 2007).

Trawls generally have a high degree of bycatch of non-targeted species and the catches consist of a large range of bottom living species such as crabs, shellfish and other bottom dwelling species (Gislason, et al., 2014). The poor selectivity of the gear and the impact on the seabed causes beam trawling to have a high degree of environmental impact and a low sustainability. Beam trawling consists of long hauls of several km where the trawls are hauled hundreds of meters behind the vessel to ensure a horizontally pull on the trawl. Therefore, trawl vessels have limited manoeuvrability and especially larger vessels with very long trawl systems requires vast sandy areas without obstacles (rocks, reefs etc.) to execute the fishery successfully.

4.3.2 Bottom trawl and pelagic trawl

Since the first trawl was introduced to Denmark in approximately 1907, the trawl design has undergone a major development over the past 100 years (Korsgaard, et al., 2007). From the original design resembling the modern beam trawl, trawl doors were developed to keep the trawl bag open with the outwards drag created by the doors. Furthermore, the weight of the doors helps to keep the trawl near the bottom. The bottom trawl (Figure 4-3) is designed to catch fish that live on or near the bottom. This includes cod, saithe, haddock, plaice, prawn, Norway lobster and sand eel. The characteristics of the bottom trawl is that the roof of the trawl is longer than the underside of the trawl, which ensures that the fish does not flee upwards and out of the trawl but is instead caught by the roof of the trawl. The width of the trawl is larger than the height, and the largest bottom trawl can be 100 m wide and 30 m high.

The pelagic trawl is similar to the bottom trawl, but the doors lift the trawl up into the water column and off the bottom to catch fish species living in the water column, primarily schooling fish such as herring, sprat and mackerel.

The trawl fishery (all types combined) is by far the most important in Denmark in terms of the value of the catch as well as the total weight of the catch (DFPO, 2019). This is also the case in the North Sea.

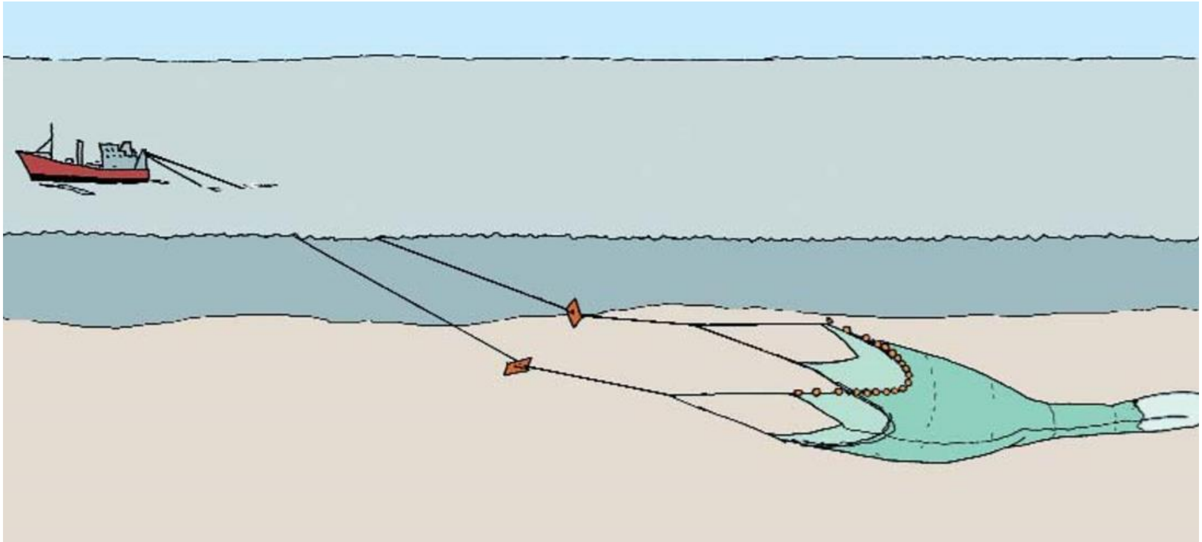

Figure 4-3 Schematic illustration of a fishing vessels hauling a single trawl. From: (Korsgaard, et al., 2007).

4.3.3 Gillnet

A gillnet is a wall of net stretched out between the floats attached to the rope at the top and sink or lead line at the bottom of the net (Figure 4-4). The mesh size determines which species the gill net catches. Gillnet for catching herring and other smaller fish has a smaller mesh size compared to gill nets for catching larger fish such as flatfish. The position of the gill net in the water is important for which species it catches. Gillnets for catching flatfish and cod is positioned at or near the bottom, while pelagic gill nets for catching mackerel and herring floats near the surface. Most gill nets are anchored to the seabed in each end of the nets. However, some types of net may float with the current only attached to the fishing vessel.

Due to the low environmental impact on the seabed and the low rate of bycatch, gillnets are considered a highly sustainable fishing method. Fish caught in gillnets are usually of a higher quality because of the low amount of handling compared to trawl fishing, where the fish usually spend hours in the trawl before landing.

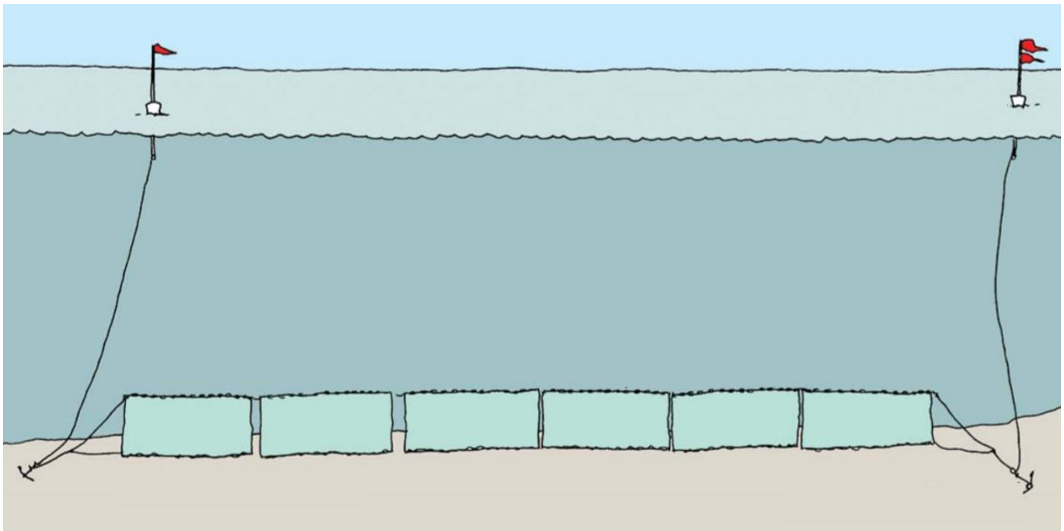

Figure 4-4 Schematic illustration of a gillnet. From: (Korsgaard, et al., 2007).

4.3.4 Seine

Fishing with seine was originally a Danish invention (Korsgaard, et al., 2007). The gear consists of a mesh bag and two long rows of nets each attached to long ropes. Originally, the seine was sailed out in a circle from a small boat and afterwards pulled into shore from the beach. However, the method used today is more developed. When deploying the seine, a big anchor and buoy marks the one end of the gear. The boat sails in a large circle while setting the net and mesh bag overboard. When the boat has completed the circle and returns to the anchor and buoy, both ropes are pulled towards the ship while the ropes "scare" the fish into the mesh bag and is caught. The seine is ideal for catching food fish due to the high quality of the catch and the landing price is therefore generally high. The fish species targeted in the seine fishery is flatfish such as plaice, but also cod and haddock.

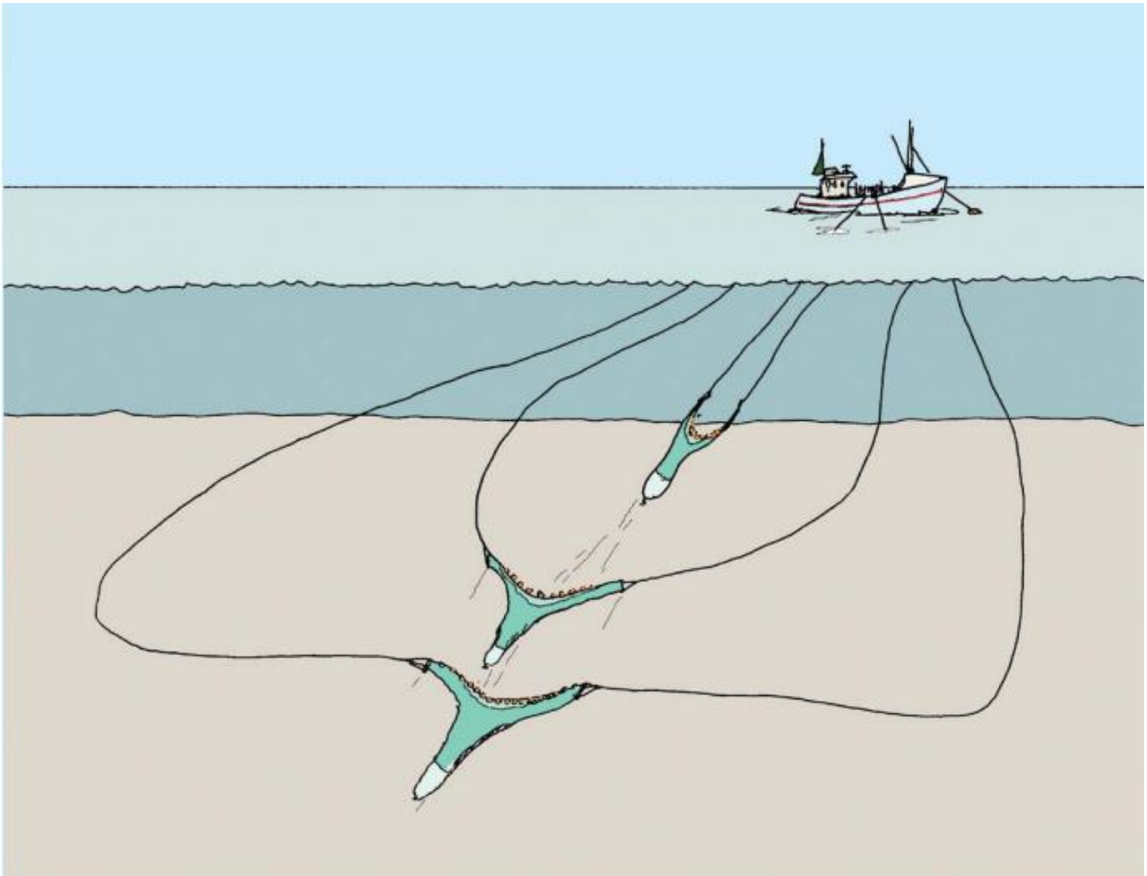

Figure 4-5 Schematic illustration of a seine fishery. From: (Korsgaard, et al., 2007).

4.4 The commercially important fish species in the North Sea

The construction, operation and demolition of offshore turbines and their cables will influence the commercial fisheries in different ways, depending on the behavior and nature of the various fish species in the area. For a better understanding of the consequences for the commercial fisheries, a description of the eight most economically important fish species of the area is given below.

4.4.1 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. It feeds mainly on thin-shelled mollusks and polychaetes. Spawning occurs in the same way as for most flatfish in the North Sea (Figure 4-6); The European plaice is the most important flatfish for the commercial fisheries in Europe (Muus & Nielsen, 2006) and caught especially in bottom trawl and gillnets.

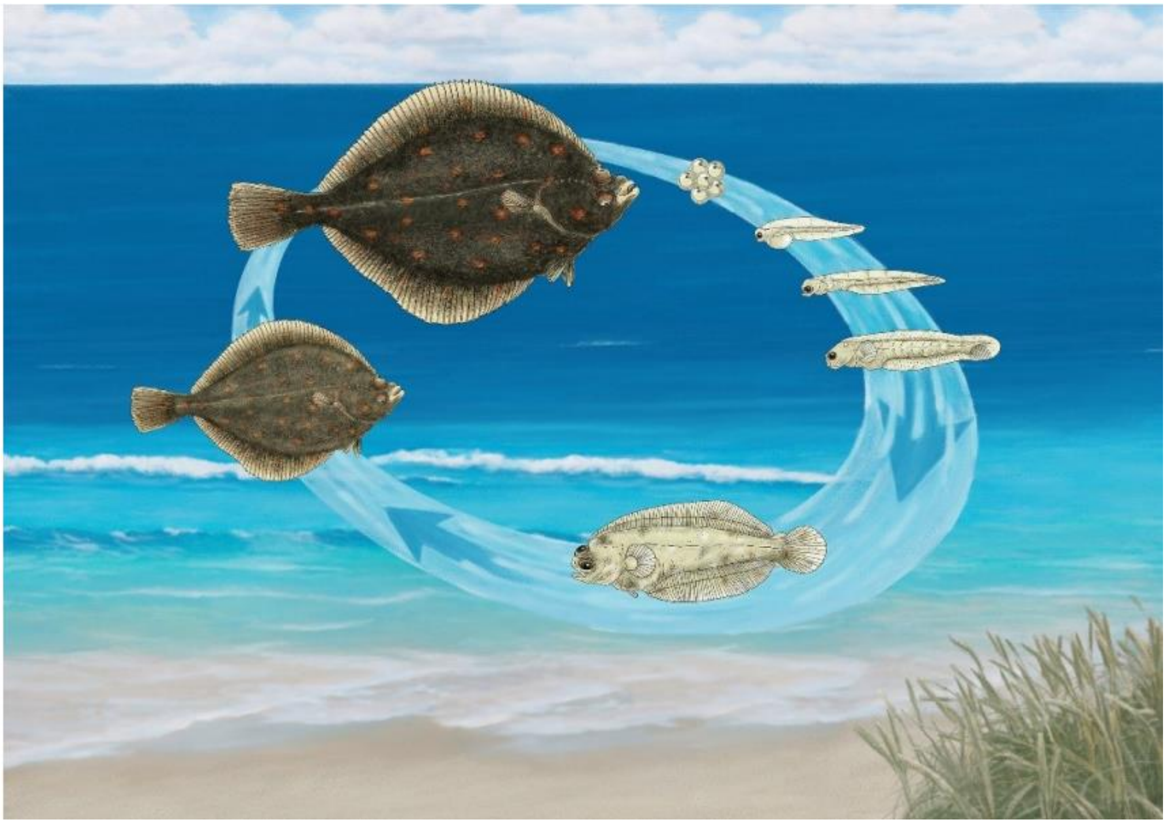

Figure 4-6 Life cycle of the European plaice and most other flatfish. The eggs hatch in the pelagic and the juveniles subsequently settle in shallow sheltered areas where they grow up. During winter the plaice migrate gradually into increasingly deeper waters until they reach maturity and migrate to the spawning sites (Støttrup, et al., 2019).

4.4.2 Sand eel (*Ammodytes marinus* R. and *Ammodytes tobianus* L)

Sand eel 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 sand eel (*Ammodytes tobianus*). The lesser sand eel is usually found further offshore compared to the small sand eel. 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 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. Both species of sand eel are caught using a bottom trawl with small mesh sizes. The species is important in the industrial fisheries where the catch is processed into fish meal and oil.

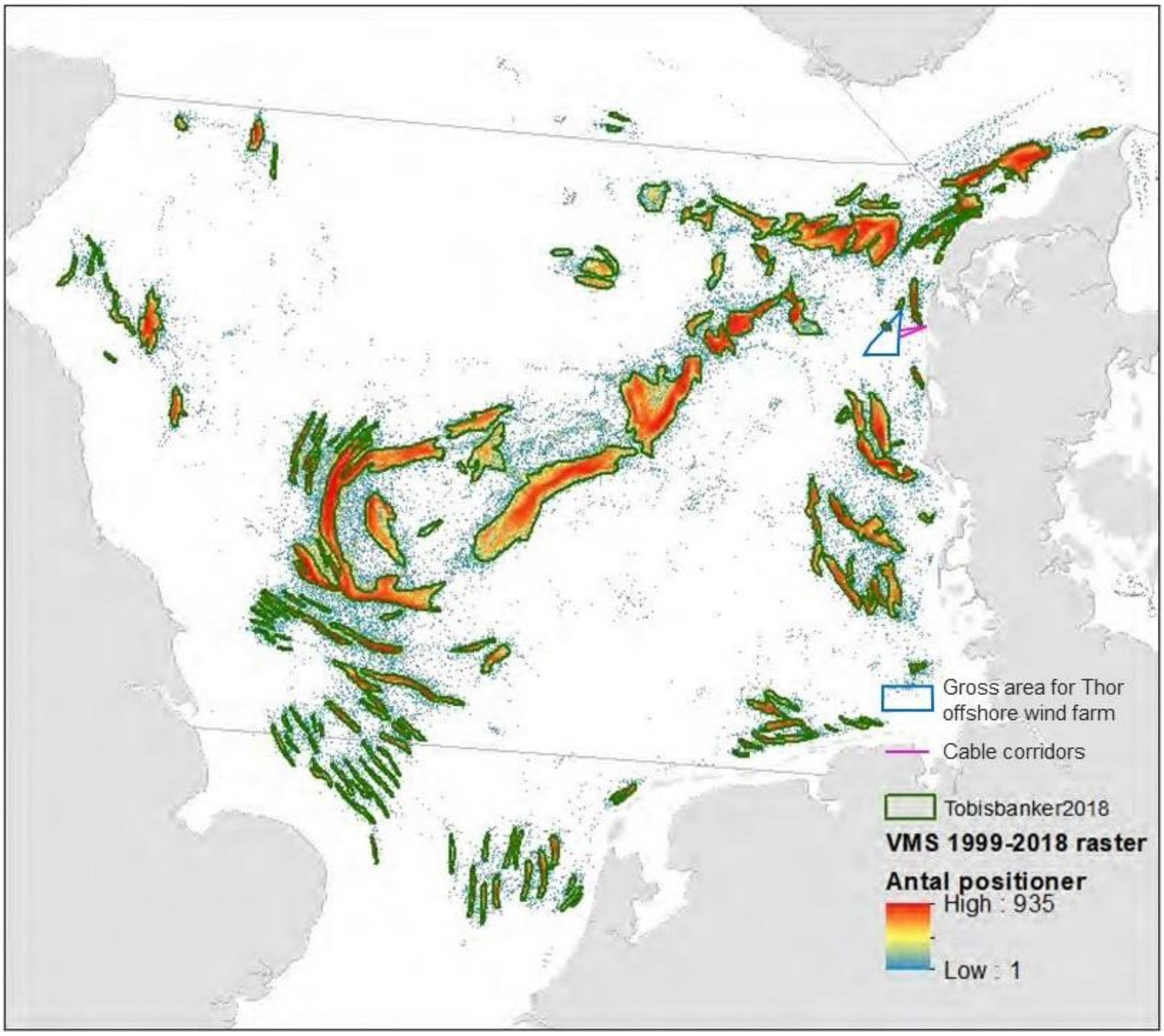

Figure 4-7 Sand eel fishing grounds digitalised from VMS data collected in 2018 (green lines) compared with sand eel fishing grounds registered in 1999-2018 (red: high intensity fishing ground, blue: low intensity (Deurs, 2019). Modified with the illustration of Thor OWF gross area (blue) and cable corridors (pink).

4.4.3 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 tends 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. Sprat is caught using pelagic or bottom trawl and is an important part of the industrial fisheries in the North Sea, where it is processed into fish meal and oil or preserved and tinned.

4.4.4 Atlantic cod (*Gadus morhua* L.)

The Atlantic cod is a round fish 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 are 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. Generally, cod spawns in January to April and the eggs drift with the pelagic water current. 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 are caught with bottom trawl or gillnets for human consumption, but catches have been declining for several decades due to fishing pressure and climate change.

4.4.5 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 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 4-6). The eggs and larvae drift with the current until they reach the nursery grounds in shallow sandy areas where they grow until winter, after which they swim to deeper and warmer waters. The sole is an important and very valuable food fish caught in trawl or seine in the commercial fisheries.

4.4.6 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 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 4-6). The turbot is caught using bottom trawl or gillnets and is an important and very valuable food fish in the commercial fisheries.

4.4.7 Brown crab (*Cancer pagurus* L.)

The brown crab is a species of crab found widespread throughout the North Sea. The brown crab bears an oval shell of orange-brown colour, usually of a width of 30 cm, and up to 6 kg (Muus & Nielsen, 2006). The species lives on rocky bottoms, from 1-30 m down in summer months, and above 30 m in colder winter months. The brown crab feeds on small invertebrates, snails and mussels. Egg production takes place in the autumn, where the female carries up to 3 million eggs until summer, where hatching occurs. The brown crab is caught using pots baited with fresh fish, or as bycatch from the trawling fishery, and especially the claws represent a valuable resource for the commercial fisheries.

4.4.8 Brown shrimp (*Crangon crangon* L.)

The brown shrimp is found well distributed throughout the North Sea (Muus & Nielsen, 2006). The species is grey, and stays grey after exposure to high temperatures, unlike other shrimp species. The adult brown shrimp reaches a maximum length of 8 cm, and normally dwells in shallow waters from 0- 20 m. The food source consists of all smaller bottom dwelling creatures. The brown shrimp has hermaphroditic abilities meaning that the species lives as male for the first two years and then changes to female. Spawning occurs thrice per year. The brown shrimp is caught using beam trawling or push nets.

4.4.9 Norwegian lobster (*Nephrops norvegicus* L.)

The Norwegian lobster is recognised by its long, slim claws, with a maximum length of 24 cm (Muus & Nielsen, 2006). The species is found widespread in the North Sea, and in particular along the coast of Norway. The Norwegian lobster dwells in holes on soft bottoms up to a depth of 250

m. Feeding occurs during nightfall, preying mainly on small bottom dwelling creatures and serpent stars. Spawning occurs every other year from March to November, and the eggs are carried by the female for up to nine months before hatching. The Norwegian lobster is caught during the night using trawl in a targeted fishery, but the species is also an important and valuable by-catch from the shrimp fishing industry.

5. BASELINE SITUATION

5.1 Commercial fisheries in the North Sea

The available logbook data describes the fishery in a larger geographical context (the three ICES statistical rectangles (41F7, 41F8 and 42F7)). The gross area of Thor OWF only covers a small part of the three ICES statistical rectangles, in which the investigation area is set in (see also Figure 4-1). For this reason, it is difficult to describe the exact weight and value of the catches in the gross area of Thor OWF. However, the VMS data gives an indication of the fishing effort in the gross area of Thor OWF area, and the additional interviews with local fishermen gives an indication of the importance of the gross area of Thor OWF area for the commercial fisheries.

5.2 Fisheries within the gross area of Thor OWF

The importance of the gross area of Thor OWF for the commercial fisheries can be illustrated when comparing the number of VMS-points inside the gross area of Thor OWF relative to the number of points outside the area. However, data is slightly biased since commercial fishing vessels of less than 12 m were not included in the VMS-register before year 2011. So, before 2011, only fishing activity for vessels of 15 meters or longer was registered.

For the commercial fishery inside the gross area of Thor OWF, less than 5% of all the VMS-points in ICES square 41F7, 41F8 and 42F7 were positioned inside the gross area of Thor OWF area (Table 5-1). The relative size of the gross area of Thor OWF comprised 12,7% and 0.06%, respectively, of the total ICES square areas of 41F7 and 42F7.
For beam trawl fishery, the importance of the gross area of Thor OWF was low. For the ICES statistical rectangles 42F7 and 41F7, respectively, 0 % and 8.3 % of the VMS points occurred inside the gross area of Thor OWF. For bottom trawl, the gross area of Thor OWF was also of low importance as merely 0 and 4.4% of the fishing occurred in the gross area of Thor OWF for 42F7 and 41F7, respectively. The gross area of Thor OWF was of low importance for the pelagic fishery, with 5% and 0% of the VMS point occurring in the 42F7 and 42F7 placed inside the gross area of Thor OWF. The gross area of Thor OWF was of moderate importance for the gillnet fishery, with 16.7 % of the VMS point occurring in the 41F7 and 0 % in 42F7. The gross area of Thor OWF was of low importance to the seine fishery, although 10 % of the VMS point for 41F7 were in the gross area of Thor OWF. However, very few VMS points for the seine fishery occurred in general in the 41F7, so the few points in the gross area of Thor OWF quickly add up to 10%. However, very little seine fishing is carried out in ICES 41F7, and therefore, the few VMS points comprise to 10% of the VMS points positioned inside the project area. None of the seine fishery in 42F7 occurs in the gross area of Thor OWF.

For the commercial fishery within the cable corridors less than 0,5% of the overall VMS-points were positioned inside the cable corridor area (Table 5-2). The importance of the area within the cable corridors to both beam, bottom and pelagic trawl as well as for gillnet and seine fishing was of low importance for the commercial fisheries, as less than 5% of the VMS points of ICES square 42F7 occurred inside the cable corridor area.

Table 5-1 The number and percentage of VMS points for each vessel type inside the GA relative to outside the area.

Method	Number of VMS points in windfarm area				
	ICES Rectancle	Outside GA	Inside GA	Total in ICES-rectangles	% of VMS in GA
Beam trawl	41F7	8,043	731	8,774	8,3%
	42F7	5,357	0	5,357	0,0%
Bottom trawl	41F7	21,179	965	22,144	4,4%
	42F7	29,943	0	29,943	0,0%
Gill net	41F7	17,886	3590	21,476	16,7%
	42F7	15,602	0	15,602	0,0%
Pelagic trawl	41F7	2,288	119	2,407	4,9%
	42F7	4,311	0	4,311	0,0%
Seine	41F7	1,492	166	1,658	10,0%
	42F7	5,782	0	5,782	0,0%
SUM	**41F7 + 42F7**	**111,883**	**5,571**	**117,454**	**4,7%**

Table 5-2 The number and percentage of VMS points for each vessel type inside the CC relative to outside the area.

Method	Number of VMS points in cable corridor				
	ICES Rectancle	Outside CC	Inside CC	Total in ICES-rectangles	% of VMS in CC
Beam trawl	41F7	8771	3	8774	0,0%
	41F8	18267	53	18320	0,3%
Bottom trawl	41F7	22133	11	22144	0,0%
	41F8	9563	22	9585	0,2%
Gill net	41F7	21351	125	21476	0,6%
	41F8	6091	200	6291	3,2%
Pelagic trawl	41F7	2407	0	2407	0,0%
	41F8	447	0	447	0,0%
Seine	41F7	1654	4	1658	0,2%
	41F8	534	1	535	0,2%
SUM	**41F7 + 41F8**	**91218**	**419**	**91637**	**0,5%**

5.3 Fishing vessels and landings

5.3.1 Logbook data

The logbook data comprises information on the fishing vessel, home port, date and weight and estimated value of the catches. The catches are referred to ICES square number, and not to an exact position in the North Sea. But as presented in section 5.2, only a few percentages of the fishing trips in each ICES square occurred inside the gross area of Thor OWF. Therefore, the fisheries are described based on weight and estimated value.

5.3.2 Fishing vessels and ports

Smaller fishing vessels (<12 m) usually fish in the vicinity of the home port due to limited engine power and the extensive travel time to and from the fishing grounds (pers. comm. commercial fishermen interviewed for this report – please see section 2.7.1). Thus, there is reason to assume that, at least to some degree, the smaller local vessels utilize the gross area of Thor OWF as fishing grounds.

The number of fishing vessels have generally decreased over the past 10 years(The Danish Fisheries Agency, 2019) . The same pattern was evident in the number of fishing vessels with homeport in the three ports closest to the gross area of Thor OWF - Hvide Sande, Thorsminde and Thyborøn. In these three ports, the number of fishing vessels have decreased with 17% from 247 to 203 vessels in the past decade (Table 5-3). The decrease was especially pronounced in longliners, seiners, side trawlers and beam trawlers which account for 80% of the decrease. The most common vessel type is gillnetters and there is a tendency towards an increase in gillnetters among the smaller vessels.

Table 5-3 The number of Danish fishing vessels with homeport in Hvide Sande, Thorsminde and Thyborøn in 2009 and 2018, respectively. Dinghies and aiding vessels are not included. The vessel types are divided into different length classes (reference: (The Danish Fisheries Agency, 2019).

Type of vessel	Vessel length													
	< 8 m		8 -10 m		10 -12 m		12 - 15 m		15 - 24 m		>24 m		Total	
	2009	2018	2009	2018	2009	2018	2009	2018	2009	2018	2009	2018	2009	2018
Other trawlers												3	**0**	**3**
Beam-/Stern trawler											1		**1**	**0**
Beam-/Side trawler									1	1			**1**	**1**
Beam trawler							1		14	12	5	2	**20**	**14**
Gillnetters /longliners	3	1	5	9	2	1	3		6				**19**	**11**
Gillnetters /trap setters	4	3	1										**5**	**3**
Gillnetters /trawler	3	9	11	4	2	2	4	3	1	3			**21**	**21**
Gillnetters	48	51	17	21	10	6	11	7	19	14	1		**106**	**99**
Stern trawler	1		2	2			2	1	8	4	19	20	**32**	**27**
Multipurpose vessel (stern/side)									3	2	3	5	**6**	**7**
Hook vessel			1	1									**1**	**1**
Side trawler			1	1			4	1	11	3	4	1	**20**	**6**
Seiners									13	6			**13**	**6**
Seiners /stern trawler		1									2	3	**2**	**4**
Total	**59**	**65**	**38**	**38**	**14**	**9**	**25**	**12**	**76**	**45**	**35**	**34**	**247**	**203**

In addition to the commercial fishing vessels, fishing also occurred from vessels which conducted fishery as a secondary business. The number of these vessels increased slightly from 2009 to

2018 (The Danish Fisheries Agency, 2019). The fishing vessels conducting fishery as a sideline business were smaller vessels with relatively low fishing effort, and therefore, their part of the total landings only comprised few percentages.

5.3.3 Fishery landings

The total Danish landings in 2018 was 671,288 tons equivalent to 3.3 billion DKK (DFPO, 2019). The North Sea was by far the area where most fish were landed and thereby, represented the largest value – 2.1 billion DKK. Trawl fishery accounted for 1.6 billion DKK while gillnet fishery represented 143 million DKK.

The national landings from ICES square 41F7, 41F8 and 42F7 in 2018 was approximately 7,619 tons comprising approximately 1% of the total Danish landings in terms of amount (Danish Fisheries Agency, 2020). In estimated value, the catches from ICES square 41F7, 41F8 and 42F7 in 2018 was 77 mill DKK and the equivalent of 2% of value of the total national landings.

For the past decade, the estimated yearly average value of landings from ICES statistical rectangles 41F7, 41F8 and 42F7 for all gear types were 62 mil. DKK. Gillnet fishery is the gear type which represents the greatest value compared to other gear types (Figure 5-1). The average yearly estimated value of gillnet landings in 2009-2019 was approximately 28 mil. DKK which represents 45%. In comparison, bottom trawl has had an average yearly estimated value of 20 mil. DKK representing 32%. Pelagic trawl accounted for approximately 9% of the average yearly landings or 5.6 mil. DKK. The estimated value from the different gear types have developed over the past 10 years and most have increased. Especially the estimated value of gillnet fishery has increased while estimated value of seine fishery has decreased in the same period.

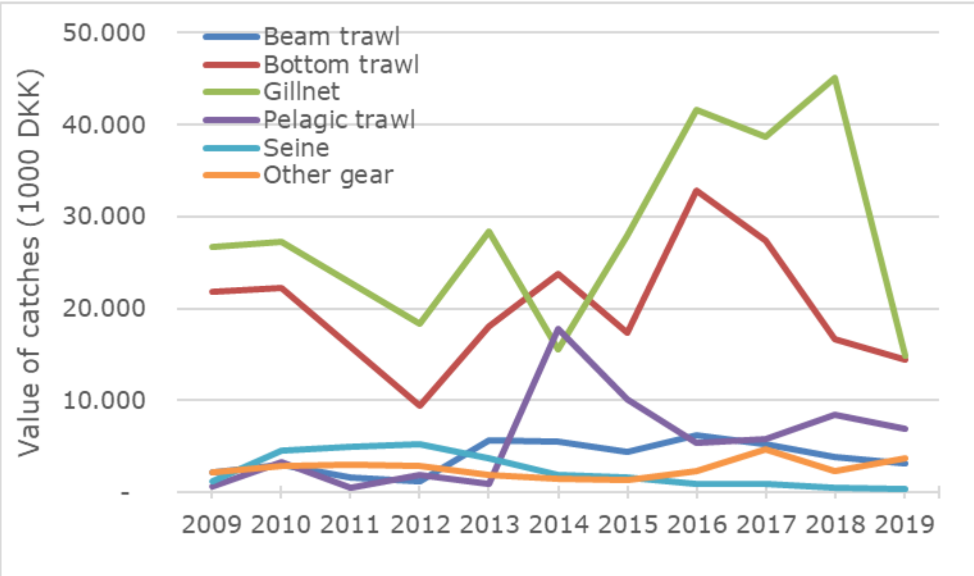

Figure 5-1 The development in estimated value of yearly landings for the different gear types in ICES statistical rectangles 41F7, 41F8 and 42F7. The landings are in thousands DKK.

For the past decade, the average yearly catch from ICES statistical rectangles 41F7, 41F8 and 42F7 for all gear types were 10.769 tons. For some gear types, the weight of the catches has fluctuated greatly for the past decade (Figure 5-2). Especially bottom trawl and pelagic trawl landings have had peaks up to four times the normal catches. For the past few years an increase in catches of other gear types has been observed.

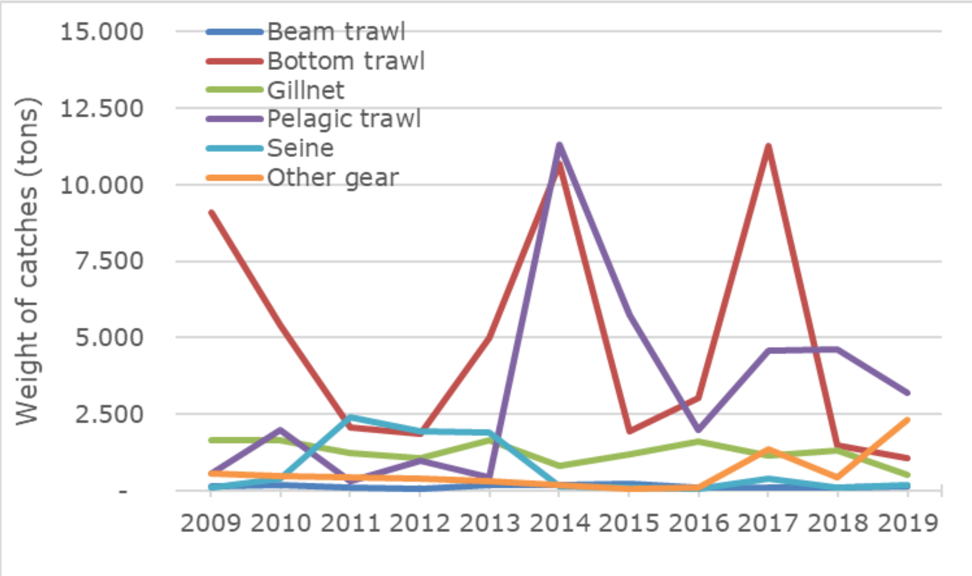

Figure 5-2 The development in yearly total landings for the different gear types in ICES statistical rectangles 41F7, 41F8 and 42F7.

The trawl fishery (bottom, pelagic and beam trawl) is the most important type of fishery in the ICES statistical rectangles 41F7, 41F8 and 42F7, comprising 76% of the combined total catches from 2009-2019 (Figure 5-3) (Danish Fisheries Agency, 2020). In comparison, gillnet fishery comprised approximately 12% of the total weight of landings in the same period and area. This is the same amount comprised by "other" fishing gears.

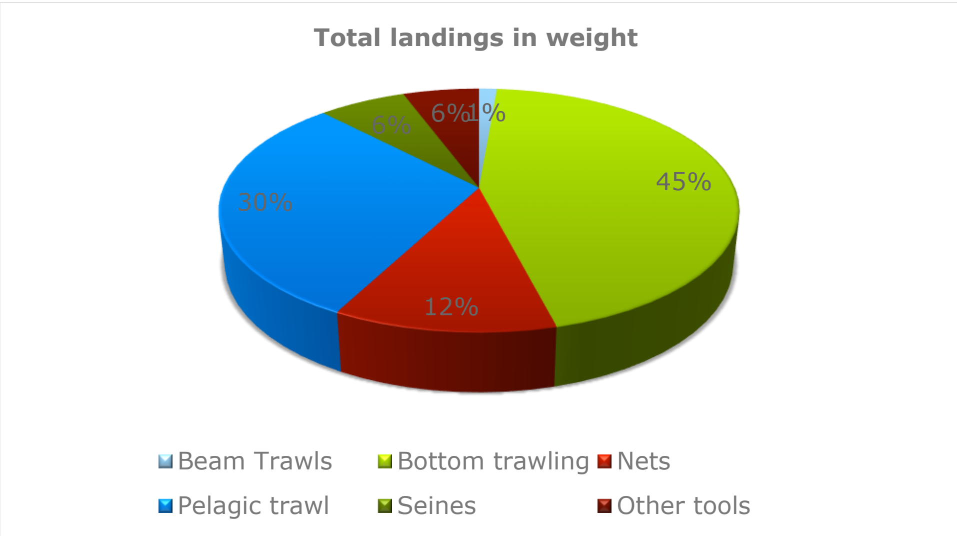

Figure 5-3 The total landings in tons for ICES square 42F7, 41F7 and 41F8 divided into gear type:

In terms of estimated value, the trawl fishery is still the most valuable fishery as the estimated earnings for this gear type comprised 47% of the total catch in 2009-2019 in ICES statistical rectangles 41F7, 41F8 and 42F7 (Figure 5-4) (Danish Fisheries Agency, 2020). However, gillnet fishery comprised a total value of 45% in the area while other fishing gears accounted for the remaining 8% of the total value. There has been a general tendency towards an increase in the estimated earnings for gillnet fishery in 2009-2019, whereas e.g. the earnings for beam trawl fishery has decreased.

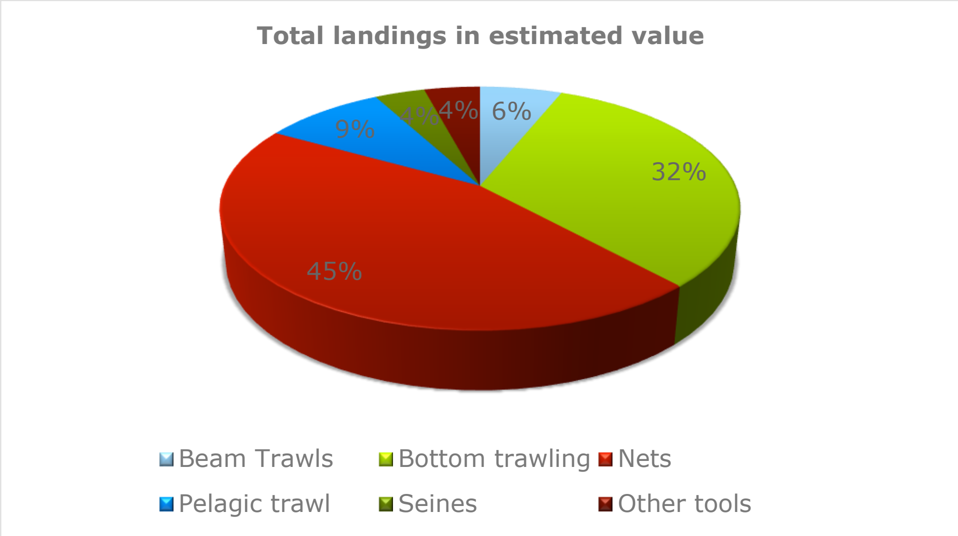

Figure 5-4 Total sum of estimated value of species for each fishery tool

It is assumed that the majority of the vessels with home port in Hvide Sande, Thorsminde, Thyborøn have caught their fish in or near the gross area of Thor OWF as the limited vessel size and engine power puts a limit to the mobility of the vessel. Overall, the species comprising the largest average yearly landings in tons for ICES Square 41F7, 41F8 and 42F7 was sand eel with just above 4500 tons (Table 5-4). Approximately 64% of the sprat catches belonged to vessels from other ports than the three local ports ("other vessels" in Table 5-4). The second and third most abundant species in the catches was sprat and plaice with a total of 2,370 tons and 1,519 tons, respectively. For sprat landings, local and other vessels each caught 50% of the total landings, while for plaice, 82% of the landings belonged to the local vessels. In general, local vessels seem to focus more on fish of high quality for consumption compared to other vessels which mostly caught industrial fish species. The fact is supported by the findings of Table 5-4 and the following tables. This complies with the importance of high-quality food fish and the need for short fishing journeys while it is less important for industrial fish to be of high quality and therefore, longer fishing journeys are acceptable.

ICES square 41F7 is very representative for the overall landings with the dominant species being sprat, sand eel and plaice. In ICES square 41F8, sprat, herring and brown shrimp were the dominant species, while in addition to sand eel and plaice, large quantities of cod and hake were caught in ICES 42F7.

Table 5-4 Average yearly landings from 2009-2019 for each ICES area divided into most commonly landed species. The given averages are divided into local vessels, which includes landings from vessels with home port in Hvide Sande, Thorsminde and Thyborøn. Other vessels indicate landings from vessels belonging to all other ports.

Average yearly landings in tons							
	ICES 41F7		ICES 41F8		ICES 42F7		Total
Species	Local vessels	Other vessels	Local vessels	Other vessels	Local vessels	Other vessels	
Brill	6.57	2.66	0.45	1.01	3.93	0.64	**15.26**
Brown crab	42.04	3.46	10.77	0.19	4.19	0.96	**61.61**
Brown Shrimp	3.71	0.57	76.64	7.28	0.48	0.24	**88.92**
Cod	91.40	4.92	6.18	0.19	174.50	50.65	**327.84**
Dab	29.43	4.62	6.04	1.13	47.88	9.26	**98.36**
Plaice	652.04	115.56	46.13	11.80	560.17	134.13	**1,519.83**
Hake	4.16	0.70	0.07	0.17	59.01	90.91	**155.02**
Herring	13.09	17.06	195.65	11.66	35.14	17.21	**289.851**
Lemon sole	2.22	0.22	0.04	0.01	12.73	2.70	**17.92**
Monkfish	1.48	0.04	0.00	0.00	10.68	2.05	**14.25**
Sand-e el	226.48	304.68	77.41	123.78	1,342.94	2,493.90	**4,569.19**
Sole	63.11	8.19	8.36	0.34	23.72	4.91	**108.63**
Sprat	745.01	774.15	367.55	388.16	70.37	24.95	**2,370.19**
Turbot	40.14	6.88	2.82	1.49	13.37	2.44	**67.14**
Total	**1,920.88**	**1,243.71**	**798.11**	**547.21**	**2,359.11**	**2,834.95**	**9,703.97**

In ICES square 41F7, the total annual average catch is 3,164 tons with an estimated value of 25,6 mil. DKK (Table 5-5). With a lower total weight of the catch but nearly the same average estimated earnings, ICES square 41F7 could be characterised as the area with the most valuable fish.

Although local vessels caught a little more than 60 % of the total landings of area 41F7, local vessels were estimated to earning more than four times the amount compared to other vessels with an annual average value of 21.6 mil. DKK. The most important catch in terms of weight was sprat (Table 5-5). This was the case for both local and other vessels. The yearly average catch of sprat from 2009-2019 was 1,519 tons, where local vessels landed approximately 50%. For local vessels, plaice was the species that comprised the second largest landing of approximately 652 tons yearly. Due to the relatively high landing price, plaice was the most important fish species with regards to estimated value for the local vessels, earning just over 8 mil. DKK pr. year. The local landings of plaice comprised 85% of the total landings of plaice from ICES square 41F7. Sand eel was the second most important catch in terms of weight for both local and other vessels. However, the sand eel was characterised as an industrial fish, and the value was thus significantly lower than food fish. The local vessels caught approximately 43 % of the total landings of sand eel.

Table 5-5 The average yearly landings from 2009-2019 in tons and DKK for ICES square 41F7

Average yearly landed tons and value, ICES 41F7				
	Local vessels		**Other vessels**	
Species	*Landings in tons*	*Value DKK*	*Landings in tons*	*Value DKK*
Brill	6,57	306.550	2,66	124.736
Brown crab	42,04	968.865	3,46	78.341
Brown Shrimp	3,71	86.025	0,57	13.152
Cod	91,40	1.582.287	4,92	89.485
Dab	29,43	230.327	4,62	34.354
Plaice	652,04	8.058.159	115,56	1.410.385
Hake	4,16	62.966	0,70	10.485
Herring	13,09	38.179	17,06	50.832
Lemon Sole	2,22	76.945	0,22	7.605
Monkfish	1,48	57.430	0,04	1.569
Sand Eel	226,48	328.368	304,68	362.998
Sole	63,11	5.189.001	8,19	686.432
Sprat	745,01	1.267.578	774,15	1.294.793
Turbot	40,14	2.771.185	6,88	488.257
Total	**1.920,88**	**21.023.864**	**1243,71**	**4.653.423**

The total annual catches in ICES square 41F8 were approximately 1,300 tons and with an estimated value of 7,3 mil. DKK (Table 5-6). Catches in 41F8 were lower compared to 41F7 and 42F7, which was expected due to the low proximity to land – 41F8 is situated just off the Danish Westcoast.

Sprat comprised the largest proportion of the catch in terms of weight. This was the case for both the local vessels and other vessels, and both groups had an annual average landing of sprat of well over 350 tons. For the local vessels, herring was an important species in terms of landed weight, while sand eel was more important for other vessels. However, the most important species in terms of estimated value was the brown shrimp, which was caught just off the coastline using beam trawl. The local vessels were estimated at selling a catch worth of 2.6 mil. DKK on average pr. year. In comparison, other vessels caught approximately 10% of the brown shrimp compared to the local vessels.

Table 5-6 The average yearly landings from 2009-2019 in tons and DKK for ICES square 41F8

Average yearly landed tons and value, ICES 41F8				
	Local vessels		**Other vessels**	
Species	*Landings in tons*	*Value*	*Landings in tons*	*Value*
Brill	0,45	21.592,57	1,01	47.018,70
Brown crab	10,77	247.515,95	0,19	4.723,39
Brown Shrimp	76,64	2.625.299,40	7,28	257.270,88
Cod	6,18	124.230,76	0,19	3.223,41
Dab	6,04	49.618,47	1,13	8.390,88
Plaice	46,13	535.210,43	11,80	135.043,42
Hake	0,07	1.142,96	0,17	2.708,52
Herring	195,65	656.800,47	11,66	39.418,22
Lemon Sole	0,04	1.357,53	0,01	245,21
Monkfish	0,00	14,48	0,00	117,00
Sand Eel	77,41	95.465,89	123,78	158.628,68
Sole	8,36	691.635,30	0,34	28.729,34
Sprat	367,55	642.658,44	388,16	663.828,17
Turbot	2,82	197.906,15	1,49	104.309,18
Total	**798,11**	**5.890.448**	**547,21**	**1.453.655**

In ICES square 42F7, the average landings amounted to just over 5,000 tons pr. year and an estimated value of 25.7 mil. DKK (Table 5-7). This made ICES square 42F7 the most important area in terms of both estimated value and weight of catches. The landings for local vessels were approximately the same as for other vessels. However, the estimated earnings for the local vessels (17.3 mil. DKK) was more than twice the earnings estimated for the other vessels (8.4 mil. DKK).

The species comprising the largest landings in terms of weight was sand eel. Vessels from other ports than the three local ports caught approximately 65% of the total landings. In terms of value, sand eel was the species that earned other vessels the majority of the earnings from ICES square 42F7, with an estimated value of 3.5 mil. DKK. The second and third most profitable species were plaice and hake. For the local vessels, plaice was the species comprising the highest estimated earnings with just over 6.5 mil DKK on average pr. year. Cod was the second most profitable species with approximately 3.2 mil. DKK on a yearly average.

Table 5-7 The average yearly landings from 2009-2019 in tons and DKK for ICES square 42F7

Average yearly landed tons and value, ICES 42F7				
	Local vessels		**Other vessels**	
Species	*Landings in tons*	*Value*	*Landings in tons*	*Value*
Brill	3,93	187.792	0,64	30.380
Brown crab	4,19	93.292	0,96	23.064
Brown shrimp	0,48	9.265	0,24	4.761
Cod	174,50	3.248.873	50,65	921.972
Dab	47,88	370.457	9,26	71.203
Plaice	560,17	6.567.879	134,13	1.554.345
Hake	59,01	987.210	90,91	1.439.850
Herring	35,14	145.401	17,21	53.997
Lemon sole	12,73	445.142	2,70	92.115
Monkfish	10,68	412.453	2,05	78.937
Sand eel	1.342,94	1.808.404	2.493,90	3.521.319
Sole	23,72	1.988.471	4,91	405.272
Sprat	70,37	117.950	24,95	44.739
Turbot	13,37	944.675	2,44	169.593
Total	**2.359,11**	**17.327.264**	**2.834,95**	**8.411.547**

Vessel size

For all three ICES squares (41F7, 42F7 and 41F8), the larger vessels had the largest landings and highest estimated values of the catch (Table 5-8). ICES square 41F7 and 42F7 are the two areas furthest away from shore of the three ICES statistical rectangles included in this analysis. In these two areas, the dominance by the larger vessels was especially pronounced. The reason for the dominance of the larger vessels is simply that the motor power of the smaller vessels is insufficient to travel the distance back and forth to the fishing grounds that far from shore. This statement is verified by the interviewed fishermen (see section 2.7.1). The smallest vessels (<12m) comprise 14% and 12% of the total estimated value and 9% and 4% of the total catch weight in ICES square 41F7 and 42F7, respectively. In comparison, the smaller vessels represent approximately 20% of both the total weight of the catches and estimated value of the catches in the ICES square nearest to shore (41F8).

Table 5-8 The total landings and estimated value from 2009-2019 for the different vessel sizes.

Vessel size	41F7		41F8		42F7	
	Catch (tons)	**Estimated value (mil. DKK)**	**Catch (tons)**	**Estimated value (mil. DKK)**	**Catch (tons)**	**Estimated value (mil. DKK)**
<10m	156	2.7	2.373	11.1	240	3.4
10-11.99m	3.044	38.6	3.254	7.8	2.474	31.6
12-14.99m	6.581	63.6	6.154	19.6	4.163	46.8
>15m	25.573	185.4	13.552	63.1	50.891	210.4
Total	**35.357**	**290.3**	**25.335**	**101.6**	**57.769**	**292.2**

5.3.4 Fishing seasons

The extent of the fisheries in the North Sea varied greatly over the year Figure 5-5. The largest catches occurred in summer – May through July and especially in June. The lowest catches occurred in winter and especially in February.

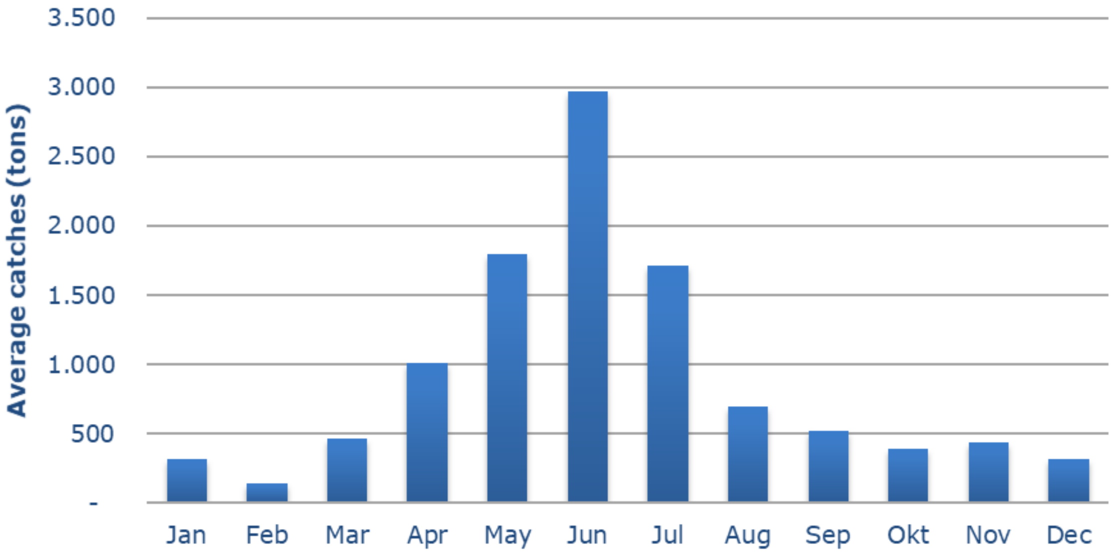

Figure 5-5 The average monthly catches of all species by Danish fishermen in ICES statistical rectangles 41F7, 41F8 and 42F7 from 2009-2019 (Danish Fisheries Agency, 2020).

Most species were targeted during different seasons of the year. Generally, flatfish were caught during spring and early summer (Figure 5-6). Plaice, sole and brill tended to be in season from March through to May, while turbot and dab were slightly later, occurring from April through June. However, plaice was so abundant in the catches that even the month of lowest plaice catches, it exceeded the peak seasons of the other flatfishes.

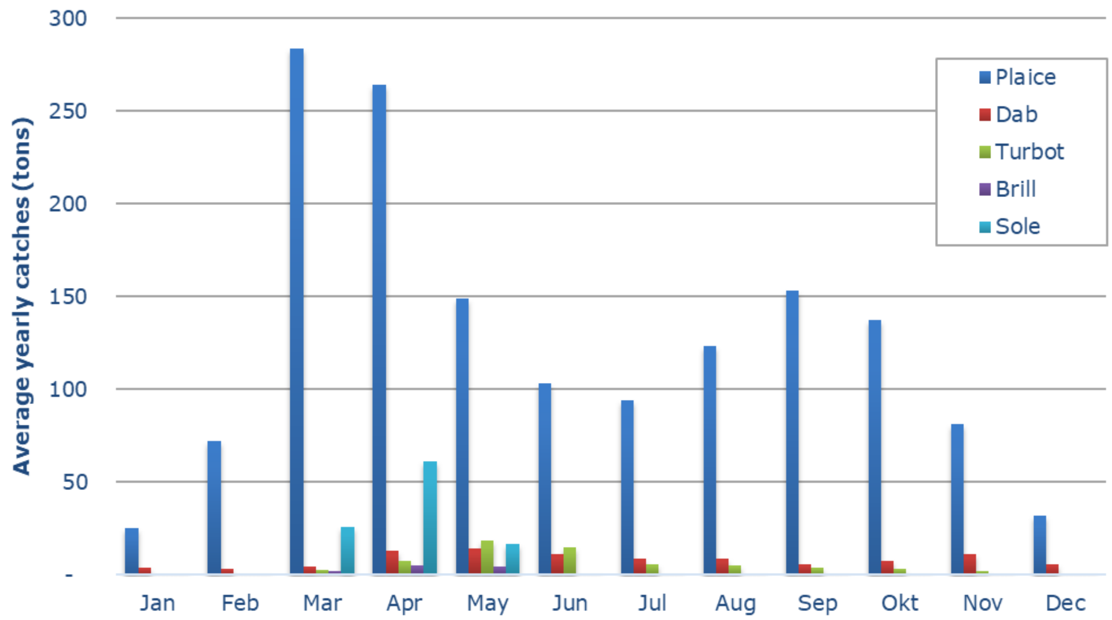

Figure 5-6 The seasonal variation in the average yearly catches of flatfish in ICES statistical rectangles 41F7, 41F8 and 42F7 from 2009-2019 (Danish Fisheries Agency, 2020).

The catches of herring peaked in spring, and two thirds of the total herring catch was caught during April and May (Table 5-9). The same pattern was seen for brown shrimp. Lumpsucker fishery was by far the most seasonal fishery, where 75% of all catches occurred in March only. The fishery targeted cod was more evenly distributed throughout the year with highest catches in November through January. The catches of sprat were highest during summer and then gradually decreased over autumn. Hardly any sprat was caught in winter and spring. Sand eel peaked in June but catches in May and July were also high.

Table 5-9 The high and low seasons for the 11 most caught species in the North Sea ICES 41F7, 41F8, 42F7 in 2009-2019. The figures are tons per year. Red markings are high seasons, yellow markings indicate low seasons and no markings indicate that the species is out of season.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Okt	Nov	Dec
Plaice	25	73	284	264	149	103	94	124	153	137	81	32
Dab	4	3	5	13	14	11	9	9	6	7	11	6
Turbot	1	1	3	8	19	15	6	5	4	3	2	1
Brill	0	0	2	5	4	1	0	1	1	1	1	0
Sole	1	0	26	61	17	1	0	0	0	1	1	1
Cod	40	24	23	21	18	28	21	19	17	26	40	49
Brown shrimp	3	1	6	26	26	9	3	1	1	2	6	5
Lumpsucker	0	1	4	1	0	0	-	-	-	-	-	0
Herring	40	0	11	111	71	18	15	11	6	2	0	4
Sprat	30	-	-	0	13	605	685	445	283	184	113	12
Sandeel	-	-	-	371	1.426	1.997	775	0	-	-	-	-

Table 5-10 Definitions of high and low season and not season for fish catches.

	High season	Low season	Not season
Plaice	>200 t	200-50 t	<50 t
Dab	>10 t	5-10 t	<5 t
Turbot	>10 t	5-10 t	<5 t
Brill	>2 t	1-2 t	<1 t
Sole	>20 t	20-5 t	<5 t
Cod	>30 t	20-30 t	<20 t
Brown shrimp	>20 t	5-20 t	<5 t
Lumpsucker	>2 t	1-2 t	<1 t
Herring	<100 t	25-100 t	<25 t
Sprat	>400 t	100-400 t	<100 t
Sandeel	<1000 t	250-1000 t	<250 t

5.4 Fishing methods

In the following, the intensity of the various fishing types in and near the gross area of Thor OWF is described based on VMS data filtered based on vessel speed. Thus, the VMS points illustrated here only represent active fishing and not vessels passing through the area at high speed to and from fishing grounds. The maps show a yearly average of all relevant VMS points for the past decade (2009-2019).

5.4.1 Beam trawl

For the past ten years, the main beam trawl fishery has occurred in the south western and south eastern part of the gross area of Thor OWF with a line of VMS points located across the central gross area of Thor OWF towards north (Figure 5-7). In addition, along the west coast of Jutland a more intense fishery for brown shrimp occurred, but with a low intensity in the cable corridor area. The beam trawl fishery for brown shrimp is especially intense further south of the cable corridors near Ringkøbing Fjord.

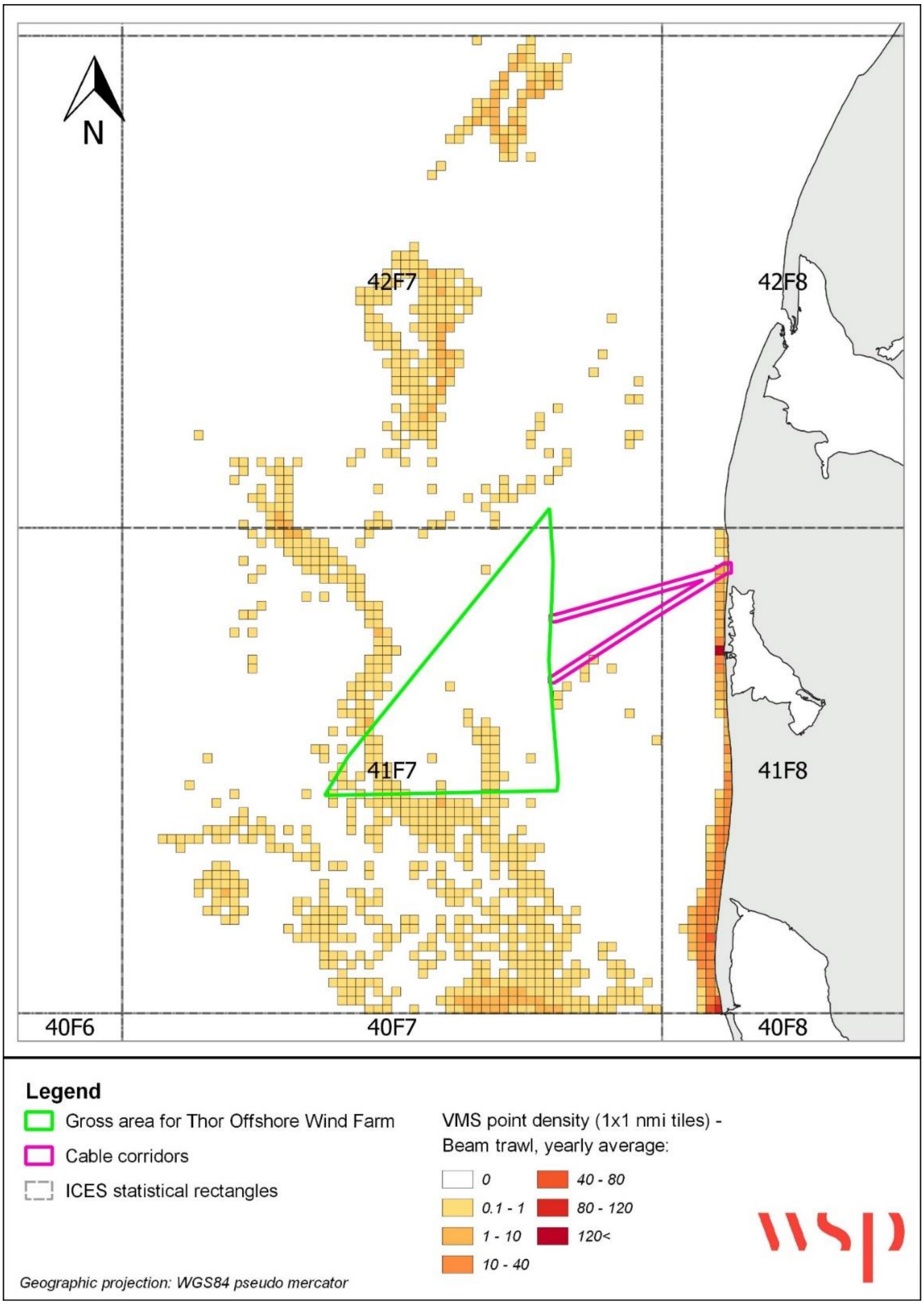

Figure 5-7 The distribution of the main fishing grounds for beam trawl based on VMS data on a yearly average in the period 2009-2019.

When dividing the VMS data into quarters, is evident, that the beam trawling only occurred in the gross area of Thor OWF in the 3rd quarter of the year (Figure 5-8). Beam trawling for brown shrimp occurred in the cable corridors in the 2nd quarter of the year.

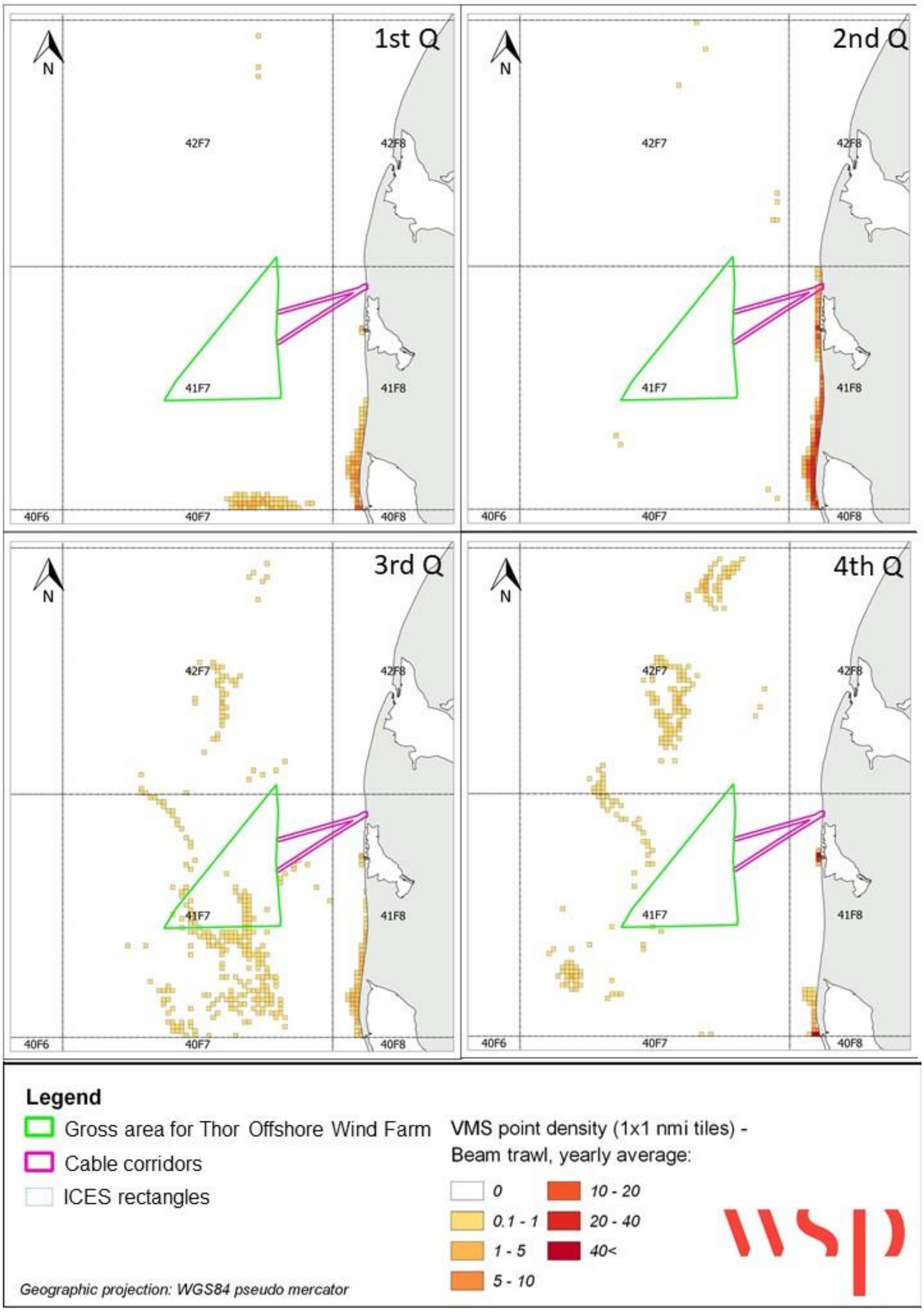

Figure 5-8 The distribution of the main fishing grounds for beam trawl divided into quarters of the year. Data is based on VMS data on a yearly average in the period 2009-2019.

5.4.2 Bottom trawl

For the past ten years, the fishery with bottom trawl has occurred in most of the gross area of Thor OWF, but with increasing frequency towards the south western part of the project area (Figure 5-9). The area is characterized as homogenic soft bottom habitat where even larger trawling vessels can haul the trawl without obstruction from stone reefs or other hard bottom habitats. A somewhat more scattered fishery with bottom trawl also occurs in the cable corridors. The bottom trawling is especially intense in a large area near the coastline just west of Ringkøbing Fjord, stretching to just south of the gross area of Thor OWF. Two smaller but also intense areas for bottom trawling is situated north of the gross area of Thor OWF.

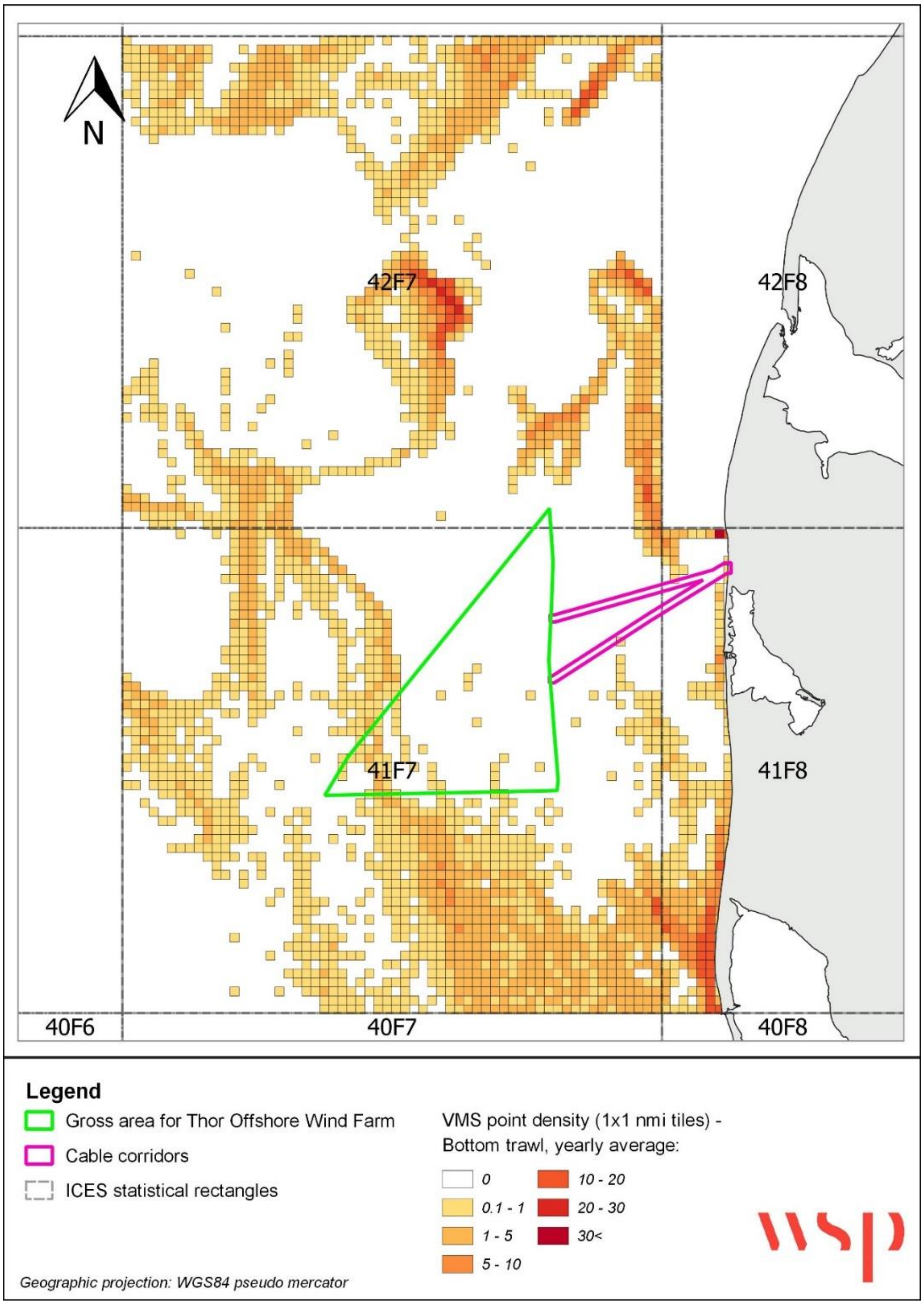

Figure 5-9 The distribution of the main fishing grounds for bottom trawl based on VMS data on a yearly average in the period 2009-2019.

Bottom trawling in the gross area of Thor OWF occurred in the 2nd, 3rd and 4th quarter of the year for the past decade (Figure 5-10). Bottom trawling in the cable corridors mainly occurred in the 2nd and 3rd quarter of the year.

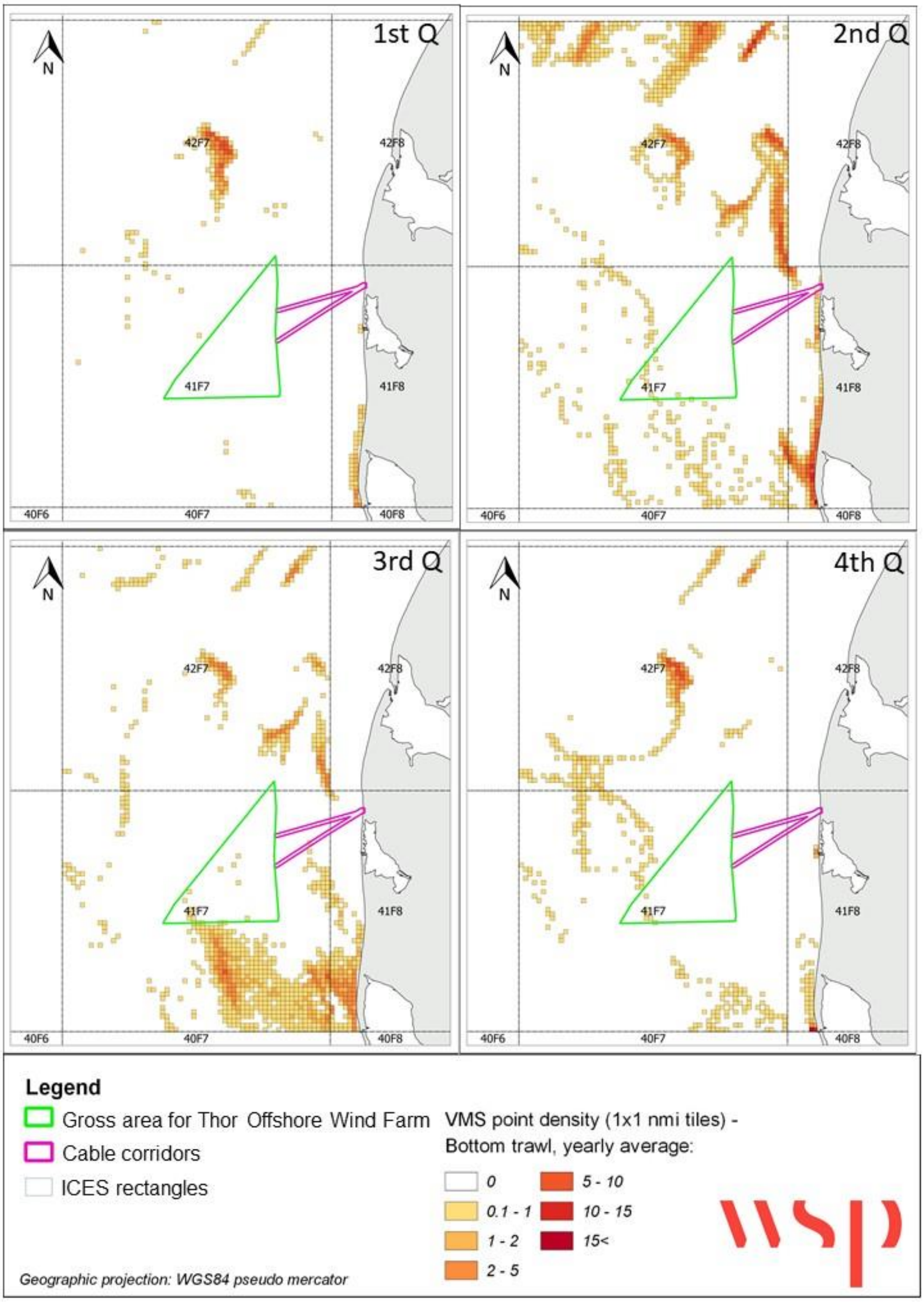

Figure 5-10 The distribution of the main fishing grounds for bottom trawl divided into quarters of the year. Data is based on VMS data on a yearly average in the period 2009-2019.

5.4.3 Pelagic trawl

For the past decade, only very few occasions of pelagic trawling have occurred inside the gross area of Thor OWF and none in the cable corridors, which can also be seen in the map below, which is based on WMS data (Figure 5-11).

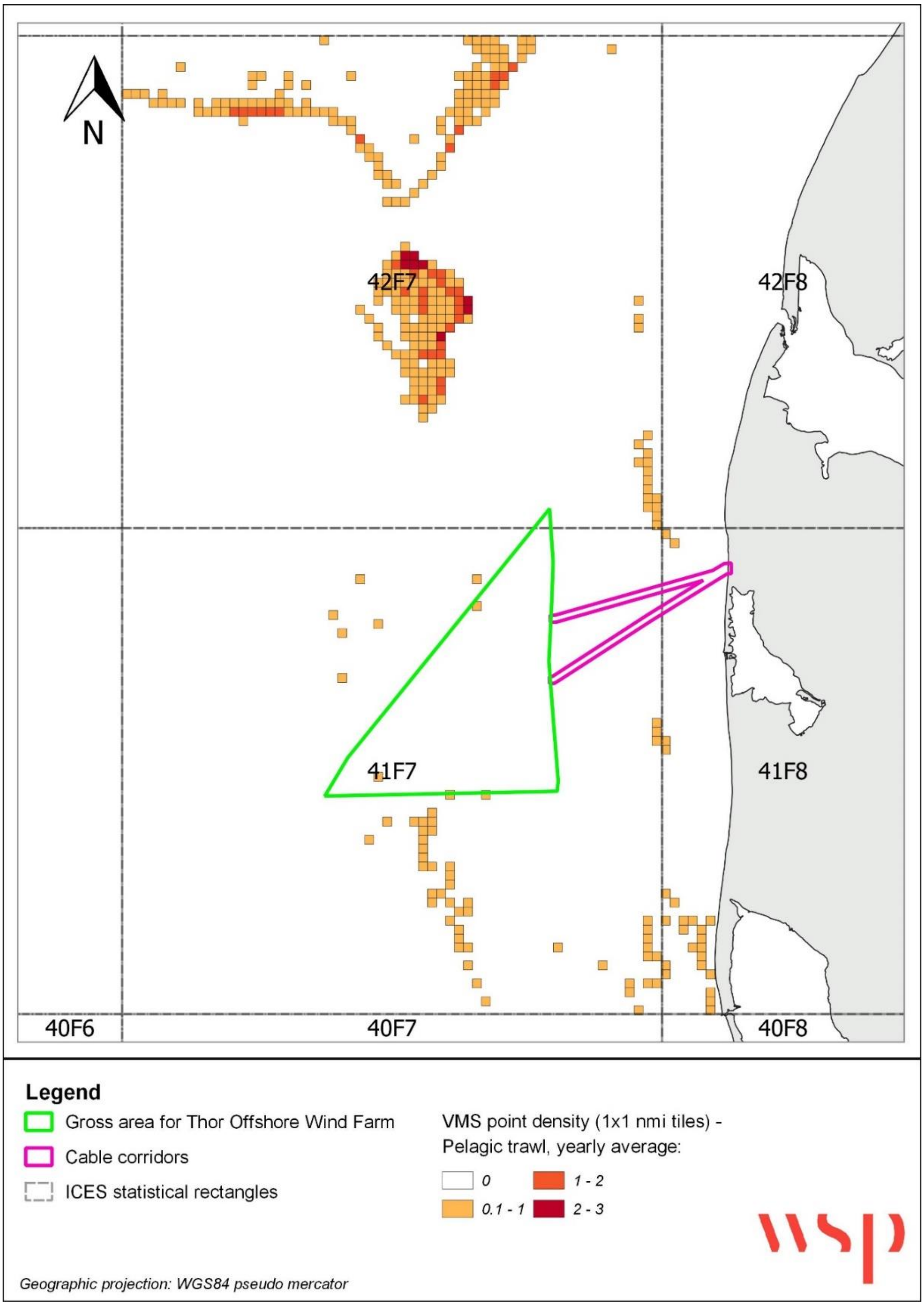

Figure 5-11 The distribution of the main fishing grounds for pelagic trawl based on VMS data on a yearly average in the period 2009-2019.

Pelagic trawling in the gross area of Thor OWF have occurred only in the 2nd quarter of the year for the past decade Figure 5-12. No pelagic trawling took place in the cable corridors.

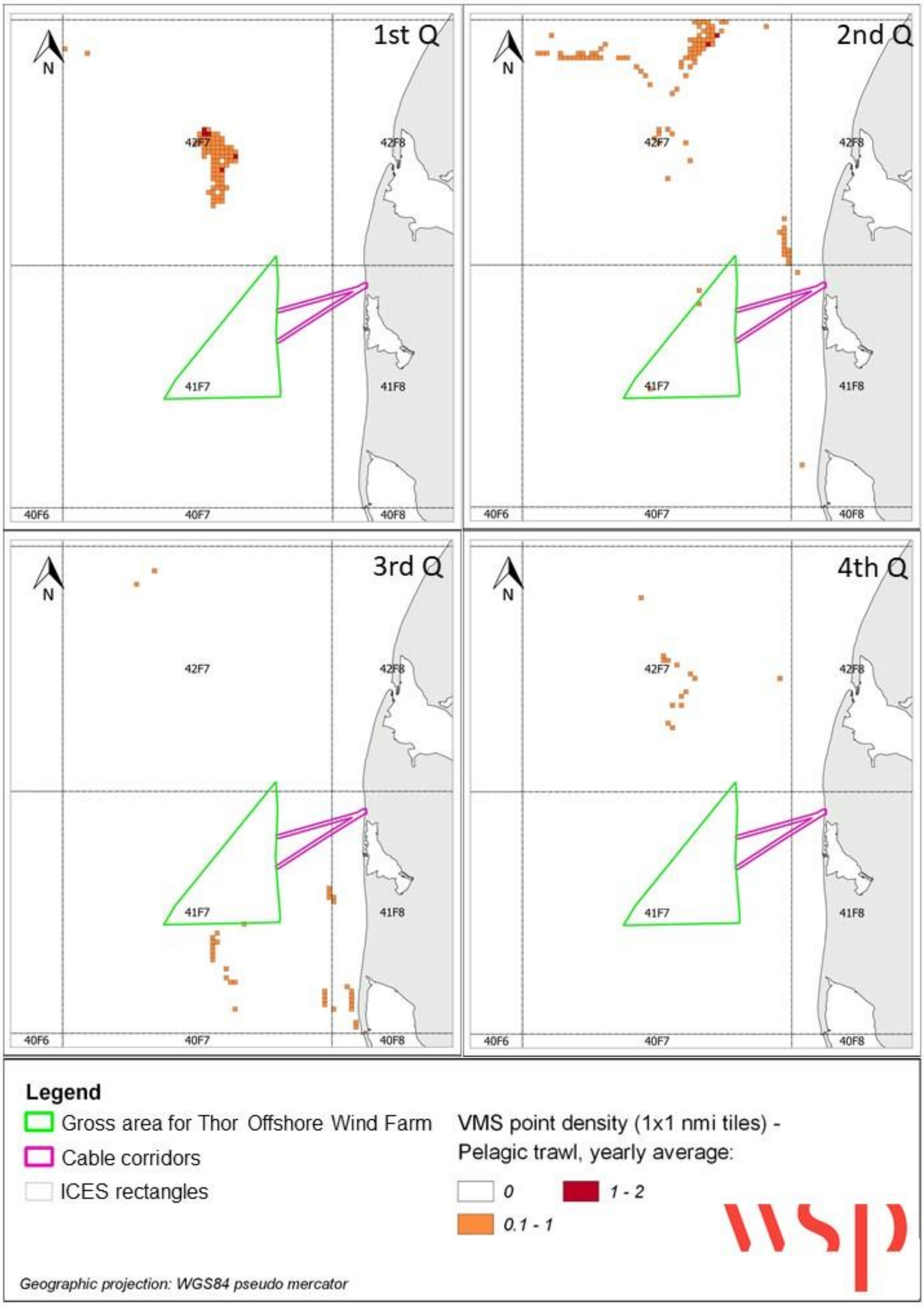

Figure 5-12 The distribution of the main fishing grounds for pelagic trawl divided into quarters of the year. Data is based on VMS data on a yearly average in the period 2009-2019.

5.4.4 Gillnets

VMS data from the past decade showed widespread gillnet fishery in the North Sea (Figure 5-13). Gillnet fishery occurred in the entire area, except for the northernmost tip of the triangle and more scattered in the central gross area of Thor OWF. The gillnet fishery was especially intense in the south eastern part of. The gillnet fishery was intense in both cable corridors and with increasing intensity towards east near the coastline.

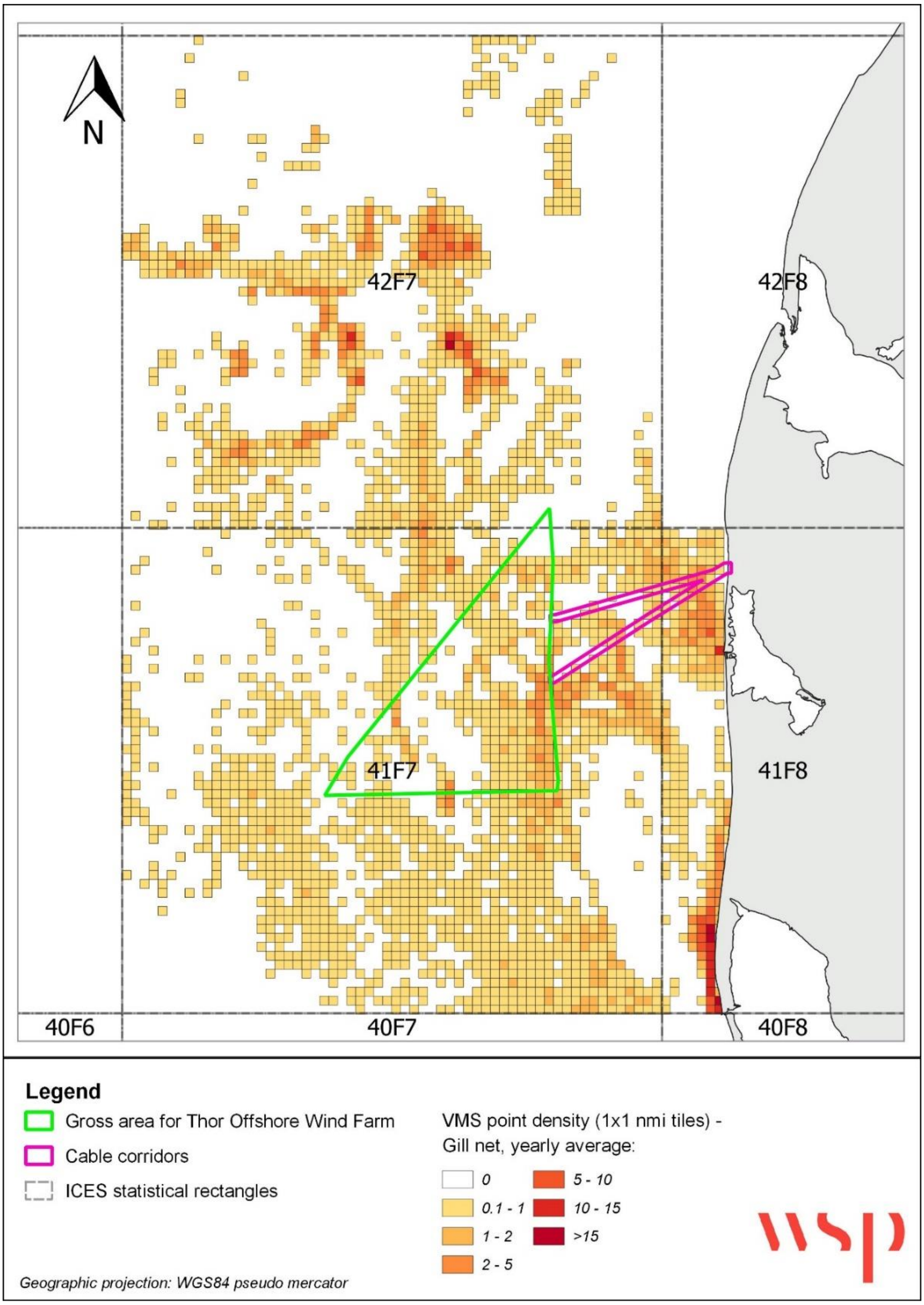

Figure 5-13 The distribution of the main fishing grounds for gill nets based on VMS data on a yearly average in the period 2009-2019.

Gillnet fishing in the gross area of Thor OWF have only occurred in all quarters of the year for the past decade. However, the intensity was highest in the 2nd quarter (Figure 5-14). The gillnet fishing in the cable corridors took place in the 1st, 2nd, and 3rd quarter. However, the intensity was highest in the 2nd quarter.

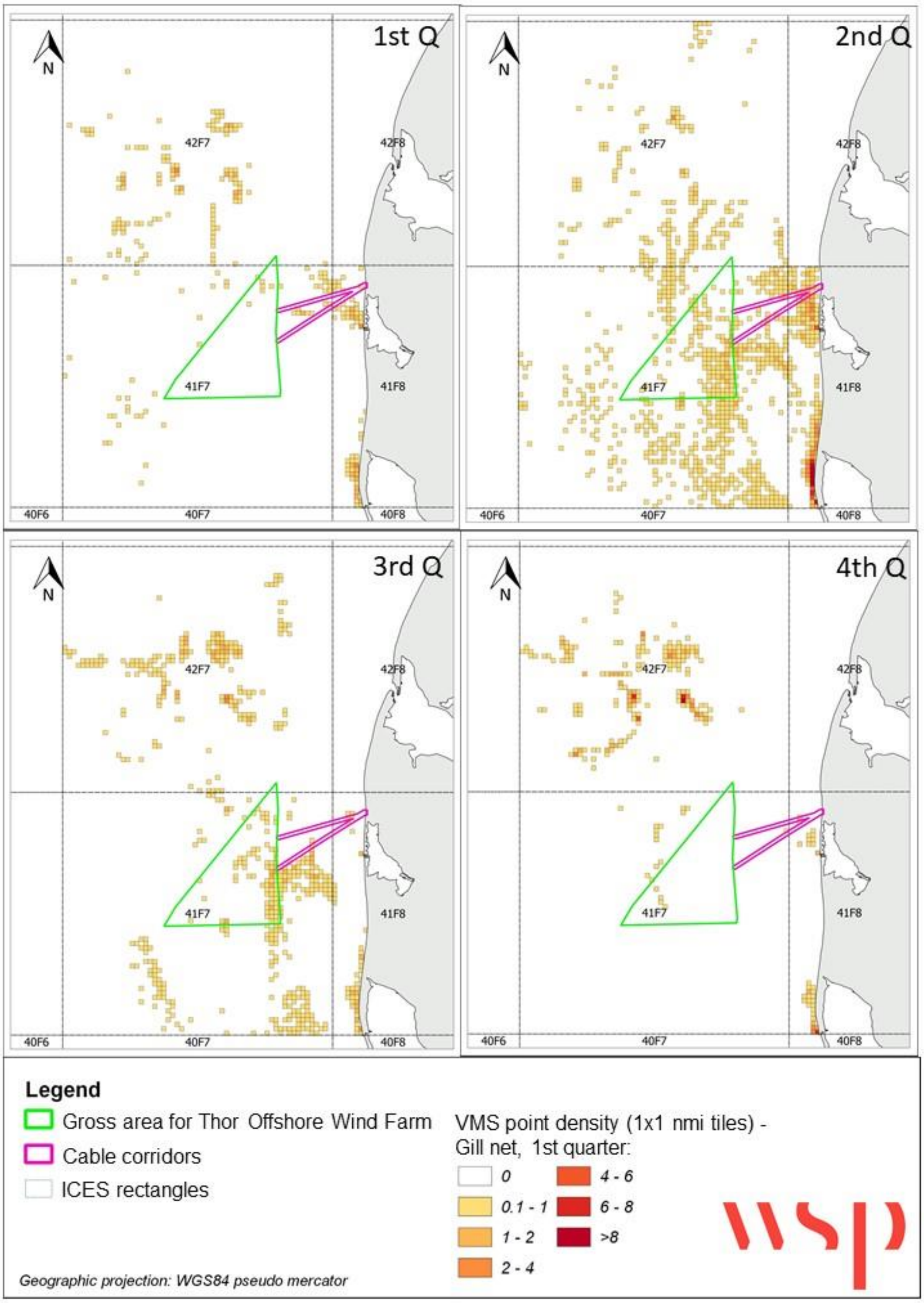

Figure 5-14 The distribution of the main fishing grounds for gill net divided into quarters of the year. Data is based on VMS data on a yearly average in the period 2009-2019.

5.4.5 Seine

Fishery with seine has been very rare and only occurred in the south central part of the gross area of Thor OWF, and in a scattered line from the south eastern part of the gross area of Thor OWF across the centre of the project area (Figure 5-15).

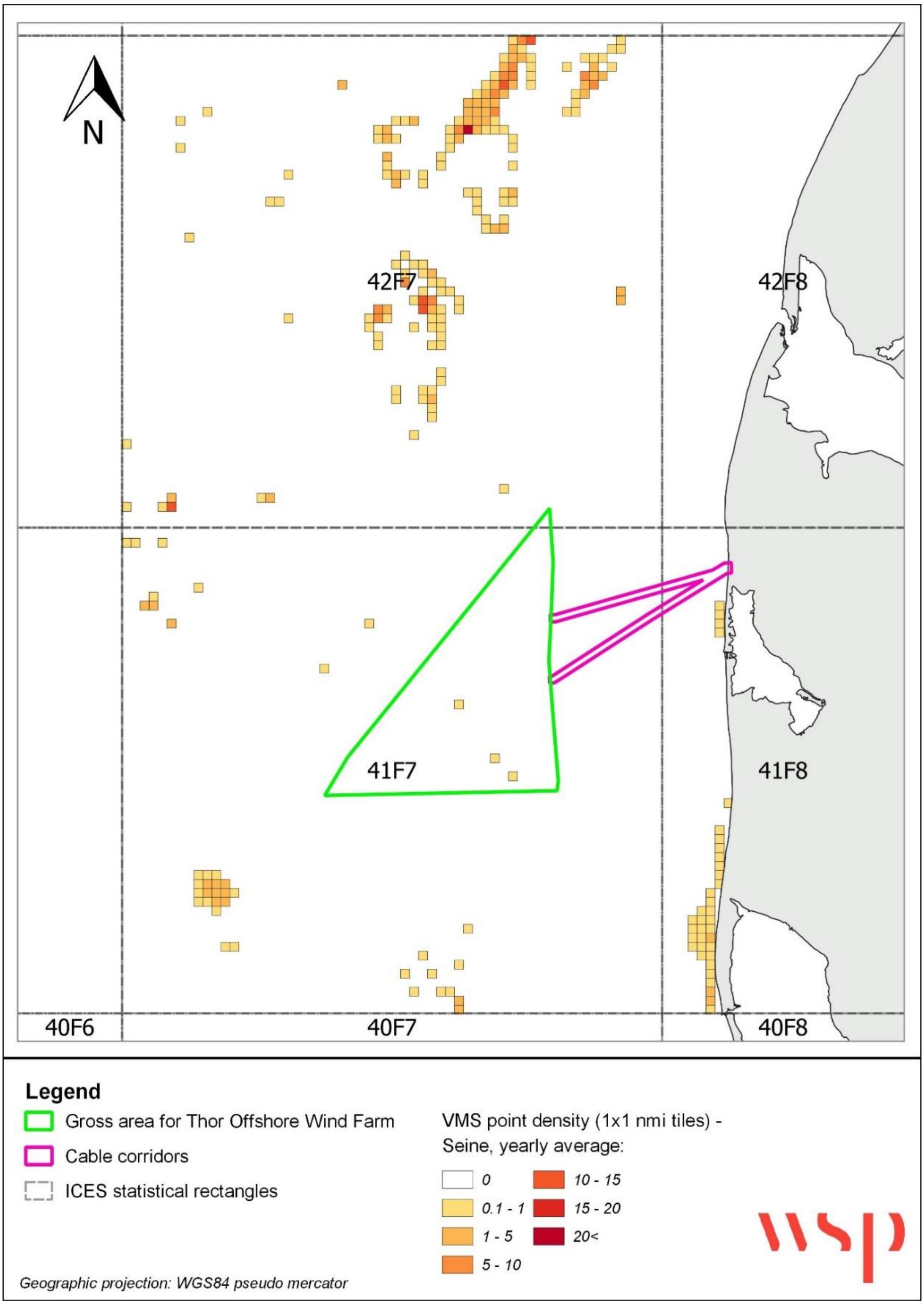

Figure 5-15 The distribution of fisheries with seine based on VMS data on a yearly average in the period 2009-2019.

Seine fishing have occurred only in the 2nd and 3rd quarter for the past decade (Figure 5-16). No Seine fishing took place in the cable corridors.

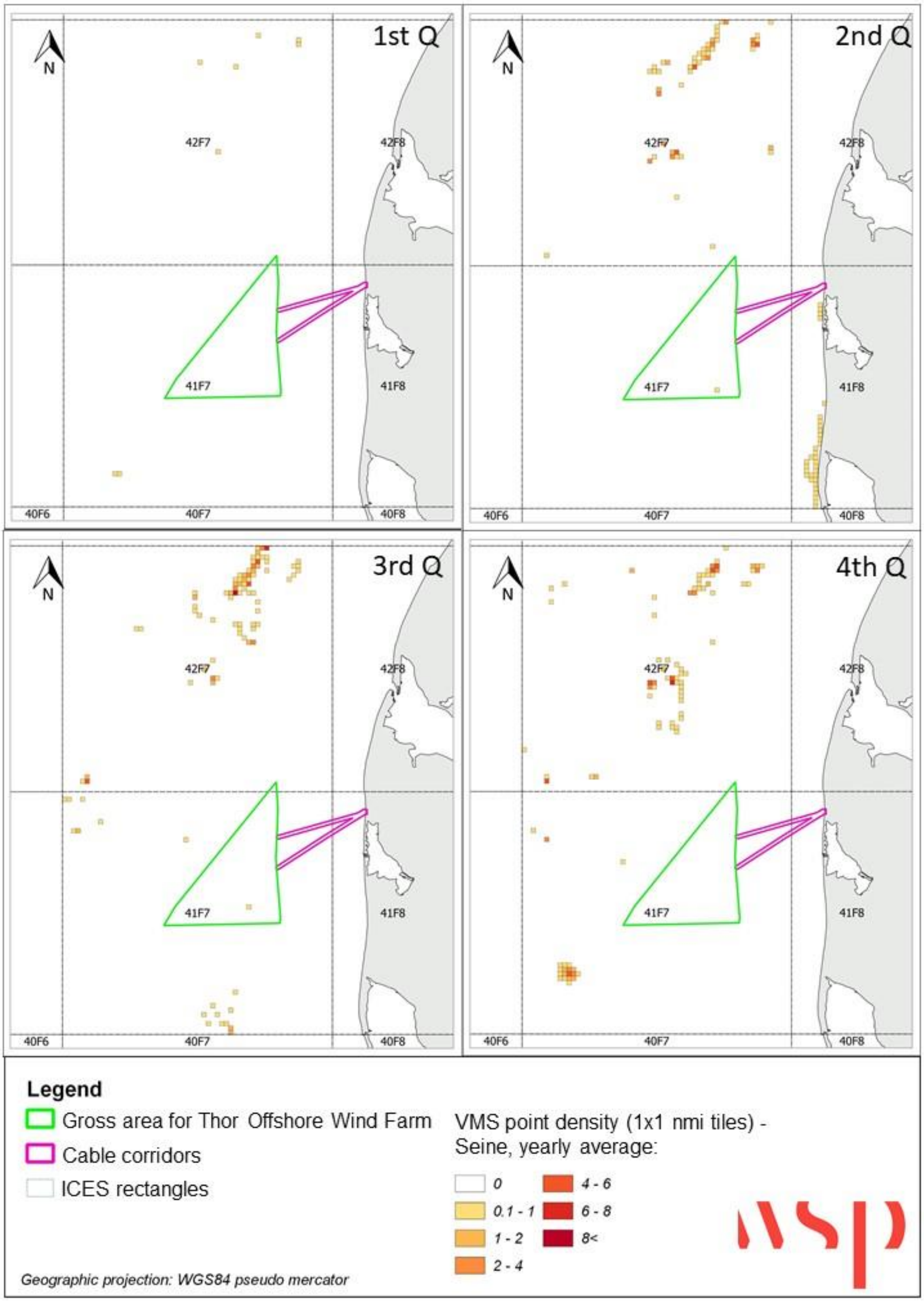

Figure 5-16 The distribution of fisheries with seine fishing divided into quarters of the year. Data is based on VMS data on a yearly average in the period 2009-2019.

5.5 Data from local fishermen utilizing the gross area of Thor OWF

5.5.1 Interviews

A total of three fishermen were interviewed based on requests made to the DFPO, DPPO and FSK fisheries organisations. They had homeport in Hvide Sande and Thorsminde and they all utilized the gross area of Thor OWF for fishing. The vessels were of varying sizes ranging from 9.99 m to 21 m in length. The gear types utilized by the three fishermen were bottom trawl and beam trawl, but they also had previous experience with gillnets in the area. Gillnet fishing still occurs in the area, but no interviews were conducted with active gillnet fishermen.

The beam trawl fishery targets brown shrimp from January to June near the west coast of Jutland crossing both cable corridors.

The bottom trawl fisheries target flatfish such as plaice, turbot and brill with bycatch of especially dab and gurnard. For the larger vessels, this fishery takes place only on the sandy areas of the south western part of the gross area of Thor OWF. For the smaller vessels with greater manoeuvrability, bottom trawling also occurs in the central gross area of Thor OWF where the substrate is more mixed. Especially turbot and brill prefer this sediment type. The bottom trawl fisheries occur from approximately March through October.

Gillnet fishery targets flatfish and cod. This fishery takes place in most of the gross area of Thor OWF, as the gillnets can be deployed almost everywhere except for directly on stone reefs and wrecks, where the nets may get snagged and damaged.

The smaller vessels (<12 m) have limited engine power and cannot fish more than 25 nautical miles from shore. This is approx. at the western tip of the gross area of Thor OWF. Especially on of the two smaller vessels state that most of his fishing occurs in the gross area of Thor OWF today.

The three interviewed fishermen were asked to point out the areas where the location of the turbines would cause the least disturbance to their fishery. The largest vessel (21 m) pointed toward the entire eastern area of the gross area of Thor OWF, as the substrate was too mixed for him to manoeuvre the bottom trawl around the stones and structures on the seabed. For the two smaller vessels (<12 m) the least disturbing location of the turbines would be in the northern part of the gross area of Thor OWF, and possibly also central area towards north west. The substrate here is too mixed and hard for even the smaller trawlers to operate.

The fishermen also point towards important fishing grounds north west of the gross area of Thor OWF and that an important sailing route towards these fishing ground cross the central gross area of Thor OWF.

5.5.2 Fishing effort based on chart plotter data

The obtained chart plotters from interviewed fishermen illustrated the fishing pattern over the past 5 years for different sized vessels and fishing gear. The data varies for different vessel sizes. The smaller vessels of <12 m with bottom trawl target most of the project area for flatfish especially plaice, turbot and brill (Figure 5-17). The larger vessels (20+ m) mainly fish in the westernmost corner of the gross area of Thor OWF and just south and west of that (Figure 5-18). According to the fishermen, the reason for the difference is that the central area of the project area consists of scattered hardbottom habitats where only smaller trawl vessels can manoeuvre between the stones. In the northernmost part of the project area, the density of the stony areas is too high for even the smaller vessels to operate a trawl. Gill nets can still be deployed in the northern part of the gross area of Thor OWF. Furthermore, the reason for the high-quality fishing grounds in the project area is the heterogeneity of the seabed which attracts fish.

Of the interviewed fishermen, primarily the smaller vessel utilized the cable corridors to conduct fishery. Especially the southern cable corridor was utilized for bottom trawling, while the northern cable corridor was not. The larger vessel (20+ m) had only had a few hauls across the cable corridors over the past 4 years, which the chart plotter gathered data from.

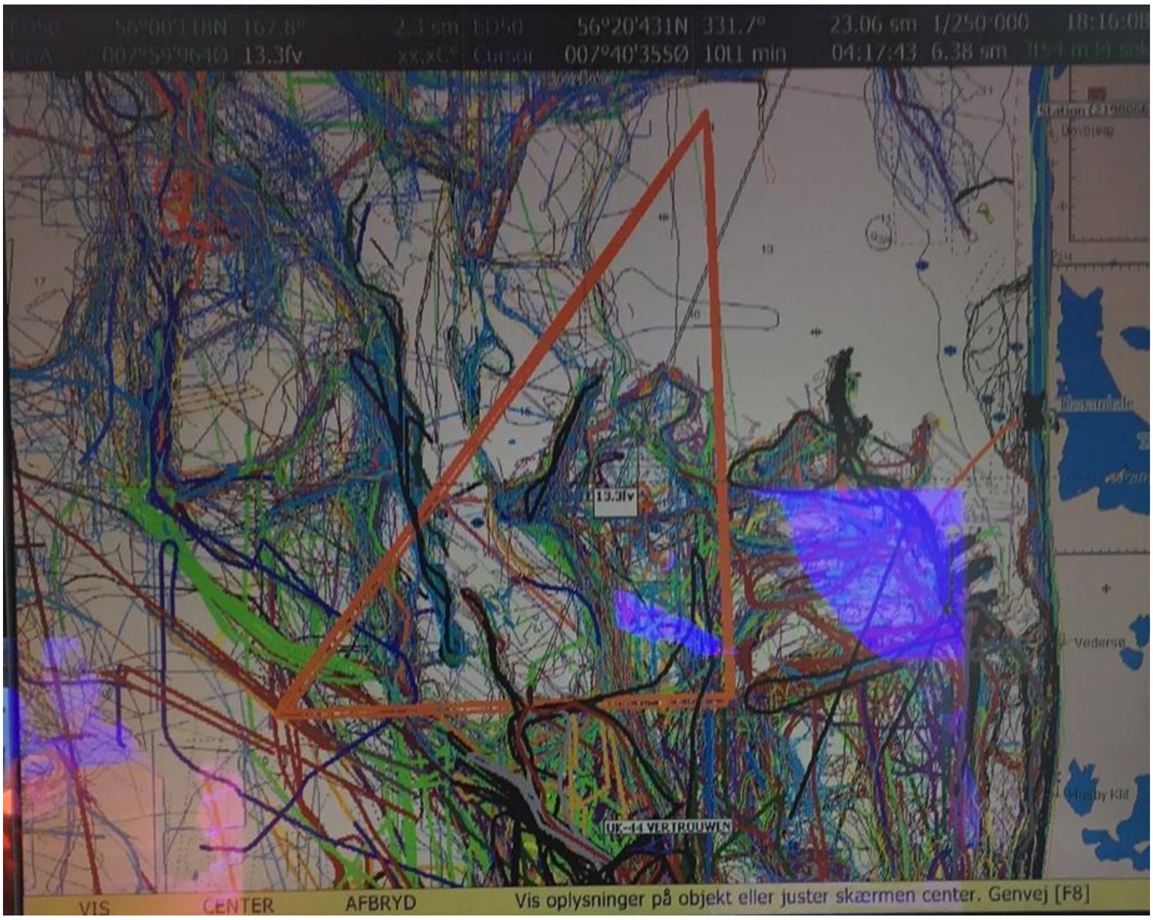

Figure 5-17 Screen dump from the chart plotter onboard fishing vessel LI140 – a bottom trawler of 9.99 m. The chart illustrates the fishing effort over a longer period. The lines represent the fishing effort with bottom trawl for flatfish (plaice, turbot, brill). LI140 sails out from Hvide Sande and trawl towards Northwest in various angles. The project area is illustrated with an orange line. Notice how the small fishing vessel utilize most of the gross Thor OWF area except for the norther part and the northern cable corridor (Photo: Bo Balle-Svendsen)

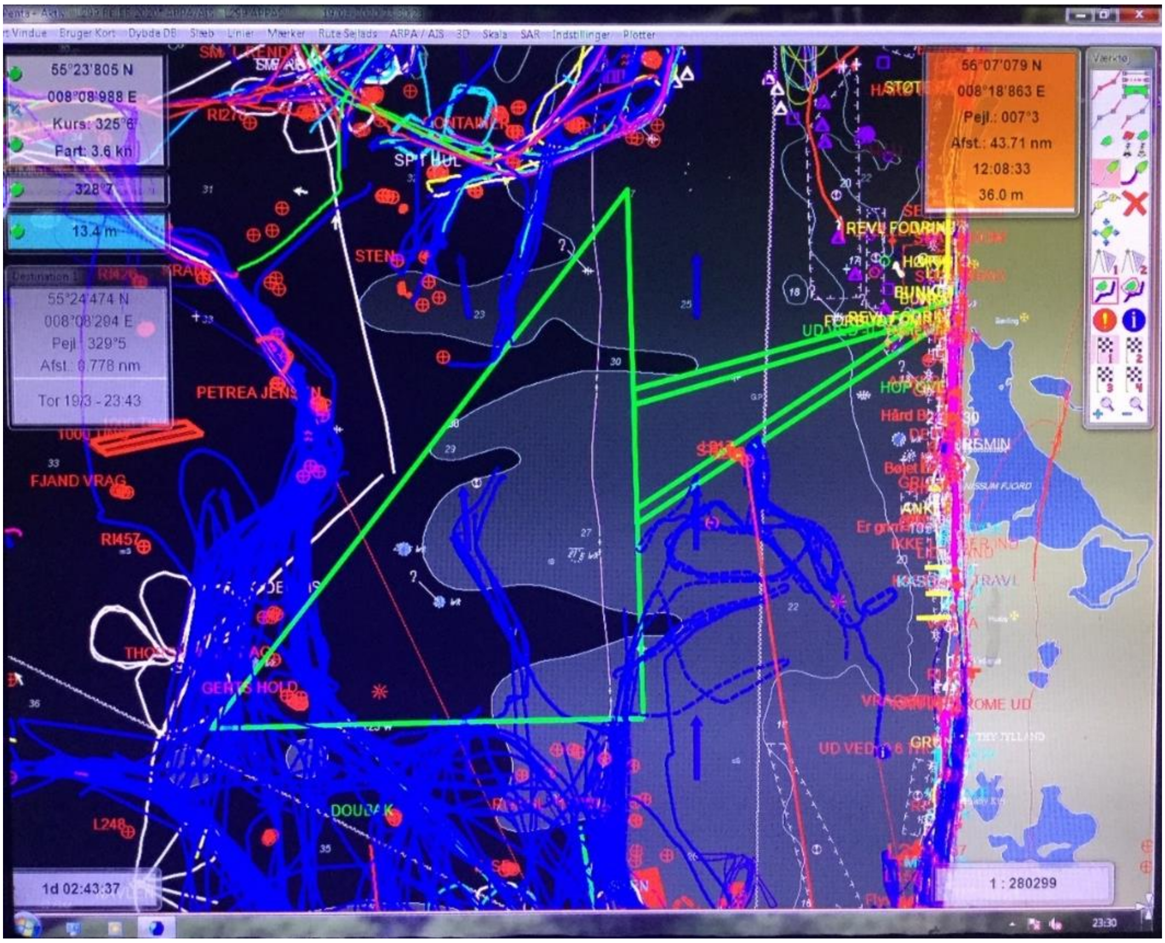

Figure 5-18 Screen dump from the chart plotter onboard vessel L299 – a bottom trawler of 21 m. The chart illustrates the fishing effort in the area for the past 4 years. The tracks east of the project area represent fishing targeted brown shrimp using beam trawl while the tracks south and west of the project area represent bottom trawl fishing for flatfish (plaice, turbot and brill). Notice how the larger fishing vessel rarely utilize the gross Thor OWF area except for the south western area.

6. SENSITIVITY ANALYSIS AND POTENTIAL IMPACTS

In the following, the sensitivity of the commercial fisheries in relation to establishment of Thor OWF and cable corridors is described. A sensitivity analysis of the commercial fisheries is included, and finally potential impacts are assessed.

6.1 Potential impacts

Identification and assessment of potential impacts on the commercial fisheries is carried out based on the activities defined in the plan for Thor OWF.

The THOR offshore wind farm could lead to the following potential impacts on the commercial fisheries:

Temporary impacts (construction phase)

- Temporary safety zones around cables and turbines
- Impact on fish populations

Permanent impacts (operational phase)

- Permanent safety zones around cables and turbines
- Impact on fish populations

6.2 Analysis of potential impacts

In the following, potential impacts of the planned Thor OWF and cable corridors for the commercial fisheries are assessed.

6.2.1 Construction phase

6.2.1.1 Temporary safety zones around turbines

The most important fishing gear types in the gross area of Thor OWF are beam trawl, bottom trawl and gillnets.

The construction of the Thor OWF will may potentially have a negative impact on the commercial fisheries as no fishing will be allowed inside a safety zone around the construction of turbines in the construction phase.

The south-western part of the gross area of Thor OWF is characterised by homogenous sandy sediment (Figure 6-1) which is ideal for dredging gears due to the lack of structures on the seabed. The main fisheries activities here include beam trawl, bottom trawl, gillnet fishery and a limited seine fishery. This complies with the fact that species such as plaice, sole and brill, which are caught in trawl fishery, prefer sandy habitats, where they can easily burry into the sediment.

The south eastern and central part of the gross area of Thor OWF was, according to the interviews with local fishermen, used for trawling by the small vessels. The same pattern is evident from the VMS data of bottom trawl, beam trawl and seine fishery. Gillnetters also fish this area frequently. The substrate of the central south eastern gross area of Thor OWF is characterised by a sandy bottom with scattered gravel and a few areas with mixed substrate, where primarily the smaller vessels can manoeuvre the fishing gear around. This manoeuvrability is lacking in the larger vessels, which therefore tend to avoid the central gross area of Thor OWF (see Figure 5-9).

All fishing vessels except gillnetters avoid the northern part of the gross area of Thor OWF as well as a trail from the central south part of the gross area of Thor OWF and in north-western direction. These two areas are characterised by sandy areas with gravel, mixed substrates and scattered stone reefs. This makes the area unsuited for dredging fishing gear. Gillnetters are more flexible and can deploy their fishing net in most areas of the gross area of Thor OWF, which is evident from the VMS data.

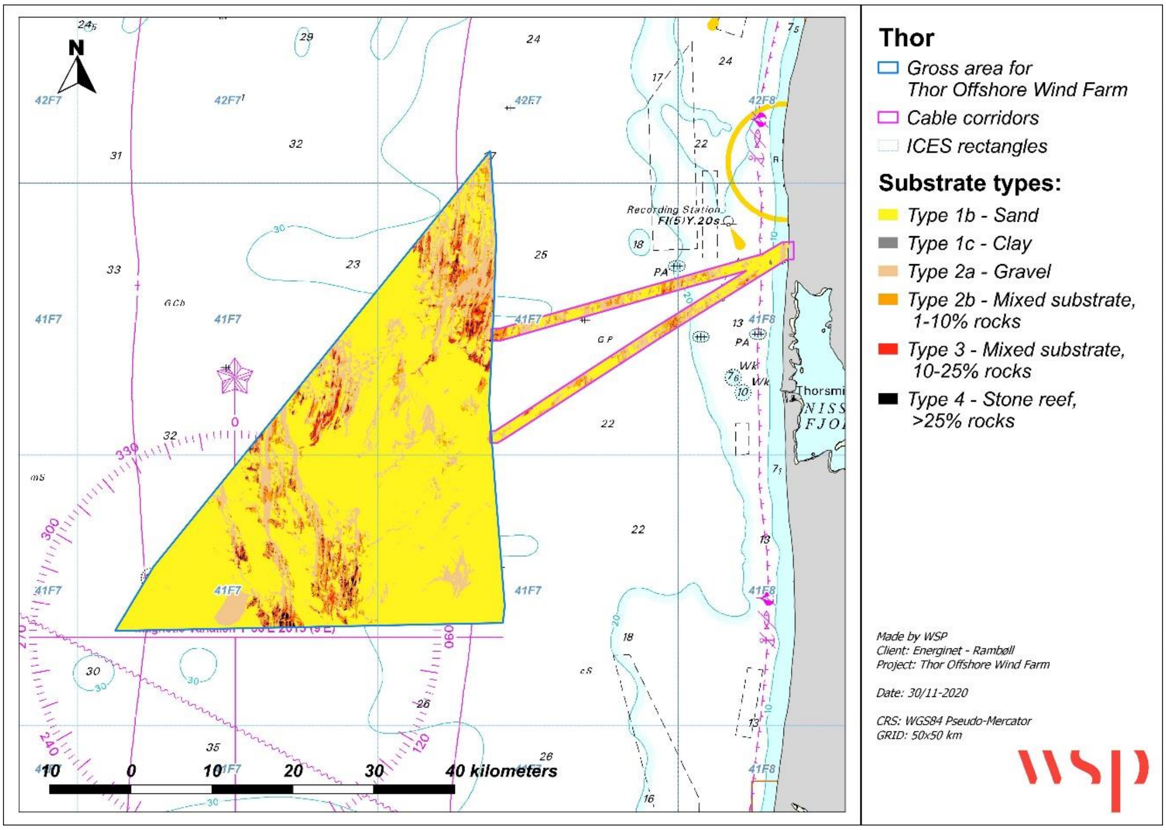

Figure 6-1 Substrate map of the gross area of Thor OWF.

Regarding the fishing activities, the northern part of the gross area of Thor OWF would be the preferable area to locate the OWF, as this is the area of least conflict with the commercial fishery. The area is too heterogenic and has too much structure on the seabed to perform most fishing activity except for gillnetters, which are flexible and can deploy their nets elsewhere during the construction phase expectedly without any major effects on the catches.

With a temporary fishing ban in a safety zone around the construction of the Thor OWF turbines, the commercial fisheries will be negatively impacted. The beam and bottom trawl consist of long hauls of several km where a change in direction is difficult. The establishment of temporary safety zones will potentially result in the trawl fishery moving to other areas where the catch may be less abundant and the fishery less profitable compared to the area fished today, and expenses may increase if travel time to the fishing grounds increase. However, the ban is local and of short duration and the impact for the beam and bottom trawl fisheries is therefore assessed to be *minor*, regardless of location. For the gillnet fishery that can deploy their gillnets almost anywhere, the impact is assessed to be *none to minor*, regardless of location.

6.2.1.2 Temporary safety zones around cable corridors

The most important fishing gear types in the cable corridor area are beam trawl, bottom trawl and gillnets.

The construction of the Thor OWF will inevitably have a negative impact on the commercial fisheries, as no fishing will be allowed inside a safety zone around the construction of cable corridors in the construction phase.

Along the west coast of Jutland, there is an intensive beam trawl fishery for brown shrimp. The northern boundaries of the fishing grounds are just north of the cable corridors, and as illustrated in Figure 5-7, the beam trawl fishery for brown shrimp is far more intense further south near Ringkøbing Fjord. The beam trawl is a large trawl dragged after the vessel for hours, and it is difficult to stop and change direction with this fishing gear.

Extensive gillnet fishery occurs in both cable corridors. But unlike the dredging fishery, the gillnet fishery can move fishing grounds more easily. However, it may still result in a less profitable fishery and increased travel expenses if fishing grounds are moved elsewhere.

The establishment of temporary safety zones will potentially result in the trawl and gillnet fishery moving to other areas where the catch may be less abundant and the fishery less profitable compared to the area fished today and expenses may increase if travel time to the fishing grounds increase. However, the ban is local and of short duration and the impact for the beam and bottom trawl fisheries is therefore assessed to be *minor*, regardless of whether one or both cable corridors are chosen for the further Thor project. For the gillnet fishery that can deploy their gillnets almost anywhere, the impact is assessed to be *minor*, regardless of whether one or both cable corridors are chosen for the future project.

6.2.1.3 Impacts on fish populations

During the construction phase, the largest impacts on the fish and fish populations are expected from increased sedimentation and underwater noise from the piling of the turbine foundations. However, both in terms of increased concentrations of suspended sediment in the water column and increased underwater noise, fish species are mobile organisms demonstrating avoidance behaviour when conditions become suboptimal. The fish species along the west coast of Jutland are generally adapted to the dynamic environment with frequent occasions of high concentrations of suspended sediment and large transport of sand along the Danish coastline. During severe storms, more than 1 m of sand can be removed or applied (COWI, 2015), and fish tend to flee the area when concentrations become higher than 10-50mg/l (FeBEC, 2013) (Støttrup, et al., 2006). In addition, fish are known to demonstrate avoidance behaviour when underwater noise exceeds 90 dB (Nedwell, et al., 2007). For further details, please see the technical report for Fish & Fish Populations (Rambøll & WSP, 2020). The fish species in the gross area of Thor OWF and cable corridors are assessed to be robust and able to handle local disturbances from the Thor OWF. Even if few individual juvenile or adult fish are injured or die during the construction of the Thor OWF this has no impact on the overall fish populations. Therefore, the impact on the commercial fisheries is assessed to be *minor*.

6.2.2 Operational phase

6.2.2.1 Permanent safety zones around turbines

The construction of the Thor OWF will have a negative impact on the commercial fisheries as a permanent fishing ban will prevent fishing in the permanent safety zone around the turbines in the operation phase.

The mapping of the commercial fishery has demonstrated bottom and beam trawl fishery in the south west and south east part of the gross area of Thor OWF. Extensive gillnet fishery occurs throughout the entire gross area of Thor OWF.

A permanent ban on dredging fishery in the Thor OWF is assessed to impact the commercial fishery the most if the turbines are positioned in the southwest or southeast part of the area, where the fishery is most intense. It is possible to move the dredging fishery elsewhere, but it may result in lower catches and increase the travel distance to reach the fishing grounds and thereby also the expenses combined with it.

It is expected that gillnetters may deploy their gear inside the permanent safety zones. The impact on the gillnet fishery is therefore limited. The gillnetters may even benefit from the reef effect expected from the foundations and scour protection of the turbines where several fish species are known to be attracted due to the shelter from water current, shelter from predators and increased feeding opportunity provided by the structures (Reubens, et al., 2011) (Leonhard & Pedersen, 2006) (van Hal, et al., 2017).

The impact of the permanent safety zones on beam and bottom trawlers is local but of long duration and therefore, it is assessed to be *minor to moderate*, regardless of location. For the gillnet fishery that can deploy their gillnets almost anywhere, the impact is assessed to be *none to minor*, regardless of location.

6.2.2.2 Permanent safety zones around cables

One or two cable corridors will connect the Thor Offshore Wind Farm with the grid connection at land. In the operational phase dredging is not allowed across the cables connecting the turbines and connecting the Thor OWF with the grid at shore (BEK 939, 1992). However, it is possible to apply for a dispensation from this law if the cables are buried deeper.

Beam trawl fishing for brown shrimp occurs along the Danish west coast through both proposed cable corridors. A permanent fishing ban for dredging gear will have a negative impact on the beam trawl fishery regardless of whether one or both cable corridors are chosen for the Thor OWF. The beam trawl is carried out through long hauls where stopping and changing direction is difficult and if there is a permanent fishing ban, the beam trawl fishery will have to move fishing grounds to a less favorable area with increasing travel time and expenses to boot. The ban is local but of long duration, and the impact on the beam trawl fishery is therefore assessed to be *moderate*, regardless of the chosen corridor.

The extensive gillnet fishery occurring in both cable corridors is not expected to be impacted by the permanent safety zones around the cable corridors. The gillnet fishery is expected to be able to carry on fishing in the cable corridor(s) for the Thor OWF. The impact on the gillnet fishery is therefore assessed to be *none*, regardless of whetherone or both cable corridors are chosen.

6.2.2.3 Impact on fisheries resources

In the operational phase, the largest impact on fish and fish populations are expected from electromagnetic fields around the cables between turbines and the shoreline and a so-called reef effect from the structure provided from the turbines and the scour protection.

It is assessed that the risk of electromagnetic currents being higher than the background currents in Danish waters is extremely low but will depend on the final design of the cables.

The turbines and scour protection increase the complexity of the benthic habitat and the added structures function as an artificial reef, attracting certain species of macroalgae, invertebrates and fish species. The artificial reef provides food, shelter from predators and shelter from water current and attracts fish species usually found in hardbottom habitats, such as cod and saithe, which are also economically important species (Reubens, et al., 2011) (Leonhard & Pedersen, 2006). The extent of the colonization depends on the final positioning of the turbines, their depth, level of exposure and current as well as construction material. The reef effect is expected to have a local positive effect on the abundance of reef associated fish, although the effects will be insignificant due to the small overall area comprised by the turbines and scour protection. For further detail on the impact on fish populations in the operation phase, please see the Technical report for Fish & Fish Populations (Rambøll & WSP, 2020). The impact on fish and fish populations from the operational phase is expected to small and local but long term. Therefore, the impact on the commercial fisheries is assessed to be *none to minor*.

6.2.3 Conclusion

The impact of the temporary safety zones around the turbines and the cable corridors on the commercial fisheries will be local and of short duration. Therefore, the impact for the beam and bottom trawl fisheries of the temporary safety zones in the gross area of Thor OWF is assessed to be *minor*, regardless of location. For the gillnet fishery that can deploy their gillnets almost anywhere, the impact is assessed to be *none to minor*, regardless of location. The impact of the permanent safety zones in the cable corridors is likewise local and of short duration and the impact for the beam and bottom trawl fisheries is therefore also assessed to be *minor*, regardless of whether one or both cable corridors are chosen for the further Thor OWF. For the gillnet fishery in the cable corridors, the impact is assessed to be *minor*, regardless of whether one or both cable corridors are chosen for the future project.

The impact of the construction phase on fish and fish populations is not expected to impact the fisheries resources and overall landings. The fish species in the gross area of Thor OWF and cable corridors are robust and able to handle local disturbances from the Thor OWF and will flee the area if conditions become suboptimal in terms of underwater noise and increased concentrations of suspended sediment in the water column. Even if few individual juvenile or adult fish are injured or die during the construction of the Thor OWF this has no impact on the overall fish populations. Therefore, the impact on the commercial fisheries is assessed to be *minor*.

The impact of the permanent safety zones on beam and bottom trawlers is local but of long duration and therefore assessed to be *minor to moderate*, regardless of location. For the gillnet fishery that can deploy their gillnets almost anywhere, the impact is assessed to be *none to minor*, regardless of location. A fishing ban in relation to the cable corridors is local but of long duration, and the impact on the beam trawl fishery is therefore assessed to be *moderate*, regardless of the chosen corridor. The extensive gillnet fishery occurring in both cable corridors is not expected to be impacted by the permanent safety zones around the cable corridors. The gillnet fishery is expected to be able to carry on fishing in the cable corridor(s) for the Thor OWF. The impact on the gillnet fishery is therefore assessed to be *none*, regardless of whether one or both cable corridors are chosen.

In the operational phase, the largest impact on the fisheries resources are expected from electromagnetic fields around the cables between turbines and the shoreline and a reef effect from the structure provided from the turbines and the scour protection. The impact on the fisheries resources from the operational phase is expected to be small and local but long term.

Therefore, the impact on the fisheries resources and, thus, the commercial fisheries is assessed to be *none to minor*.

To summarize, the potential impact on the commercial fisheries is assessed to be from none to moderate. The largest impact is expected to arise from the permanent safety zones restricting the commercial fisheries.

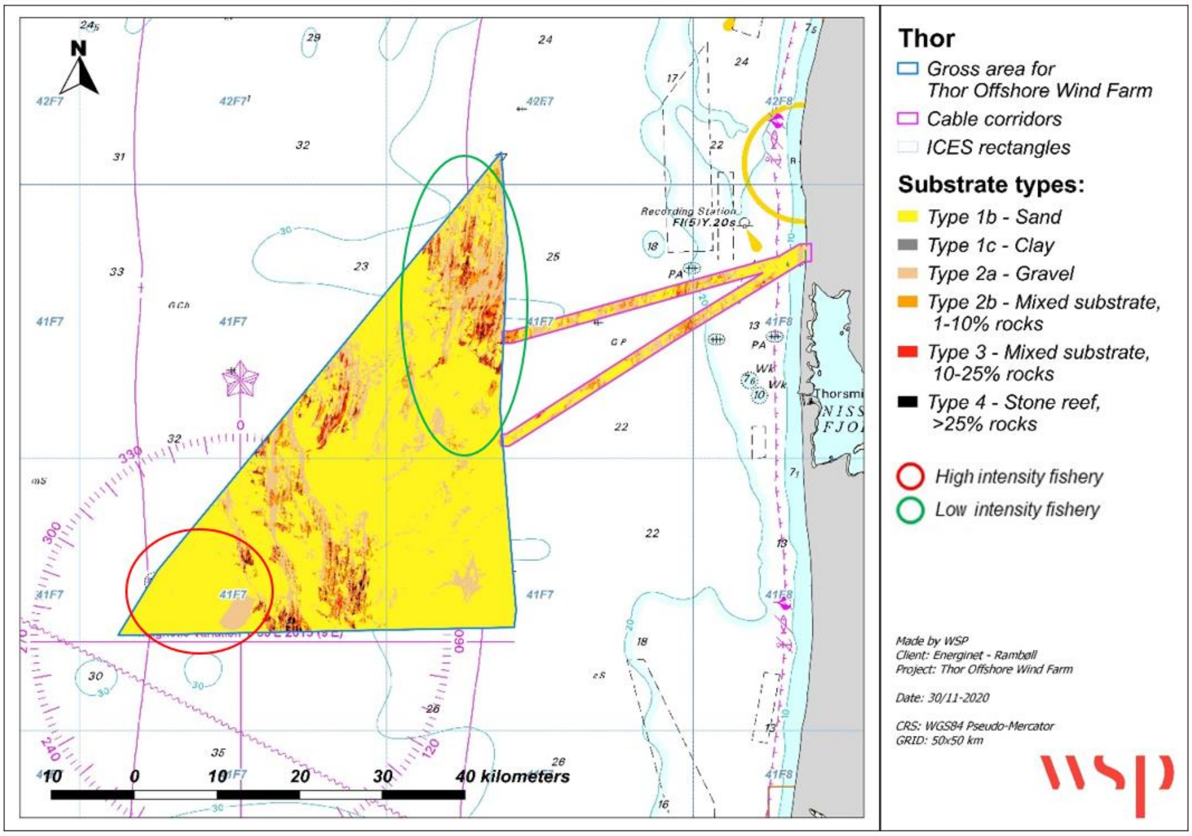

Figure 6-2 The intensity of commercial fishery and sailing routes. Red: high intensity fishery, Orange: main sailing route from Hvide Sande to north western fishing grounds, Green: area of least conflict with the commercial fishery.

6.3 Sensitivity of the commercial fisheries

The sensitivity of the commercial fisheries is determined by impact of the industry based on estimated value.

The commercial fisheries in the North Sea is by far the area where most fish were landed and thereby, represented the largest value in 2018 – 2.2 billion DKK (DFPO, 2019). Trawl fishery accounted for 1.6 billion DKK, while gillnet fishery represented 143 million DKK. The average yearly estimated value of gillnet landings in 2009-2019 of the three relevant ICES subareas (41F7, 41F8 and 42F7) was approximately 28 mil. DKK. Of this, only approx. 16% from 41F7, 0% from 42F7 and 3% from 41F8 was caught in the gross area of Thor OWF and cable corridors. In comparison, bottom trawl has had an average yearly estimated value of 20 mil. DKK in the same period. Of this, 4% originated from the gross area of Thor OWF for 41F7 and less than one percent from 41F8 and 42F7, respectively. It is also important to keep in mind that the future Thor OWF area is smaller (approximately 220 km^2) than the gross area of Thor OWF (440 km^2)

and thus, the impact will be even smaller than what is calculated here. Based on the landings of the commercial fishery is robust and able to handle the Thor OWF, regardless of location.

However, the smaller vessels are not represented in the above VMS data as they are not obliged to carry the VMS onboard. But they are, on the other hand, included in the logbook data with the information on landings and estimated value. According to the interviewed fishermen, the importance of the gross area of Thor OWF may be relatively larger for the smaller vessels (<12 m) with limited engine power and therefore, a limited sailing range.

When consulting the VMS data and the interviewed fishermen, the Thor OWF may impact the commercial fisheries differently depending on the final location of the turbines. The area with more intense fishery is the south western and south eastern part of the gross area of Thor OWF, where both beam trawl, bottom trawl and gillnet fishing occur (Figure 5-7, Figure 5-9 and Figure 5-13). Especially for the smaller vessels with high manoeuvrability, the central part of the gross area of Thor OWF is also utilized for beam and bottom trawling (Figure 5-7, Figure 5-9, and Figure 5-11) and for gillnet fishing (Figure 5-13).

The areas where the future location of the Thor turbines would impact the commercial fisheries least, is the northern part of the gross area of Thor OWF, where the substrate is too complex for dredging gears. The northern part of the gross area of Thor OWF is also the area where the gillnet fishing is least intense, along with the central east part of the gross area of Thor OWF where no gillnet fishing occurs in a circular area (Figure 5-13).

According to the VMS data, no difference is evident for choosing one or both of the two proposed cable corridors. But when analysing the content of the interviewed fishermen’s chart plotters, there appears to be more fishing activities in the southern cable corridor compared to the northern cable corridor. The cause for this is not just the vessel size (and thus engine size and possible sailing range from Hvide Sande), as the larger vessel (20+m) has the same tendency, although less evident.

To summarize, the commercial fishery is most sensitive to placing the turbines in the south western, south eastern and central part of the gross area of Thor OWF. The northern part of the gross area of Thor OWF is the area where the commercial fisheries is least sensitive towards locating the future turbines. With regards to the cable corridors, there is very little difference between the fishing intensity in the two areas. However, based on the interviewed fishermen, the northern cable corridor would be the one with least conflict with the fishery. But, regardless of location, the commercial fishery is robust and able to handle the future Thor OWF and cable corridors.

7. CUMULATIVE EFFECTS

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

Potential cumulative effects for the commercial fisheries is concentrated around restricted access to fishing grounds due to safety zone, temporary or permanent, when constructing or operating OWFs or during sediment extraction from appointed sites.

The following projects are relevant to consider in relation to the cumulative effects on the commercial fisheries (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

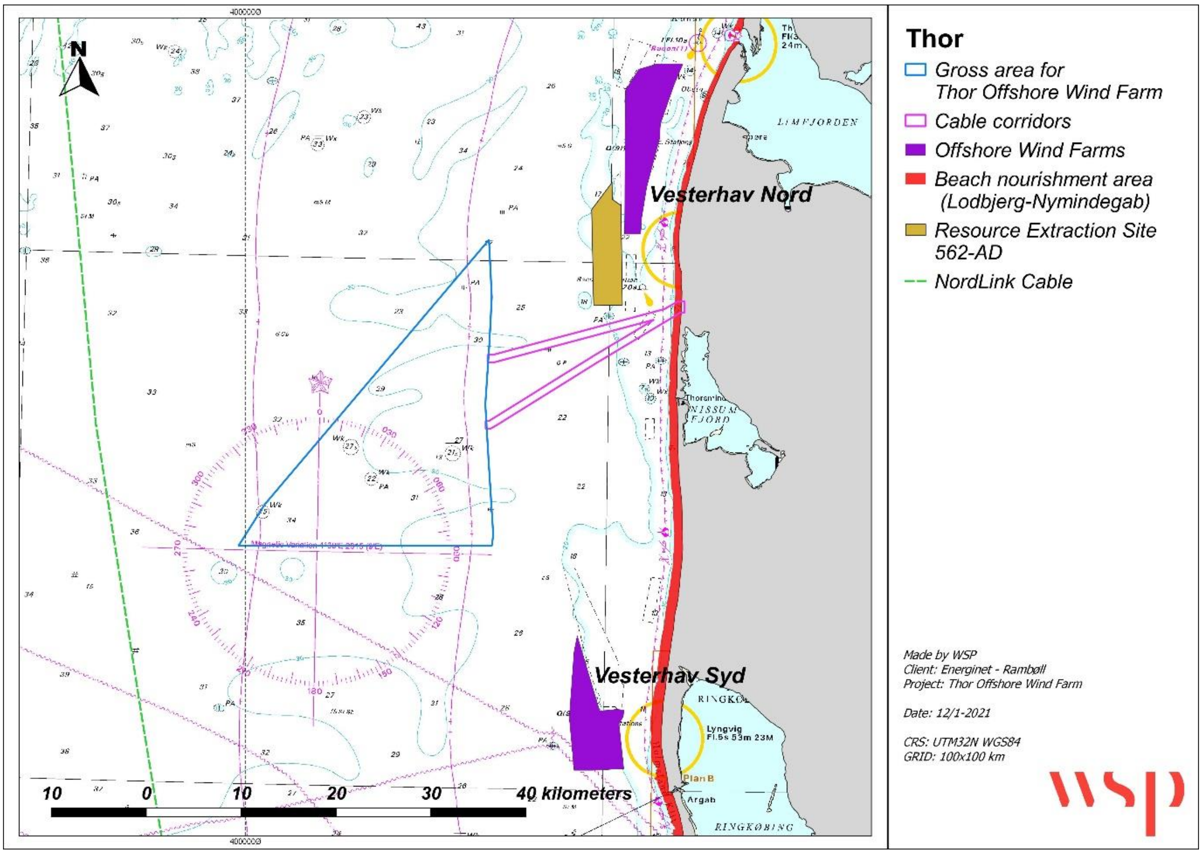

Figure 7-1 Nearby projects that may cause cumulative effects on fish and fish populations

It is expected that construction of the Thor Offshore Wind Farm 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 (located 13-14 km from Thor OWF) are expected to be constructed during 2023 with full commissioning at the end of 2023 (Rambøll, 2020b).

Along the west coast, a few sediment extraction areas are placed – primarily regarding nourishment of the beaches for coastal protection. These extraction sites have a 500 m protection zone only during extraction of sediment. The nearest extraction zone is 562-AD Ferring approximately 1 km north of the planned area for Thor OWF.

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 is expected to be completed in March 2021 (Statnett, 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 trenched into the seabed (NorSea Group, 2021) and fishing in the area is again possible, no cumulative effects are expected on the commercial fisheries.

Specification of overlapping time periods (Rambøll, 2020b)**:**
Based on schedules for the establishment of a Thor Offshore Wind Farm in relation to the Vesterhav Nord and Vesterhav Syd, no cumulative impacts are expected from temporary safety zones and fishing bans, as construction of Thor will not take place until 2024, after Vesterhav Nord and Vesterhav Syd is supposed to be fully commissioned. However, in the operation phase, a permanent fishing ban is expected across all cables from the OWFs to shore. The area along the coastline of Jutland is utilized by beam trawlers targeting brown shrimp.

There can potentially be a cumulative effect in the form of temporary or permanent fishing bans from the construction of THOR and co-occurring sediment extraction from the appointed sites, which takes place every year and is planned in the period (2020 - 2024).

The temporary safety zones from Vesterhav Nord, Vesterhav Syd and Thor OWF is not assessed to have any cumulative impact on the commercial fishery, as the three OWFs are not scheduled to be constructed simultaneously. However, the permanent safety zones from Vesterhav Nord, Vesterhav Syd and Thor OWF will impact the dredging fisheries in these areas cumulatively. This has the biggest impact on the beam trawl fishery which targets brown shrimp along the west coast of Jutland, while gillnetters are still expected be able to fish in the cable corridors. Therefore, the cumulative impact is assessed to be *none to moderate*.

8. MITIGATION MEASURES

To assess the possible necessity of mitigation measures, this report has included VMS data from the past ten years, which has been used as a basis for analysing potential impacts on the following fishery types:

- Bottom trawling
- Beam trawling
- Pelagic trawling
- Gillnet fishing
- Seine fishing

The potential impacts are all considered *none* to *minor* and the owner of the OWF will be required to make an agreement with the fishermen about possible compensation. Therefore, the overall impact is considered to be negligible. Based on the findings, no mitigation measures are deemed necessary.

9. KNOWLEDGE GAPS

Existing VMS and logbook data in combination with the comprehensive field sampling of fish in the gross area of Thor OWF ensures a solid and sufficient base for the baseline mapping and the impact assessment of the commercial fisheries.

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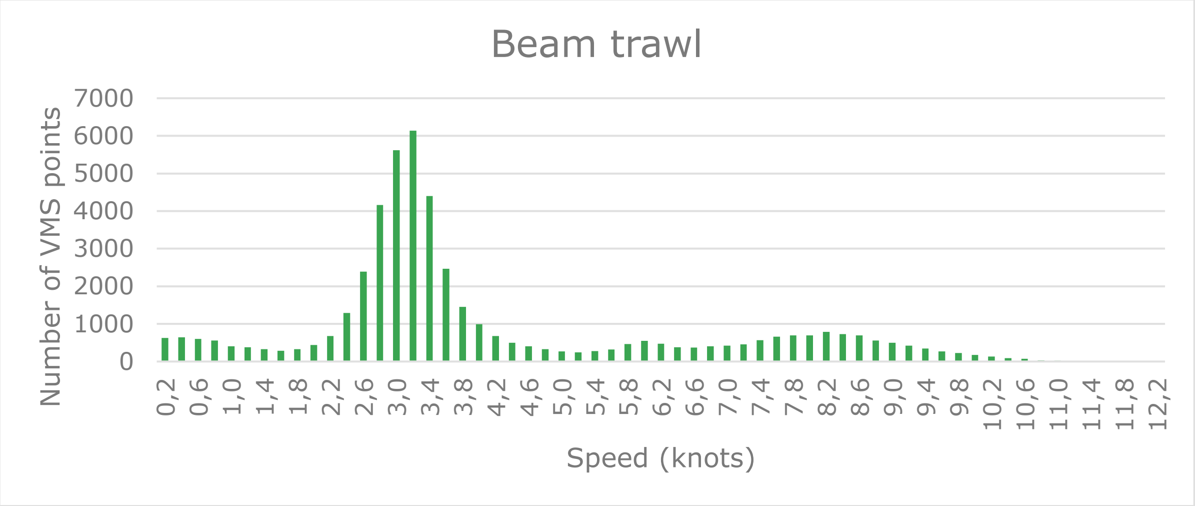
APPENDIX 1
LIST OF INTERVIEWED FISHERMEN

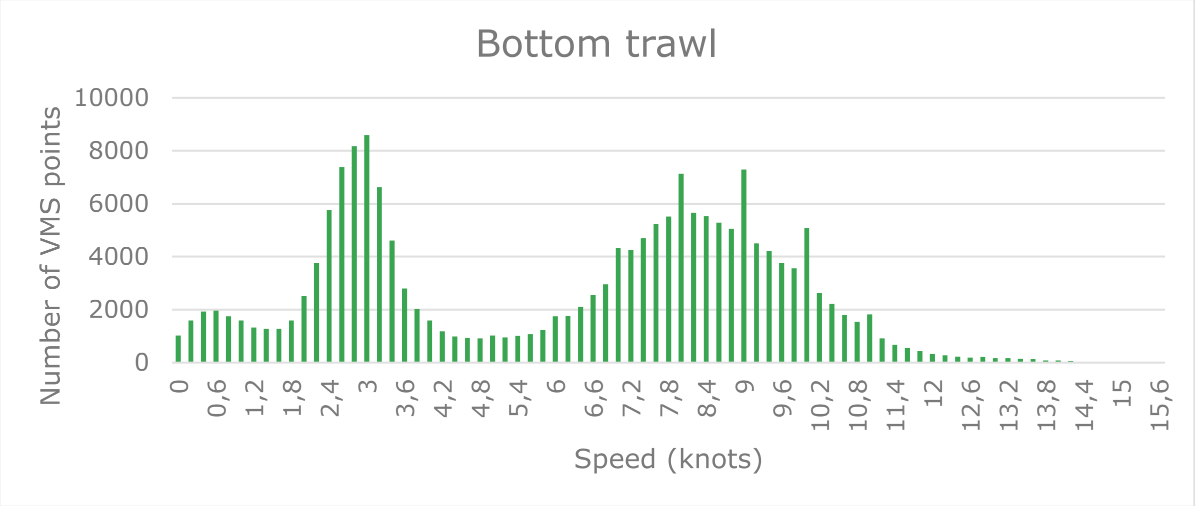
Bo Balle-Svendsen, RI140, Hvide Sande

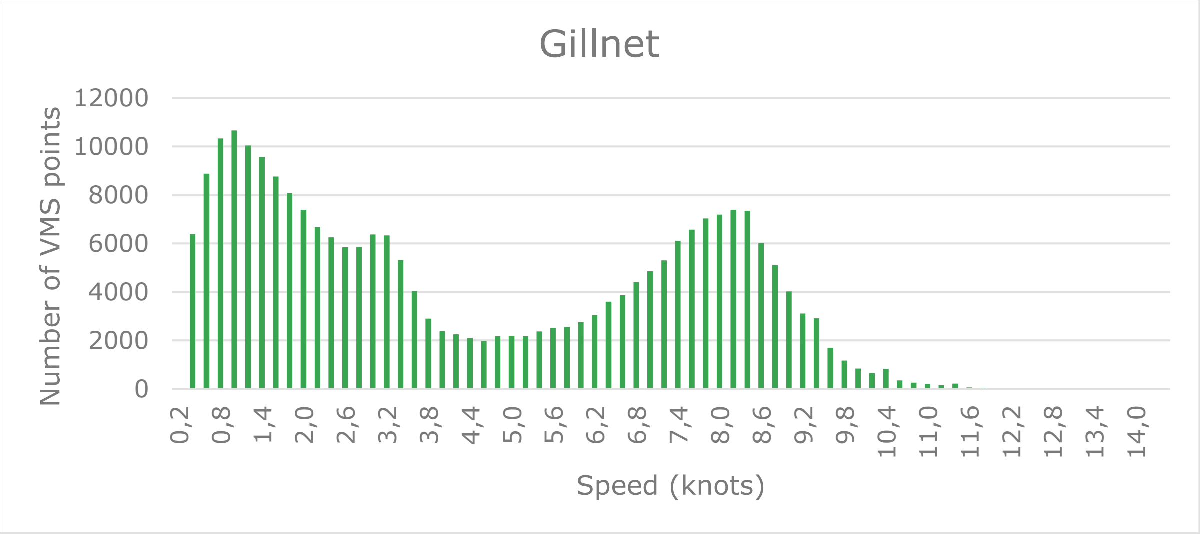
Thomas Hansen, RI146 Polaris, Hvide Sande

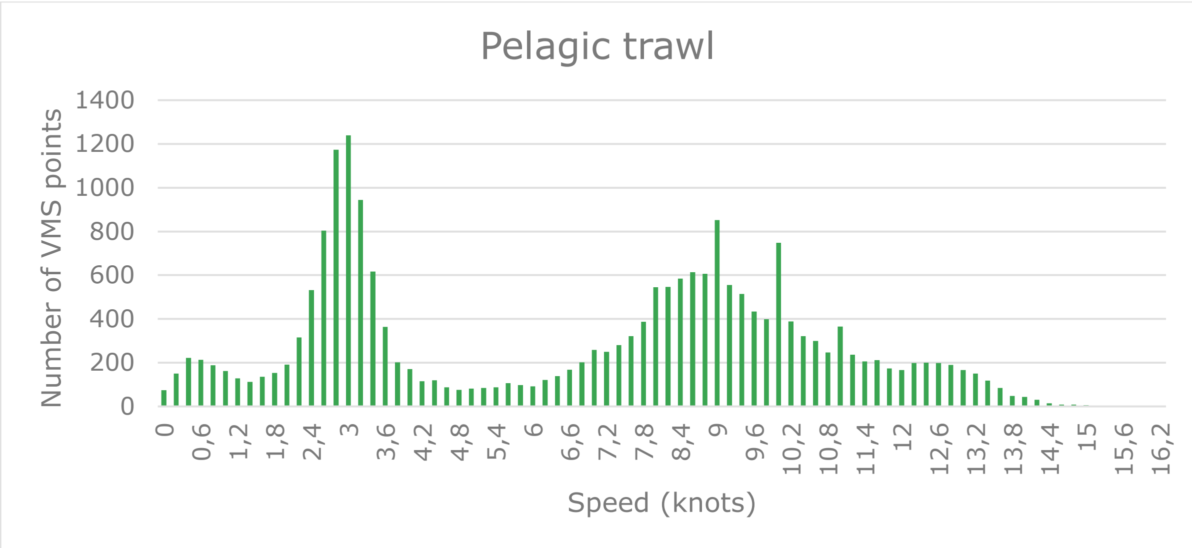
Jesper Kobberholm, Mallemukken L299, Thorsminde

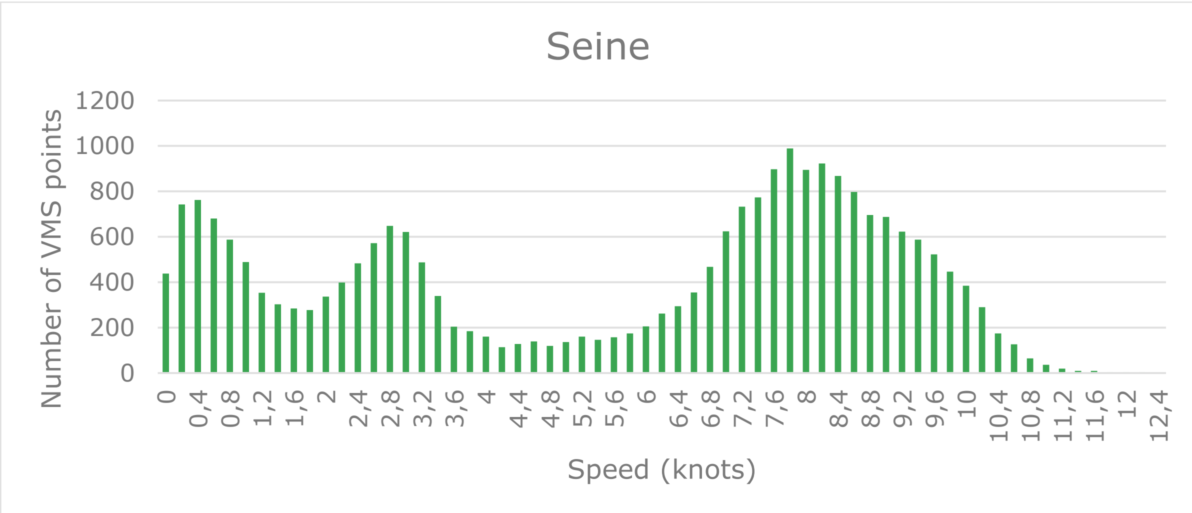
APPENDIX 2
HISTOGRAMS OF VESSEL SPEED AND ACTIVE FISHING








Pelagic trawl
Number of VMS points
1400
1200
1000
800
600
400
200
0
0
0,6
1,2
1,8
2,4
3
3,6
4,2
4,8
5,4
6
6,6
7,2
7,8
8,4
9
9,6
10,2
10,8
11,4
12
12,6
13,2
13,8
14,4
15
15,6
16,2
Speed (knots)


Seine
Number of VMS points
1200
1000
800
600
400
200
0
0
0,4
0,8
1,2
1,6
2
2,4
2,8
3,2
3,6
4
4,4
4,8
5,2
5,6
6
6,4
6,8
7,2
7,6
8
8,4
8,8
9,2
9,6
10
10,4
10,8
11,2
11,6
12
12,4
Speed (knots)