Hesselø Offshore Wind Farm

Fish

Technical report

Energinet Eltransmission A/S

Date: 18. March 2022

Rev.no.	Date	Description	Prepared by	Verified by	Approved by
02	March 17th 2022	Technical report – Fish Final version	JOCA	Carsten Krog, Krog Consult (baseline) IGP, VEST (senstivity analysis)	RHO

Contents

1 Summary

This technical report presents information on the fish species and fish communities present in and near the planning area for Hesselø Offshore Wind Farm (Hesselø OWF) and export cables. Empirical data of fish in the planning area was acquired from fish surveys, which included two trawl surveys (one in the spring and one in the autumn) in soft bottom areas and a gillnet fish survey undertaken in the autumn in the coastal hard bottom areas. This data was supplemented with available information from other existing sources (DTU-Aqua fish studies, ICES data, Helcom database and the Fish Atlas project) to form a baseline description of the fish communities present in the available seabed habitats within the planning areas for the offshore wind farm and the export cables.

Results indicated the demersal fish community in the soft bottom habitats were dominated by a variety of flatfish species with dab and plaice being the most abundant. Other demersal or semi-pelagic fish species of abundance were whiting, grey gurnard, common dragonet, long rough dab and lemon sole and the greater weever primarily in the soft bottom areas during the latter part of the year (autumn). The pelagic species sprat and herring were common in the early part of the year and much less abundant in the autumn. Only 19 cod, of which only a few were adults, were caught in the planned project area. Catches in the near-shore hard bottom habitats were dominated by the stone reef associated gold-sinny wrasse with catches of corkwing wrasse, along with a variety of other species (sole, brill, greater weever, black goby, whiting and a few small cod) with preferences for many different habitats supporting the presence of mixed bottom habitats including stone reefs.

Length frequency diagrams indicated that the planning area for Hesselø OWF and export cables is a nursery area for both dab and plaice. The gonad status from the relatively few adult plaice and dab (most prominent flatfish species) and few adult cod indicated that no spawning was taking place for any of these species during either the spring or autumn survey periods. This was also supported by the general lack of mature adults throughout the surveyed areas.

A sensitivity analysis providing a categorisation of sensitivity of the different fish communities represented as receptors (pelagic fish, demersal fish and early life stages; fish eggs and larvae) to different project pressures (underwater noise, sediment spillage, temporary and permanent loss/change of habitat and electromagnetic fields from operating cables) is presented.

The key pressures for the fish receptors are underwater noise from pile driving of the monopile turbine foundations, for which the sensitivity is medium/high for pelagic and demersal fish communities and high for the early life stages of fish (fish eggs and larvae). Furthermore, fish larvae and eggs are also relatively sensitive to sediment spillage which can have a considerably negative effect on this receptor close to the pressure source where the levels of increased suspended sediment and sedimentation during construction activities are greatest.

For the receptors pelagic and demersal fish sensitivity to the pressures of increased underwater noise from vessel activity and from turbines during operation, sediment spillage, and electromagnetic fields from operating cables is ranked as low or not sensitive.

The sensitivity ratings will be used to support the strategic environmental assessment, at which point pressures will be elaborated on with reference to other factors, such as their spatial and temporal extent to determine an overall impact significance and identify potential mitigation requirements.

2 Introduction and aim

With the Energy Agreement in June 2018 and the following ‘Climate agreement for energy and industry, etc. 2020’ in June 2020, the Danish parliament decided to tender for a new offshore wind farm of 800 – 1200 MW with grid connection in 2027. The offshore wind farm will be located in Kattegat approx. 30 km north of Gilbjerg Hoved on the north coast of Zealand. The wind farm is named Hesselø Offshore Wind Farm (Hesselø OWF) after the small uninhabited island of Hesselø, which is located southwest of the area. The Hesselø OWF will have an installed capacity of minimum 800 MW and maximum 1,200 MW.

The planning area for Hesselø OWF is shown in Figure 2.1.

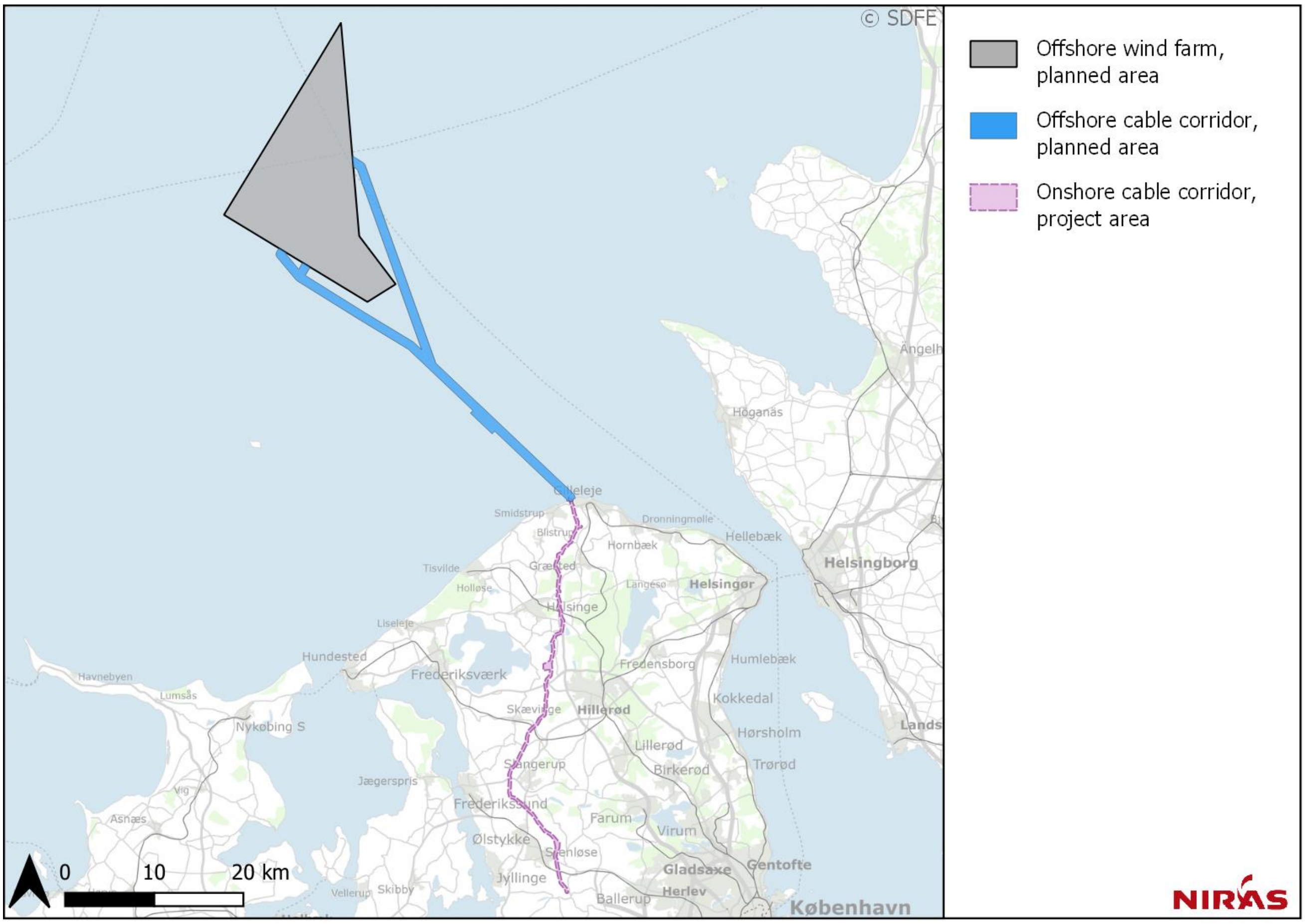

Figure 2.1: Planning area for Hesselø Offshore Wind Farm.

In order to ensure that Hesselø OWF will be supplying electricity by 2027, the Minister of Climate, Energy and Utilities has instructed Energinet to initiate the preliminary studies for the project – both offshore and onshore. This includes strategic environmental assessment (SEA) of the plan for the overall project, completion of relevant environmental surveys etc., investigation of a grid connection from the coast to the connection point at Hovegaard High Voltage (HV) station and preparation of an environmental impact report (EIA) for the onshore facilities.

The location of Hesselø OWF is based on a detailed screening of multiple areas for offshore wind farms in Danish waters carried out for the Danish Energy Agency and reported in spring 2020 (COWI, 2020).

The plan for Hesselø OWF is described in a memorandum from the Danish Energy Agency (Energistyrelsen, 2021a) and in the scoping report for the environmental assessment of the plan (Energistyrelsen, 2021b), which was issued in connection with the first public consultation (February 12th to March 19th 2021).

2.1 Aim

This technical report presents baseline information on fish and their communities expected and observed in the planning area for Hesselø OWF and export cables. The first part of the report presents the planning for Hesselø OWF including a description of project scenarios followed by a method description. The next part of the report presents the existing (baseline) conditions, including data and results from trawl and gillnet fish surveys as well as data and information from other sources concerning fish communities present in and around the proposed plan area of Hesselø OWF, including the export cable corridor. Finally, a sensitivity analysis of fish communities in relation to expected pressures from the activities planned for the construction, operation and decommissioning of the Hesselø OWF is presented.

3 Methods and surveys

3.1 Scenarios for Hesselø Offshore Wind Farm

In the order to Energinet, the Minister of Climate, Energy and Utilities has instructed Energinet to initiate a series of preliminary studies for the offshore part of the project. The results of the studies will be provided to the tenders for the offshore wind farm and will form important input for the environmental impact assessment of the specific project. To ensure that the studies have the right focus and are relevant for an offshore wind farm (anno 2027) of 800 – 1,200 MW, a set of key technical parameters has been considered and a number of scenarios have been developed. The key technical parameters and scenarios are listed in Table 3.1.

Wind turbines with a capacity in the range of 8-20 MW is the base for the assessment. The minimum turbine capacity of 8 MW corresponds to the installation of up to 150 turbines, and the maximum turbine capacity of 20 MW corresponds to the installation of up to 60 turbines. A grid of inter-array cables (66kV) installed in the seabed will connect the individual turbines to the offshore transformer platform, which will connect the wind farm to the onshore grid via 2-3 export cables also installed in the seabed.

Table 3.1: Technical parameters for the scenarios for Hesselø OWF included in this report.

Offshore wind turbines			
	8 MW turbine	15 MW turbine	20 MW turbine
No. of WTGs	100 - 150	54 - 80	40 - 60
Rotor diameter, meter	170	260	280
Hub height, meter	105	150	170
Tip height, meter	190	280	310
Nacelle (length, width, height), meter	20x8x8	29x13x13	32x15x15
Fundaments			
Monopile diameter, meter	10	13	15
Pile driving; hammer size, blow strength and blow rate	IHC S-4000, 6000kJ, 7000 blows. Rate: 4 seconds for 'soft start-procedure' thereafter 2 seconds.		
Scour protection	15 – 20 meter in diameter		
Offshore transformer platform*			
Dimensions (length/width), meter	40/25		
Inter array cables			
	66 kV	66 kV	66 kV
Export cables			
No. of cables	2-3		
Voltage level	220 kV – 345 kV (AC)		
Investigated cable corridor (offshore), meter	1.000		
Distance between cables in Natura 2000 sites/other areas, meter	50/150-200		
Depth of cable trench, centimeter	60-100		
Length of directional drilling (at landfall), meter	Up to 1,000		

* One platform is expected to be established, but two possible locations are included in the preliminary investigations and in the strategic environmental assessment.

The parts of the project located on land are described in the technical project description that forms the basis for the environmental impact assessment of the project on land.

The layout of the offshore wind farm and turbines is not decided at present, as this will be determined by the future Concessionaire. The current assessments have therefore been made at an overall level, taking into account the different variations regarding total installed capacity, sizes of turbines and the consequent difference in the number of turbines and layouts of Hesselø OWF. An environmental impact assessment will be prepared for the specific offshore project by the Concessionaire.

3.2 Characteristics of the planning area for Hesselø OWF and export cables

The planning area for Hesselø OWF (i.e. the offshore wind farm area) located in the southern Kattegat, north of Hesselø, is 247 km^2. The planning area for export cables from Hesselø OWF to the landfall at Gilbjerg Hoved is approximately 70 km^2. Because the objective of the fish surveys was to produce baseline data on the fish species and fish communities for the entire planning area for Hesselø OWF it was essential to know what seabed fish habitats are present to design a satisfactory sampling program and associate fish species with their preferred habitats. Data from EUNIS habitat maps and geological surveys indicated that the seabed characteristics of the wind farm area and the outer cable corridor were predominantly homogeneous soft bottom habitats at depths ranging between 25-34 meters. Here the sediment composition is a mixture of muddy and sandy sediment habitats with small areas in the western part of the wind farm area and outer cable corridor made up of slightly coarser sediment/gravel habitats (Figure 3.1). Closer to the shore of Zealand in the inner section of the cable corridor at depths ranging from 6-20 meters, which includes parts of the export cable that passes through the Natura 2000 site 'Gilleleje Flak and Tragten' (not shown), the seabed habitats become more heterogeneous and are dominated by mixed bottoms of sand, gravel and boulder fields that make up stone reef habitats (Environmental Protection Agency, 2020) (Figure 3.1). The nearshore habitats are described in more detail in the hard bottom technical report (NIRAS & DCE, 2021a).

The hydrography of the water column of the planned project area is permanently stratified with a halocline situated at about 15 meters depth separating a bottom water mass of high saline water originating from the Skagerrak/North Sea from the brackish less saline surface water layer that represents a mix of Baltic water and more saline bottom water. Bottom salinity is approximately 30 ppt or above while the surface salinity is approximately 20 ppt; however, with considerably more temporal variation than the bottom water. Oxygen conditions are generally good and oxygen depletion events occur only rarely in the area.

More details on the seabed characteristics in the Hesselø OWF planned project area can be found in the Hesselø OWF benthic flora and fauna soft bottom and hard bottom technical reports (NIRAS & DCE, 2021b; NIRAS & DCE, 2021a).

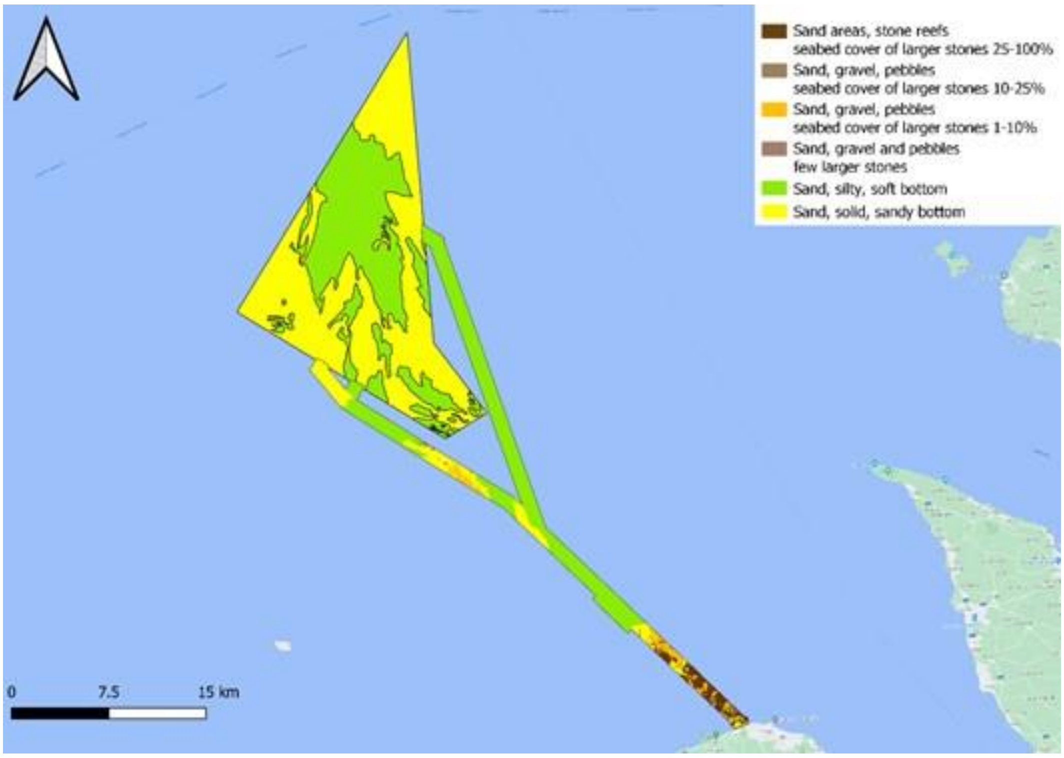

Figure 3.1 Seabed characteristisc of the Hesselø Offshore Wind farm planned project area including the cable corridor to land.

3.3 Fish surveys – soft bottom habitats / hard bottom habitats

The objectives of the fish surveys were to obtain site-specific information on the presence, density and distribution of the fish species in the planning area for Hesselø OWF and export cables and to gain information of the planning area's potential importance as a spawning and nursery area.

In general, large spatial and temporal variability and species- and size-specific variation in catchability with different types of fishing gear, complicates the process of reliably sampling all fish species in the open sea. Spatial variability is particularly large in many pelagic fish species whose distribution is often highly aggregated because they swim in schools and are often less stationary (seasonal/migratory). Furthermore, the presence/absence of pelagic fish is not necessarily associated with seabed habitats, but more often with changing hydrographic conditions (water currents, water temperature, salinity etc.) and the immediate presence of their prey. Thus, the choice of gear for the fish surveys was a specialized bottom trawl that primarily focused on sampling benthic and bottom dwelling fish species (albeit while also catching some pelagic species), as bottom dwelling species are often more stationary and more associated with the seabed habitats where they are present. Because seabed characteristics in the lower section of the export cable corridor route are made up of mixed bottoms (sand, gravel and stones) where stone reef areas are present, it is not possible to trawl in this area. Thus, information on the fish assemblages that are present in the hard bottom habitats in the nearshore cable corridor section were gathered by performing a bottom gillnet fish survey targeting bottom and reef habitats within the same sections that were investigated in the benthic flora and fauna hard bottom survey (NIRAS & DCE, 2021a).

The methods for the fish surveys, laboratory procedures and analysis of results are described in detail in the following sections.

3.3.1 Trawl surveys

Bottom trawl surveys were undertaken in compliance with ICES fish sampling guidelines (ICES, 2014) and gear requirements for fish monitoring surveys that included using a standard TV3 bottom trawl (ICES, 2017). Two bottom trawl surveys were undertaken, one in the early spring to coincide with the spawning period of several important species and one in the autumn to expose potential temporal/seasonal differences in the fish communities and to indicate the importance of the planning area for Hesselø and export cables as a potential nursery area. Based on the homogeneous soft bottom (sand/sand-silt) seabed characteristics in the planning area for the Hesselø OWF turbines, a total of 10 trawl hauls throughout this area and 4 hauls in the outer export cable corridor were considered to be sufficient to obtain data to indicate which fish species are present, their relative abundance, and to obtain length frequencies. Because of the predominantly homogeneous soft bottom habitats, sampling stations were distributed evenly throughout the surveyed area (Figure 3.2).

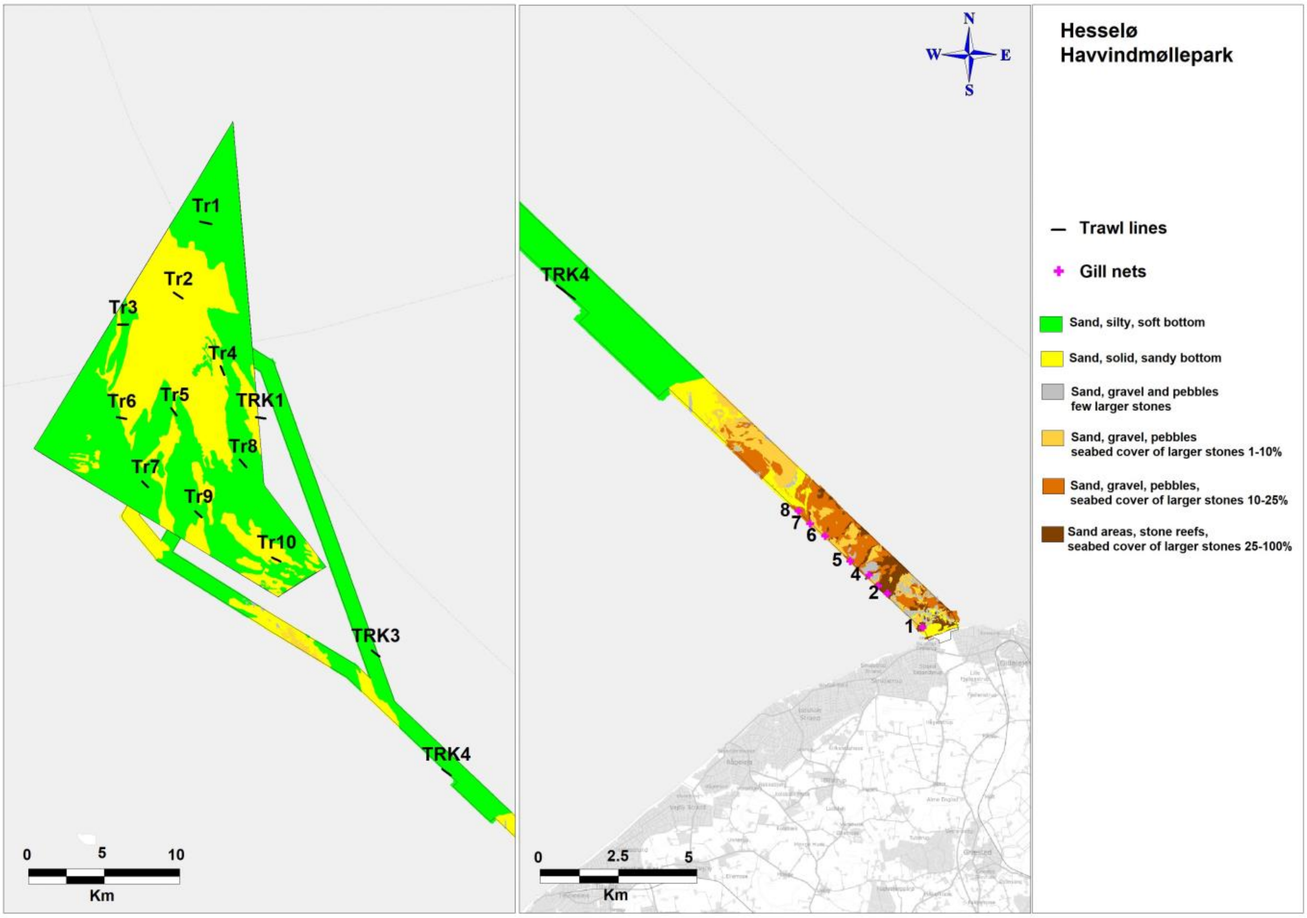

Figure 3.2. The placement of trawl stations in the soft bottom habitats during the spring (April 6-9th) and autumn (October 17-20th) surveys (map on left) and gillnet stations in the near shore hard bottom habitats (map on right).

Both bottom trawl surveys were undertaken using the research vessel "R/V Aurora" (IMO number 9681596). The spring fish survey including mobilization, field sampling and sample analysis of fish was undertaken from the 6-9th of April, 2021. The autumn fish survey including mobilization, field sampling and sample analysis of fish was undertaken from the 17-20th of October, 2021.

The following is description of the design and procedures of the spring and autumn trawl surveys:

- The sampling equipment was a standard TV3- 520/80 survey trawl, which is the standard ICES gear for undertaking fish monitoring and investigations in Danish waters. This trawl is a bottom trawl, however with a relatively high vertical opening designed to sample both benthic and semi-pelagic species. The high vertical trawl opening increases its effectivity for also catching pelagic species, thus increasing the ability of sampling a wider range of species (both benthic and pelagic). Details of the TV3 trawl are described in the Manual for the Baltic International Trawl Surveys (BITS) (ICES, 2014).
- After a screening of the catch and abundance of fish species in the first trawl haul (haul time 30 minutes) in the spring, the standard haul time was set at approximately 15 minutes for the remainder of the survey hauls. This was based on discussions with DTU Aqua on their procedures, where hauls can be shortened under certain conditions (large catches, sampling on relatively homogeneous substrate types or weather). Similarly, after an initial haul of 15 minutes in the autumn survey, haul times were set at approximately 12 minutes to ensure the possibility of sampling all 13 trawl stations in one day with good weather (low wind speeds) between two longer periods of bad weather and high winds (>12 m/s) that would not allow trawling.
- Standard speed for hauls was approximately 2.5-3 knots (speed over the bottom). This led to hauls of approx. 0.8 - 1.5 km long.
- Trawling was only undertaken in daylight hours (determined as the period 15 minutes after sunrise until 15 minutes before sunset. An exception to this was the final haul in the autumn survey that was taken just after sunset to complete the survey due to an expected increase in prevailing winds in the following days. This decision was also based on the knowledge that the catches of the pelagic species sprat and herring were probably most affected by their diurnal activity. These species were already consistently represented in the catches and thus the baseline description of the fish community, and would therefore already be included as fish species present in the area.
- The catch from each trawl haul was sorted onboard by separating the prominent species (typically sprat, dab, herring and in the autumn greater weever) and large fish into separate containers and the rest of the catch into plastic bags and placed in large ice containers until transported back to the laboratory for species determination and analysis (see section 3.4).

3.3.2 Gillnet survey

The gill net fish survey was performed using special NOVANA nets – Ny Nordisk Norm. Each net was 35 meters long and 1.5 meter high and made up of 12 separate sections with mesh sizes ranging from 5-55 mm (Table 3.2). The different mesh sizes allows for a wide variety of fish of different lengths and body forms to be captured. To target larger fish at each station, NOVANA nets were supplemented with 1 extra gillnet of a larger mesh size (either 70 mm or 110 mm) that were 50 meters long.

Table 3.2: Mesh sizes of NOVANA – Ny Nordisk Norm gillnets used in the gillnet survey.

Section no.	1	2	3	4	5	6	7	8	9	10	11	12
Mesh size (mm)	43	19,5	6,25	10	55	8	12.5	24	15,5	5	35	29
Line diameter (mm)	0.2	0.15	0.1	0.13	0.23	0.1	0.13	0.16	0.15	0.1	0.2	0.16

The gillnet survey was undertaken from 1st-2nd of September 2021 using the small (7 meters) research vessel Niisa. Gillnets were set at 8 stations in the near shore hard bottom areas of the cable corridor between 16-18 o'clock in the afternoon and retrieved the following morning between 7-9 o'clock, and thus soak times were approximately 15 hours. The location of the gillnet stations were chosen to coincide with the location of ROV stations that investigated the epifauna on the hard bottom habitats within the export cable corridor that also included the Natura 2000 site 'Gilleleje Flak and Tragten'.

After net retrieval, all fish were kept on ice in containers and taken back to the laboratory to be removed from the nets, sorted according to species, measured and weighed in accordance with the methods described in 3.4.

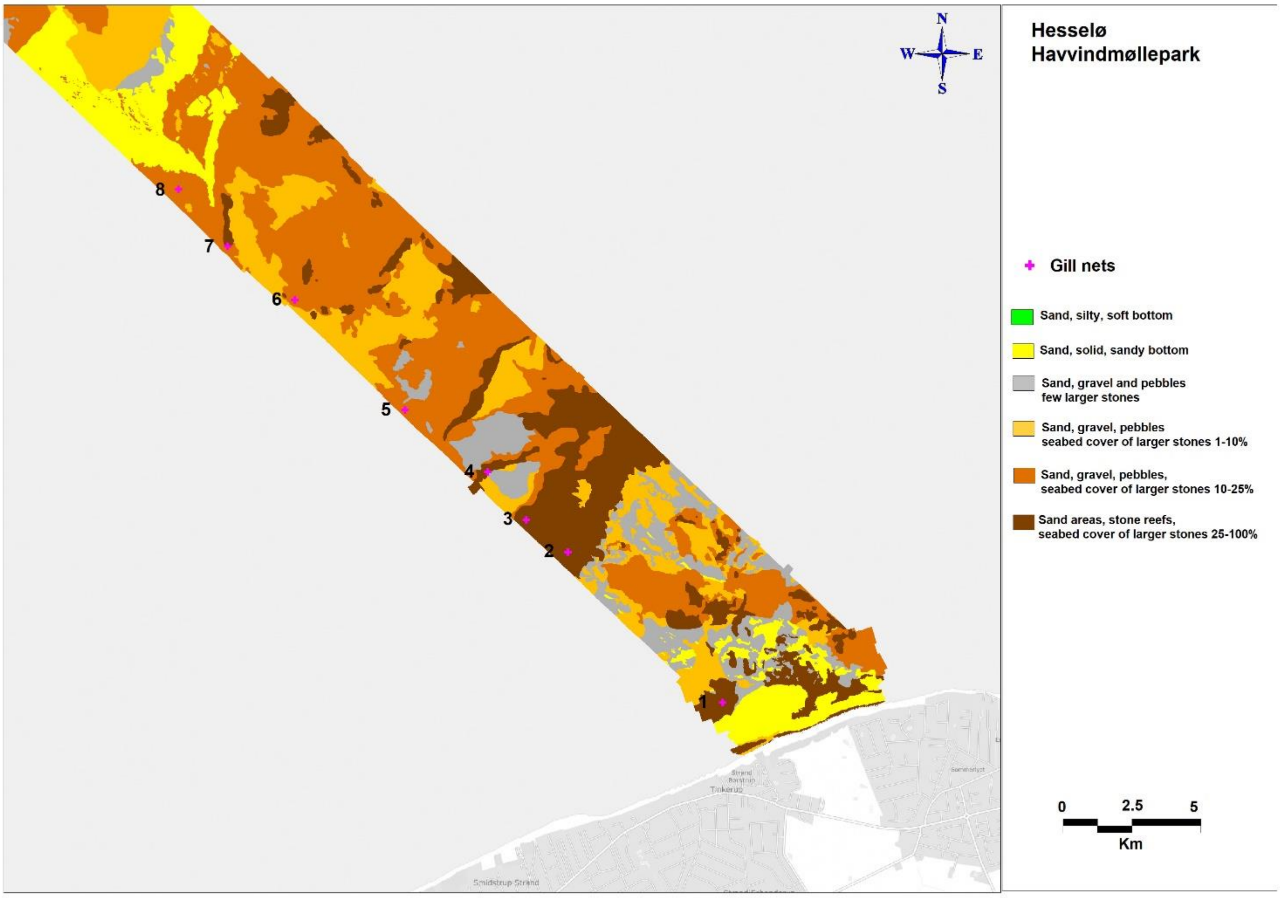

Figure 3.3: Location of the 8 gillnets stations within the hard bottom habitats in the inner part of the planning area for export cables.

No fish surveys targeting wrecks were undertaken

According to Denmarks Cultural Heritage information (Slots og Kulturstyrelsen-Kulturarv.dk), there are several artifacts on the seabed in the planned area for Hesselø OWF such as ship wrecks etc. These introduced objects, that are typically considered to represent hard substrate habitats, may present habitats for reef associated fish species in contrast to the primarily benthic/semi-benthic species associated with the predominantly soft bottom habitats of the area. However, due to great depths in the area (25-30 meters) and therefore lack of vegetation, only a limited number of reef associated fauna species are expected in these habitats. It is therefore unlikely that these hard substrate habitats will present areas that will promote substantial recruitment to fish species associated with hard substrate habitats. More likely they will be limited habitats where fish species already present in the area, and that are attracted to hard structures, such as juvenile and adult cod, will congregate and use these habitats as refuge. Fish studies targeting these wrecks are thus not expected to give more information on which species are in the area or the importance of the planned area for Hesselø OWF to fish.

3.4 Survey information and laboratory procedures for fish analysis

During the trawl surveys, information on the start and stop positions and length of time of the each haul was recorded to determine swept area and water volume sampled for each haul. For hauls with large catches (>20 kg) of a specific species, random sub-samples of these species (typically sprat, herring, dab and greater weever) were taken to obtain length frequency analysis.

- Species information (e.g. species, numbers per length and weights per species).
- Biological information of some of the prominent species based on sub-samples and anticipated spawning (e.g. sex, gonad maturity stage, weight and age). Maturity stage will be assessed according to ICES maturity key for fish (ICES, 2007). Modelling the proportion of mature and ripe fish to the individual lengths with a binomial distribution will make it possible to calculate what lengths juvenile fish become mature and the possible extent of the spawning population in the area.

3.4.1 Analysis of fish samples

For all three fish surveys (spring and autumn trawl surveys and autumn gillnet survey) the following procedures and information of the fish samples was registered for each trawl haul and for each gillnet station:

- Number and total weight (gram) of each species
- All individual fish were measured (total length down to the nearest half cm).
- The individual length (total length 0.5 cm) and corresponding weight (0.1 g) of 5 specimens in each centimetre group (when possible) was measured.

All data was registered and secured digital in the program FishBase which runs with a SQL server saving data continuously.

3.4.2 Analysis of gonad maturity in mature fish

To determine the potential importance of the planning area for Hesselø OWF area as a spawning site for the most important species, the maturity stages of gonads was examined in all cod above 20 cm in lenght and for a selection of the dominant flatfish (dab, plaice, and flounder) above 15 cm in length in both the spring and autumn surveys. Gonad maturity was determined according to a maturity index key based on the development stage of gonads in mature (adult) fish according to modified guidelines for cod by Tomkiewicz (Tomkiewicz J. , 2005) and other fish species in the ICES sexual maturity sampling report (ICES, 2007).

3.4.3 Post-processing of catch data

Data from analysis of the fish samples will be used to determine the following parameters:

- Total number and species-specific biomass (weight) of all species to determine species diversity and key species (dominant species).
- Calculating CPUE (catch-per-unit-effort) to determine the mean catches of fish pr. swept area - 1000m^2 in the trawl surveys.

- The extent of the spawning population of cod and the most abundant flatfish (plaice, dab and flounder) in the area to determine the importance of the planning area for Hesselø OWF and export cables as a spawning ground
- Length frequency histograms to identify cohorts (age-groups) and help determine the importance of the planning area to different life-stages of the individual species, including the use of the planning area as a nursery ground according to the number of juvenile fish, and the importance of the area as a spawning ground according to the number of mature fish (adults) combined with the degree of gonad maturity.

3.5 Other sources of information on the fish community

To supplement trawl and gillnet survey data indicating which fish species are present in and near the planning area for Hesselø OWF and export cables, information was gathered from other existing sources, which included a fish study in the area (Fiskeøkologisk Laboratorium, 2000), information from the Fish Atlas Project (Fiskeatlas, 2022) and fishery data from logbooks (from relevant ICES rectangles), and finally associating fish species known to be in the Kattegat with observed habitats in the planning area for Hesselø OWF and export cables.

4 Baseline description of fish communities

The Kattegat and the coastal region along the northern coast of Zealand is a marine area in a transition zone between the North Sea and Baltic Sea and can be characterized by being in an environmental gradient between the fully marine North Sea and the brackish Baltic Sea. As mentioned in section 3.2, the seabed in the planned project area is made up of both large soft bottom areas in the planned wind farm area and outer cable corridor, with a mosaic of mixed bottoms (sand, gravel and small stones), and areas with stone reefs in the near coastal regions. An area as diversified as the Kattegat and the overall plan area that contains many different fish habitats can have many different fish species. In the nearby Sound (Øresund) up to 155 fish species have been registered over time, while in the more saline North Sea up to 230 fish species have been registered (Øresundsvandsamarbejdet, 2018; Fiskeatlas, 2022; HELCOM, 2012).

Fish have different life strategies and preferred habitats and in general, can be separated into fish that live in the water column (pelagic fish species) or fish species linked to habitats on the seabed (demersal or bottom living fish species). Pelagic fish species in the Kattegat and inland Danish waters include common species such as herring (*Clupea harengus*), sprat (*Sprattus sprattus*) and seasonal guests such as mackerel (*Scomber scombrus*), garfish (*Belone belone*), horse mackerel (*Trachurus trachurus*) and in shallower waters the two-spotted goby (*Gobiusculus flavescens*).

The number of demersal fish species is much higher than pelagic species and can be further separated according to their preference to different bottom habitat types and water depths. Based on information on the seabed characteristics of the planned area for Hesselø OWF (see section 3.2) and results from the soft bottom and hard bottom surveys, the seabed can be divided into the following three primary fish habitats: 1) Soft bottom habitats (mud, fine sand and sand), 2) mixed bottom habitats containing a "mosaic" or mixture of sand, gravel and smaller stones, and 3) stone reefs where rocks and/or large boulders supply a suitable substrate for macroalgae and epifauna (hard-bottom animals) that can provide refuge and feeding opportunities for a number of fish species.

The deeper soft bottom areas in the Kattegat, including the planned areas for the Hesselø OWF and the outer parts of the exports cable corridor are habitats often dominated by benthic species preferring soft bottoms that include flatfishes, primarily plaice (*Pleuronectes platessa*), dab (*Limanda limanda*), sole (*Solea solea*) and flounder (*Platichthys flesus*), as well as codfish, which primarily includes the semi-pelagic whiting (*Merlangius merlangus*) and pollack (*Pollachius pollachius*), and cod (*Gadus morhua*) (Muus & Nielsen, 1999).

Nearer the coastline in the export cable corridor, the seabed characteristics are made up of mixed habitats where sand, gravel, shells and stones are mixed in patches. Mixed bottoms create a variety of habitats that often leads to a high biodiversity of both benthic flora and fauna species, and a high diversity of fish species, as these habitats contain both hard and soft bottom fish habitats preferred by different fish species.

On mixed bottom habitats, flatfish species such as turbot (*Psetta maxima*) and brill (*Scophthalmus rhombus*) can be found along with adult and juvenile cod and a variety of sculpins (*Cottidae* spp.) and goby species such as sand goby (*Pomatoschistus minutus*), black goby (*Gobius niger*) and common goby (*Pomatoschistus microps*), as well as juvenile plaice and flounder. Other fish species found only periodically on mixed bottoms and areas with rocky bottoms, either at special times of the day or during special periods of the year, when they use the habitat as a foraging area or area of refuge include sea trout (*Salmo trutta*), garfish (*Belone belone*) and whiting (Muus & Nielsen, 1999). A fish gillnet survey conducted in mixed bottoms in 2000 near the coast in Hornbæk Bay to the east of the planned area for Hesselø OWF, showed that the most important catches in the area were cod and whiting (*Merlangius merlangus*) and gold-sinny wrasse (*Ctenolabrus rupestris*), which are associated with hard bottom habitats, and the pelagic species herring (Fiskeøkologisk Laboratorium, 2000). In addition, saithe (*Pollachius virens*), horse mackerel (*Trachurus trachurus*), sole and eelpout (*Zoarces viviparus*) were also caught in the bay. Particularly numerous non-commercial species caught or observed in the coastal area were species of gobies (*Pomatoschistus* spp.), snake-pipefish (*Entelurus aequoreus*), shorthorn sculpin (*Myoxocephalus scorpius*), three-spined sticklebacks (*Gasterosteus aculeatus*) and hooknose (*Agonus cataphractus*) (Fiskeøkologisk Laboratorium, 2000).

Areas with stone reefs provide a large degree of spatial heterogeneity. This varied seabed habitat gives many fish species opportunities to both search for food and to find refuge. Some species live here more or less permanently, such as species belonging to the family of wrasses (*Labridae*) which include gold-sinny wrasse (*Ctenolabrus rupestris*), corkwing wrasse (*Symphodus melops*), ballan wrasse (*Labrus berggylta*) and cuckoo wrasse (*Labrus bimaculatus/Labrus mixtus*) along with rock gunnels (*Pholis gunnellus*) and lumpsuckers (*Cyclopterus lumpus*).

The shallow nearshore seabed characteristics in the planning area for the export cables are once again dominated by sand bottom habitats where fish species such as sand and common gobies (*Gobiidae* spp.), sandeel and juvenile plaice and flounder are most probably abundant. Besides fish, shallow sand habitats are often home to brown shrimp (*Crangon crangon*), which is an important prey for many fish species.

In addition to the fish species already mentioned, one study showed the presence of a small local population of autumn spawning herring along the northern Zealand coast, particularly near Hornbæk Bay and Gilleleje (Worsøe et al., 2002).

4.1 Fish communities in the planned area for Hesselø OWF and export cables – results from the fish surveys

All fish surveys, two trawl surveys in the soft bottom habitats of the planned wind farm area and outer cable corridor and 1 gillnet survey in the hard bottom habitats in the near-shore section of the cable corridor were successfully undertaken. The results of each survey is presented in the following sections, together with a short summary of the key species and protected species.

4.1.1 Fish surveys with bottom trawl

In the spring (6-9th of April) and the autumn (17-20th of October) a total of 13 trawl stations, 10 stations within the wind farm area and 3 stations in the outer export cable corridor were successfully sampled (see Figure 3.2). A trawl station originally planned in the outer section of the southern arm of the cable corridor was not undertaken, as this area was found to be off limits to bottom activities, due to the dangers of the potential presence of ammunitions on/in the seabed.

The prevailing direction of trawl hauls in the spring survey were primarily made from northwest to southeast due to the south-easterly direction of the wind and windy conditions (approx. 8 m/s) at the time of sampling. The direction of hauls in the autumn survey were primarily made in the opposite direction (southeast to northwest) due to the north-westerly direction of the wind and windy conditions (approx. 8 m/s) at the time of sampling.

The start and stop positions, length/time of hauls, swept area and sampled volume of the trawl hauls in the spring and autumn surveys are given in Table 4.1.

In all, a total of 43,661 fish and 31 different fish species were caught during both trawl surveys, which amounted to approximately 749,7 kg.

Table 4.1: Start-stop positions, approximate length/time of each trawl haul, swept area and sampled volume of the 13 trawl transects during the spring trawl survey (top table) and during the autumn trawl survey (bottom table).

Transect	Zone	Start		Stop		Length	Trawl width	Trawl height	Swept area	Volume	Trawl time
		X-UTM	Y-UTM	X-UTM	Y-UTM	m	m	m	m²	m³	Approx. Min.
TR1	32	674627	627215	675662	6271908	1063	14,5	2,1	15414	32368	15
TR2	32	673871	626713	674778	6266536	1266	14,5	2,1	18357	38550	15
TR3	32	669696	626522	670961	6265168	949	14,5	2,1	13761	28897	20
TR4	32	676457	6262905	676854	6262043	1188	14,5	2,1	17226	36175	15
TR5	32	673583	6259538	674220	6258535	1945	14,5	2,1	28203	59225	15
TR6	32	668434	6259484	670329	6259044	1094	14,5	2,1	15863	33312	30
TR7	32	671343	6255083	672188	6254388	1104	14,5	2,1	16008	33617	15
TR8	32	677757	6256515	678520	6255717	1084	14,5	2,1	15718	33008	15
TR9	32	675016	6252905	675856	6252220	1081	14,5	2,1	15675	32916	15
TR10	32	680066	6249888	681030	6249398	1085	14,5	2,1	15733	33038	15
TRK1	32	679894	6259011	680936	6258858	1053	14,5	2,1	15269	32064	17
TRK3	32	315111	6243926	316114	6243188	1245	14,5	2,1	18053	37910	15
TRK4	32	319214	6235513	320032	6234892	1027	14,5	2,1	14892	31272	15

Transect	Zone	Start		Stop		Length	Trawl width	Trawl height	Swept area	Volume	Trawl time
		X-UTM	Y-UTM	X-UTM	Y-UTM	m	m	m	m²	m³	Approx. Min.
TR1	32	675292	627195	676060	6271788	787	14,5	2,1	11407	23954	10
TR2	32	673560	626724	674145	6266878	712	14,5	2,1	10324	21679	9
TR3	32	669877	6265141	670570	6265174	694	14,5	2,1	10070	21147	9
TR4	32	676647	6262434	676902	6261843	644	14,5	2,1	9336	19607	10
TR5	32	673392	6259663	673752	6259156	622	14,5	2,1	9018	18937	11
TR6	32	669784	6259072	670429	6258934	660	14,5	2,1	9566	20089	11
TR7	32	671471	6254846	671880	6254451	568	14,5	2,1	8236	17295	9
TR8	32	677916	6256264	678360	6255762	670	14,5	2,1	9718	20409	9
TR9	32	674956	6252859	675401	6252477	587	14,5	2,1	8515	17882	9
TR10	32	680042	6249825	680597	6249543	622	14,5	2,1	9023	18949	10
TRK1	32	678977	6259078	679611	6258966	662	14,5	2,1	9601	20161	11
TRK3	32	686604	6243680	687133	6243283	712	14,5	2,1	10330	21693	15
RK4	32	691265	6235873	691836	6235446	644	14,5	2,1	9333	19599	10

4.1.1.1 Spring survey

During the spring survey a total of 38,467 fish representing 27 fish species were caught, Table 4.2. The total weight of all the fish from all 13 stations was 541.7 kg, Table 4.3. The number of fish species caught in each station varied between 9 to 16 with the fewest caught near the middle of the wind farm area in transect 4 (TR4) and the most in the cable corridor transect, TRK4. Figure 4.1 shows the sorting of the a catch and a picture of a boarfish in from one of the stations.

The most abundant species by number and weight were the pelagic species sprat (*Sprattus sprattus*) and herring (*Clupea harengus*), which combined for 86% of the total number of fish caught and 66.1% of the catches by weight

(Table 4.2 and Table 4.3). Sprat were present in large numbers and weight at every station sampled, while herring were more prevalent in the middle to northern parts of the wind farm area (station TR 1-6). The reason that these pelagic species were regularly sampled with the bottom trawl is that sprat and herring are often aggregated near the seabed seeking refuge during daylight hours.

Other abundant fish caught at every station were the bottom dwelling dab (10.2% by number and 21.2% by weight), plaice (1.2% by number and 5.2% by weight) and the semi-pelagic whiting (*Merlangius merlangus*) (1.1% by number and 3.8% by weight (Table 4.2 and Table 4.3).

Other fish species observed at most stations but in small abundances were grey gurnard (*Eutrigla gurnardus*), common dragonet (*Callionymus lyra*), long rough dab (*Hippoglossoides platessoides*) and lemon sole (*Microstomus kitt*), which corresponds well with these species' preference for the soft bottom habitat that is predominant throughout the investigation area, Table 4.2. Also, interesting to note is the catch of Fries's goby (*Lesueurigobius freisi*) which is a small fish that burrows in muddy/soft bottoms and is often associated with sharing the same burrow with the crustacean Norway lobster (*Nephrops norvegicus*), which is very abundant in the soft bottom areas of the Kattegat and the planned area for Hesselø OWF.

There were very few cod in the catches as only 8 cod distributed between 6 stations and ranging in length between 14-33 cm were caught during the entire spring survey.

To account for different trawl lengths at each survey station, the abundance of different species was standardized to a catch-per-unit effort (CPUE) of numbers of fish per 10,000 m² sampled. Results indicated that although there were large variations in the abundance of the different species caught, there was no indication that there was a difference in the density of the most abundant benthic species in the catch (dab: CPUE 187 ind., plaice: CPUE 22 ind. and whiting: CPUE 20 ind. per 10,000 m²) that would indicate particular areas of the planned area for Hesselø OWF with its homogeneous soft bottom habitat was more important than others to these species. Similarly, the densities of sprat and herring varied considerably between stations (sprat: CPUE 77 to 3471 individuals per 10,000 m² and herring CPUE 2-1,728 individuals per 10,000 m²) but did not show any clear pattern of being more dense in some sections of the planned area for Hesselø OWF than others.

Figure 4.1: Sorting the catch from the trawl survey – figure on the right is a boarfish (Capros aper).

Table 4.2: Total number of fish caught for each species at each trawl station in the spring bottom trawl fish survey

Species	Number of fish												
	TR01	TR02	TR03	TR04	TR05	TR06	TR07	TR08	TR09	TR10	TRK1	TRK3	TRK4
Micromesistius poutassou											1		
Clupea harengus	39	110	2378	4	226	1464	8		6	6	13		7
Engraulis encrasicholus	1	5								55			
Eutrigla gurnardus	8	7	6	7	2	14	6	4	4	1	2	1	
Gadus morhua		1				1	1	1	2				2
Capros aper			1										
Hippoglossoides platessoides	1	2	2	2	1			4	5	3	1	12	3
Limanda limanda	110	199	199	137	137	227	698	279	326	227	201	393	773
Lumpenus lampretaeformis					8		1		1	1	4	1	
Melanogrammus aeglefinus		2			1	1							
Merlangius merlangus	19	42	10	32	42	21	23	53	31	34	40	43	42
Microstomus kitt	3		1	1	2		4	3	1	1		2	
Myoxocephalus scorpius							2						4
Phrynorhombus norvegicus													2
Platichthys flesus					2		1	2		2		4	1
Pleuronectes platessa	68	13	58	11	46	46	47	17	20	28	11	32	75
Psetta maxima								1					
Raja radiata												1	
Rhinonemus cimbrius					2			1			1		1
Scophthalmus rhombus						3		1					
Solea solea			1				4	1				1	1
Lesueurigobius freisi					4				2	1		1	1
Sprattus sprattus	1337	4820	3344	187	217	3803	811	4766	121	1370	388	6266	1616
Callionymus lyra	4	4	10	4	9	7	6	6	3	10	15	10	1
Mullus surmuletus	1				1								1
Trachinus draco							1				1		
Arnoglossus laterna													1
Number of species	11	11	11	9	15	10	14	14	12	13	12	13	16

Table 4.3: Total weight (kg) for each species at each trawl station in the spring bottom trawl fish survey.

Species	Weight (gram)												
	TR01	TR02	TR03	TR04	TR05	TR06	TR07	TR08	TR09	TR10	TRK1	TRK3	TRK4
Micromesistius poutassou											59		
Clupea harengus	1889	5747	47199	534	5628	33296	179		93	120	808		134
Engraulis encrasicholus	8	49								636			
Eutrigla gurnardus	406	459	238	481	122	469	253	258	256	26	80	53	
Gadus morhua		282				69	43	25	261				303
Capros aper			25										
Hippoglossoides platessoides	7	43	38	18	63	0	0	81	234	130	44	434	94
Limanda limanda	3350	5624	4788	4252	8944	6018	11628	7726	9100	5342	6561	21162	20485
Lumpenus lampretaeformis					65		9		7	13	37	11	
Melanogrammus aeglefinus		121			121	132							
Merlangius merlangus	989	2649	502	1755	1985	1228	819	2745	1496	1105	2351	1834	1121
Microstomus kitt	566		102	76	449		706	225	74	155		197	0
Myoxocephalus Scorpius							189						1003
Phrynorhombus norvegicus													27
Platichthys flesus					502		244	339		435		870	116
Pleuronectes platessa	3592	1039	3285	740	3301	2285	3202	983	987	2126	766	1537	4236
Psetta maxima								461					
Raja radiata												524	
Rhinonemus cimbrius					49			29			12		29
Scophthalmus rhombus						1009		295					0
Solea solea			18				227	111				192	168
Lesueurigobius freisi					23				9	7		9	5
Sprattus sprattus	14117	47168	39523	1711	2684	45983	8268	49363	1094	12986	3831	18607	17279
Callionymus lyra	144	209	507	158	328	423	251	283	133	251	591	281	77
Mullus surmuletus	16				14								67
Trachinus draco							17				49		
Arnoglossus laterna													7

4.1.1.2 Autumn survey

During the autumn trawl survey 5,194 fish representing 26 species, which was one less than the spring survey, were caught in the 13 trawl stations that were sampled in the planned area for Hesselø OWF and export cables (Table 4.4). The total catch by weight amounted to 208 kg (Table 4.5). The number of fish species caught in each sampling station varied between 10 to 19 with the fewest caught in the trawl transect TR7 in the southern part of the wind farm area, and the most in transect TR1 in the northern part of the planning area for the Hesselø OWF.

In contrast to the spring survey, there was a large abundance of the bottom dwelling greater weever (10.2% by number and 13.2% by weight) throughout the survey area. Whereas catches of the pelagic species sprat and herring were much less than in the spring, and although they were present at almost every station, they only amounted to 22.1% of the total catch by number and 8.1% of the total catch by weight, Table 4.4 and Table 4.5.

Similar to the spring survey, the flatfish dab (45.7% by number and 45% by weight) and plaice (7.5% by number and 16.3% by weight), along with the semi-pelagic fish whiting (4.3% by number and 7.4% by weight) were also represented at every trawl station. For dab, their numbers and weight in both autumn and spring survey indicated that they were once again the dominant benthic species caught throughout the survey area.

The presence of grey gurnard, long rough dab, lemon sole, common dragonet, Fries's goby and Atlantic horse mackerel were also observed at many stations, although only in small numbers. There were also a few individuals of several other species

Also, similar to the spring survey, a number of Fries's goby, which as mentioned is a small fish that often shares the same burrow with the crustacean Norway lobster, was also in the catch at 7 sampling sites. Furthermore, a school of anchovy (*Engraulis encrasicholus*) were caught at station TR8 in the lower part of the planned area of Hesselø OWF.

Only 11 cod (distributed between 7 stations) were caught during the autumn survey. Only two were larger than 20 cm in length.

The CPUE of the most abundant benthic species in the catch measured as the number of individuals (ind.) per 10,000 m^2 trawled area was for dab: CPUE 188, plaice: CPUE 31 and whiting: CPUE 18. Similar to the spring survey, the standardized CPUE values for these benthic species throughout the planned area for Hesselø OWF indicated that there was no area in the particular areas of the soft bottom in the planned area for Hesselø OWF that appeared more important than others (CPUE values in appendix 1).

The density of the pelagic species (sprat and herring) in the autumn survey was much lower in the autumn survey than the spring survey and only amounted to an average CPUE of 81 for sprat (range: CPUE 5-205 ind. per 10,000 m^2) and a CPUE 11 for herring.

Table 4.4: Total number of fish caught for each species at each trawl station in the autumn bottom trawl fish survey

Species	Number of fish												
	TR01	TR02	TR03	TR04	TR05	TR06	TR07	TR08	TR09	TR10	TRK1	TRK3	TRK4
Agonus cataphractus													2
Clupea harengus	62	23	4	28	3	3	1	3	4	1	4		2
Engraulis encrasicholus			10					113	3	34		7	
Eutrigla gurnardus	12	3	7	1	4	4	2	5	3	8	4		8
Gadus morhua	1	2	1	1		1		4					1
Gaidropsarus vulgaris	4											2	2
Hippoglossoides platessoides	1	3	1	2	5	1		1	1	2	6	2	
Limanda limanda	399	163	166	52	124	160	108	192	157	138	182	78	453
Lophius piscatorius									1				
Lumpenus lampretaeformis	1											1	
Melanogrammus aeglefinus					1								
Merlangius merlangus	15	18	23	9	19	12	11	15	21	11	19	32	20
Microstomus kitt	11	1		1	2	1		1			5		
Molva molva	1												
Myoxocephalus scorpius		1											1
Platichthys flesus					1	1		2	1			1	
Pleuronectes platessa	50	43	50	23	38	32	12	26	33	22	32	19	9
Mullus surmuletus	1									1			
Scophthalmus rhombus								1				1	
Solea solea	2					2	1					1	5
Lesueurigobius freisi	8	2	2		1	1			1	1		7	
Sprattus sprattus	37	212	73	72	77	27	4	124	164	35	22	67	95
Callionymus lyra	21	4	2	3	5	3	5		1	1		5	2
Trachinus draco	81	17	62	17	26	102	44	22	67	49	20	13	11
Trachurus trachurus	2	6	5		9	11	26	6	35	1	9		6
Arnoglossus laterna	5	1	1			1		1	1	2	2		1
Number of Species	19	15	14	11	14	16	10	14	15	14	11	14	15

Table 4.5: Total weight (gram) for each species at each trawl station in the autumn bottom trawl fish survey.

Species	Weight (gram)												
	TR01	TR02	TR03	TR04	TR05	TR06	TR07	TR08	TR09	TR10	TRK1	TRK3	TRK4
Agonus cataphractus													8
Clupea harengus	2214	748	64	908	52	103	21	79	87	17	99		82
Engraulis encrasicholus			88					1438	31	251		60	
Eutrigla gurnardus	435	145	209	40	166	141	66	195	116	351	199		397
Gadus morhua	225	495	252	90		178		617					90
Gaidropsarus vulgaris	154											74	50
Hippoglossoides platessoides	31	167	81	63	100	34		28	49	81	214	37	
Limanda limanda	15498	6782	6738	2029	4745	7107	3707	8339	5763	6037	7687	3347	15767
Lophius piscatorius									4287				
Lumpenus lampretaeformis	7											7	
Melanogrammus aeglefinus					16								
Merlangius merlangus	1072	1493	1928	806	1294	915	548	993	1624	629	1656	1840	657
Microstomus kitt	1305	121		77	199	182		121			547		
Molva molva	127												
Myoxocephalus scorpius		42											115
Platichthys flesus					318	226		352	256			232	
Pleuronectes platessa	3806	4692	3471	2374	3096	2707	697	2323	2799	2000	3552	1840	557
Mullus barbatus	15									30			
Scophthalmus rhombus								173				519	
Solea solea	284					546	156					114	979
Lesueurigobius freisi	49	12	12		7	8			6	2		32	
Sprattus sprattus	481	2512	932	837	965	312	61	1528	2077	448	269	855	1035
Callionymus lyra	345	87	40	34	51	109	151		7	11		37	18
Trachinus draco	4269	1072	3048	742	1225	6421	2045	1166	3251	1879	1057	771	528
trachurus trachurus	21	22	41		72	92	199	43	295	8	88		47
Arnoglossus laterna	28	18	5			6		7	5	8	11		5

4.1.1.3 Seasonal variation in the catches

The abundance of fish was higher in the spring survey (38,467 individuals) and only slightly more diverse (27 species) compared to the autumn survey (5,194 individuals and 26 species). Standardized abundances according to swept area in the trawling to account for differences in trawling distance, indicate the greater total abundance and also greater biomass of fish in the spring survey is solely due to the comparatively large numbers of the pelagic species sprat (CPUE 1,369) and herring (CPUE 237) that were caught in the spring survey compared to the numbers of sprat (CPUE 81) and herring (CPUE 11) that were caught in the autumn survey.

The only other species with comparatively large ecological importance that showed a seasonal variation in its presence in the soft bottom habitats was the greater weever. During the spring survey only one individual of this species was caught in two stations, while in contrast 531 individuals of this species was caught in the autumn survey where it was present in each of the 13 sampling stations.

Comparisons of the densities (number of individuals per 10,000 m^2) of the bottom living fish species in both surveys, strongly indicates that the abundance of dab, plaice, whiting as well as numerous other species caught in comparatively low numbers on the seabed, were more or less the same in the spring and autumn survey (see CPUE table in appendix 1). Thus, other than the presence of one to a few individuals of 5 species caught only in the spring survey (boarfish, blue whiting, topknot (flatfish), turbot, thorny skate and a four-beard rockling) and one to a few individuals of 4 species caught only during the autumn survey (three-bearded rockling, monkfish, common ling and brill), there was no noticeable seasonal change in the abundance or diversity of the majority of the benthic fish community in the planned area of Hesselø OWF.

4.1.2 Spawning areas

The Kattegat, including the coastal areas off North Zealand, probably contain a number of important spawning and nursery areas for many species, but knowledge of this is sparse. During spawning periods, fish typically congregate in species-specific spawning grounds. The spawning time and duration of the spawning period are also species-specific, but spawning is typically completed within 3-4 months, and for most species is primarily undertaken during the first half of the year. Species that spawn in the open water (pelagic spawners, such as most flatfish species, cod and sprat etc. – see Table 4.6) often spawn a very large number of eggs freely, where they hatch and the larvae develop further. These spawning areas are most often large, and can move from year to year depending on the hydrographic conditions such as water current, salinity and temperature (Warnar, et al., 2012).

East and north of the planning area for Hesselø OWF there are important spawning areas for the Atlantic cod (Figure 4.2). During the fish surveys the gonad maturity status of all cod equal to or above 20 cm were investigated. For flatfish, the gonad maturity status was examined in a selection of the flatfish equal or above 15 cm. In general, there were very few adult codfish or flatfish species in both the spring and autumn surveys. During the spring trawl survey it was determined that only 3 adult cod were caught. Two of the adult cod were males, while the female cod had a gonad status of 5 i.e. regenerating ovaries. In the autumn trawl survey, the gonad status was investigated in the 2 adult cod, both of which were males that were not in a condition of spawning.

In both the spring and autumn surveys, the gonad status from the relatively few adult plaice and dab (most prominent flatfish species) indicated that no spawning was taking place for any of these species during either periods.

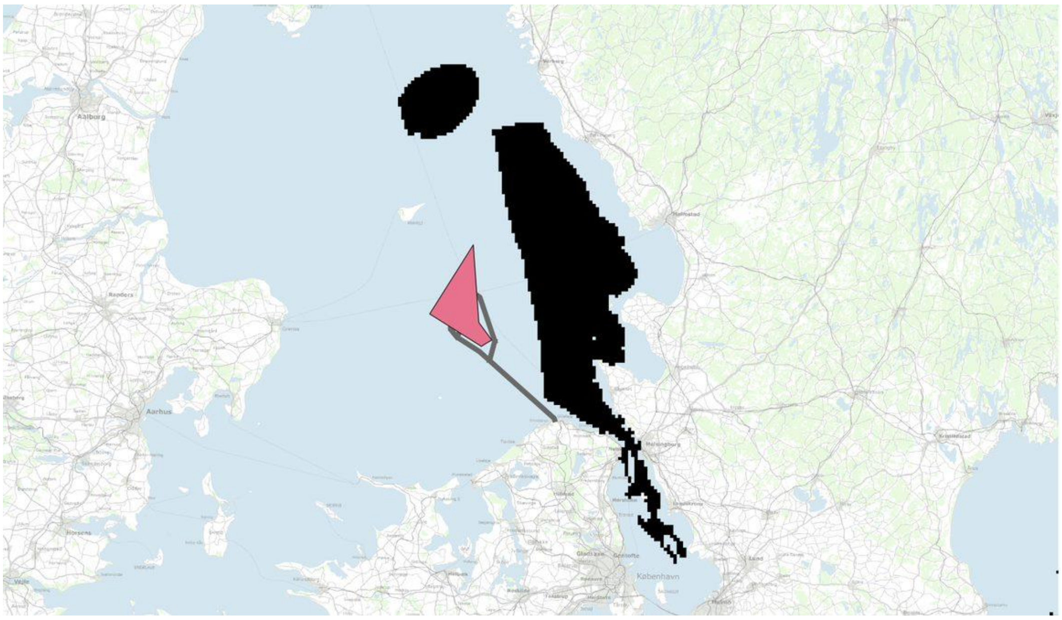

Figure 4.2: Spawning areas for Atlantic cod (Gadus morhua) in relation to the planned area for Hesselø OWF (HELCOM, 2020).

If the planned area for Hesselø OWF was important as a spawning area then catches of more adult (mature) fish would be expected. Thus, the very low number of adult (mature) fish and the investigations of the gonad maturity undertaken during the fish surveys in 2021 did not give any indication that spawning was taking place and that the planned area for Hesselø OWF contained any important spawning areas for either cod, or for the investigated flatfish species (plaice and dab). There were no catches of adult (mature) flatfish of any other species during the fish surveys.

Several of the bottom living fish species, except for most of the flatfish species, spawn their eggs on or near the seabed, particularly in the shallower hard bottom areas in the near shore cable corridor, which is expected to contain habitats for many of the non-commercial demersal fish species. Species such as gobies (Gobiidae), and sculpins (Cottidae) have developed forms of parental care during where the adults look after the eggs that are spawned in a form of nest or amongst shells or gravel. There are also some pelagic species such as herring and the seasonal garfish that spawn their eggs on or near the bottom where eggs typically stick to hard bottom substrates or vegetation.

In general, the maturity stages of fishes of different lengths together with the abundance of adult individuals in the planned area for Hesselø OWF is the most direct route to estimating the value of the area as a potential spawning area. However, because different species spawn at different times of the year (see Table 4.7) and often at slightly different times between years, results from the surveys only show a small window of time during potential spawning periods and thus indications of little or no spawning taking place in the area should be accepted cautiously.

Table 4.6: *Fish species caught in the fish surveys (both trawl and gillnet surveys) and their primary habitat preference and spawning behaviour.*

Fish name	Species name	Behavior	Habitat preference	Spawning behaviour
Herring	*Clupea harengus*	Pelagic	-	Pelagic / Demersal spawner
Sprat	*Sprattus sprattus*	Pelagic	-	Pelagic spawner
Anchovy	*Engraulis encrasicholus*	Pelagic	-	Pelagic spawner
Horse mackerel	*Trachurus trachurus*	Pelagic	-	Pelagic spawner
Dab	*Limanda limanda*	Benthic	Soft bottoms	Pelagic spawner
Plaice	*Pleuronectes platessa*	Benthic	Soft bottoms	Pelagic spawner
Long rough dab	*Hippoglossoides platessoides*	Benthic	Soft bottoms	Pelagic spawner
European flounder	*Platichthys flesus*	Benthic	Soft bottoms	Pelagic spawner
Turbot	*Psetta maxima*	Benthic	Mixed bottoms	Pelagic spawner
Brill	*Scophthalmus rhombus*	Benthic	Mixed bottoms	Pelagic spawner
Sole	*Solea solea*	Benthic	Soft bottoms	Pelagic spawner
Lemon sole	*Microstomus kitt*	Benthic	Soft bottoms	Pelagic spawner
Topknot (flatfish)	*Phrynorhombus norvegicus*	Benthic	Soft bottoms	Pelagic spawner
Scaldfish (flatfish)	*Arnoglossus laterna*	Benthic	Soft bottoms	Pelagic spawner
Atlantic cod	*Gadus morhua*	Benthic/Semi-pelagic	Mixed bottoms / reefs	Pelagic spawner
Haddock	*Melanogrammus aeglefinus*	Semi-pelagic	Mixed bottoms	Pelagic spawner
Whiting	*Merlangius merlangus*	Semi-pelagic	Mixed bottoms	Pelagic spawner
Blue whiting	*Micromesistius poutassou*	Semi-pelagic	-	Pelagic spawner
Common ling	*Molva molva*	Benthic	Hard bottoms	Pelagic spawner
Greater weever	*Trachinus draco*	Benthic	Sand/ soft bottoms	Pelagic spawner
Monkfish	*Lophius piscatorius*	Benthic	Mixed bottom / sand	Pelagic spawner
Grey gurnard	*Eutrigla gurnardus*	Benthic	Sand	Pelagic spawner
Hooknose	*Agonus cataphractus*	Benthic	Soft bottoms	Demersal spawner
Snakeblenny	*Lumpenus lampretaeformis*	Benthic	Soft bottoms / Mud	Demersal spawner
Four-bearded rockling	*Rhinonemus cimbrius*	Benthic	Soft bottoms	Pelagic spawner
Three-bearded rockling	*Gaidropsarus vulgaris*	Benthic	Gravel / stone reef	Pelagic spawner
Thorny skate	*Raja radiata*	Benthic	Mixed bottom / sand	Demersal spawner
Fries's goby	*Lesueurigobius friesi*	Benthic	Soft bottoms	Demersal spawner
Black goby	*Gobius niger*	Benthic	Mixed bottoms	Demersal spawner egg/larvae care
Dragonet	*Callionymus lyra*	Benthic	Soft bottoms	Pelagic spawner
Striped mullet	*Mullus surmuletus*	Bentisk	Mixed bottoms	Pelagic spawner
Boarfish	*Capros aper*	Semi-pelagic	Sand/ Mixed bottoms	Pelagic spawner
Gold-sinny wrasse	*Ctenolabrus rupestris*	Benthic	Hard bottoms /stone reefs	Demersal spawner
Corkwing wrasse	*Symphodus melops*	Benthic	Hard bottoms / stone reefs	Demersal spawner
Sandeel	*Hyperoplus lanceolatus*	Benthic	Sand	Demersal spawner
Mackerel	*Scomber scombrus*	Pelagic	-	Pelagic spawner

Table 4.7: Overview of spawning periods and for a selection of the fish registered in the planning area for Hesselø OWF.

Species	Spawning period												Pelagic spawner	Demersal spawner
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Plaice (*Pleuronectes platessa*)	■	■	■	■									X	
Dab (*Limanda limanda*)	■	■	■	■	■	■	■						X	
Flounder (*Platichthys flesus*)		■	■	■	■								X	
Greater weever (*Trachinus draco*)				■	■	■	■	■					X	
Grey gurnard (*Eutrigla gurnardus*)			■	■	■	■	■						X	
Cod (*Gadus morhua*)	■	■	■									■	X	
Whiting (*Merlangius merlangus*)		■	■	■	■	■	■						X	
Shorthorn sculpin (*Myoxocephalus scorpius*)	■	■	■									■		X
Hooknose (*Agonus cataphractus*)		■	■	■										X
Rock gunnel (*Pholis gunnellus*)	■										■	■		X
Dragonet (*Callionymus lyra*)			■	■	■	■							X	
Sprat (*Sprattus sprattus*)	■	■	■	■	■	■							X	
Herring (*Clupea harengus*)			■	■	■									X

4.1.2.1.1 Length distributions of the most common species in fish surveys

The length frequency of the catches from the spring and autumn trawl surveys are shown for the most abundant fish species in Figure 4.3 and Table 4.4. The entire catch of dab in both surveys had lengths between 10-19 cm, indicating that all the individuals were more or less juveniles between the ages of 1-2 years (Muus & Nielsen, 2006). The lengths of plaice in the trawl catches varied from 11-29 cm in the spring survey, and from 13-32 cm in the autumn survey. Similar to dab, the largest majority of the individuals of plaice were juveniles between 11-21 cm in the spring and only slightly larger in the autumn surveys where the same cohorts (year classes) were present. This indicated that, with the exception of a few adults, the majority of the plaice population was also made up of juveniles, albeit no young-of-the-year (juveniles from same year) individuals. For whiting, the lengths of the fish caught in the spring survey were between 11-27 cm with only 1 fish over 30 cm. Similarly, the lengths of whiting in most of the catch in the autumn survey were similar, although there were more individuals from 7-11 cm indicating that young of the year (YOY) individuals were now present in the area. Thus the abundances and lengths of dab, plaice and whiting indicate the entire soft bottom area that characterize the majority of the planned area for Hesselø OWF and outer export cable corridor is used as a nursery area for these fish species.

As mentioned, only a total of 20 cod between the lengths of 14-33 cm (8 and 11 individuals in the spring and autumn survey, respectfully) were caught in a total of 26 trawls, suggesting that neither juvenile or adult cod are present and utilize the soft bottom habitats of the planned area for Hesselø OWF.

Spring survey (April)

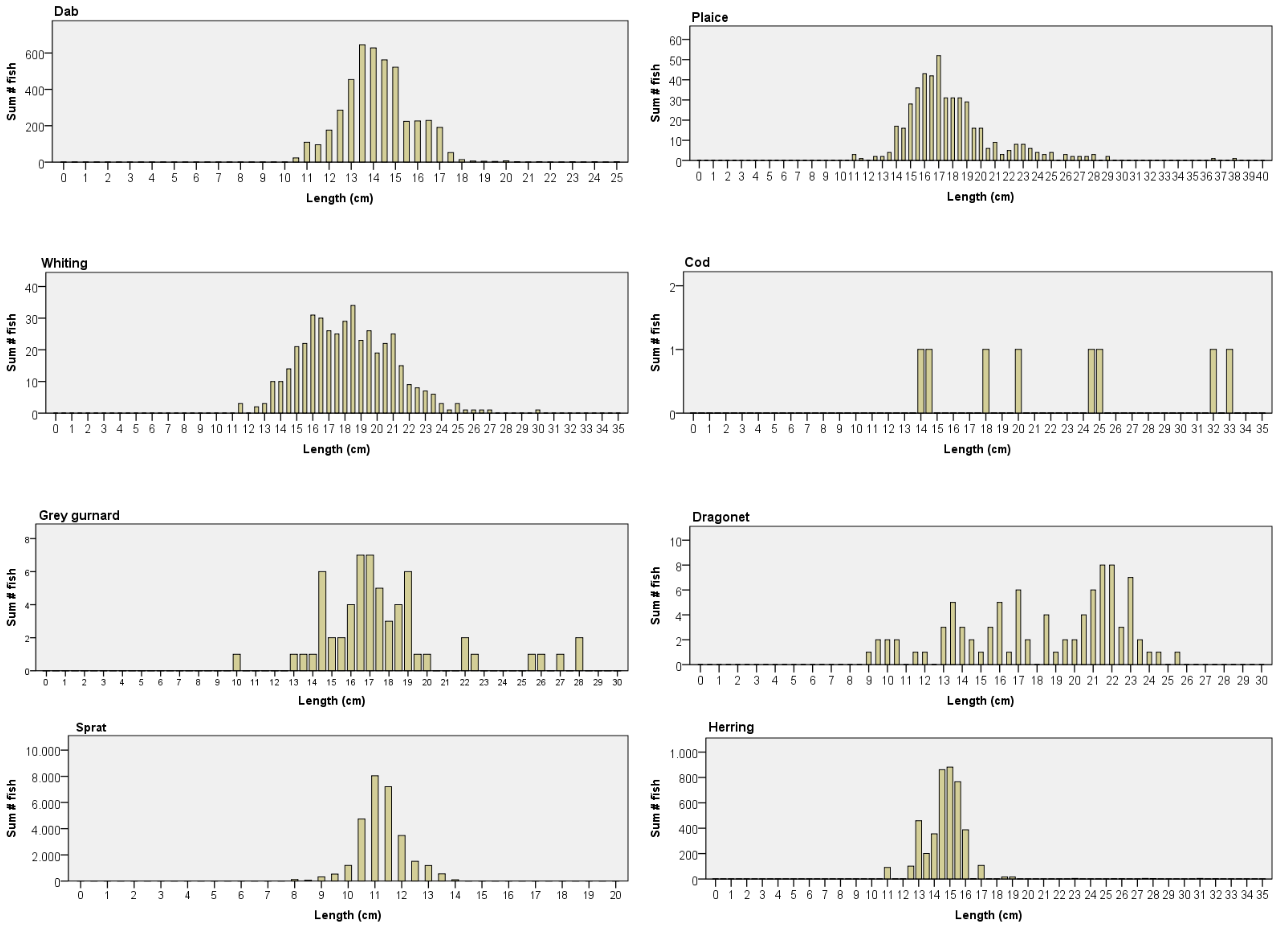

Figure 4.3: Length frequency diagrams for the most abundant fish species in the spring survey, April 2021.

Other species that were abundant enough in the surveys to make reliable length-frequency diagrams were greater weever, grey gurnard, dragonet, sprat and herring.

Greater weever was almost absent from the soft bottom areas in the spring survey while this species was caught in comparatively large abundances in the autumn survey (see Table 4.2 and Table 4.4). The length frequency diagram indicates that there are several cohorts of the greater weever in the soft bottom areas as lengths ranged from 11-33 cm (2-4 age groups), see Figure 4.4.

Grey gurnard were present in the spring and autumn trawl surveys in lengths between 10-28 cm (spring survey) and 13-25 cm (autumn survey). The length distributions of grey gurnard indicate the greatest majority of the fish in the area are between 13-20 cm and are thus considered to be 2-3 year old juveniles (Muus & Nielsen, 2006). Dragonet were caught in lengths between 9-26 cm in both the spring and autumn survey, where length frequency diagrams indicate several year classes (Figure 4.3 and Table 4.4). The lengths of the pelagic species sprat in both surveys were between 8-14 cm, while the lengths of herring were between 11-20 cm.

Autumn survey (October)

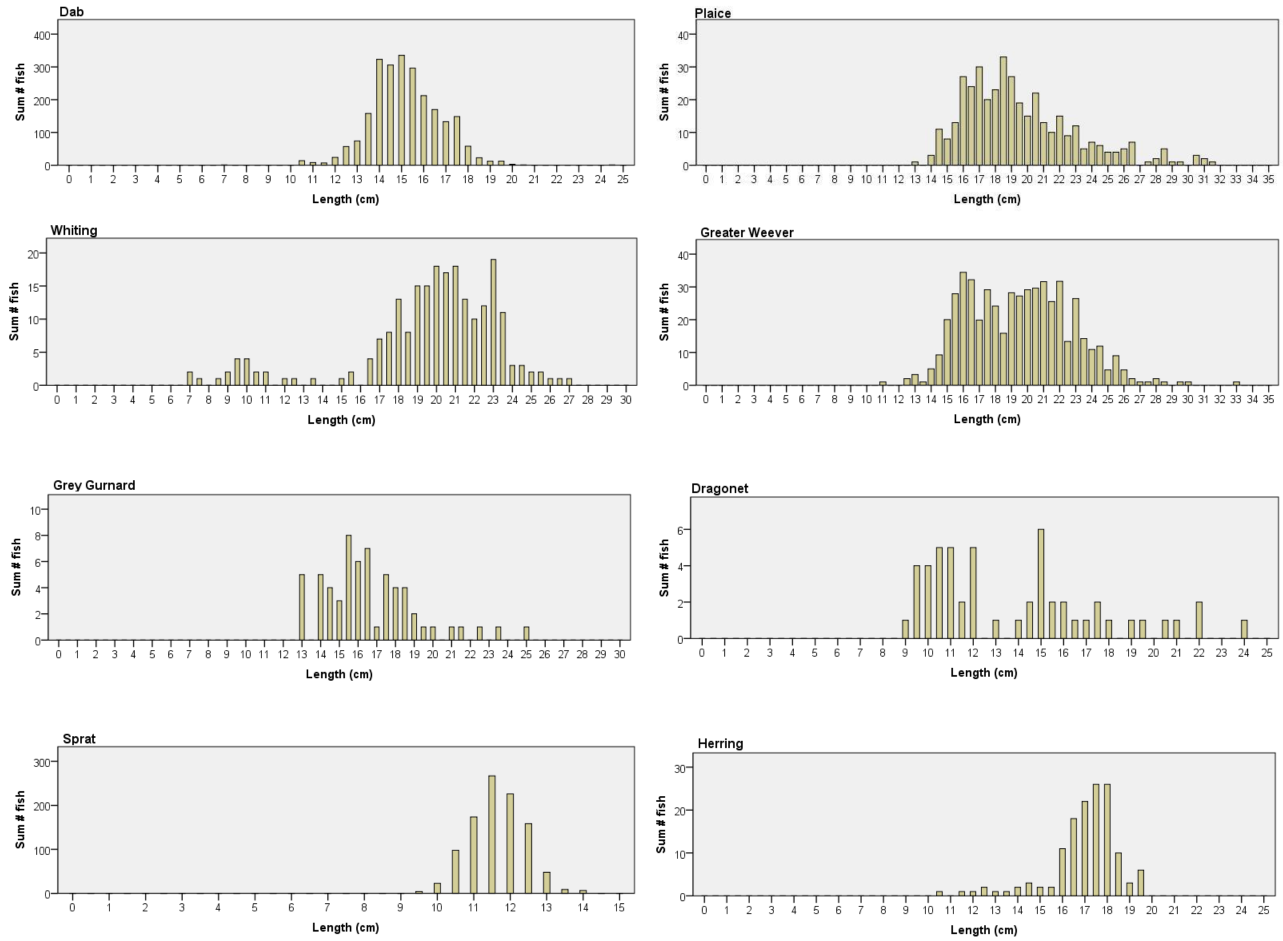

Figure 4.4: Length frequency diagrams for the most abundant fish species in the autumn survey in October, 2021.

4.1.3 Gillnet survey in hard bottom habitats

As mentioned, the fish survey with gillnets was undertaken in the mixed bottom habitats (sand, gravel, stones 10-25%) and stone reef habitats (stone reef > 25% hard bottom) that were near the coast in the planned area for Hesselø OWF (see Figure 3.3 and section 3.2). These habitats typically characterize areas with a high diversity of both vegetation (in the photic zone where light is available to plants) and fauna including fish (see Figure 4.5) due to the greater variation of available habitat types.

Figure 4.5: Retrieval of gillnets and example of a typical stone reef species on right (corkwing wrasse- Symphodus melops) caught during gillnet survey.

The gillnet survey undertaken from 1st-2nd of September, involved setting two sets of gillnets (1 x standardized Nordic-norm net and 1 x gillnet with larger mesh size of 70 or 110 mm) at 8 stations with differing hard bottom characteristic in the near shore hard bottom areas (Table 4.8).

Table 4.8: Start position of the 8 gillnet stations in the hard bottom gillnet fish survey, 2021.

Transect	Start position / from north to south		Gillnets Nordic-norm + 1 x (70 mm or 110 mm mesh)	Depth (meters)	Habitat	Soak time (hours)
	X-UTM	Y-UTM				
Station 1	702662	6225223	1 NN+ 1 x 70 mm	7	Stone reef > 25% hard bottom	15
Station 2	701565	6226291	1 NN+ 1 x 110 mm	9	Stone reef > 25% hard bottom	15
Station 3	701271	6226521	1 NN+ 1 x 70 mm	11	Stone reef > 25% hard bottom	15
Station 4	700998	6226858	1 NN+ 1 x 110 mm	12	Mixed bottom (sand, gravel, stones 10-25%)+section with stone reef (>25% large stones)	15
Station 5	700410	6227295	1 NN+ 1 x 70 mm	15	Mixed bottom (sand, gravel, stones 10-25%)	15
Station 6	699629	6228076	1 NN+ 1 x 110 mm	17	Mixed bottom (sand, gravel, stones 10-25%)	15
Station 7	699155	6228456	1 NN+ 1 x 70 mm	18	Mixed bottom (sand, gravel, stones 10-25%)+section with stone reef (>25% large stones)	15
Station 8	698804	6228858	1 NN+ 1 x 110 mm	18	Mixed bottom (sand, gravel, stones 10-25%)	15

As shown in Table 4.9, a total of 241 fish were caught amounting to a total weight of 13.4 kg and representing 17 different fish species. The most numerous fish species caught was the gold-sinny wrasse, which together with the presence of the corkwing wrasse, are species strongly associated with stone reef habitats. Other fish species included both benthic species such as the flatfish dab, sole and brill, greater weever, sandeel, the small black goby, greater weever and semi-pelagic species of the codfish whiting and Atlantic cod. Many of these fish species would characteristically be found on mixed habitats where the different habitats of preference (both soft bottom and hard bottom habitats) are available. Also to note, was an individual of the hooknose that are typically found in very fine-sand/silt environments. Also observed in the catches were the typically pelagic species mackerel, herring and sprat.

Table 4.9: The total numbers of fish caught in each of the net types according to species in the hard bottom gillnet survey, 2021.

Common name	Species (*Latin name*)	Ny Nordic norm gillnets		70 and 110 mm gillnets	
		Number	Weight (g)	Number	Weight (g)
Herring	*Clupea harengus*	22	2298	1	33
Sprat	*Sprattus sprattus*	1	15,2		
Cod	*Gadus morhua*	2	174	1	556
Whiting	*Merlangius merlangus*	14	1670	1	140
Hooknose	*Agonus cataphractus*	3	87		
Dab	*Limanda limanda*	21	1528	1	127
Plaice	*Pleuronectes platessa*	2	194		
Brill	*Scophtalmus rhombus*			1	592
Sole	*Solea solea*	6	531		
Mackerel	*Scomber scombrus*	6	2088	2	1464
Gold-sinny wrasse	*Ctenolabrus rupestris*	131	1245		
Corkwing wrasse	*Symphodus melops*	7	203		
Black goby	*Gobius niger*	5	92		
Great sandeel	*Hyperoplus lanceolatus*	2	15		
Striped mullet	*Mullus surmuletus*	1	121		
Dragonet	*Callionymus lyra*	1	32		
Greater weever	*Trachinus draco*	3	157		
Total	17 species	234	10451	7	2,913

The mixed and hard bottom habitats of the along the northern Zealand coast can also be expected to be home to a number of other numerous non-commercial species such as sand goby (*Pomatoschistus minutus)*, Three-spined sticklebacks (*Gasterosteus aculaeatus*), eelpouts (*Zoarces viviparus*) and other shallow waters fish species (Fiskeøkologisk Laboratorium, 2000).

The distribution of the catches of the different species (species composition) observed in the gillnet survey were analysed (by number) in relation to water depth and habitat type (mixed habitat and stone reef habitat) to determine if either of these two parameters had influence on the species present in the catches. Results from a SIMPER analysis indicated that depth did not have an influence on which species were present in the gillnet survey stations. The abundance of dab was, however, influenced by the presence of mixed bottom habitats, probably as a result of dabs' need for soft bottoms to bury themselves in for refuge. Similarly, the abundance of gold-sinny wrasse was slightly greater in the stations with stone reef habitats, which are habitats favored by this species.

4.1.4 Key species

Fish species that are abundant and are important ecologically for an area can be considered key species. With reference to a number of reviews, a total of more than 150 to 230 species have been registered in the marine waters (North Sea and The Sound) surrounding the Kattegat (Øresundsvandsamarbejdet, 2018; Fiskeatlas; HELCOM, 2012). Fisheries data registering the fish species in all the landings from the fishing areas (ICES 41G2, 41G1, and 42G2) that include the planned area for Hesselø OWF have registered 51 different fish species over a 10 year period (2011-2020). On the basis of results from the fish surveys and the other existing data from the planned areal for Hesselø OWF that includes a large areas of soft bottom habitats in the wind farm area and outer cable corridor and mixed habitats (sand, gravel and stones) including stone reefs in the coastal cable corridor, the key species in the planned area for Hesselø OWF are considered to be: Dab, plaice, cod, whiting, greater weever, sprat and herring. In the following their general distribution, preferred habitat and biology are briefly described.

4.1.4.1 Dab (*Limanda limanda*)

Dab is a flatfish species that is widespread throughout the marine waters of Denmark and was the most abundant demersal or bottom living fish species observed in the trawl fish surveys. Dab prefer soft bottom habitats similar to plaice, though often on bottoms of finer material such as fine sand/silt bottoms and at depths from 20-150 meters (Muus & Nielsen, 2006). Although there is some competition between dab and plaice for food, dab prey more prominently on benthic marine worms and crustaceans and small mussels, which they have the ability to crush. Dab will also prey on small fish such as gobies. Dab spawn their eggs pelagically throughout their distribution from January-August, and juveniles prefer habitats at depths around 10-20 meters, in contrast to other common juvenile flatfish species (plaice and flounder) that often have their nursery areas in very shallow water (<2 meters).

4.1.4.2 Plaice (*Pleuronectes platessa*)

Plaice is a demersal species and an important commercial species and is generally spread out over much of the Kattegat as well as in and around the planned area for Hesselø OWF. Plaice prefer soft bottom habitats (sand/sand silt) where it finds its prey and can bury itself when seeking refuge. In the Kattegat, plaice can be found from 5-100 meters depth, but is most abundant at depths between 10-20 meters (Sørensen et al., 2016). Juvenile plaice are almost exclusively found in sand bottom habitats in shallow water (1-5 meters) during their first year, whereafter during the autumn juveniles move into deeper waters during their first winter. Adult plaice are also found primarily in sand bottom habitats, which may also be in mixed bottom areas where they can also seek refuge in areas with gravel and some vegetation. Plaice feed on small crustaceans, bristle worms and thin shelled mussels (Muus & Nielsen, 1999). Larger individuals will also eat small fish. Plaice spawn at water temperatures around 4°C (Ulrich, Boje, & Cardinale, 2013) primarily around February-March in the deeper pelagic at depths of around 30-40 meters (Svedäng H. et al., 2010). Here females can spawn up to 500,000 eggs.

4.1.4.3 Atlantic cod (*Gadus morhua*)

Cod is found throughout the Danish marine waters from coastal regions to several hundred meters deep. In the Kattegat they are categorised as a very important fish species for the commercial fisheries. Normally, cod are considered to be a demersal species spending most of their time on the bottom, however, depending on the area, season and whether they are juveniles or adults they can also be found in the pelagic. In the Kattegat, cod are found in large numbers from depths of 5-100 meters (Sørensen et al., 2016). Cod are general considered to be omnivores and opportunistic feeders, preying on both benthic invertebrates and other fish. Juvenile cod eat a wide variety of benthic fauna including bristle worms and crustaceans (crabs and shrimp) while larger cod have a greater tendency to eat other fish (herring, sprat, other cod etc.), particularly the larger they become (Hüssy K, et al., 1997). In January-February mature cod gather in large schools over deeper waters to spawn. In the Kattegat, these areas are generally in the northern parts of The Sound and the eastern parts of the southern Kattegat (se Figure 4.2). Spawning is often limited to areas where the water salinity is high enough (15-16 per thousand for cod in the western part of the Baltic and the Kattegat (Vallin og Nissling, 2000; Sørensen et al., 2016)). Cod eggs are pelagic and drift with water currents over large areas as eggs hatch and cod larvae grow. Results from the fish surveys did not indicate that the planning area for Hesselø OWF was a spawning ground for cod.

4.1.4.4 Whiting (*Merlangius merlangus*)

Whiting is a semi-pelagic codfish that at times can be found both near the bottom and in the pelagic. Whiting were consistently caught in the bottom trawl in the fish surveys as well as in the gillnet survey in the near shore hard bottom habitats that they use as nursery areas. There are no known spawning areas that whiting use in the Kattegat (Worsøe et al., 2002), as larvae and juveniles generally drift into the Kattegat and inner Baltic waters from spawning areas in the North Sea. As juveniles in their first year whiting prefer both soft bottom and mixed habitats generally in coastal areas, where at the age of 2-4 years they become mature and begin to migrate back to towards their primary spawning areas in the North Sea. The exact migration routes and seasonal migrating patterns are not well known.

4.1.4.5 Greater weever (*Trachinus draco*)

The species greater weever is a bottom living fish that is particularly abundant in the Kattegat, but also common in Skagerrak and the North Sea and primarily associated with soft bottom habitats such as sand and sand/silt habitats. Characteristic for greater weever is that its distribution and abundance can vary considerably during the year for unknown reasons. This was also observed in the surveys as greater weever were more or less absent during the spring survey and very abundant in the autumn survey. Greater weever primarily spend the day buried in the bottom, particularly in shallow waters during the warmer months of the year, however they have also been known to swim in schools in the pelagic at night and thus can be found throughout the water column at different times. During the winter months greater weever move to deeper waters to spend their winters. Greater weever feed on a variety of food items such as crustaceans (brown shrimp) and small fish, particularly, gobies, sandeel and during the autumn on small whiting and herring (Bagge, 2004). Greater weever spawn from April and into the warmer months of the year (April-August) depending on water temperature, where they will leave the shallower warmer waters to spawn in the pelagic at water depths around 10-20 meters. Their eggs remain pelagic where they drift with the current until hatching and juveniles seek soft bottom habitats near the coast.

4.1.4.6 Sprat (*Sprattus sprattus*)

Sprat is a pelagic species similar to herring that is also an important prey item ecosystem often as prey for a number of important predatory fish (for example cod). Sprat was abundant in the planned area for Hesselø OWF during the spring trawl survey. Sprat is found throughout much of the Danish waters particularly in coastal areas, fjords and in increasing abundance towards the inner Baltic waters (Muus & Nielsen, 2006). Sprat, like herring feed on zooplankton and although they don’t prefer any particular habitat, they will seek areas near the bottom during daylight hours as a refuge from predators, whereafter they will move up and spread out in the water column during the night to feed. Sprat can be found at depths from 5-100 meters often seeking deeper areas during the winter months. Sprat spawn pelagically from January to July throughout their distribution, albeit often in general areas where large schools of sprat gather or are present. Spawned eggs and larvae are spread out as they drift with ocean currents, whereafter juveniles start to school with adults as soon as they can swim and thus there are no specific habitats or areas that can be considered specifically as nursery areas (Warnar et. al, 2012)

4.1.4.7 Herring (*Clupea harengus*)

Herring is a pelagic species that swim together in large schools over large areas of the Danish marine waters including the Kattegat. It is an important fish for the marine ecosystem, just as it is an important commercial species for the fisheries. Herring are split into many different populations that separate themselves both by where they spawn and that spawning times can vary. In the Kattegat, there may be a small local population of autumn spawning herring along the northern Zealand coast, particularly near Hornbæk Bay and Gilleleje (Worsøe et al., 2002), however, most herring belong to a large population that spawn in the inner Baltic in areas near Rügen, where during the spring herring migrate from the Kattegat/Skagerrak through the Sound and inner waters of Denmark to their destination at Rügen (Øresundsvandsamarbejdet, 2018). Herring spawn in shallow waters over vegetation and mixed bottoms where their eggs sink towards the bottom and stick to vegetation, gravel, stones and other solid substrates until they hatch. Juvenile herring gather in large schools along much of the Danish coastline where there is vegetation (for example, eelgrass and macroalgae) where they grow while feeding on zooplankton. After spawning the large schools of herring migrate back through the inner Danish waters towards the deeper parts of the Sound, Kattegat and Skagerrak where they spend their winters.

4.1.5 Protected fish species

Only a single fish species, houting (*Coregonus oxyrhynchus*), is on the Annex IV species list in the Habitat Directive. This fish species is only found in the Wadden Sea and in the southern parts of the west coast of Denmark, and the large watercourses that run into these areas, and is thus not relevant for the planned area for Hesselø OWF.

Fish species listed in the Annex II species list, and that are appointed in some Natura 2000 sites and that can potentially occur in the planned area for Hesselø OWF are the sea lamprey (*Petromyzon marinus*), European river lamprey (*Lampetra fluviatilis)*, Atlantic salmon (*Salmo salar)*, twaite shad (*Alosa fallax)* and allis shad (*Alosa alosa)*. Effects of appointed species in the nearby Natura 2000 site 'Gilleleje Flak and Tragten' are dealt with in a separate technical report (NIRAS, 2022a), however the Natura 2000 site is not designated for fish.

The Danish Red List only contains freshwater fish, however amongst these the European eel, Atlantic salmon, and aea lamprey can be found in shorter or longer periods in the marine environment (Wind, P. & Pihl. S.(red.), 2010). In relation to the fish species that potentially could occur in the planning area for the Hesselø OWF and export cables, eel is considered critically endangered (CR) on the Danish Red List. Atlantic salmon and sea lamprey, which are predominantly found in Danish west coast and northern Jutland rivers, but can also be found periodically in the Kattegat as these fish migrate to and from salmon rivers on the Swedish west coast, and for sea lamprey through the Kattegat. Both of these species are listed as vulnerable (VU).

Historically, the Atlantic bluefin tuna (*Thunnus thynnus*) is a seldom guest in Scandinavian marine waters, however in recent years this species has been observed more often in the waters around Denmark, including the southern parts of the Kattegat where the planned area for Hesselø OWF is located.

Atlantic bluefin tuna generally occur during the late summer and early autumn months. While its presence has become more common, its abundance varies considerably from year to year, where there have been long periods and large differences as to how far in the inner Danish waters bluefin tuna have been observed. Atlantic bluefin tuna is on the IUCN's (International Union for Conservation of Nature) red list and at present is listed as threatened.

5 Sensitivity

In the following, a sensitivity analysis for fish communities is performed based on descriptions in chapter 4, information on activities, pressures and effects arising from the establishment of the Hesselø OWF as well as existing knowledge on fish species in relation to resistance to pressures and recovery time.

The method behind the sensitivity analysis provided by this technical report is based on the Marine Evidence-based Sensitivity Assessment (MarESA) methodology (Tyler-Walters, Tillin, d'Avack, Perry, & Stamp, 2018). The MarESA method is a systematic approach to determine the sensitivity of species and habitats towards external impacts. The approach was developed for application on especially benthic organisms and habitats, so for the purpose of this report, some modifications to the method have been made in order to make it more applicable to fish. The sensitivity score classification system used in the MarESA method, as well as similar approaches, have recently been applied in technical reports or environmental impact assessments in relation to establishment of offshore wind farms in the North Sea, e.g. Hornsea 4 (Ørsted, 2019) and Moray OWF (Moray Offshore Windfarm (West) Limited, 2018), as well as the Fehmarnbelt tunnel in the Baltic Sea connecting Denmark and Germany (FEMA, 2013a) (FEMA, 2013b). These examples have applied the method in relation to assessments of benthic communities, and this report will extend the application of the method in order to assess sensitivity of fish in relation to the planned establishment of Hesselø OWF.

In biology and ecology, sensitivity analysis is applied in order to assess how sensitive a species, population, community or habitat is towards environmental change caused by external, human-mediated activities. In the following, the methodology behind the sensitivity analysis is described, including the modifications to the MarESA method in order to make it more applicable to fish. The sensitivity analysis of fish is performed in relation to the planned establishment of Hesselø OWF.

5.1 Method description

The **sensitivity** of a **receptor** (species or population, community or habitat) is defined as a product of:

- intolerance to changes due to an external pressure (**resistance**) *and*
- time taken for subsequent recovery (**recoverability**)

Expanding on these terms, where resistance to a particular pressure is high, a receptor can absorb or tolerate disturbance or stress without changing character; conversely, receptors with low resistance are more readily affected by the same external pressure. Recoverability, or resilience, describes the ability to return to a previous state once the pressure is removed.

Pressures are mechanisms through which an activity has an effect on receptors, and can be of physical, chemical or biological character. Different activities (e.g. cable laying and foundation construction) can cause a similar pressure (e.g. seabed disturbance or habitat change), but different pressures (e.g. habitat change and increased underwater noise) can also result in similar effects (e.g. avoidance response) (Figure 5.1). The MarESA method includes a classification of potential pressures, which has been reviewed to identify those that are relevant to the activities associated with the proposed development. The standard pressure descriptions within the MarESA methods have also been adapted so that they relate directly to the Hesselø OWF.

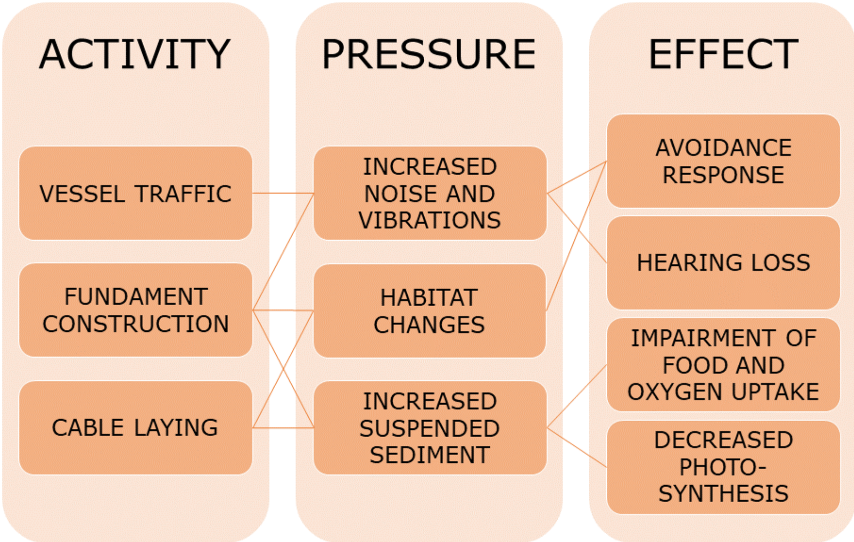

Figure 5.1: Overview of some of the relationships between activity, pressure and effect including examples relating to establishment of offshore wind farms.

Where appropriate, pressures can be described in terms of intensity (force of pressure, quantitative where possible), duration (time span of pressure) and range (spatial extent of pressure). In the case of Hesselø Offshore Wind Farm, which is not a defined project, these pressure descriptors will be determined on the basis of professional experience and general knowledge on offshore wind farms.

The resistance of a receptor is scored using a scale of none, low, medium and high resistance (Table 5.1), which are defined either quantitatively or qualitatively (Tyler-Walters, Tillin, d'Avack, Perry, & Stamp, 2018). A receptor with high resistance to a pressure will experience no significant change, although it may still experience effects on feeding, respiration and reproduction rates.

Table 5.1: Scale for scoring resistance to a pressure modified from (Tyler-Walters, Tillin, d'Avack, Perry, & Stamp, 2018).

Resistance	Effect	Quantitative description
None	Severe change	1) Considerable amount of mortality of the receptor 2) A large permanent reduction of a limited essential habitat – spawning ground, nursery area, feeding ground, home habitat i.e. no alternative essential habitat areas
Low	Significant change	1) Mortality of a receptor occurs 2) Threshold levels trigger an avoidance response causing the receptor to flee far (several kilometers) from the source of pressure 3) Permanent reduction of a limited essential habitat – spawning ground, nursery area, feeding ground, home habitat i.e. no alternative essential habitat areas
Medium	Some change	1) None or only little mortality occurs to receptor at the site of the pressure 2) Threshold levels trigger an avoidance response causing the receptor to temporarily flee a relatively short distance (kilometer) from the pressure

		3) Temporary reduction of a limited essential habitat – spawning ground, nursery area, feeding ground, home habitat i.e. no alternative essential habitat areas
High	No change	1) No mortality occurs 2) Threshold levels trigger an avoidance response causing the receptor to temporarily flee a very short distance (meters) from the site of the pressure 3) No or very low impact on the population of the fish community not effecting ecological function for the species 4) No reduction of an essential limited habitat – nursery ground, feeding ground, home habitat

The recoverability of a receptor is scored using a scale of very low, low, medium and high recoverability (Tyler-Walters, Tillin, d'Avack, Perry, & Stamp, 2018) (Table 5.2). Recoverability assumes that the pressure is relieved or stopped, and that the receptor experiences the conditions that existed prior to the pressure.

Table 5.2: Scale for scoring recoverability after a pressure has been relieved. Modified from (Tyler-Walters, Tillin, d'Avack, Perry, & Stamp, 2018).

Recoverability	Description
Very low	Negligible or no ability to recover
Low	Limited or slow recovery (e.g. years)
Medium	Moderate ability to recover (weeks to months)
High	Strong ability to recover (hours to days)

The combination of a receptor's resistance and recoverability scores gives the overall sensitivity score of the receptor, which can be categorized as not sensitive, low, medium or high sensitivity (Tyler-Walters, Tillin, d'Avack, Perry, & Stamp, 2018) (Table 5.3).

Table 5.3: The combination of resistance and recoverability scores to categorize sensitivity (Tyler-Walters, Tillin, d'Avack, Perry, & Stamp, 2018).

		Resistance			
		None	Low	Medium	High
Recoverability	Very low	High	High	Medium	Low
	Low	High	High	Medium	Low
	Medium	Medium	Medium	Medium	Low
	High	Medium	Low	Low	Not sensitive

In cases where a sensitivity analysis is not possible, following terms can be used:

- Not relevant. Recorded where the evidence suggests unlikely or no direct interaction between pressure and receptor.
- No evidence. Recorded where there is not enough evidence to assess the sensitivity.

At this stage of the assessment process (sensitivity determination) it is important to note the following:

- The duration (length of time) of an impact is not a factor in determining receptor sensitivity. For example, if a pressure (e.g. 'habitat change') is permanent, receptor recoverability following theoretical reinstatement of the original conditions is evaluated.

- Sensitivity is a key element of the future impact assessment process, but not in itself necessarily an indicator of impact importance (significance). The future impact assessment will consider other factors including the duration and magnitude of pressures.

The sensitivity analysis of fish provided here is composed of the following parts:

- A summarized baseline description of fish as **receptors** occurring in and around the planning area for Hesselø OWF and export cables, this includes an evaluation of the areas importance for fish.
- A list and description of possible **activities** during construction, operation and decommission of Hesselø OWF and export cables that may cause **pressures** and **effects** relevant for fish. As Hesselø OWF is not a defined project, the description of pressures will be determined on the basis of professional experience and general knowledge on establishment and operation of offshore wind farms.
- Scoring of **resistance** and **recoverability** of fish to relevant pressures based on knowledge from existing literature and professional experience.
- Scoring of **sensitivity** of fish to relevant pressures caused by possible activities during construction, operation and decommission of Hesselø OWF.

5.2 Sensitivity analysis

In the following, a sensitivity analysis for fish is performed based on descriptions in chapter 4, information on activities, pressures and effects arising from establishment of Hesselø OWF, as well as existing knowledge on fish species in relation to resistance and recovery time.

5.2.1 Receptors

This section summarizes main conclusions from chapter 4 on baseline description of fish species occurring in and around the planning area for Hesselø OWF and export cables, including the area's importance to fish. The baseline description is based on existing knowledge and the result of field work undertaken in this project.

5.2.1.1 Pelagic fish species/communities

During fish surveys there were several pelagic species caught throughout the planning area for Hesselø OWF and export cables. The most abundant species by number and weight were sprat (*Sprattus sprattus*) and herring (*Clupea harengus*), which were caught at almost every survey station. Combined, they accounted for 86% of the total number of fish caught and 66.1% of the catches by weight in the spring trawl survey, and although they were caught considerably less during the autumn survey, these two species were still present throughout most of the planning area for Hesselø OWF and outer area for the export cables. Similarly, herring and sprat were also caught in the gillnet surveys in the hard bottom habitats in the inner sections of the planning area for the export cables, suggesting that these species are also found in the near shore area close to the shoreline. Other pelagic species observed in the survey catches in less abundance were the seasonally abundant mackerel (*Scomber scombrus*), horse mackerel (*Trachurus trachurus*), anchovy (*Engraulis encrasicholus*), and the more common semi-pelagic species whiting (*Merlangius merlangus*), with a few individuals of boarfish (*Capros aper*), haddock (*Melanogrammus aeglefinus*) and blue whiting (*Micromesistius poutassou*). Other seasonally common pelagic species that can be expected in the Kattegat, but were not observed in the fish surveys are garfish (*Belone belone*), typically arriving in the spring months (April) and spending the summer in the Kattegat before migrating back to the North Sea in the autumn, and seatrout (*Salmo trutta*) along the coast. These pelagic species can be expected to be some of the most common species and therefore susceptible to the potential pressures from the realization of the plan for Hesselø OWF.

Baseline data indicate varying presence of the pelagic species sprat and herring from trawl survey as well as mackerel from gillnet survey. Other pelagic fish species that are known to seasonally visit the area during the early spring are lumpfish and garfish, or species such as seatrout and Atlantic salmon that potentially visit the area during their feeding migrations along the coastline.

5.2.1.2 Benthic fish species/communities

The relatively homogeneous soft bottom habitat in the planning area for the Hesselø OWF and the outer export cables corridor had a variety (23 species) of demersal (bottom living) fish caught in the spring and autumn surveys. Nine species of flatfish were caught of which juvenile dab (*Limanda limanda*) and plaice (*Pleuronectes platessa*), were consistently the most abundant demersal fish throughout the entire soft bottom habitats of the planning area. Another abundant demersal fish species observed in large abundance in the planning area in the autumn, was the greater weever (*Trachinus draco*). Other demersal species consistently present in the majority of the planning area but in lower abundances were grey gurnard (*Eutrigla gurnardus*), long rough dab (*Hippoglossoides platessoides*), common dragonet (*Callionymus lyra*), lemon sole (*Microstomus kitt*) and European flounder (*Platichthys flesus*), which corresponds well with these species' preference for soft bottom habitats. Also, interesting to note is the presence a goby (Fries's goby, *Lesueurigobius freisi*), which is a small fish often associated with sharing the same burrow in the sediment with the crustacean Norway lobster (*Nephrops norvegicus*), a very abundant crustacean in the soft bottom areas of the Kattegat and the planning area for Hesselø OWF (NIRAS & DCE, 2021b). One or a few individuals of several other demersal species (*Raja radiata*), monkfish (*Lophius piscatorius*), hooknose (Agonus cataphractus), sole (Solea solea), common ling (*Molva molva*), four-bearded (*Rhinonemus cimbrius*) and three-bearded rocklings (*Gaidropsarus vulgaris*), and sandeel (*Hyperoplus lanceolatus*) among others were also caught in the soft bottom habitats of the planning area for Hesselø OWF. Only a total of 19 cod, almost all juveniles or very small adults (lengths between 14-33 cm) were caught during the surveys in the entire planning area for both the wind farm and export cables.

In the hard bottom habitats including stone reef areas in the near shore areas of the planning area for the export cables, the most numerous demersal fish species caught in the gillnet survey was gold-sinny wrasse (*Ctenolabrus rupestris*), which together with the less abundant corkwing wrasse (*Symphodus melops*), and Cuckoo wrasse (*Labrus bimaculatus*) and snake pipefish (*Entelurus aequoreus*) that were observed during the benthic flora and fauna hard bottom survey, are species strongly associated with stone reef habitats. Other fish species in the hard bottom habitats and mixed bottom habitats included demersal species such as turbot (*Psetta maxima*), brill (*Scophthalmus rhombus*), black goby (*Gobius niger*) and the semi-pelagic codfish species whiting and individuals of juvenile cod. Many of these fish species would characteristically be found in areas with mixed habitats where different habitats of preference (hard bottom mixed with soft bottom) are available. Other fish surveys and sources of information indicate that the mixed and hard bottom habitats along the northern Zealand coast can also expect to be home to a number of other numerous non-commercial species such as sand goby (*Pomatoschistus minutus)*, rock gunnel (*Pholis gunnellus*), species of sculpins (Cottidae), three-spined sticklebacks (*Gasterosteus aculaeatus*), eelpouts (*Zoarces viviparus*), and seasonally, lumpfish (*Cyclopterus lumpus*) and other shallow water fish species (Fiskeøkologisk Laboratorium, 2000).

5.2.1.3 Early life stages - fish eggs and larvae

During the spawning season many fish species will gather in large numbers in specific areas or habitats to spawn. Most flatfish species, codfish, and pelagic fish such as sprat spawn in the pelagic where eggs and larvae continue their development in the open water as they drift with water currents. The majority of bottom living species, and some pelagic species such as herring and garfish etc., however, lay their eggs close to or on the bottom, often over particular habitats made up of vegetation, gravel or stone substrates. Some species such as gobies (*Gobidae*), sculpins (*Cottidae*) and pipefish (*Syngnathus spp*.) etc. have developed parental care, where adults protect their eggs/larvae during development. Eggs are often laid in clutches in a form of nest on hard and mixed bottom substrates such as mussel shells or in stone or gravel material.

Investigation of potential spawning by the most abundant flatfish species and cod in the planning area for Hesselø OWF an export cables by checking gonad development and abundance of mature adults during surveys, indicated that the planning area was not a primary spawning area for any of these species. In general, there were very few adults of cod, or the most abundant fish species dab or plaice caught during all surveys, indicating mature fish were not gathering in the area to spawn. Although survey data indicated there were no major spawning events being undertaken in or near the planning area for Hesselø OWF and export cables, because pelagic eggs and larvae drift with currents from other spawning areas, there will probably still be some eggs and developing larvae present in the planning area, as they drift throughout the Kattegat during their development. Spawning duration is species-specific and the period varies considerably from species to species, but spawning is typically completed within 3-4 month, and for most species is primarily undertaken during the first half of the year (January-June). Thus, it is anticipated that the density of eggs and fish larvae from a number of pelagic spawners will be greatest during the first half of the year and early summer months.

5.2.2 Activities, pressures and potential effects

This section describes possible activities during construction, operation and decommissioning of Hesselø Offshore Wind Farm that may cause pressures relevant for fish, as well as the potential effects of these pressures on fish. An overview of possible activities from establishment of Hesselø OWF and the following pressures and effects relevant for fish is provided in Table 5.4.

Table 5.4: Overview of activities during construction, operation and decommissioning of Hesselø OWF and the relating possible pressures and effects for fish species/communities. Pel = pelagic fish, Dem = demersal fish, ELS= early life stages

Receptor	Activity	Pressure	Effect
		CONSTRUCTION	
Pel, Dem, ELS	Pile driving	Increased underwater noise	Avoidance response Temporary or permanent hearing loss Increased mortality on early Life Stages (eggs and fish larvae)
Pel, Dem, ELS	Vessel traffic	Increased underwater noise	Avoidance response
Pel, Dem, ELS	Installation of foundations	Suspended sediment Sedimentation Seabed disturbance	Avoidance response Decreased visibility – effecting foraging Increased mortality on early life stages (eggs and larvae) i.e. decreasing the buoyancy of pelagic eggs
Pel, Dem, ELS	Cable laying	Seabed disturbance / temporary habitat loss	Avoidance response Increased mortality on early life stages (eggs and larvae)
Pel, Dem, ELS	Cable laying	Suspended sediment Sedimentation	Avoidance response Decreased visibility – effecting foraging Increased mortality on early life stages (eggs and larvae) i.e. decreasing the buoyancy of pelagic eggs
		OPERATION	
Pel, Dem, ELS	Operating turbines	Increased underwater noise from turbines, gearbox and generator	Avoidance response

Pel, Dem, ELS	Vessel traffic - maintenance	Increased underwater noise	Avoidance response
Pel, Dem, ELS	Foundation and scour protection material / introduction of rock for cable protection	Introduction of new hard substrate material	Avoidance response Habitat loss/change due to Introduction of new hard substrate habitat (reef effect)
Pel, Dem, ELS	Cables	Electromagnetic fields	Avoidance response, barrier effect
		DECOMMISSIONING	
Pel, Dem, ELS	Decommissioning work	Increased underwater noise	Avoidance response Temporary hearing loss (TTS)
Pel, Dem, ELS	Decommissioning work	Sedimentation Suspended sediment	Avoidance response Decreased visibility Increased mortality on Early life stages (eggs and larvae) i.e. decreasing the buoyancy of pelagic eggs

The following sections describe each pressure further and thresholds and potential effects on fish are outlined in more detail.

5.2.2.1 Underwater noise from pile driving

Pile driving turbine foundations into the seabed will cause extreme underwater noise and is one of the largest potential pressures to fish in all life stages in areas where turbines will be established. Fish eggs and fish larvae are not particularly sensitive to underwater noise and are primarily effected when underwater noise is so high that it can damage their tissue (Andersson et al., 2017). Generally, the frequency range, where fish hear best is similar to the frequencies similar to the largest part of sound energy from the underwater noise generated by pile driving (Bellmann M. K., 2018; Richardson, Malme, Green, & Thomson, 1995).

Fishes have a wide range of hearing capabilities to perceive underwater noise and can be classified as hearing generalists or hearing specialists (Fay et al. , 1999) (Sand & Karlsen, 2000) depending on the species. The most perceptive fish species to underwater noise are those with swim bladders linked to inner ears, which include clupeids such as the pelagic species sprat and herring (Popper et al., 2014), which were abundant in the planning area. These species can hear frequencies that span from infrasound (<20 Hz) up to approximately 8 kHz, however with decreasing sensitivity the higher the frequency (Enger, 1967; Sand & Karlsen, 2000). Other species with swim bladders but less specialized internal connections with inner ears, are codfish and mackerel, which can be considered hearing generalists with slightly less sensitivity to perceive underwater noise (Chapman & Hawkins, 1973) (Popper, et al., 2014). These species can hear sound from infrasound up to 500 Hz (Chapman & Hawkins, 1973). In almost all demersal fish, such as flatfish, the swim bladder degenerates after the larval stage and thus demersal fish species have poor hearing capabilities and are not particularly sensitive to underwater noise (Karlsen, 1992). These and other demersal fish species associated with seabed habitats in the planning area such as gobies (Gobidae), sculpins (Cottidae), dragonet etc. are hearing generalists with poor hearing capabilities and low sensitivity to noise that typically hear in the range from infrasound up to a few 100 Hz (Sand & Karlsen, 2000).

Specific knowledge of how different fish species react to noise is relatively limited, however almost all fish respond to noise levels above 90 dBht by eliciting an avoidance response and swimming away from the source of sound or pressure (Nedwell et al., 2007). Higher levels of underwater noise as well as continuous and accumulated noise (SEL_{cum}) can impair the hearing of fish and create temporary hearing loss (TTS) (Popper, et al., 2014). Extreme levels of noise from for example, pile driving can be so high that they can cause permanent hearing loss (PTS) from damage to tissue and hearing organs when in the near vicinity of the activity, which can be fatal for fish, fish eggs and fish larvae (Andersson et al., 2017).

Auditory threshold shift (TTS and PTS)
Pile driving noise exposure can result in a decrease in hearing sensitivity in fish either permanently or temporarily, termed threshold shift. If hearing returns to normal after a recovery time, the effect is a temporary threshold shift (TTS); otherwise, it is a permanent threshold shift (PTS). Sound intensity, frequency, and duration of exposure are important factors for the degree and magnitude of hearing loss, as well as the length of the recovery time (Neo et. al., 2014) (Andersson et al., 2017).

Guidelines for temporary hearing loss (TTS) in fish species with a swim bladder similar to herring and cod (Popper et al., 2014) are given in Table 5.5. Similarly, thresholds for tissue damage and hearing loss leading to mortality in fish, fish eggs and larvae have been derived by Andersen et al. (2017) and are also given in Table 5.5. Fish species without swim bladders (primarily demersal species) including all flatfish species (important in the planning area) and other demersal species found in the planning area, are much less perceptive to noise than fish species with swim bladders (primarily pelagic) and codfish, and it can be expected that actual tolerance thresholds for demersal fish are higher than pelagic fish. However, because information of threshold values is very limited, the threshold values for the least tolerant fish species are used for all species including demersal species in this analysis.

Threshold levels for when fish begin to experience hearing loss depending on their hearing capabilities, begins at around 185 dB for fish least tolerant to noise (Table 5.5). Conservatively, the noise level where irreversible hear loss and permanent injuries leading to mortality is set at 204 dB for all fish, and at 207 dB for mortality to fish eggs and larvae (Table 5.5).

Table 5.5: Threshold levels for fish, and their early life stages (fish eggs and larvae) where temporary hearing loss (Popper, et al., 2014), and tissue damage and death will occur (Andersson et al., 2017). Continuous and accumulated noise or Sound exposure level (SEL_{cum}) is the accumulated dose of noise with repeated ramming of monopiles. Because thresholds in this study are not based on demersal fish without swim bladders and thus less sensitive to underwater sound, the threshold for this group of fish is slightly higher than expressed in the table.

Effect	Thresholds for adult fish	Threshold for eggs and fish larvae	References
Temporary hearing loss (TTS)	185 dB re 1 μPa^2s SEL_{cum}	-	Popper et al. (2014)
Irreversible tissue damage leading to death for the least tolerant fish species and fish eggs and larvae (PTS)	204 dB re 1 μPa^2s SEL_{cum}	207 dB re 1 μPa^2s SEL_{cum}	Andersson et al. (2017)

Although the underwater noise from pile driving is of high intensity and has the possibility of effecting fish in a relatively large geographical range primarily by causing a behavioral response (fleeing), the noise will still be of relatively short duration and not continuous, and only occur during the establishment of turbine foundations. An overview of the worst case impact distances for cod and herring for PTS (injury) and TTS as well as injury to fish larvae and eggs for the planning area of Hesselø OWF under the expected use of Noise Abatement Systems (NAS) is provided in the technical report for underwater noise (NIRAS, 2022b). Results indicated that impact distances for PTS or injury to fish will occur within 25 meters of the pile driving activity, while the impact distances for TTS in fish will occur up to 4.9 km and up to 9.5 km from the noise source depending on the species and in a worst case scenario when pile driving the largest foundations of 15 m in diameter. For fish eggs and fish larvae, which are not perceptive to sound, but can experience tissue damage and injury (mortality) if they experience sound levels of 207 dB re 1 μPa^{2}s SEL_{cum} and greater, modelling indicated that this will occur at distances up to 700 meters from the pile driving activities.

Thus, the worst effects from the pressure of underwater noise from pile driving (PTS and injury) will be to individuals that are within the close vicinity of the pile driving activity. Beyond this the majority of fish will flee from the source of pressure and return when the noise has ceased, and possibly experience temporary hearing loss that is reversible over time. Injury to fish larvae and eggs will also occur in a relatively limited area near the vicinity of the pile driving.

At present, there is very limited knowledge of the short-term and long-term consequences of PTS and TTS in fish. However, unlike the physiological damage to internal organs associated with PTS and in a worst case scenario mortality, both flight behavior and hearing damage are linked to the species' specific sensitivity to frequency and sound intensity and with existing literature, it is not possible to assess whether flight behavior or the time to recover from TTS negatively affects fish communities at the population level, or whether the effect of the impact is only related to the area of impact linked to the duration of the temporary hearing loss.

Mortality to fish larvae and eggs is naturally very high in nature and although there will be some loss of recruitment due to the mortality of eggs and larvae close to the source of pressure, this is considered very limited and is not expected to have any significant effect at the population level.

5.2.2.1.1 Resistance and recoverability – underwater noise from pile driving

The pressures from underwater noise from pile driving above a threshold level can cause permanent injury or death (PTS) for all fish receptors in the near vicinity of the source, thus resistance is ranked as none and recoverability to PTS for all fish receptors (pelagic fish, demersal fish and early life stages) is ranked as very low.

Close to the source of the high underwater noise from pile driving, but not within range where fish will experience injury, the pressure will trigger an avoidance response causing juvenile and adult fish to flee from the pressure and possibly experience a temporary hearing loss (TTS). For both pelagic and demersal fish species the resistance to these effects are low.

Effects of short-term temporary hearing loss or having to flee from a pressure on survival and reproduction success of individual fish is unknown (Andersson et al., 2017), but could possibly effect the ability of fish to function normally which could lead to a decrease in fitness. Similarly, there are no direct field studies that address how the negative effects of pile driving noise affect a species at the population level (Popper et al., 2014; Skjellerup, et al., 2015). Because of this uncertainty the recoverability of fish (pelagic and demersal) that have fled an area of high noise intensity and experienced a short-term temporary loss of hearing that can last several weeks is ranked as medium.

Early life stages are not effected by noise levels below the high threshold levels that will cause injury and potentially mortality and therefore there is no evaluation on their resistance or recoverability in relation to lower noise levels. The immobility of fish eggs and larvae means that they can experience a longer exposure than fish. Harmful noise levels from pile driving only occur near the sound source, and because the eggs and larvae exhibit naturally high levels of mortality in the wild, mortality caused by high impulsive noises is assessed to be insignificant for the population.

5.2.2.2 Underwater noise from vessel activity - construction and maintenance

During wind farm construction and operational maintenance an increase in ship traffic of both small and large vessels is expected within and near the planning area for Hesselø OWF. Increased vessel traffic will primarily lead to a brief increase in the amount of low frequency noise typically from a few Hz to 100 kHz (Ross, 1976). Demersal fish species with and without swim bladders but not specialized hearing organs (for example codfish), hear frequencies that span from <20 Hz to 500 Hz (Sand & Karlsen, 2000; Chapman & Hawkins, 1973), while species with specialized hear organs (hearing specialists), such as the pelagic species sprat and herring, can also hear higher frequency sound (up to 8 KHz) (Enger, 1967; Sand & Karlsen, 2000). Thus, the general frequency levels of noise where fish hear best, coincide with the frequency range of the noise produced by boats and shipping vessels.

The noise level of small boats is between 130-160 dB re 1 µPa@1meter (Erbe, 2013; Erbe, Liong, Koessler, Duncan, & Gourlay, 2016), while the underwater noise levels from larger vessels is up to 200 dB re 1 µPa@1 meter (Erbe & Farmer, 2000; Simard, Roy, Gervaise, & Giard, 2016; Gassmann, Wiggins, & Hildebrand, 2017). While the general noise levels of construction and maintenance vessels are at a level (>90 dB) that will potentially induce a behavioral response in most fish, such as moving away from vessel (Nedwell et al., 2007), it appears that only the larger ships will create noise levels (>185 dB) that can temporarily induce hearing loss (see Table 5.5). Thus, fish can be affected by the underwater noise created by construction and maintenance vessels, but the effect of noise from vessels will for most fish only induce a fleeing response away from the vessel and in worse case for individuals very close to the source (within meters), a temporary hearing reduction/loss that will last a few weeks (Webb, Popper, & Fay, 2008).

5.2.2.2.1 Resistance and recoverability – underwater noise from vessel activity

At worse, underwater noise from large vessels can be high enough to elicit temporary hearing loss in fish if they are close (within a few meters) to the source, otherwise underwater noise from vessel activity will only trigger a behavioral response for pelagic and demersal fish to flee from the area where underwater noise is above threshold levels causing this behavior. The planning area for Hesselø OWF is located in close vicinity to the main ship routes and an intense commercial fishery in the central part of Kattegat and is therefore an area with substantial vessel traffic. Thus, the area is already expected to be dominated by vessel traffic creating underwater noise and fish in the area are likely to be adapted to a certain amount of underwater noise from vessel noise. Thus, the resistance of both pelagic and demersal fish to underwater noise from vessel activity is considered to be medium.

The consequences for the few individual fish that may experience a temporary but reversible hearing loss and the likely scenario that fish will return to an area after the underwater noise from a vessel has ceased, suggests the recoverability to both individual fish and the fish population to underwater noise from an increase in vessel activity is high.

For the early life stages, fish eggs and larvae, the level of underwater noise from vessels is not high enough to induce tissue damage or mortality (Table 5.5) and there is no evidence to assess the resistance and recovery of early life stages to underwater noise from vessel activity.

5.2.2.3 Sediment spillage

During the construction phase, periods of increased amounts of suspended material in the water column (and subsequently increased sedimentation) will occur during the installation of foundations, inter-array cables and export cables. Increased amounts of suspended material in the water column can reduce visibility of fish when foraging, decrease the efficiency of gills, (Moore, P., 1991; Newcombe & MacDonald, 1991; Engell-Sørensen & Skytt, 2002) and reduce the buoyancy of fish eggs (Hansson, 1995; Westerberg et al, 1996). The overall effect of increased suspended sediment on fish, eggs and larvae is determined by sediment concentrations and duration of exposure.

The impact from sediment spills and increased sediment concentrations is species-specific and typically related to whether a fish lives pelagically or on the bottom. Demersal or bottom dwelling fish such as the many flatfish and demersal fish observed in the soft bottom areas of the majority of the planning area for Hesselø OWF, are more tolerant of high suspended sediment concentrations and sedimentation than the observed pelagic fish, primarily sprat and herring. The most likely effect of elevated suspended material is an evasive behavior where fish will move out of an area with increased suspended sediment. For the more sensitive pelagic species to increased suspended sediment, a literature review in connection with establishing Fehmarnbelt, a sink tunnel on the ocean floor, came to the conclusion that, as a conservative estimate, increased suspended sediment >10 mg/l will trigger avoidance behavior by pelagic fish (FeBEC, 2013). The same review set the threshold level for triggering an avoidance response to suspended sediment levels by demersal species at >50 mg/l (FeBEC, 2013). Despite the considerably low levels of sediment concentrations triggering an avoidance response, most fish species have a tolerance for periodically high concentrations of suspended sediment before they are negatively affected. This is particularly true for fish communities in coastal areas, which are often exposed to increased concentrations of suspended sediment and sedimentation during strong winds and storms for example in soft bottom areas of the Wadden Sea where concentrations of suspended sediment can be as high as 800-1000 mg/l after storms (Andersen & Pejrup, 2002). Particularly, benthic species such as flatfish are adapted to environments of high turbidity and can survive suspended sediment concentrations as high as 3,000 mg/l (Engell-Sørensen & Skytt, 2002).

The early life stages of fish, eggs and larvae, exposed to increases in suspended sediment will typically be exposed over a longer time, as they have none or at most, only limited mobility to escape from an area with sediment spillage and increased suspended sediment. Pelagic eggs can be affected by the suspended material adhering or sticking to eggs and making them less buoyant and more susceptible to sinking to the bottom (Auld & Schubel, 1978; Isono et al, 1998) where they are at risk of suffocating due to lack of oxygen, which is typically lower on the seabed surface. Studies of cod eggs that are pelagic have shown that concentrations of suspended sediment above 100 mg/l have decreased their buoyancy and increased their mortality (Hansson, 1995; Westerberg et al, 1996). Similarly, demersal fish eggs may be harmed by suffocation caused by overloads of settled particles (Griffin, Smith, Vines, & Cherr, 2009). In contrast, eggs that are spawned near or on the seabed have been shown to have a high tolerance for high suspended sediment and sedimentation. For example, herring eggs that are spawned in shallow areas where they stick to vegetation and hard substrates were not affected by being exposed to suspended concentrations up to 500 mg/l for more than 24 hours (Kioerboe, Frantsen, Jensen, & Nohr, 1981) or concentrations >50 mg/l for 14 days (FeBEC, 2010). Other species particularly gobies (Gobidae), sculpins (Cottidae), pipefish (Syngnathinae), stickelbacks (Gasterosteidae) etc. expected to spawn benthic eggs in the shallow mixed and hard bottom habitats along the export cable corridor of the planning area for Hesselø OWF where periodic increases in suspended sediment and sedimentation due to strong winds and currents are periodically experienced and tolerated. For fish species with parental care of eggs, it can be expected that adult fish will keep eggs and fry free of sediment deposits and thereby prevent the eggs from being buried and strongly affected.

5.2.2.3.1 Resistance and recoverability – sediment spillage

The resistance of the impact from sediment spills and increased sediment concentrations is species-specific and typically related to whether a fish lives pelagically or on the bottom. Increased amounts of suspended material in the water column will reduce the visibility of fish when foraging and potentially affect their oxygen uptake by clogging their gills, and create a behavioral response in juvenile and adult fish by triggering a fleeing response away from the source of pressure and potentially their respective habitat. Most fish are tolerant of moderate and short-term increases in suspended sediment and sedimentation that will come from construction activities, and although a number of individual fish will be affected by these pressures the effects are expected to not create any mortality or have an effect on the population and thus the resistance to this pressure is considered to be medium for pelagic species which respond to lower levels of suspended sediment and sedimentation and high for demersal fish species as they are more tolerant to increased suspended sediment and sedimentation.

It is anticipated that the duration of increased suspended sediment concentrations and sedimentation during construction activities will be short and that the greatest pressure to fish from increased suspended sediment and sedimentation levels will be in the near vicinity of the construction and cable laying activities. The pelagic and demersal fish that have been affected by the pressures of sediment spillage and fled from the impacted area, will most likely return after the levels of increased suspended sediment and sedimentation have subsided. Because the effects of sediment spillage will not lead to any lasting effects on individual fish or their populations, the recoverability of pelagic and demersal fish to increased suspended sediment and sedimentation is considered to be high.

Closest to the activities where increased suspended sediment and sedimentation are highest, pelagic eggs may lose their buoyancy, sink and die and fish larvae may experience clogged gills and thus increased mortality. Similarly, fish eggs spawned on the bottom near the activities where sediment spill is greatest may be covered and perish. Some fish eggs and larvae have, however, some tolerance to increased suspended sediment and sedimentation and thus the resistance of the early life stages to increased suspended sediment and sedimentation due to sediment spillage is considered low.

Survey data indicated that the planning area for Hesselø OWF and export cable is not an important spawning area for the most abundant flatfish species or codfish. Furthermore, fish eggs and larvae will only be exposed to levels of increased suspended sediment and sedimentation that can have negative consequences for their survival in a limited area, and for a limited time during wind farm construction and cable laying activities. Although there will be some mortality to the early life stages of some fish species in the planning area, the magnitude of this mortality is considered to be limited because the pressure is limited and because mortality rates are generally naturally very high in the early life stages of fish, thus the effects on the recruitment to fish species and population as a whole, is considered low and the recoverability from the pressures of increased sediment spillage is considered medium.

5.2.2.4 Habitat disturbance - temporary

Physical disturbance of the seabed will occur with activities such as when establishing turbine foundations and platforms, burial (ploughing or jetting) of inter-array and export cables and using jack-up barges during the construction phase. The primary effects will be a temporary impact in the form of short-term disturbances and destruction of some soft bottom fish habitats in the planned wind farm area and outer export cable corridor, and mixed and hard bottom (stone reef) fish habitats found in the nearshore sections of the export cable corridor.

The principal effects to fish will be a behavioral response to flee the local area of activity and disturbance. Because of the limited mobility of the early life stages (eggs and larvae) the local physical disturbances could lead to injury or death in the immediate vicinity of the activities. Note that the replacement of the naturally occurring bottom substrate with introduced hard bottom substrates from establishing turbine foundations and eventually rock protection of cables in the hard bottom areas is considered as habitat loss/change and is dealt with in section 5.2.2.5.

The bottom substrate in the wind farm and outer cable corridor of the planning area for Hesselø OWF is dominated by soft bottom fish habitats. These habitats and their benthic fauna communities have been characterized as being highly disturbed from extensive bottom trawling fisheries and thus the benthic community is characterized by organisms that are opportunistic and quick to recover from these disturbances (NIRAS & DCE, 2021b). Thus, restoration of the original seabed is expected to occur naturally and in a short time as the original seabed material and re-migration of soft bottom fauna, which is food for many of the benthic fish, will only take a few months to a year (Hygum, 1993; Newell, Seiderer, & Hitchcock, 1998).

Based on the above, it is estimated that the direct physical impact on various fish habitats and fish communities as a result of disturbances to the seabed habitats will only be short-term, reversible and because of the relatively small area of impact from jack-up supports and relatively small width (few meters) of seabed disturbance during ploughing/jetting of cables during their burial, will only effect a small area close to the areas of installation activities. Fish will flee from the areas of disturbance, and will return to the area after construction activities cease. Within and close to areas of seabed disturbances, fish eggs and larvae will be injured or die. However, only a short distance from the source of disturbance negative effects on the early life stages of fish is not expected and it is not expected that these disturbances will have any effect on fish recruitment and the fish community as a whole.

The same effects to fish and early life stages can be expected during the cable laying activities in the near shore mixed and hard bottom fish habitats. Disturbed hard bottom fish habitats may, however, take a longer time to recover than soft bottom habitats and thus the disturbance to fish communities in the local area of impact due to the temporary loss of habitat will possibly last for a longer period of time. However, because many common hard bottom fish species return to and recolonize rehabilitating or newly established hard bottom habitats during their recovery (DTU Aqua, 2013), and over time the hard bottom habitats are expected to fully recover (DTU Aqua, 2013), the overall effects on the fish communities in the hard bottom habitats due to the local disturbances can be expected to be minimal.

5.2.2.4.1 Resistance and recoverability – temporary habitat disturbance

Because the physical disturbances will occur locally on the seabed, and pelagic species are generally in the water column and thus will only be slightly exposed to these pressures, the resistance of pelagic species to physical seabed disturbances is high.

Potential effects from seabed disturbances to pelagic species can create a behavioral response where pelagic fish will move or stay away from the area where activities disturbing the seabed occur until they cease, whereafter they will return. Thus, the effects of the pressures on pelagic fish and their populations from habitat disturbance are negligible and their recoverability from temporary disturbances on seabed habitats is high

Demersal fish, which are more associated with seabed habitats, will experience temporary disturbance and short-term loss of seabed habitats due to ploughing, jetting or potentially using rock protection in hard bottom areas that they may be associated with. The disturbances from these pressures will cause fish to use energy and move away (flee) from an area of activity, and possibly create a temporary reduction in available habitat. This response allows the different fish species affected by the pressures from habitat disturbance and temporary loss of habitat to limit the impact of these disturbances without any significant impact on the condition or survival of effected individuals or them experiencing injury. Furthermore, the planning area for Hesselø OWF and export cables is located in an area with substantial seabed disturbance due to bottom trawling and therefore the demersal fish community are, to a certain extent, compatible with seabed disturbances and thus their resistance to these pressures are considered medium

When the activities disturbing the seabed are completed, it is anticipated that fish (primarily demersal fish) will return to the area of impact within a short period of time. In general, the resistance of demersal fish species associated with bottom habitats are dependent on the magnitude and recovery time of their disturbed habitat. As the habitat disturbances are considered to have only limited spatial impact on the bottom habitats and their associated fish and of the expected quick return of fish, which will not experience significant consequences to the fish communities, the recoverability of all juvenile and adult fish species to disturbances on the bottom seabed habitats is considered high.

The effect of local physical seabed disturbances is relevant to the early life stages that are on the bottom, and due to their immobility eggs and fish larvae the Early life stages that are directly impacted by these pressures can´t avoid injury or experiencing increased mortality. Thus, the resistance of early life stages to disturbances on the seabed is low.

Because negative effects to the early life stages from disturbances to the seabed will only be local and in a relatively small area around the pressure, and because natural mortality to fish eggs and larvae in the environment is generally high, it is estimated that recoverability is considered to be high due to limited negative effects to Early Life stages and recruitment as a whole.

5.2.2.5 Habitat loss/change – permanent

The placement of wind farm turbine foundations, erosion protection material and transformer platforms in the planning area for Hesselø OWF will lead to a loss of existing soft bottom fish habitats where these installations will be placed. Pelagic fish species (herring, sprat, etc.) are not expected to be directly affected by the changing seabed conditions but demersal fish species associated with soft bottom habitats, such as the various flatfish species (dab, plaice, lemon sole, long rough dab, etc.) and other abundant demersal species (dragonet, grey gurnard, Fries´s goby etc.) observed in the soft bottom habitats of the planning area for Hesselø OWF will have their preferred habitat reduced by the area the introduced hard substrates will occupy.

Habitat loss will be permanent, but in relation to the total area lost and the abundance of soft bottom habitats in the planning area for Hesselø OWF, the effect on the demersal fish community is considered to be negligible. The final impact of this loss and pressure to fish will depend on final project descriptions such as the number and size of turbines, and the choice of foundation and magnitude of the use of protective material (scour material).

The new hard bottom substrate will lead to a stabilization of the seabed by helping prevent scouring from water currents and increase the physical complexity and bottom structure in the predominant soft bottom habitats of the planning area. Over time, the introduced hard bottom substrates in the form of concrete, rock formations and steel will develop a hard bottom habitat and function as a so-called artificial reef. The reef will rapidly develop a succession of reef associated organisms and a reef community consisting of macroalgae species and a series of epibenthic invertebrates (bottom-dwelling invertebrates) and associated fish species depending on water depth and current conditions, and on the material from which the foundation is built, including its heterogeneity (DTU Aqua, 2013; Støttrup et al. , 2014). It is expected that an artificial reef will attract fish species associated with hard bottom and stone reefs, such as Labridae (gold-sinny wrasse, corkwing and cuckoo wrasse), juvenile cod, rock gunnels and others species who find refuge and food here (Støttrup et al. , 2014) (Kristiansen et al,, 2017).

The export cable will either be buried or laid on top of the seabed and covered with stones in the nearshore hard bottom habitats. Here, the excavated material from the area along with comparable hard bottom and stone reef material will be reused for backfilling. Thus, the hard bottom habitats will be temporarily effected and the fish habitats temporarily lost until the hard bottom organisms recover and reestablish themselves, while regaining their functionality as a hard bottom habitat for fish.

In summary, it can be said that the total area of the introduced substrate and the associated communities will be modest, and that only in the immediate vicinity of new hard bottom substrates can an effect on the composition of the fish fauna be expected. Overall, however no effects on the fish community as a whole is expected.

5.2.2.5.1 Resistance and recoverability – permanent habitat loss/change

Loss of fish habitat due the installation of turbines and protective material is a permanent effect leading to the change of one fish habitat type to another fish habitat in the form of an introduction of hard substrate.

As pelagic species that are generally not associated or affected by the introduction of hard substrate habitats, the resistance and recoverability for all pelagic fish is ranked as high.

Because the change of one fish habitat to another is considered to cause only a limited pressure on the demersal species by forcing them to experience a loss of habitat which is not considered to effect their individual condition their resistance to this pressure is considered to be medium.

The demersal species in the planning area that prefer soft bottom habitats will experience a loss of habitat and be forced to move into other soft bottom areas where soft bottom habitats of preference are available. These soft bottom associated species are, in general, not specifically dependent on the one particular soft bottom habitat and have the ability to adapt to a variety of the similar soft bottom habitats available in the planning area, thus the recoverability of demersal species to the change in habitat is considered high.

The lost habitats due to installations and use of protective material in the wind farm area and outer cable corridor are soft bottom, which is by far the most abundant fish habitat type in the entire planning area for Hesselø OWF. Because the effect of this pressure is small, the lost soft bottom fish habitat is insignificant to the fish receptors most associated with softbottom habitats (demersal fish and early life stages such as fish eggs laid on bottom substrates) and will not have an effect on the existing fish communities, thus their recoverability is high.

Fish associated with hard bottom habitats are generally only found in these environments and thus their resistance to loss of this habitat is low. Over time, the introduced hard bottom substrates in the form of concrete, rock formations and steel in soft bottom areas will develop a hard bottom habitat and function as a so-called artificial reef for the reef associated fish that have experience a loss or change in their habitat, thus the recoverability of fish associated with hard bottoms due to the introduction of hard substrates is high.

Because negative effects to the early life stages from the introduction of change in habitat will only be local and in a relatively small area around the pressure, and because natural mortality to fish eggs and larvae in the environment is generally high, it is estimated that their resistance and recoverability is considered to be medium due to limited negative effects to early life stages and recruitment as a whole.

5.2.2.6 Operational underwater noise

In connection with the operation of the Hesselø OWF, there will be an increase in underwater noise, originating from each turbine in operation (gearboxes and generators etc.). Underwater noise and vibrations from these installations are transmitted from the wind turbine towers through the steel foundations to the surrounding sea and seabed. Noise from the wind turbines' gearbox, turbine and generator in the operational phase differs from noise in connection with the construction phase and from the noise from ship traffic in that it is less intensive, but continuous.

The character and strength of the operational noise makes it probable that they can be heard (detectable) by sound-sensitive pelagic fish such as clupeids (sprat and herring) and codfish at a distance of up to a few hundred meters from the source while for demersal fish with only small or no swim bladders such as flatfish, gobies and sculpins (Cottidae) etc., wind turbine noise is only detected within short distances <50 meters (DFU, 2000).

Although, both pelagic and benthic species of fish are able to hear the ultrasonic underwater sounds from the mechanical components of wind turbines, there are no indications that they will exhibit a behavioral response and flee or move out of the area. On the contrary, the presence of fish around operating turbines has been studied, at the Horns Rev 1 Offshore Wind Farm, where seven years after its establishment, the abundance of fish and more species were observed near the wind turbines than in the nearby reference area (Stenberg et.al., 2011), possibly due to good feeding and refuge possibilities around the wind farm foundations.

Potential habituation to the operational sounds produced by wind turbines is supported by studies of other offshore wind farms at Nysted OWF and Horns Rev OWF, where a large number of fish species, including dense schools of two-spotted gobies, sculpins, gold-sinny wrasses, black gobies and cod, were registered in and around the wind turbine foundations (Stenberg et.al., 2011) (Hvidt et.al., 2006).

Underwater operational noise is not high enough to have any effect on the early life stages (fish eggs and larvae) of fish, and thus the early life stages will not be effected by underwater noise from wind farm operations.

5.2.2.6.1 Resistance and recoverability – operational underwater noise

Despite the fact that both pelagic and demersal fish can probably hear the operational underwater noise from the mechanical components of wind turbines, they do not appear to be noticeably effected and thus the resistance to underwater noise for both pelagic and benthic fish is ranked as high. Furthermore, if underwater noise caused by the operation of turbines in a worse-case scenario did trigger a temporary behavioral response, causing fish to move away from the near vicinity of the turbines, this effect appears to be only be for a short time period, whereafter fish return after a period of acclimation. Because there are no indications that suggest a difference in fish communities near working turbines in comparison to the surrounding area, recoverability is considered high.

5.2.2.7 Electromagnetic fields

Localized electric and magnetic fields are associated with operational power cables that will include the inter array cables that are buried within the wind farm area and export cables placed in the cable corridor to land. Due to the difference in current strengths, the electromagnetic fields around the inter array cables connecting the turbines will be significantly lower than the export cable to land. In general, the intensity of the magnetic fields weakens quickly with increasing distance (meters) to the cable and the propagation of the magnetic field is directly dependent on the current flowing through in the cable.

Only limited information is available on the potential effects on fish resulting from this pressure (Öhman et al, , 2007), but there is a potential for electric and magnetic fields altering the behavior of some sensitive fish species, either by creating a barrier effect or causing them to move away from cables. There are only a few fish in the Kattegat that are expected to respond to magnetic fields. These include cartilaginous fish (sharks and rays) that have electroreceptors, which they use to perceive electromagnetic fields around prey and to orient themselves in their surroundings (Kalmijn, 1978). There is also evidence that some bony fish such as plaice and eel have the ability to use magnetic signals in orientation of their surroundings (Metcalfe et.al., 1993) (Karlson, 1985). In a study around the SwePol HVDC cable (between Sweden and Poland), a magnetic field of 200µT 1 meter from the cable did not have an effect on the migration pattern of observed fish, including eel (Westerberg & Lagenfelt, 2008). In another study of migratory eel, it was observed that eels' swimming speed was slightly reduced when moving over an AC cable (Øland cable) laid on the seabed surface. Results in another study investigating the distribution of fish communities in relation to an operating AC cable connecting an offshore with a transmission network indicated there was no change in the fish fauna on both sides of the cable after it was put into service (Hvidt et al., 2004).

In general, overall conclusions indicate that some fish species in and around the planning area for the export cables may to some extent be able to detect a magnetic field around operating cables, but that the effect on local fish communities including elasmobranchs and other species most sensitive to electromagnetic fields, is probably very modest, partly due to the relatively weak electromagnetic fields and partly due to the limited range of electromagnetic fields that could potentially have an impact on fish. Overall, the fish surveys indicate the fish communities in the planning area of Hesselø OWF and export cables do not have many fish species that are sensitive to the pressures from electromagnetic fields generated by operating electric cables.

5.2.2.7.1 Resistance and recoverability – electromagnetic fields

Localized electric and magnetic fields produced from operational power cables could alter the behavior or development of fish highly perceptive to electromagnetic fields such as sharks, rays and skates and some bony fish. However, very little is known about the overall effects of electromagnetic fields created around electric cables during operations on these fish. Because studies in general indicate that there appear to be no obvious differences in behaviour or well-being by fish highly perceptive to electromagnetic fields or fish in general around operational cables transmitting electromagnetic fields, the resistance and recoverability of both pelagic and demersal fish towards electromagnetic fields is ranked as high.

There is no evidence available to suggest there is an effect of electromagnetic fields on the early life stages of fish, eggs and fish larvae.

5.2.2.8 Decommissioning work

During decommissioning of the offshore wind farm, pressures on fish and early life stages are expected to be less than those of the construction phase of the wind farm. This includes underwater noise emission due to decommissioning work and increased ship traffic in the planning area for Hesselø OWF and ECC. As the decommissioning procedure is not known and there is limited experience from decommissioning of other offshore wind farms, the impact on fish caused by activities during the decommissioning phase is difficult to predict. However, it is expected that the underwater noise and sediment spillage will for example be less intense compared to the construction phase, as there will be no pile driving activities.

5.2.2.8.1 Resistance and recoverability - decommissioning work

Underwater noise from decommissioning work is expected to only cause a minor pressure on fish and none on early life stages and the resistance is ranked as medium whereas the recoverability is ranked as high for all three receptors both at the individual level as well as at the population level.

5.3 Sensitivity assessment

In this section, the sensitivity scores of fish towards relevant pressures and effects are provided. The sensitivity scores result from a combination of the resistance and recoverability scores explained in section 5.1 and derived from Table 5.3, where sensitivity is determined by the resistance and recoverability attributes of each receptor (as assessed in section 5.2.2). Sensitivity scores into categories: not sensitive, low, medium and high for pelagic fish, demersal fish and early life stages (fish eggs and larvae) are listed for each pressure in Table 5.6.

Table 5.6: Overview of sensitivity scores to relevant pressures for pelagic fish, demersal fish and early life stages (fish eggs and larvae)

Pressure	Pelagic species			Demersal species			Early life stages (eggs and larvae)		
	Resistance	Recoverability	Sensitivity	Resistance	Recoverability	Sensitivity	Resistance	Recoverability	Sensitivity
Increased underwater noise from pile driving	None/PTS Low/TTS	Very low/PTS Medium/TTS	High/PTS Medium/ TTS	None/PTS Low	Very low/PTS Medium/TTS	High/ PTS Medium/TTS	None/PTS	Very Low/PTS	High
Increased underwater noise vessel traffic construction/maintenance	Medium	High	Not sensitive/ Low	Medium	High	Not Sensitive/ Low	No evidence	No evidence	No evidence/ Low
Sediment spillage Fundament construction	Medium	High	Low	High	High	Not Sensitive	Low	Medium	Medium
Sediment spillage Cable laying	Medium	High	Low	High	High	Not Sensitive /Low	Low	Medium	Medium
Seabed disturbance - Fundament construction / Cable laying	High	High	Not Sensitive	Medium	High	Low	Low	High	Low
Habitat loss/change Addition of new substrate "Reef Effect"	High	High	Not Sensitive	Medium	High	Not Sensitive	Medium	Medium	Medium
Increased underwater noise- operating turbines	High	High	Not sensitive	High	High	Not sensitive	No evidence	No evidence	No evidence
Electromagnetic fields	High	High	Not sensitive	High	High	Not sensitive/ Low	No evidence	No evidence	No evidence
Increased underwater noise from decommissioning work Avoidance response	Medium	High	Not sensitive/ Low	Medium	High	Not sensitive/ Low	High	High	Not sensitive
Sediment spillage from decommissioning work: Avoidance response	Medium	High	Low	High	High	Not Sensitive/ Low	Low	Medium	Medium

Underwater noise from pile driving, can be one of the most intense pressures to the fish community if not mitigated. Sensitivity to PTS, which is the permanent hearing loss and/or damage to tissue from being close to the source is high for all three fish receptors (pelagic and demersal fish and their early life stages) as this damage is considered to lead to mortality. Despite soft start procedures where the intensity of hammering during pile driving is gradually increased and expected application of abatement systems to reduce the level of sound into the environment from hammering during pile driving, most fish (both pelagic and demersal) in the local area where pile driving is taking place will exhibit a fleeing response that will take them further away from the source of pressure as the pile driving activity is in progress. This response will result in that fish that are effected by the high underwater noise will primarily experience a temporary hearing loss (TTS). Despite the potential long range effects (several kilometers) of the pressure that lead to temporary hearing loss in fish (NIRAS, 2022b), it is expected that all the fish with temporary hearing loss will recover over time (within weeks) and thus have a medium sensitivity to underwater noise from pile driving.

The sensitivity of pelagic fish species to sediment spillage is greater than demersal fish which generally live in the bottom environment where many species utilize the soft bottom substrates to find food and/or for burial and protection as well as being more adapted to a greater variety of disturbances causing suspended sediment and sedimentation during storms or due to water currents etc. In all cases however, both pelagic and demersal fish will exhibit a fleeing response away from the source of pressure and activity when the level of sediment spillage (suspended sediment and sedimentation) becomes too great and triggers this response. Because juvenile and adult fish will not experience an effect, other than a short-term displacement from the source of the sediment spill, their recoverability is high and thus their sensitivity to sediment spillage low.

The sensitivity of the early life stages (eggs and fish larvae) to sediment spillage is medium. This is a result of the resistance of fish eggs and larvae being low as they are not mobile and cannot flee from the pressures of sediment spillage, however their recoverability is medium as the pressure is only local and in a relatively small area, and some eggs have the ability to withstand increased sediment for short periods of time, thus this pressure will not have an effect on the overall population of eggs and fish larvae in the area and therefore not to recruitment and the fish populations.

Pelagic fish are not sensitive to local physical disturbances on the seabed due to temporary disturbances, seabed abrasions, local areas of penetration as they are not associated with the seabed where these pressures will be experienced. In contrast, both demersal fish and the early life stages of some species where their eggs and larvae are on the bottom are not as resistant to these pressures, but because these pressures are very local and will only affect these receptors on a small spatial scale their recovery is considered to be high and their sensitivity low.

Similarly, pelagic fish are not considered to be sensitive to habitat loss or change in habitat as they are much less associated with the seabed or the hard substrates that will be introduced with turbines and protective scour material. Demersal fish will in theory experience a loss/change in their seabed habitat that will cause some displacement to other areas, however because of the relatively small amount of habitat that is lost and the availability of alternative areas and similar habitats of preference, their recovery will be high and thus their sensitivity to this pressure low. Similarly, some local habitats needed by or beneficial to the early life stages of fish will be lost, but the relatively small amount of area lost, will not have an effect on their recoverability as the availability of alternative areas of similar habitat types are commonly available, thus their sensitivity to habitat loss or change is medium.

For pelagic and demersal fish, the sensitivity to the pressures of increased underwater noise from vessel activity and from turbines during operation, as well as electromagnetic fields from operating cables is ranked as low or not sensitive, primarily due to fishes medium to high resistance as well as high recovery to these pressures.

In conclusion, the pressure, which fish and their early life stages (larvae and eggs) are most sensitive to and that potentially can have the most detrimental effects on both individuals and local populations of fish, is underwater noise from pile driving. Furthermore, fish larvae and eggs are also relatively sensitive to sediment spillage which can have a considerably negative effect on this receptor close to the pressure source, where the levels of increased suspended sediment and sedimentation during construction activities are greatest.

6 References

Andersen, T., & Pejrup, M. (2002). Biological mediation of the settling velocity of bed material eroded from an intertidal mudflat, the Danish Wadden Sea. *Estuarine, Coastal and Shelf Science, 54, 4*, 737-745.

Andersson et al. (2017). A Framework for regulating underwater noise during pile driving. Stockholm: Swedish Environmental Protection Agency .

Andersson et al. (2017). Underlag för reglering av undervattensljud vid pålning. Stockholm: Naturvårdsverket.

Auld & Schubel. (1978). Effects of suspended sediment on fish eggs and larvae: a laboratory assessment. (6) pp 153-164. Estuarine and Coastal Marine Science.

Bagge. (2004). The biology of the greater weever in the commercial fishery of Kattegat.

Bellmann, M. A., May, A., Wendt, T., Gerlach, S., Remmers, P., & Brinkmann, J. (2020). *Underwater noise during percussive pile driving: Influencing factors on pile-driving noise and technical possibilities to comply with noise mitigation values.* Oldenburg, Germany: ITAP.

Bellmann, M. K. (2018). *Noise mitigation for large foundations (Monopile L & XL) - Technical options for complying with noise limits, Noise mitigation for the construction of increasingly large offshore wind turbines.* Berlin.

Chapman, C., & Hawkins, A. (1973). A field study of hearing in the cod, Gadus morhua L. *Journal of comparative physiology*, 85: 147-167.

COWI. (2020). Miljø- og planmæssige forhold for Nordsøen I, Hesselø og Krigers Flak II.

DFU. (2000). *Effects of marine windfarms on the distribution of fish, shellfish and marine mammals in the Horns Rev area.* DFU-Rapport.

DTU Aqua. (2013). Stenrev: Gennemgang af den biologiske og økologiske viden, der findes om stenrev og deres funktion i tempererede områder. *DTU Aqua-rapport 266-2013*. Institut for Akvatiske Ressourcer, Danmarks Tekniske Universitet.

Energistyrelsen. (12. februar 2021a). Udkast til plan for Hesselø Havvindmøllepark til brug for strategisk miljøvurdering (SMV).

Energistyrelsen. (12. februar 2021b). Udkast til udtalelse om afgrænsning af miljørapport (SMV) for planen for Hesselø Havvindmøllepark.

Energistyrelsen. (4. maj 2021b). Udtalelse om afgrænsning af miljørapport (SMV) for planen for Hesselø Havvindmøllepark.

Engell-Sørensen, K., & Skytt, P. H. (2002). *Evaluation of the effect of Sediment Spill from Offshore Wind Farm Construction on Marine Fish.* Report to SEAS, Denmark.

Enger, P. (1967). Hearing in herring. *COmparative Biochemistry and physiology*, 527-538.

Environmental Protection Agency. (May 2020). Natura 2000-basisanalyse 2022-2027 Gilleleje Flak og Tragten Natura 2000-område nr. 195 Habitatområde H171.

Erbe, C. (2013). Underwtaer noise of small personal watercrafts (jet skis). The Journal of Acoustical Society of America. 133, EL326-EL330.

Erbe, C., & Farmer, D. (2000). Zones of impact around icebreakers affecting beluga whales in the Beaufort Sea . The Journal of the Acoustic Society of America. 108. 1332-1340.

Erbe, C., Liong, S., Koessler, M., Duncan, A., & Gourlay, T. (2016). Underwater sound of rigid-hulled inflatable boats. The Journal of Acoustical Society of America. 139. EL223-EL227.

Erbe, C., MArley, S., Schoeman, R., Smith, J., Trigg, L., & Embling, C. (2019). The effectsof ship noise on marine mammals - a review. Frontiers in Marine Ecology. Vol 6. Artikel 606.

Fay et al. . (1999).

FeBEC. (2010). Sediment Dsoe Response Study - Technical Report. Femern A/S Doc. No. E4-TR-036.

FeBEC. (2013). *Fish Ecology in Fehmarnbelt. Baseline Report.* Fehmarn A/S.

FeBEC. (2013). *Fish Ecology in Fehmarnbelt. Environmental Impact assessment Report.* FehmarnBelt A/S.
FEMA. (May 2013a). Fehmarnbelt Fixed Link EIA. Marine Fauna and Flora – Impact Assessment. Benthic Fauna of the Fehmarnbelt Area. Report No. E2TR0021 - Volume II.
FEMA. (May 2013b). Fehmarnbelt Fixed Link EIA. Marine Fauna and Flora – Impact Assessment. Benthic Flora of the Fehmarnbelt Area. Report No. E2TR0021 - Volume I.
Fiskeatlas. (2022). https://fiskeatlas.ku.dk/artstekster/.
Fiskeøkologisk Laboratorium. (2000). Fiskeundersøgelser i Fjorde og kystnære, marine områder. Udredning.
Gassmann, M., Wiggins, S., & Hildebrand, J. (2017). Deep-water measurements of container ship radiated noise signatures and directionality. The journal of the Acoustical Society of America 105:2493-2498.
Griffin, F., Smith, E., Vines, C., & Cherr, G. (2009). Impacts of suspended sediments on fertilization, embryonic development, and early larval life stages of the Pacific herring, Clupea pallasi. *216*, *2*, 175-187. The Biological Bulletin.
Hansson, S. (1995). En litteraturgenomgång av effekter på fisk av muddring och tippning, samt erfarenheter från ett provfiske inför Stålverk 80. *Tema Nord, no. 513*, , 73-84.
HELCOM. (2012). *HELCOM - FISH Group (https://portal.helcom.fi/default.aspx).* Helcom.
HELCOM. (2020). Map and data service. Biodiversity. Essential fish habitat maps. Potential spawning areas for cod. Hentet fra https://maps.helcom.fi/website/mapservice/
Hermannsen, L., Beedholm, K., Tougaard, J., & Madsen, P. (2014). High frequency components of ship noise in shallow water with a discussion of implications for harbor porpoises (Phocoena phocoena). . J. Acoust. Soc. Am. 136(4):1640-1653.
Hvidt et al., C. (2004). *Fish along the cable trace Nysed Offshore Wind Farms - final report.* Dong Energy A/S.
Hvidt et.al. (2006). Fish along the Cable Trace Nysted Offshore Wind Farm Final Report. Dong Energy / Orbicon AS.
Hygum. (1993). Miljøpåvirkninger ved ral- og sandsugning. Et litteraturstudie om de biologiske effekter af råstofindvinding i havet. *Faglig rapport fra DMU, nr. 81.* Danmarks Miljøundersøgelser.
Hüssy K, et al. (1997). *Food resource utilization by juvenile Baltic Cod Gadus Morhua.* Mar Ecol Prog Ser 1997;155:199-208.
ICES. (2007). Report of the Workshop on Sexual Maturity Sampling (WKMAT), 15–19 . ICES - Lisbon, Portugal. ICES CM 2007/ACFM:03. 85 pp.
ICES. (2014). *Manual for the Baltic International Trawl Surveys (BITS). Series of ICES Survey Protocols SISP 7 - BITS. 71 pp.* Copenhagen: ICES.
ICES. (2017). Manual for the Baltic International Trawl Surveys (BITS). Series of ICES Survey Protocols SISP 7 - BITS. 95 pp. http://doi.org/10.17895/ices.pub.2883. International Council for the Exploration of the Sea.
Isono et al. (1998). Acute effects of kaolinite suspension on eggs and larvae of some marine teleost. Comparative Biochemisttry and Physiology.
Kalmijn, A. (1978). Experimental Evidence of geomagnetic orientation in elasmobranch Fishes. I K. S.-K. (eds.), *Animals migration, navigation and homing* (s. 354-355). New York: Springer Verlag.
Karlsen. (1992). Infrasound sensitivity in the plaice (Pleuronectes platessa) Vol. 171, pp 173-187. J. Exp. Biology .
Karlson, L. (1985). Behavioral response of European silver eels (Anguilla anguilla) to the magnetic field. Helgoländer Meeresuntersuchungen, 39, 71-81.
Kioerboe, T., Frantsen, E., Jensen, C., & Nohr, O. (1981). Effects of suspended-sediment on development and hatching of herring (Clupea harengus) eggs. *Estuarine, Coastal and Shelf Science*, , 13: 107-111.
Klima-, Energi- og Forsyningsministeriet. (2. juli 2020). Pålæg om gennemførelse af forundersøgelser og om etablering af nettilslutningspunkt til Hesselø Havvindmøllepark.
Kristiansen et al,. (2017). ehavioural changes of Atlantic cod (Gadus morhua) after marine boulder reef restoration: Implications for coastal habitat management and Natura 2000 areas. Fisheries Management and Ecology.

Kystdirektoratet. (2020). Miljøkonsekvensrapport - Kystbeskyttelse Lodbjerg Nymindegab. Kystdirektoratet.

Madsen, P., Wahlberg, M., Tougaard, J., Lucke, K., & Tyack, P. (2006). Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs. *Marine Ecology Progress Series 309: 279-295*.

Metcalfe et.al. (1993). Orientation of plaice (Plueronectes platessa) in the open sea: evidence of the use of external directional clues. Marine Biology, 117, 559-566.

Miljøkonsekvensrapport-Kystbeskyttelse Lodbjerg Nymindegab. Hovedrapport. (2020). Kystdirektoratet.

Moore, P. (1991). Inorganic particulate suspensions in the sea and their effects on marine animals. Oceanogr. Mar. Biol. Ann. Rev., 15, pp. 225-363.

Moray Offshore Windfarm (West) Limited. (2018). Offshore EIA Report. https://marine.gov.scot/sites/default/files/00538033.pdf.

Muus & Nielsen. (1999). Sea Fish, Scandanavian Fish Year Book . Hedehusene Denmark.

Muus & Nielsen. (2006). Havfisk og fiskeri i Nordvesteurop - 6 udgave . Gyldendal.

Nedwell et al. (2007). A validation of the dB ht as a measure of the behavioural and auditory effects of underwater noise. Subacoustech Report No 534R1231, s.l.: Subacoustech.

Neo et. al. (2014). Temporal structure of sound affects behvioral recovery from noise impact in European seabass. Biological Conservation 178:65-73.

Newcombe & MacDonald. (1991). Effects of suspended sediment on aquatic ecosystems. Am J Fish Manag, 11, pp. 72-82.

Newell, R., Seiderer, L., & Hitchcock, D. (1998). The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. Oceanography and Marine Biology 36, 127-178.

NIRAS & DCE. (2021a). Hesselø Offshore Wind Farm. Benthic flora and fauna: Hard bottom. Technical Report. Energinet.

NIRAS & DCE. (2021b). Hesselø Offshore Wind Farm: Benthic flora and fauna: Soft bottom. Technical Report. Energinet.

NIRAS. (2022a). Hesselø Havvindmøllepark. Natura 2000-vurdering.

NIRAS. (2022b). Hesselø Offshore Wind Farm. Underwater noise. Technical report.

Popper et al. (2014). Sound exposure guidelines for fishes and sea turtles: A technical report prepared by ANSI. Springer.

Popper, A., Hawkins, A., Fay, R., Mann, D., Bartol, S., Carlson, T., & Travolga, W. (2014). Sound exposure guidelines for fishes and sea turtles: A technical report prepared by ANSI-accredited standards committee S3 s–1C1 and registered with ANSI. New York: Springer.

Richardson, W., Malme, C., Green, C. R., & Thomson, D. (1995). *Marine Mammales and noise.* San Diego, California, USA: Academic Press.

Ross, D. (1976). Mechanics of underwater noise. New York, NY: Pergamon Press.

Rådet for de europæiske fællesskaber. (1992). Rådets direktiv 92/43/EØF. af 21. maj 1992. om bevaring af naturtyper samt vilde dyr og planter.

Sand, O., & Karlsen, H. (2000). Detection of infrasound and linear acceleration in fishes. *Philosophical Transactions of The Royal Society B Biological Sciences*, 355(1401):1295-8.

Simard, Y., Roy, N., Gervaise, C., & Giard, S. (2016). Analysis and modeling of 225 source levels of merchant ships from an acoustic observatory along St. LAwrence Seaway. The Journal of the Acoustic Society of America. 140. 2002-2018.

Skjellerup, P., McKenzie, C., Tarpgaard, E., Thomsen, F., Schack, H., Tougaard, J., . . . Heilskov, N. (2015). Marine mammals and underwater noise in relation to pile driving – Working Group 2014. Report to the Danish Energy Authority.

Slots og Kulturstyrelsen-Kulturarv.dk. (u.d.). Fund og fortidsminder - ikke fredet fortidsminde. Slots og Kulturstyrelsen.

Stenberg et.al. (2011). Effects of the Horns Rev 1 Offshore Wind Farm on Fish Communities. Follow-up seven years after construction. DTU Aqua Report No 246.

Støttrup et al. . (2014). Restoration of a temperate Reef: Effects on the Fish Community - (4), pp. 1045-1059. Journal of Ecology .

Svedäng H. et al., A. C. (2010). *igratory behaviour and otolith chemistry suggest fine-scale sub-population structure within a genetically homogenous Atlantic Cod population.* Environ Biol Fishes. 2010; 89(3): 383-397.

Sørensen et al., T. E. (2016). *Kortlægning af fiskenes levesteder i den danske del af Øresund.* DTU Aqua.

Thiele, L. (1988). Underwater noise study from the icebreaker "John A. MacDonald". . Ødegaard & Danneskiold-Samsøe ApS. Report 85.133.

Tomkiewicz, J. (2005). Hvornår er en fisk moden og gydeklar? Danmarks Fiskeriundersøgelser - Afd. for Havøkologi og Akvakultur.

Tomkiewicz, J. e. (2002). Manual to determine gonadal maturity of Baltic Cod. Danish Institute for Fisheries Research.

Tsouvalas, A. (2020). Underwater Noise Emission Due to Offshore Pile.

Tyler-Walters, H., Tillin, H., d'Avack, E., Perry, F., & Stamp, T. (2018). Marine Evidence-based Sensitivity Assessment (MarESA) – A Guide. Marine Life Information Network (MarLIN).

Tyler-Walters, H., Tillin, H., d'Avack, E., Perry, F., & Stamp, T. (2018). Marine Evidence-based Sensitivity Assessment (MarESA) – A Guide. Marine Life Information Network (MarLIN).

Ulrich, C., Boje, J., & Cardinale, M. (2013). *Variability and connectivity of plaice populations from the Eastern North Sea to the Western Baltic Sea, and implications for assessment and management.* J. Sea Res. 2013:84: 40-48.

Vallin og Nissling. (2000). Maternal effects on eggs size and egg buoyancy of Baltic cod. Fisheries Research; 49, s. 21-37.

Warnar et. al. (2012). Fiskebestandenes struktur. Fagligt baggrundsnotat til den danske implementering af EU's Havstrategidirektiv. DTU Aqua-rapport nr. 254-2012, s.l.:. DTU Aqua.

Warnar, H. B., Vinter, M., Egekvist, J., Sparvohn, C. K., Dolmer, P., Munk, P., & Sørensen, T. (2012). *Fiskebestandenes struktur Fagligt bag-grundsnotat til den danske implementering af EU's Havstrategidirektiv.* DTU Aqua-rapport nr. 254.

Webb, J., Popper, A., & Fay, R. (2008). Fish Bioacoustics. Springer handbook of auditory research.

Westerberg et al, H. R. (1996). Effects of suspended sediment on cod eeg and larvae and the behaviour af adult herring and cod. *ICES Marine Environmental Quality Commitee, CM.*

Westerberg et al., L. I. (2007). Silver eel migration behavior in the Baltic. *ICES Journal of Marine Science*, s. Vol. 64, 1457-1462.

Westerberg, H., & Lagenfelt, I. (2008). Sub-sea power cables and the migration behaviour of the European eel. *Fisheries Management and Ecology 15*, pp. 369-375.

Wind, P. & Pihl. S.(red.). (2010). Den danske rødliste: redlist.dmu.dk (opdateret april 2010). Danmarks Miljøundersøgelser, Aarhus Universitet.

Worsøe et al., L. (2002). *(2002). Gyde- og opvækstpladser for kommercielle.*

Öhman et al, . (2007). Offshore Windmills and the Effects of Electromagnetic Fields on Fish, 36 (8), pp. 630-633. Ambio A Journal of the Human Environment.

Øresundsvandsamarbejdet. (2007). *Fisk i Øresund / Fisk i Öresund.* Øresundsvandsamarbejdet.

Øresundsvandsamarbejdet. (2018). *Fiskeri i Øresund 2017.* Øresundsvandsamarbejdet.

Ørsted. (2019). Hornsea Projekt Four: Preliminary Environmental Information Report (PEIR). Volume 2. Chapter 2: Benthic and Intertidal Ecology. https://orstedcdn.azureedge.net/-/media/www/docs/corp/uk/hornsea-project-four/01-formal-consultation/pier/volume-2/peir-volume-.

Appendix 1

CPUE tables

CPUE numbers of fish caught per 10000m3 in the April TV3 trawl survey.

Species	# Numbers												
	Tr01	Tr02	Tr03	TR04	TR05	TR06	TR07	TR08	TR09	TR10	TRK1	TRK3	TRK4
Micromesistius poutassou	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,65	0,00	0,00
Clupea harengus	25,30	59,92	1728,13	2,32	80,13	922,90	5,00	0,00	3,83	3,81	8,51	0,00	4,70
Engraulis encrasicholus	0,65	2,72	0,00	0,00	0,00	0,00	0,00	0,00	0,00	34,96	0,00	0,00	0,00
Eutrigla gurnardus	5,19	3,81	4,36	4,06	0,71	8,83	3,75	2,54	2,55	0,64	1,31	0,55	0,00
Gadus morhua	0,00	0,54	0,00	0,00	0,00	0,63	0,62	0,64	1,28	0,00	0,00	0,00	1,34
Capros aper	0,00	0,00	0,73	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hippoglossoides platessoides	0,65	1,09	1,45	1,16	0,35	0,00	0,00	2,54	3,19	1,91	0,65	6,65	2,01
Limanda limanda	71,37	108,41	144,62	79,53	48,58	143,10	436,03	177,50	207,98	144,29	131,64	217,70	519,09
Lumpenus lampretaeformis	0,00	0,00	0,00	0,00	2,84	0,00	0,62	0,00	0,64	0,64	2,62	0,55	0,00
Melanogrammus aeglefinus	0,00	1,09	0,00	0,00	0,35	0,63	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Merlangius merlangus	12,33	22,88	7,27	18,58	14,89	13,24	14,37	33,72	19,78	21,61	26,20	23,82	28,20
Microstomus kitt	1,95	0,00	0,73	0,58	0,71	0,00	2,50	1,91	0,64	0,64	0,00	1,11	0,00
Myoxocephalus scorpius	0,00	0,00	0,00	0,00	0,00	0,00	1,25	0,00	0,00	0,00	0,00	0,00	2,69
Phrynorhombus norvegicus	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,34
Platichthys flesus	0,00	0,00	0,00	0,00	0,71	0,00	0,62	1,27	0,00	1,27	0,00	2,22	0,67
Pleuronectes platessa	44,12	7,08	42,15	6,39	16,31	29,00	29,36	10,82	12,76	17,80	7,20	17,73	50,36
Psetta maxima	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,64	0,00	0,00	0,00	0,00	0,00
Raja radiata	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,55	0,00
Rhinonemus cimbrius	0,00	0,00	0,00	0,00	0,71	0,00	0,00	0,64	0,00	0,00	0,65	0,00	0,67
Scophthalmus rhombus	0,00	0,00	0,00	0,00	0,00	1,89	0,00	0,64	0,00	0,00	0,00	0,00	0,00
Solea solea	0,00	0,00	0,73	0,00	0,00	0,00	2,50	0,64	0,00	0,00	0,00	0,55	0,67
Lesueurigobius freisi	0,00	0,00	0,00	0,00	1,42	0,00	0,00	0,00	1,28	0,64	0,00	0,55	0,67
Sprattus sprattus	867,42	2625,70	2430,14	108,56	76,94	2397,40	506,62	3032,19	77,20	870,81	254,12	3470,99	1085,18
Callionymus lyra	2,60	2,18	7,27	2,32	3,19	4,41	3,75	3,82	1,91	6,36	9,82	5,54	0,67
Mullus surmuletus	0,65	0,00	0,00	0,00	0,35	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,67
Trachinus draco	0,00	0,00	0,00	0,00	0,00	0,00	0,62	0,00	0,00	0,00	0,65	0,00	0,00
Arnoglossus laterna	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,67

CPUE numbers of fish caught per 10000 m^3 in the October TV3 trawl survey.

Species	**# Numbers**												
	Tr01	**Tr02**	**Tr03**	**TR04**	**TR05**	**TR06**	**TR07**	**TR08**	**TR09**	**TR10**	**TRK1**	**TRK3**	**TRK4**
Agonus cataphractus	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2,1
Clupea harengus	54,3	22,3	4,0	30,0	3,3	3,1	1,2	3,1	4,7	1,1	4,2	0,00	2,1
Engraulis encrasicholus	0,00	0,00	9,9	0,00	0,00	0,00	0,00	116,3	3,5	37,7	0,00	6,8	0,00
Eutrigla gurnardus	10,5	2,9	7,0	1,1	4,4	4,2	2,4	5,2	3,5	8,9	4,2	0,00	8,6
Gadus morhua	0,9	1,9	1,0	1,1	0,00	1,0	0,00	4,1	0,00	0,00	0,00	0,00	1,1
Gaidropsarus vulgaris	3,5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,9	2,1
Hippoglossoides platessoides	0,9	2,9	1,0	2,1	5,5	1,0		1,0	1,2	2,2	6,3	1,9	
Limanda limanda	349,7	157,9	165,0	55,7	137,5	167,2	131,1	197,6	184,5	153,0	189,6	75,6	485,1
Lophius piscatorius	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,2	0,00	0,00	0,00	0,00
Lumpenus lampretaeformis	0,9	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,0	0,00
Melanogrammus aeglefinus	0,00	0,00	0,00	0,00	1,1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Merlangius merlangus	13,1	17,4	22,9	9,6	21,1	12,5	13,4	15,4	24,7	12,2	19,8	31,0	21,4
Microstomus kitt	9,6	1,0	0,00	1,1	2,2	1,0	0,00	1,0	0,00	0,00	5,2	0,00	0,00
Molva molva	0,9	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Myoxocephalus scorpius	0,00	1,0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,1
Platichthys flesus	0,00	0,00	0,00	0,00	1,1	1,0	0,00	2,1	1,2	0,00	0,00	1,0	0,00
Pleuronectes platessa	43,8	41,7	49,7	24,6	42,1	33,4	14,6	26,8	38,8	24,4	33,3	18,4	9,6
Mullus barbatus	0,9	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,1	0,00	0,00	0,00
Scophthalmus rhombus	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,0	0,00	0,00	0,00	1,0	0,00
Solea solea	1,8	0,00	0,00	0,00	0,00	2,1	1,2	0,00	0,00	0,00	0,00	1,0	5,4
Lesueurigobius freisi	7,0	1,9	2,0	0,00	1,1	1,0	0,00	0,00	1,2	1,1	0,00	6,8	0,00
Sprattus sprattus	32,4	205,4	72,5	77,1	85,4	28,2	4,9	127,6	192,7	38,8	22,9	64,9	101,7
Callionymus lyra	18,4	3,9	2,0	3,2	5,5	3,1	6,1	0,00	1,2	1,1	0,00	4,8	2,1
Trachinus draco	71,0	16,5	61,6	18,2	28,8	106,6	53,4	22,7	78,7	54,3	20,8	12,6	11,8
Trachurus trachurus	1,8	5,8	5,0		10,0	11,5	31,6	6,2	41,1	1,1	9,4		6,4
Arnoglossus laterna	4,4	1,0	1,0			1,0		1,0	1,2	2,2	2,1		1,1