ENERGINET

MARINE ENVIRONMENTAL STUDIES – NORTH SEA I

TECHNICAL REPORT – FISH AND FISH POPULATIONS

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WSP DENMARK
WSP.COM

Abbreviation	Explanation
CPUE	Catch Per Unit Effort
CTDO	Conductivity-Temperature-Depth-Oxygen (Optical)
DEA	Danish Energy Agency
ECC	Export cable corridor. Three ECCs (ECC1, ECC2 and ECC3) are investigated. Results for ECC1-3 are presented separately in this report when relevant
EIA	Environmental Impact Assessment
ENOE	Energy Island Bornholm OWF
ICES	International Council for Exploration of the Sea
Landfall	Is where the cable transfers from sea to land
LARS	Launch and Recovery Systems
MES	Marine Environmental Studies
North Sea I	The name of the offshore wind farm area (OWF). NSI is divided into NSI.1 and NSI.2. The present report is based on NSI.1 including all three subareas and the shipping corridors in between the three subareas
OWF	Offshore Wind Farm area
Pre-investigation area (PA)	Gross area for the benthic survey. Within the pre-investigation area, there are the three wind farm areas (A1, A2 and A3), the three export cable routes (ECCs) and the corridors between the three OFW areas.
psu	Practical salinity unit
RBMP	River Basin Management Plan
ROV	Remotely Operated Underwater Vehicle
SEA	Strategic Environmental Assessment
Shannon-Wiener index	The Shannon-Wiener Index gives a measure of the diversity of species in a community
Subareas	The offshore wind farm area is subdivided into three subareas A1, A2 and A3
WFD	Danish Water Framework Directive
WP	Work Package

1 SUMMARY

INTRODUCTION

Denmark aims to accelerate offshore wind production by an additional 2 GW of capacity before 2030. In addition, the Climate Agreement 2022 requires areas capable of accommodating 4 GW of offshore wind to be established by the same deadline. A political agreement from May 2023 outlines the development of 9 GW of offshore wind, with potential for up to 14 GW. The Danish Energy Agency has plans for offshore wind farms (OWFs) in the North Sea, Kattegat, and Baltic Sea. The North Sea I (NSI.1) covers 1,400 km² and is divided into three sub-areas (OWF-A1, A2, and A3) for wind farm development. Export cables in export cable corridors (ECC1, ECC2, ECC3) will connect these offshore wind farms to the onshore grid.

OBJECTIVE AND METHODOLOGY

The objective of the present report is to carry out a baseline mapping of fish and fish populations in the NSI.1 pre-investigation area. This is done to determine the distribution of fish and fish populations, as well as investigate if the pre-investigation area serves as a possible spawning or nursery area for fish. Most fish species spawn in spring, after which the eggs hatch and the fish larvae grow up to be small juvenile fish of a certain size that can be sampled in the autumn. Therefore, two surveys were conducted, one in autumn (October 2023) and one in the following spring (May 2024) to collect data from the year cycle for all occurring species in the area. The sampling methods included beam trawl, multimesh gillnets and trammel nets, as well as existing data. The combined data was used to describe the spatial and temporal distribution of fish and fish populations in the pre-investigation area. To determine if the pre-investigation area consisted of possible spawning- and nursery areas, a cohort analysis was conducted, and the gonad ripeness of sampled fish were analyzed and determined.

METHODOLOGY

The fishing methods chosen to map fish species in the pre-investigation area, North Sea I.1 ECC and OWF (hereafter called NSI.1),consisted of fishing with beam trawl, multimesh gillnets and trammel net. The trawl was four meters wide and 16.35 meter long when fully deployed. The trawl was hauled for 30 minutes at 3-4 knots towing speed, which gives an average towing distance of 4,000 meter with a total area of 16,000 m^2 pr. haul. Multimesh gillnets consisted of 12 panels of various mesh sizes, ranging from 6-116 mm, while the trammel nets consisted of three layers of netting which makes trammel nets very stable when fishing in areas with strong currents such as the North Sea. Both nets were deployed in the afternoon and retrieved the following morning after approximately 16 hours of fishing. In the present study, emphasis was made on investigating whether the area was used as a spawning area and/or nursery area. Therefore, supplementary analyses of the fish catch were added to the StUK4 methodology. In addition to length and weight measurements, processing of fish gonads was therefore included to estimate gonad ripeness and spawning progress. The community structure of the fish was analyzed based on number of species on each station, as well as calculating the Shannon-Wiener Index and Evenness Index.

EXISTING DATA

In the pre-investigation area, a total of 71 different fish species have been observed and registered in the Fiskeatlas database. The observed species include numerous observations of common and economically important species such as Atlantic cod (*Gadus morhua)*, Atlantic herring (*Clupea harengus)*, European sprat *(Sprattus sprattus),* whiting (*Merlangius merlangus)* and the flatfish species common dab (*Limanda limanda)*, European plaice (*Pleuronectes platessa*), turbot (*Scopthalmus maximus)*, and European flounder (*Platichthys flesus)*. However, protected species have been observed in the pre-investigation area, including European sturgeon (*Acipenser sturio*), twaite shad (*Alosa fallax*), river lamprey (*Lampetra fluviatilis*) and the sea lamprey (*Petromyzon marinus*).

SURVEY DATA

A total of 11,505 fish were caught – 6,951 in spring and 4,554 in autumn, representing 28 different species and a few fish only determined to family. In spring, a total of 20 species were caught, and in autumn 25 species. The spring catches amounted to 343 kg, and the autumn catches to 221 kg – a total of 554 kg. In both spring and autumn, the catches were dominated by flatfish comprising between 84 % and 90 % of the catches depending on the season. The three most abundant species were common dab, solenette and European plaice. Grey gurnard and common dragonet were also well represented in the autumn catches.

Compared to existing literature and reports for nearby OWF's, the data collected here is similar with flatfish dominating the catches. However, compared to Thor OWF, the density of fish is higher in the present study. The majority of fish caught here were flatfish which are especially abundant on sandy or muddy sediments. NSI.1 consists of vast sandy and muddy flats – the preferred habitat for flatfish.

SPAWNING AREA

In the fish surveys conducted here, very few individuals physiologically ready to spawn were caught in the pre-investigation area. A total of two turbot (one male and one female) and six common dab (one female and the rest males) were physiologically ready to spawn. Common dab and solenette, should spawn from April to June and March to July, respectively, so May should be within the prime spawning season for these two species. The few spawning individuals indicate that NSI.1 has limited function as spawning area.

NURSERY AREA

The size of the European plaice caught in the present study ranged from 4 cm to 43 cm in length. Very few individuals of 10 cm or less was observed in NSI.1, both in spring and autumn. In addition, the European plaice is known to utilize shallow, sheltered, and sandy areas as nursery areas after settling, and NSI.1does not fit the profile for such a nursery area, as the area is neither shallow nor sheltered. Therefore, it is not likely that the European plaice utilizes the pre-investigation area as a nursery area.

Relatively few juveniles (13 individuals of 7 cm or smaller) of common dab were observed in NSI.1. According to size-at-age literature, these individuals were 1 year, or younger. Common dab settles at 10-20 m depth, but the range may be as large as 6-70 m depth. So, a specific type of nursery area may not be found for this species. Considering the above factors, NSI.1 does not seem important for juvenile common dab.

The size range of solenette caught here, was between 4 cm and 12,5 cm. This indicates that solenettes utilize the NSI.1 area both as juveniles, and as adults. According to existing literature, the juveniles do not have a nursery area that is separated from where the adults occur. Instead, the juveniles coexist alongside the adult individuals of solenette. Therefore, it can be concluded that solenettes utilize the NSI.1 area as a nursery area.

BIODIVERISTY

The number of species caught pr. station in NSI.1, varied between 0 and 14 species with more species being caught in the beam trawl hauls than in the multimesh gillnets and trammel nets. This is relatively similar to the findings in Thor OWF area (located north of NSI.1), where up to 19 species was found pr. station. However, the average number of species caught pr. station were higher in the Thor OWF area than in the present study of the NSI.1 area. This may be explained by the heterogeneity of the sediment in the Thor OWF area, while the sediments found in NSI.1 were dominated by large sandy areas. The more divers habitat that are present in an area, the more species are expected. In addition, Thor OWF area had areas of hard substrate, which is known to be one of the habitats hosting the largest biodiversity in Danish marine habitats.

FEEDING AREA

The most abundant infauna species in the NSI.1 area were horseshoe worm (*Phoronis* sp.), the bristle worm species *Magelona mirabilis*, the tube worm *Owenia fusiformis,* sea potato (*Echinocardium cordatum*), the sand burrowing brittle star (*Acrocnida brachiata*). The tube living bristle worm *Lanice conchilega and* bristle stars (*Ophiura* sp.), the bivalve mollusc bean-like tellin (*Fabulina fabula*), and the bristle worm species *Protodorvillea kefersteini* were also abundant in NSI.1. Generally, flatfish feed on small mussels and worms. The results from the infauna studies document the presence of several worm species in high abundances, supporting the relatively high abundance of fish observed in this survey.

CONCLUSION

The observed community structure and fish distribution is very common for the North Sea, and most fish species are widely distributed.

2 INTRODUCTION

2.1 BACKGROUND

In order to accelerate the expansion of Danish offshore wind production, it was decided with the agreement on the Finance Act for 2022, to offer an additional 2 GW of offshore wind for establishment before the end of 2030. In addition, the parties behind the Climate Agreement on Green Power and Heat 2022 of 25 June 2022 (hereinafter Climate Agreement 2022) decided, that areas that can accommodate an additional 4 GW of offshore wind must be offered for establishment before the end of 2030. Most recently, a political agreement was concluded on 30 May 2023, which establishes the framework for the Climate Agreement 2022 with the development of 9 GW of offshore wind, which potentially can be increased to 14 GW or more, if the concession winners – i.e. the tenderers who will set up the offshore wind turbines – use the freedom included in the agreement to establish capacity in addition to the tendered minimum capacity of 1 GW per tendered area.

To enable the realization of the political agreements on significantly more energy production from offshore wind before the end of 2030, the Danish Energy Agency has drawn up a plan for the establishment of offshore wind farms in three areas in the North Sea, the Kattegat and the Baltic Sea, respectively.

The North Sea I area 1 has a total area of 1.400 km^2 which is divided into three sub-areas (A1-A3) planned for offshore wind farms. The North Sea I area 1 is located 20-80 km off the coast of West Jutland and from each of the three sub-areas there will be corridors for export cables connecting the offshore wind farms to the onshore grid.

The purpose of this present report is to describe the baseline on fish and fish populations based on data gathered in fish surveys conducted specifically for this purpose, combined with existing information on fish distribution and behaviour in and around the North Sea I.1 ECC and OWF (hereafter called NSI.1). The geographical location of the NSI.1 area is illustrated in Figure 2-1.

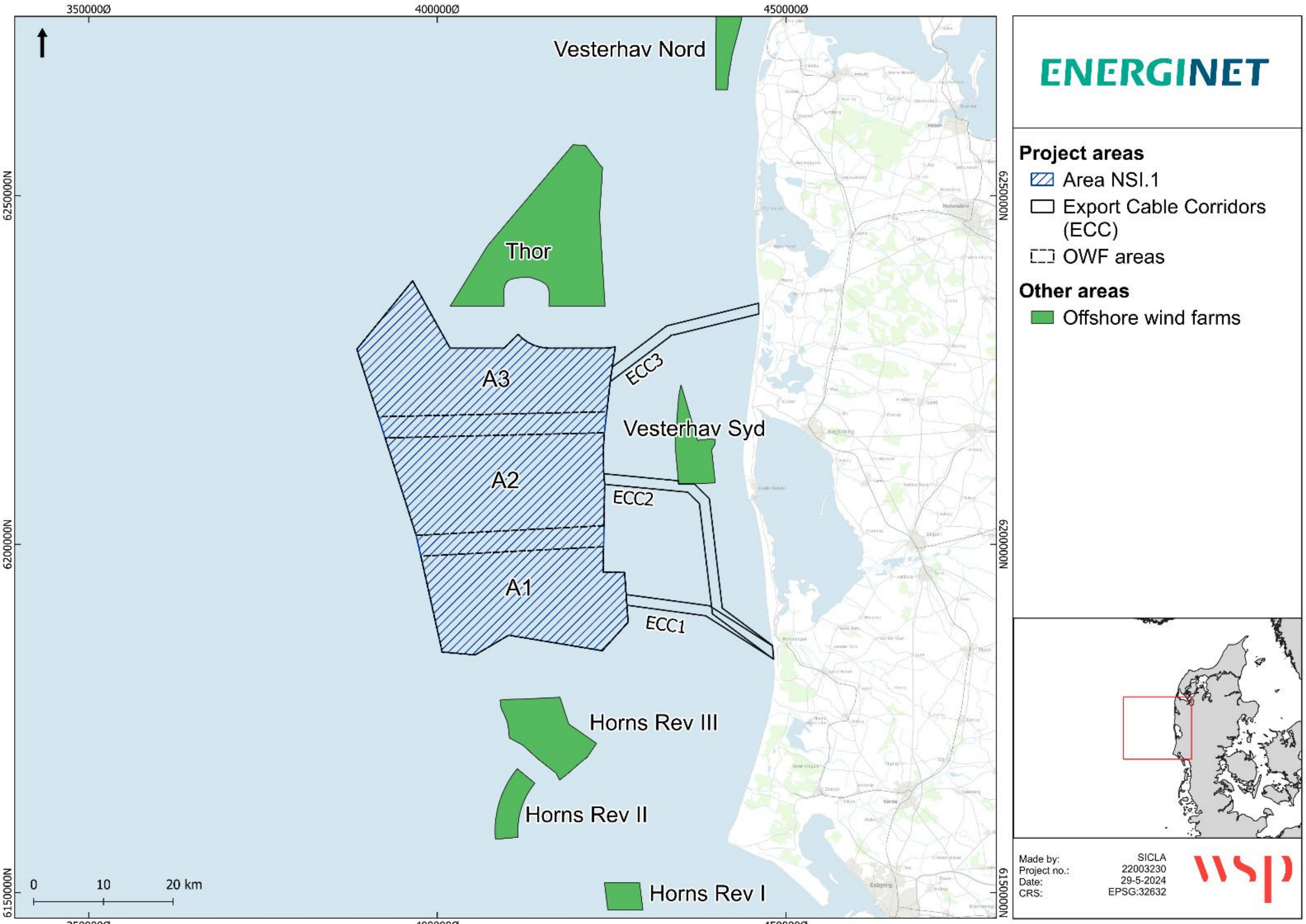

Figure 2-1. Overview of the three planned offshore wind farms (A1, A2 and A3) within North Sea I, area 1. The map also illustrates other offshore windfarms in the area (existing and approved).

3 OBJECTIVE AND METHODOLOGY

The objective of this report is to describe the baseline on fish and fish populations based on data gathered in fish surveys conducted specifically for this purpose, combined with existing information on fish distribution and behaviour in and around the NSI.1 OWF and ECC (hereafter referred to as NSI.1). The present report includes mapping of the distribution of fish species and populations, as well as known and potential spawning and nursery areas in and around NSI.1. Materials and methods relevant for the baseline mapping of fish and fish populations are presented below.

To determine if NSI.1 serves as a possible spawning area for fish, a baseline mapping of fish and fish populations was carried out. According to existing literature, most fish species spawn in spring, so in the spring survey, emphasis was placed on determining the maturity index of fish gonads for several relevant flatfish species and Atlantic cod (*Gadus morhua*) caught in NSI.1. However, maturity indexing was also conducted in the autumn survey to trace the development of the fish reproductive cycle, and because a few fish spawn in late autumn or early winter. In addition, due to the rise in ocean temperatures caused by global warming, the timing of fish spawning may change making it relevant to investigate potential spawning in NSI.1 in autumn, too. In autumn, most young of the year (YOY) juvenile fish have reached a size where they can be caught in the fishing gear utilized here. Therefore, sampling at this time of year is important to investigate if NSI.1 functions as a nursery area for fish species. This is why two surveys were conducted, one in spring (May 2024) and one in autumn (October 2023).

Sampling with dredging fishing gear is not possible on all surfaces, due to risk of damaging the trawl itself or harming hard bottom habitats on the seabed. So, prior to planning the fish survey and fishing with beam trawl, information regarding the seabed and sediment type was gathered based on existing data before positioning stations for fish sampling. The mapping of the seabed was important for designing the survey and conducting a safe and efficient fish survey. In addition, the sediment types are also an important indicator for which fish species may inhabit the area, as the various fish species have different habitat and prey preferences. Materials and methods related to the geophysical data, originates from GEUS' Marta database and is described in detail in the technical report Marine Environmental Studies – North Sea I, Technical Report – Benthic Flora and Fauna (WSP, 2024) and are also shortly presented in section 4.1.1 Sediment types, in the present report. Only geophysical parameters relevant to the fish fauna mapping and description are included. Materials and methods related to the fish surveys conducted by WSP in October 2023/May 2024 are presented in section 5.2 Fish Data.

In the present technical report, existing data from various sources have been included as a supplement to the data achieved from the fish survey conducted specifically for this technical report. Existing data for abiotic factors and fish is presented in chapter 4 Existing data, which e.g. includes a description of known spawning and nursery areas for key fish species.

3.1 EXISTING DATA

In the following section, the materials and methodology used to describe existing data for abiotic data and fish data is presented. This includes data on fish distribution, spawning sites, nursery areas and fish habitats for NSI.1 OWF and ECC.

3.1.1 FISH DATA

To describe the environmental status of NSI.1 data on fish observations from various sources was included in the present report. The reports include:

- Description of spawning and nursery areas from several sources (e.g. (Warnar, et al., 2012; Carl & Munk, 2019) etc.)
- SEA Thor OWF (Rambøll & WSP, 2021),
- EIA Vesterhav Nord OWF (Naturstyrelsen og Energistyrelsen, 2015a),
- EIA Vesterhav Syd OWF (Naturstyrelsen & Energistyrelsen, 2015b),
- Natura 2000 area 220 Sandbanks off Thorsminde (MST, 2021b)
- Natura 2000 area 246 South North Sea (MST, 2021a)

This report also includes data extraction from Fiskeatlas. Since 2019, data on fish distribution in Danish marine waters has been gathered from a long list of historical and present sources (Fiskeatlas, 2024). The database only lists information on species and number of observations – the quantity of each species is not included. The database is an important source of information on the biodiversity of fish including rare and vulnerable species in Danish waters due to the large quantities of observations that has been gathered over time.

The Danish commercial fishing vessels are obliged by Danish legislation to keep a logbook of their catches. This is done through an electronic logbook for larger vessels or a landing declaration for small vessels. In addition, Vessel Monitoring System (VMS) is also mandatory for vessels longer than 12 meters, where the system tracks the fishing vessels. The logbook and VMS contain information such as date, time and place of the fishing journey and of fish species and weight of the catches. Therefore, the logbook and VMS may provide valuable information with regards to which species can be found in specific areas of the Danish waters. The baseline for the commercial fisheries in NSI.1 was described in the technical report Marine Environmental Studies – North Sea I, Technical Report - Commercial Fisheries (WSP, 2024) and the main conclusions of the report regarding fish distribution are included here.

In the present report, all fish species are referred to by their common name (according to latest updates on Fishbase.org) and their Latin name when first mentioned in the text.

3.2 SURVEY DATA

In the following section, the methodology utilized on the fish surveys conducted for this project is described in detail. This includes data on salinity, oxygen and sampling with nets and beam trawl. The handling of fish catches is described as well as data analysis of fish distribution, spawning sites, nursery areas and fish habitats in NSI.1.

Two surveys were conducted in spring 2024 and autumn 2023. The reason two separate surveys were carried out, was to determine if NSI.1 serves as a possible spawning area (the spring survey) and nursery area (the autumn survey). The fish surveys were carried out by WSP from the vessel, M/S Skoven, using beam trawl, multimesh gillnets and trammel nets. Data was used to describe the spatial and temporal distribution of fish and fish populations in NSI.1.

3.2.1 CTDO DATA

For abiotic data registered, a CTDO sensor (Aqua Troll 600) was used to measure Conductivity, Temperature, and Depth. Before or after sampling with beam trawl, multimesh gillnet or trammel net, measurements of CTDO were conducted. Firstly, measurements at the surface level were taken, followed by a sample at the bottom. To ensure correct data, the CTDO sensor was held a few minutes at both surface and bottom, so that the CTDO sensors had time to adjust to the surrounding environment. Data was automatically logged every ten seconds. Depth data from the CTDO was supplemented with depth data from the ship's sonar equipment, which was recorded manually.

3.2.2 FISH SURVEY

The aim of the present study was to perform a baseline investigation on fish and fish populations based on field surveys. As no Danish standardized method for conducting fish surveys in OWF exists, the German method StUK4 was deemed ideal to describe the spatial and temporal distribution of fish as a baseline for offshore wind parks and other size limited areas (BSH, 2013). Furthermore, the method was suitable when determining if NSI.1 serves as nursery and spawning site. The StUK4 method also ensures comparability with other fish surveys conducted in Northern Europe, as the method is referenced to ICES monitoring standards, and has been utilized on all German OWFs as well as Thor OWF in the North Sea and Energy Island Bornholm OWF (ENOE) in the Baltic Sea.

The chosen fishing methods to map fish species in NSI.1, consisted of fishing with beam trawl, multimesh gillnets and trammel net. As emphasis was made on investigating whether the area was used as a spawning area and/or nursery area, supplementary analyses of the fish catch were added to the StUK4 methodology, such as length and weight measurements and processing of fish gonads, to estimate gonad ripeness and spawning progress. The spring survey was conducted in 2024 from April the 29th to 3rd of May and the autumn survey took place on October 12th to 19th 2023.

Depending on their life strategy, some fish species have migratory traits, so to cover the temporal variation of the fish communities, the survey was designed with a survey in spring and autumn, respectively. The spring survey was scheduled to coincide with the spawning time of several relevant fish species, and the autumn survey was intended to demonstrate the activities in NSI.1, regarding the fish utilization of the area as spawning area, when the new recruits of the year (Young of the Year = YOY) had grown into small juveniles.

For project areas smaller than 100 km^2, the StUK4 dictates that a minimum of 20 trawl hauls should be conducted. For this study, 20 hauls were planned for the OWF area and additionally 2 hauls pr. ECC, which adds up to 26 trawl hauls in total. The station grid was designed to cover a wide range of sediment types and with at least five beam trawl stations on each sediment type with soft sediments. On harder substrates (e.g. “gravel and coarse sand” and “quarternary clay and silt”), the beam trawl was substituted with trammel net, as this gear type is also ideal for catching demersal fish species. Multimesh gillnets were used as a supplement to the trawl, as the nets were designed to catch a wide range of species and sizes of fish due to the various mesh sizes. The station grid is illustrated in Figure 3-1.

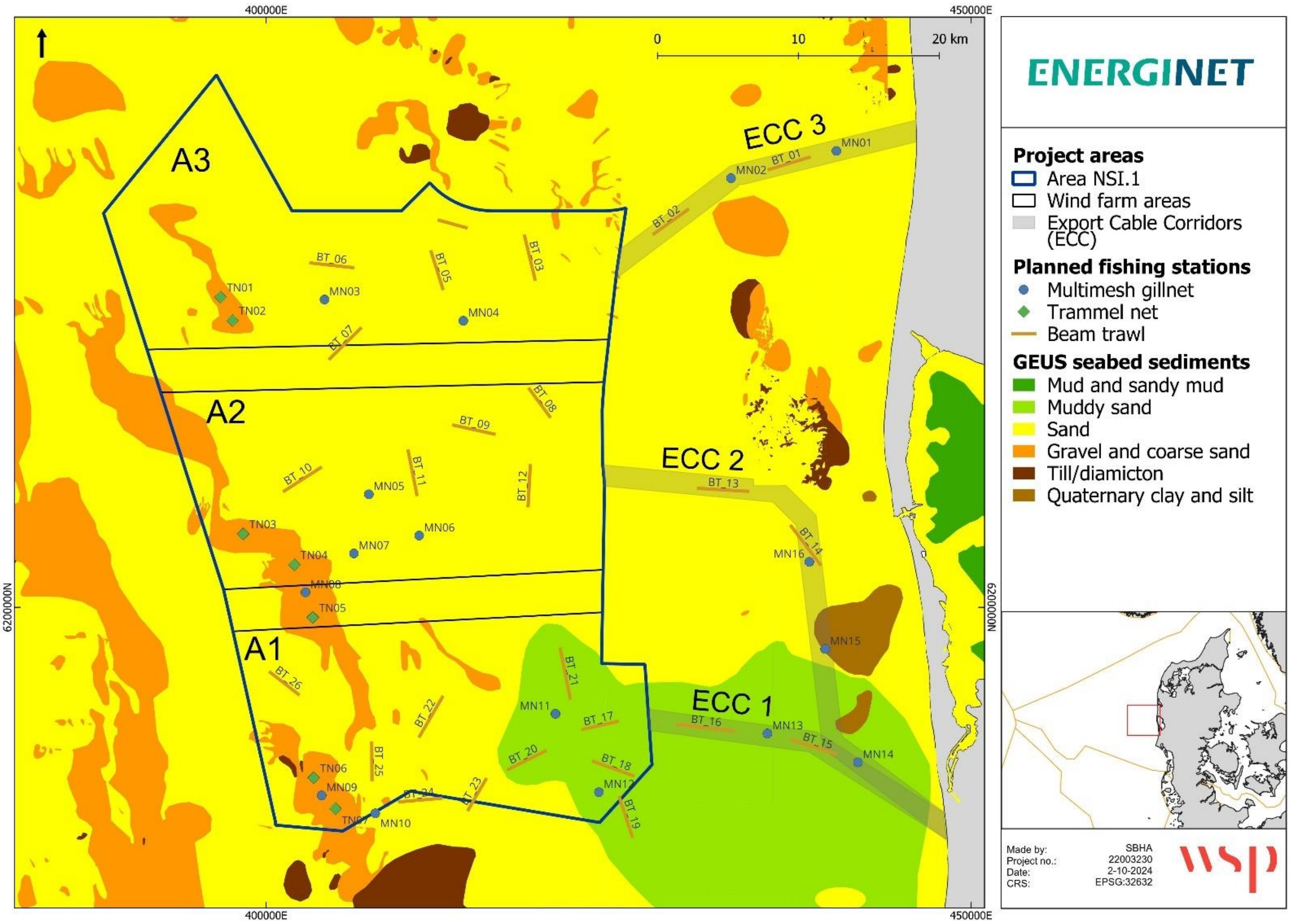

Figure 3-1 Station grid for the fish survey of NSI.1 conducted in October 2023 and May 2024. A combination of sampling with 26 beam trawl (BT) stations, and 16 multi nets (MN) stations, as well as seven trammel nets (TN) stations were utilized.

The survey program included the following activities at each station:

1. Beam trawl hauls/setting nets for biological analysis of fish community
2. Depth and position for each start and end point of trawl hauls and one position for nets
3. Measurements of CTDO (salinity, temperature, depth, and oxygen)
4. Air temperature, wind speed and direction, intensity of clouds, and wave height

3.2.3 BEAM TRAWL

The fish survey sampling method with beam trawl is based on the German standard method for describing the spatial and temporal distribution of fish as a baseline for offshore wind farms, StUK4 (BSH, 2013). The StUK4 method recommends two surveys – a spring and an autumn survey. This ensures sampling of fish within the two seasons where most fish species spawn, but also represents the period before the juveniles migrate into deeper waters when sea temperatures drop during winter. Therefore, this method will give valuable information about the usage of the area as spawning area, as well as provide information determining if the area serves as a nursery area for specific fish species. Furthermore, the StUK4 method will provide a general description of the distribution and density of the fish fauna communities within the project area.

Due to limited vessel size and engine power, a modified smaller version of the trawl was used in the present study. The trawl is built by Hvide Sande Vodbinderi and is four meters wide and 16.35 meter long when fully deployed (Figure 3-2). The cod end consists of 2 mm meshes to catch even small fish and juveniles. The smaller trawl was compensated for with longer trawl hauls, so that the overall area covered was identical to the area recommended in the StUK4. The method used in this study was identical to the one used in the Thor OWF in the North Sea and Energy Island Bornholm OWF in the Baltic Sea, where the same trawl was used for fish sampling (Rambøll & WSP, 2021; WSP, 2023).

The trawl was deployed from the side of the vessel with the Launch and Recovery System (LARS) and hauled for 30 minutes at 3-4 knots towing speed, so the overall area sampled is identical to the area recommended in the StUK4. This gives an average towing distance of 4,000 meter with a total area of 16,000 m^2 pr. haul. The trawl was hauled across the seabed which makes it ideal for catching benthic and demersal fish species incl. flatfish and Atlantic Cod. All trawl hauls were conducted during daylight hours.

Figure 3-2 Beam trawl utilized for the fish survey of NSI.1.

3.2.4 MULTIMESH GILLNETS

To sample and document a wide range of fish species and sizes present in NSI.1, multimesh gillnets were used. The mutimesh gillnets are designed for documenting the diversity of fish in an area, as each mesh size is specialized for catching a certain size of fish, and these nets are also used in the NOVANA fish survey program. The nets used in the present study consisted of 12 panels of various mesh sizes, ranging from 6-116 mm (6.5 mm, 8.5 mm, 11 mm, 15 mm, 18.5 mm, 25 mm, 30 mm, 40 mm, 55 mm, 70 mm, 90 mm, 116 mm). The mesh sizes increase geometrically with a factor 1.25. The nets were 1.5 meter high and approximately 100 meter wide (Figure 3-3). The nets have a sink line keeping the nets on the seabed, while the float line keeps the net stretched upwards. The nets are deployed with anchors in each end, attached to a buoy with contact information to the discipline manager for the fisheries authorities. The nets were deployed in the afternoon between 15-23 and retrieved the following morning after approximately 16 hours of fishing.

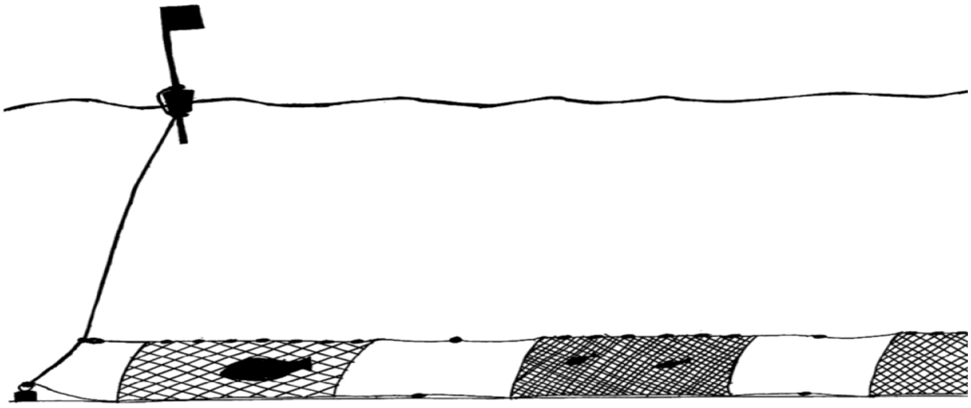

Figure 3-3 Multimesh gillnets with various mesh sizes specialized for catching a wide range of fish sizes.

3.2.5 TRAMMEL NETS

In hard bottom areas trammel nets substituted beam trawl. Trammel nets (Figure 3-4) consist of three layers of netting with the middle net (inner netting) consisting of a smaller mesh size (70-80 mm) and the two outer layers (outer netting) of larger meshes. The purpose of this type of net is, that fish swim into the inner netting and pushes it through the outer netting and thereby, catching the fish in a bag rather than catching the fish by its gills, as in traditional gill nets. The design with outer nettings makes trammel nets very stable when fishing in areas with strong currents. Trammel nets are best suited for catching flatfish such as turbot, plaice and sole. This makes the substitution from beam trawl ideal, as both gear types primarily catch benthic species.

The trammel nets were deployed on the seabed with a sink line and stretches approximately 1,5-2 meter vertically and kept buoyant by a float line. The nets were deployed with anchors in each end and subsequently attached to a buoy with contact information of the discipline manager for the fisheries authorities. The nets were set in the afternoon between 15-20 and retrieved the following morning after approximately 16 hours of fishing.

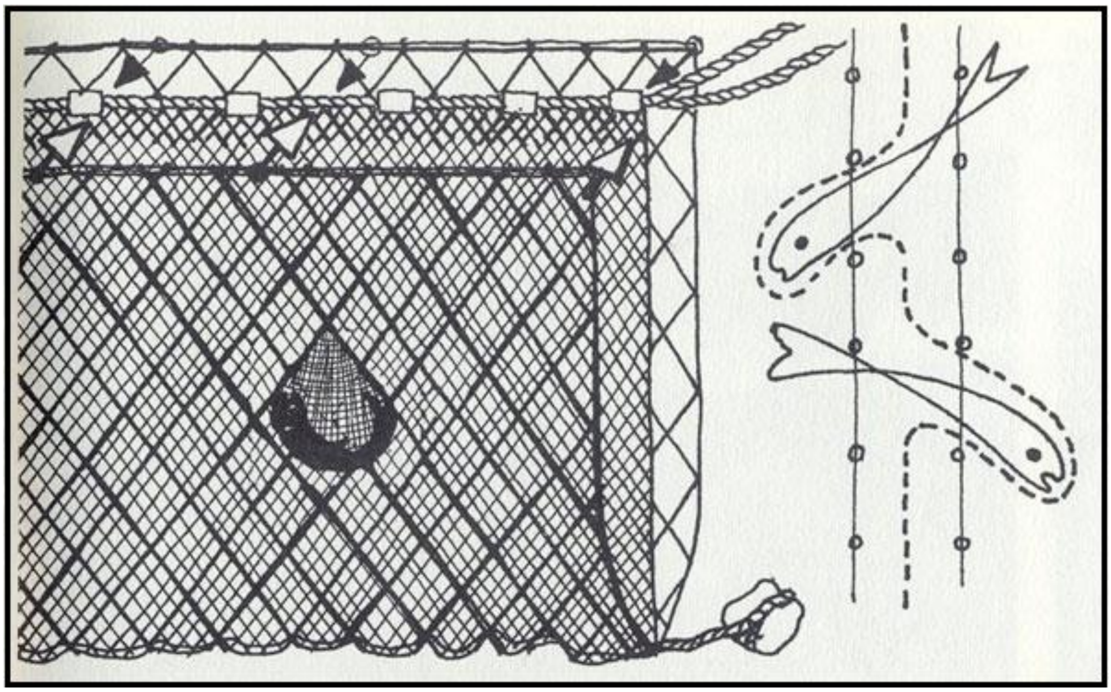

Figure 3-4 Trammel net with three layers of netting. The net layers catch the fish inside a "bag" instead of catching it by the gills (Garmer, 2023).

3.2.6 ANALYSIS OF THE CATCH AND DATA

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

ABUNDANCE, BIOMASS AND BIODIVERSITY

Similar to the Strategic Environmental Assessment (SEA) of Thor OWF in the North Sea and Energy Island Bornholm OWF, the fish density, biomass and biodiversity were divided into three categories: high, medium and low. By using the same sampling method and categories, it was possible to compare results between projects.

The abundance of fish was determined as Catch Per Unit Effort (CPUE) of number of fish per 1000 m^2 for beam trawl and number of fish per net per day for multimesh gillnets and trammel nets. The abundance was divided into three categories based on the catches made in the present study. Low abundance: < 6 fish, medium abundance: 6-11 fish and high abundance: > 11 fish.

The same method was used for biomass. The biomass of fish was determined as CPUE of grams of fish per 1000 m^2 for beam trawl and grams of fish per net per day for multimesh gillnets and trammel nets. The biomass was divided into three categories based on the catches made in the present study. Low biomass: < 250 grams of fish, medium biomass: 250-500 grams of fish and high biomass: > 500 grams of fish.

Biodiversity was also measured and divided into three categories based on number of species caught per station. This was the same for beam trawl, multimesh gillnets and trammel nets. Stations with < 10 species were listed as having low biodiversity, medium biodiversity was the range between 10-11 species pr. station, while stations with > 11 species had high biodiversity.

DETERMINATION OF GONAD MATURITY STAGE

To determine whether NSI.1 serves as a possible spawning area, the maturity stage of relevant fish species caught in the beam trawl was determined. This included all Atlantic cod, and all flatfish caught in the survey. Some species migrate to a specific spawning area where the salinity, depth, temperature, oxygen content or sediment type meet their demands, and the survival rate for the eggs and larvae are optimal. However, some species have a less specific spawning area and spawning occurs in the habitat where the adult population occurs.

As the fish grows from juvenile into adulthood, so does their reproductive system. After they reach adulthood, most marine fish spawn once a year. The reproductive system gradually prepares for the event by increasing the blood flow to the gonads, enlarging them and a color change is clear (Figure 3-5). Females produce eggs that gradually develop in the ovaries from an undefined mass to visible oocytes and finally to large waterfilled egg cells ready for spawning. The males prepare similarly, but they have milk running from the testes when they spawn. After the spawning event, the gonads of males and females go into a resting phase where they diminish again and prepare for the next spawning event.

The maturity was determined based on the visual appearance of the gonads and comparing this to a maturity index, where every stage of a fish's gonadal maturity was described (Table 3-1). The index describes in several stages whether the fish gonad was ripening, spawning, or was "spent" (regenerating the gonads). When fish are ripening the gonads and getting ready to spawn, they migrate to the relevant spawning site. So, if most individuals of a certain species caught in NSI.1 were spawning, this would indicate, that the area was utilized as a spawning area. The gonad maturity index was determined macroscopically for the Atlantic cod (*Gadus morhua*) according to (Tomkiewicz, et al., 2002) and for relevant flatfish species as well as for the Atlantic herring (*Clupea harengus*) according to (Strand, 2006). The maturity of the gonads was determined for both male and female fish.

Table 3-1 Maturity index based on macroscopical inspection of the gonads of male and female cod. Source: (Tomkiewicz, et al., 2002).

STAGE	FEMALE	MALE
I	**Juvenile** Ovaries emerge as tiny, paired organs close to bladder; glassy transparent to orange-reddish translucent in larger specimens. *LT* rarely above 30 cm;	**Juvenile** Testes emerge as a pair of thin strings along air bladder. Lobules tiny, glassy transparent to reddish translucent in larger specimens. *LT* rarely above 30 cm;
II	**Preparation** Ovaries small, but easily distinguishable posterior in body cavity; soft with even surface (flattens on a solid sheet); blurred translucent, reddish-orange. *LT*: 25-60cm;	**Preparation** Testes small, but distinguishable along air bladder. Lobules small, blurred translucent and reddish. *LT*: 20-50cm;
III	**Ripening 1: Oocyte recruitment** Ovaries still small and restricted to posterior body cavity; firmer than II and roe shaped (keep form on a solid sheet), surface uneven; opaque orange-red to dark orange with greyish cast in large females. Tiny opaque oocytes emerge towards end of stage. *LT* rarely below 30 cm;	**Ripening 1: Early spermatogenesis** Testes still small, close to air bladder. Lobules plump and soft, rich in blood vessels, completely or partially opaque, reddish. *LT* rarely below 20 cm;
IV	**Ripening 2: Late vitellogenesis** Ovaries enlarged to mid body cavity; plump and firm with prominent blood vessels; opaque, orange to creamy yellow. Oocytes clearly visible and densely packed.	**Ripening 2: Late spermatogenesis** Testes enlarged and prominent dorsal in body cavity; Lobules plump and brittle; reddish-white. Empty, transparent spermaducts with prominent blood vessels; no sperm release.
V	**Spawning 1: Initiation of spawning** Ovaries extending into anterior body cavity; distended and soft; opaque, orange to creamy yellow. Single glassy, hydrating oocytes among abundant opaque, vitellogenic oocytes (as in IV, but round and larger). Viscous fluid or hydrated eggs in lumen may occur.	**Spawning 1: Initiation of spawning** Testes extending into ventral part of body cavity. Lobules distended and brittle, opaque creamy-white. Spermaducts filled with viscous semen and a viscous droplet may be released from vent.
VI	**Spawning 2: Main spawning period** Ovaries fill most of body cavity; very distended and soft; appear granulated orange- to reddish-grey from mixture of opaque and glassy oocytes. Lumen containing viscous fluid in excess or hydrated eggs.	**Spawning 2: Main spawning period** Testes large and prominent in body cavity (as in V). Lobules still plump, but soft; completely opaque, whitish. Spermaducts filled with fluid, milky semen that easily flows from vent.
VII	**Spawning 3: Cessation of spawning** Ovaries shrunk to posterior body cavity; flabby with prominent blood vessels; unclear reddish- grey. Hydrated oocytes present; opaque oocytes few or absent. Lumen with excess fluid and frequently hydrated eggs.	**Spawning 3: Cessation of spawning** Testes shrunk to dorsal part of body cavity; soft and flabby. Lobules almost empty, opaque, reddish-white. Spermaducts still with fluid semen that easily flows from vent.
VIII	**Regeneration 1: Spent** Ovaries contracted; slack with greyish cast; rich in blood vessels; dim translucent reddish-grey. Vitellogenic oocytes absent, but single hydrated eggs or atretic oocytes (opaque, irregular granules) may occur.	**Regeneration 1: Spent** Testes contracted, close to air bladder; rich in blood vessels. Lobules empty, flabby, reddish potentially with a greyish cast. Spermaducts with signs of previous distension, often with visible remains of semen.
IX	**Regeneration 2: Resting and spawning omission** Ovaries small as in II, but with signs of previous spawning; e.g. greyish cast and somewhat uneven walls; blurred translucent, reddish-grey, but more granulated and opaque than in II.	**Regeneration 2: Resting and spawning omission** Testes small (as in Stage II), but with signs of previous spawning; e.g. lobules slightly larger than in II; spermaducts often with greyish cast.
X	**Degeneration: Reduced fertility** A: Ovaries with fibrous tissue formation; affected areas compact and hard, brownish-yellow opaque; non-affected parts with normal development. Observed in females from 65 cm. B: Other abnormalities.	**Degeneration: Reduced fertility** A: Testes with adipose tissue formation; affected parts undeveloped, hard, yellowish; non-affected parts with normal development. Observed in males from 50 cm. B: Other abnormalities.

Figure 3-5 Gonads of Atlantic cod. Left: male in late spermatogenesis estimated to be at stage IV with enlarged testes but without running milk. Right: female in late spermatogenesis estimated to be at stage IV with visible oocytes but without hydrated eggs.

SIZE DISTRIBUTION

The length of all fish caught in the surveys were measured to determine the size distribution of each species. By measuring the individual fish and determining the cohorts based on length-to-age literature, it is possible to determine whether NSI.1 serves a nursery area. Nursery areas are utilized by juvenile fish to feed and grow until they reach a size where they are less vulnerable to size-related predation. The nursery areas provide a relatively protected environment with plenty of food items, such as invertebrates. Several species in the North Sea do not have a distinct nursery area, instead the juvenile occur in the same areas as the adult population.

BIODIVERSITY AND EVENNESS BETWEEN SPECIES

To assess the biodiversity of fish in NSI.1, the Shannon Wiener index and evenness were calculated for catches for the spring and autumn survey based on abundance of fish. The calculations were separated for each gear type, as the various sampling methods cannot be compared; beam trawl data is based on abundance pr. 1000 m^2, while multimesh gillnet and trammel net catches were based on abundance of fish pr. net pr. day.

The Shannon Wiener index is the simplest measure of biodiversity. This measure is strongly dependent on sampling size and effort. The Shannon Wiener index increases as both the richness and the evenness of the infauna community increase. The values typically range between 1.5 and 4 in most ecological studies and the index is rarely greater than 4.

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

4 EXISTING DATA

Presented below, is knowledge on the existing conditions in NSI.1, including information on abiotic parameters as sediment types and biological parameters, mainly focusing on fish and fish populations. Local spawning and nursery areas are described with focus on key species and habitats in NSI.1 and the nearby area.

4.1.1 SEDIMENT TYPES

Fish are adapted – and attracted to specific sediment types, and some depend on certain habitat types to complete their life cycles. Such areas are defined as essential fish habitats. As an example, flatfish are adapted to sandy or muddy areas, in which they bury into the sediment as a cryptic behaviour, hiding from predators or to ambush prey. Other species of flatfish feed on prey that is buried into the sediment (infauna). Accordingly, flatfish are generally adapted to sandy areas without much structure (stones, reefs etc.).

In NSI.1, the distribution of seabed sediments is based on data from the national geophysical database provided by GEUS (Marta database, (GEUS, 2024)). The following substrate classification method was used to determine the roughness of the seabed sediment and the stone coverage cf. the Danish raw material order 1680 of 17-12-2018 (BEK 1680, 2018) (Table 4-1).

Table 4-1 Conversion between GEUS sediment types and sediment types used in legislation for raw materials (BEK 1680, 2018) and in this report. Not always possible to convert directly as e.g. till/diamicton include several sediment types.

GEUS sediment type	This report sediment type	Description
Mud and sandy mud	Sediment type 1a	Soft sediment
Muddy sand	Sediment type 1a/1b	Sand with a surface silt layer Soft sediment
Sand	Sediment type 1b	Sand
Gravel and coarse sand	Sediment type 2a	Sand, gravel and pebbles (large stones 1-10 %)
Till/diamicton	Sediment type 2b, 3 and 4	Sand, gravel, small stones, large stones (1-100 %)
Quaternary clay and silt	Sediment type 1c	Clay

The overall distribution of seabed sediments in NSI.1/ECC OWF is presented in Figure 4-1.

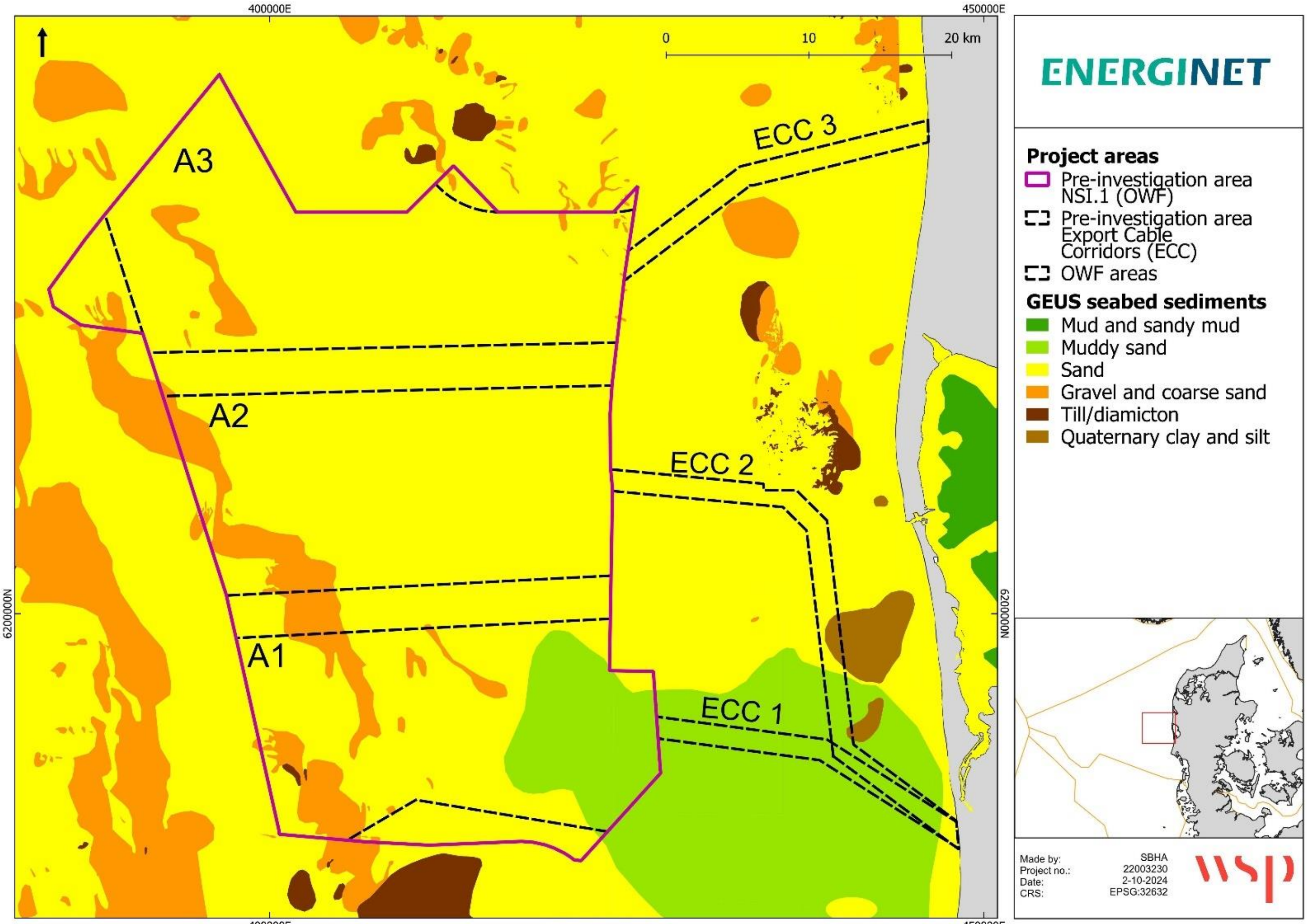

Figure 4-1. GEUS map of seabed sediment types in the two pre-investigation areas for North Sea I.1 including the OWF areas (A1-3) and the pre-investigation area for the three export cable corridors (ECC1-3) based on GEUS´ sediment map. Sources (GEUS, 2024).

NSI.1 dominated by “Sand” with small scattered local areas consisting of “Gravel and coarse sand”, “Quaternary clay and silt”, and “Muddy sand” in the southeastern part of the area (Figure 4-1). The GEUS map illustrating the distribution of sediment types in NSI.1 is relatively broad scale, thus, it does not entirely display the high natural variation in the area.

OWF AREAS

Existing data show that NSI.1 is relatively homogenously with dominance of the sediment type “Sand” and smaller local patches of “Gravel and coarse sand”. The three OWF areas A1-A3 are therefore also relatively uniform, except for a large patch of “Muddy sand”, which is found only in OWF A1 in the southeastern part of the pre-investigation area.

EXPORT CABLE CORRIDORS

The pre-investigation areas NSI.1 for the three export cable corridors (ECC1-3) have larger variation between them than the OWF areas (A1-A3). The northernmost export cable corridor (ECC3) is dominated by the sediment type “Sand”. The middle cable corridor (ECC2) is dominated by (described from north/deepest to south/shallowest) “Sand”, “Quaternary clay and silt”, a mix of “Muddy sand” and “Quaternary clay and silt” and the most southeastern part is dominated by “Muddy sand”. In the southern cable corridor (ECC1), only “Muddy sand” is mapped.

4.2 FISH DATA

According to the data extraction from the database, Fiskeatlas, of fish distribution in Danish waters, 156 different fish species have been observed over the past 100 years in the North Sea (Fiskeatlas, 2024). Of these, approximately 50 are so rare that they are of no or limited importance for the present project. The rare species include argentine (*Argentina sphyraena*), electric ray (*Tetronarce nobiliana)* and ocean sunfish (*Mola mola*).

In NSI.1, a total of 71 different fish species have been observed and registered in the Fiskeatlas database (Fiskeatlas, 2024). The list of all 71 species is shown below in Table 4-2. Over time, 67 fish species have been registered in the OWF area. A3 has the highest number with 56 species, whereas a total of 47 and 31 species have been registered in A2 and A1, respectively. A total of 35 different fish species have been registered in the ECCs.

The observed species include numerous observations of common and economically important species such as Atlantic cod, Atlantic herring, European sprat, whiting and the flatfish species common dab, European plaice, turbot, and European flounder. However, protected species have been observed in NSI.1, including European sturgeon (*Acipenser sturio*), twaite shad (*Alosa fallax*), river lamprey (*Lampetra fluviatilis*) and the sea lamprey (*Petromyzon marinus*). In recent years, an unusually high number of observations of the critically endangered Atlantic sturgeon (*Acipenser sturio*) have occurred along the west coast of Jutland and the individuals are believed to originate from reared and released individuals (Henrik Carl & Peter Rask Møller pers. comm.). Please see 4.2.3 for further details on protected and vulnerable species.

In nearby OWF areas, fish surveys have been conducted to describe the distribution of fish and fish populations. In the Thor OWF, a total of 31 different fish were observed, 25 different fish species were registered in Vesterhav Nord, and 21 species observed in Vesterhav Syd. In all three studies, flatfish and especially common dab dominated the catches. It is expected that the number of species and the community structure observed in the fish survey conducted in this study will be similar to the observations made in Thor OWF and Vesterhav Nord and Syd, due to the close proximity of the OWF areas along the west coast of Jutland.

Table 4-2 List of fish species registered in NSI.1 OWF and ECCs in Fiskeatlas. *Atlantic halibut is registered in the corridors between subareas. (Sources: (Fiskeatlas, 2024). Nearby area column lists species caught in nearby areas - 1: (BioApp og Krog Consult, 2015), 2: (BioApp og Krog Consult, 2015), 3: (Rambøll og WSP, 2021), 4: (Hoffmann, et al., 2000), 5: (Bio/consult, Carl Bro, DHI og Krog consult, 2006), 6: (Orbicon, 2014).

Common name	Latin	A1	A2	A3	ECC	Nearby area
American plaice	*Hippoglossoides platessoides*	x	x	x		2, 3, 5, 6
Angler	*Lophius piscatorius*			x		4
Atlantic bluefin tuna	*Thunnus thynnus*				x	
Atlantic cod	*Gadus morhua*	x	x	x	x	1, 2, 3, 4, 5, 6
Atlantic halibut	*Hippoglossus hippoglossus*		*			
Atlantic herring	*Clupea harengus*	x	x	x	x	1, 2, 4, 5
Atlantic horse mackerel	*Trachurus trachurus*	x	x	x	x	1, 2, 3, 4, 5
Atlantic mackerel	*Scomber scombrus*	x		x	x	1, 3, 4
Atlantic wolffish	*Anarhichas lupus*			x		
Blue skate	*Dipturus batis*			x		
Brill	*Scophthalmus rhombus*	x		x		3, 4
Common dab	*Limanda limanda*	x	x	x	x	1, 2, 3, 4, 5, 6
Common dragonet	*Callionymus lyra*	x		x	x	1, 2, 3, 4, 5, 6
Common sole	*Solea solea*	x	x	x	x	2, 3, 4, 5, 6
Crystal goby	*Crystallogobius linearis*	x				
Eelpout	*Zoarces viviparus*	x			x	1, 2, 4
Electric ray	*Tetronarce nobiliana*		x			
European anchovy	*Engraulis encrasicolus*	x	x	x	x	
European flounder	*Platichthys flesus*	x	x	x	x	1, 2, 4, 5, 6
European hake	*Merluccius merluccius*	x		x	x	4
European pilchard	*Sardina pilchardus*		x	x		
European plaice	*Pleuronectes platessa*	x	x	x	x	2, 3, 4, 5
European sturgeon	*Acipenser sturio*	x	x	x	x	
Fivebeard rockling	*Ciliata mustela*	x				3, 4
Garfish	*Belone belone*	x		x	x	4
Great sandeel	*Hyperoplus lanceolatus*	x		x	x	1, 2, 3, 4, 5, 6
Greater pipefish	*Syngnathus acus*			x		
Greater weever	*Trachinus draco*	x	x	x		3
Grey gurnard	*Eutrigla gurnardus*	x	x	x	x	1, 2, 3, 4, 5
Haddock	*Melanogrammus aeglefinus*	x		x		2, 3, 5, 6
Hooknose	*Agonus cataphractus*	x	x	x	x	1, 2, 3,4, 5, 6
John dory	*Zeus faber*			x		
Lemon sole	*Microstomus kitt*	x	x	x	x	2, 3, 4
Lesser sand-eel	*Ammodytes marinus*	x	x	x	x	2, 3, 5
Lesser spotted dogfish	*Scyliorhinus canicula*			x	x	4
Lesser weever	*Echiichthys vipera*	x	x	x		3, 4
Lumpfish	*Cyclopterus lumpus*	x	x	x		
Mediterranean scaldfish	*Arnoglossus laterna*	x	x	x		1, 2, 3, 4
Nilsson's pipefish	*Syngnathus rostellatus*	x		x	x	2
Norway pout	*Trisopterus esmarkii*			x		4
Norwegian topknot	*Zeugopterus norvegicus*	x		x		3
Painted goby	*Pomatoschistus pictus*	x				
Picked dogfish	*Squalus acanthias*			x		
Pollack	*Pollachius pollachius*			x		
Poor cod	*Trisopterus minutus*	x	x	x		2, 4
Pouting	*Trisopterus luscus*			x		4
Reticulated dragonet	*Callionymus reticulatus*	x	x			2, 3
River lamprey	*Lampetra fluviatilis*				x	4
Saithe	*Pollachius virens*			x		1
Sand goby	*Pomatoschistus minutus*	x		x	x	1, 2, 3, 5, 6
Sea lamprey	*Petromyzon marinus*				x	
Sea trout	*Salmo trutta*			x	x	4
Shorthorn sculpin	*Myoxocephalus scorpius*	x	x	x	x	1, 2, 3, 4
Small sandeel	*Ammodytes tobianus*			x	x	1, 2
Smooth sandeel	*Gymnammodytes semisquamatus*	x				
Snake pipefish	*Entelurus aequoreus*	x				4
Solenette	*Buglossidium luteum*	x	x	x	x	1, 2, 3, 4, 5, 6
Spotted dragonet	*Callionymus maculatus*	x		x		3
Sprat	*Sprattus sprattus*	x	x	x	x	1, 2, 4 5, 6
Starry ray	*Amblyraja radiata*	x		x		
Striped seasnail	*Liparis liparis*	x				1, 2
Thornback ray	*Raja clavata*		x	x		
Three-spined stickleback	*Gasterosteus aculeatus*	x		x	x	2, 4
Thresher	*Alopias vulpinus*		x			
Tope shark	*Galeorhinus galeus*			x	x	
Topknot	*Zeugopterus punctatus*	x				2
Tub gurnard	*Chelidonichthys lucerna*	x	x	x	x	3
Turbot	*Scophthalmus maximus*	x	x	x	x	3, 4, 5, 6
Twaite shad	*Alosa fallax*		x	x		
Whiting	*Merlangius merlangus*	x	x	x	x	1, 2, 3, 4, 5, 6
Witch flounder	*Glyptocephalus cynoglossus*			x		4

4.2.1 DESCRIPTION OF KEY FISH SPECIES

ATLANTIC COD (GADUS MORHUA)

The Atlantic cod *(Gadus morhua)* is a roundfish belonging to the family Gadidae. Most species within this family exhibit a characteristic chin hook (Muus & Nielsen, 2006). While Atlantic cod can grow up to 150 cm in length, individuals of this size are rare today due to intense fishing pressure. A more typical maximum size for Atlantic cod is approximately 110 cm and 15 kg. These fish inhabit coastal areas and can be found at depths ranging from 500 to 600 meters near the ocean floor, but they can also occur in the pelagic zone. The Atlantic cod inhabits the entire North Sea and Baltic Sea, with the exception of the northern part of the Bothnian Bay (Cohen, et al., 1990). The Atlantic cod is an opportunistic predatory fish, that eat a wide range of invertebrates and fish. As larvae, they begin by consuming algae, but as they grow older, they switch to eating water flea larvae and small crustaceans. The Atlantic cod can be found in various habitat types near the seabed, such as kelp belts, rocky reefs, wrecks, and other structures on the ocean floor, including bridge pillars, breakwaters, harbors, oil platforms, and wind turbine foundations. These locations provide good hiding places and a rich benthic fauna as a food source. While Atlantic cod can also be found on sandy and gravelly bottoms, they generally avoid muddy substrates (Hoffmann, et al., 2021).

ATLANTIC HERRING (CLUPEA HARENGUS)

The Atlantic herring *(Clupea harengus)* is a pelagic, silvery, schooling fish with soft fin rays. The Atlantic herring is a commercially important fish species. Its maximum size is 40 cm, and it can reach 20-25 years of age. In the North Sea, there is a tendency for Atlantic herring to grow larger than in the Baltic Sea. It lives pelagically down to approximately 200 meters depth and occurs in schools. Atlantic herring feeds on zooplankton, following the vertically movement of the plankton throughout the day. This means, that Atlantic herring generally stays higher in the water column at night and lower during the day. In Danish waters, there are several different Atlantic herring stocks. These stocks are characterized by their appearance, morphology, spawning period, migration routes, lifestyle, and growth. This species serves as a crucial food source for many other fish and is common in the North Sea. Their diet mainly consists of copepods, pelagic gastropods, and fish larvae (Warnar, et al., 2012).

EUROPEAN PLAICE (PLEURONECTES PLATESSA)

The European plaice *(Pleuronectes platessa)* is a flatfish from the family of *Pleuronectidae.* Plaice occurs on sandy or muddy bottoms, from a few meters down to about 200 meters of depth. It thrives in the open seas and in estuaries and is rarely seen entering freshwaters (Muus & Nielsen, 2006). The plaice is a commercial fish species. It reaches a maximum length of 90-100 cm and weighs approximately 7 kg. The European plaice is a right-eyed flatfish, meaning that it is the right side, where the eyes are also located, that faces upward. This contrasts with, for example, the turbot, which is left-eyed, while the flounder can be both right-eyed and left-eyed. The plaice has a smooth, brown surface on the eye side with scattered red or orange-red spots, which also extend to the fins. The blind side is white. Most adult European plaice are found at depths of 10-50 meters, while juveniles are typically found at shallower depths. As juveniles grow larger, it is easy to differentiate the European plaice from the European flounder as the European flounder develops a rough surface, while the European plaice is smooth. The European plaice inhabit sandy, gravelly, or muddy bottoms from the coast down to around 200 meters deep. After their first summer, most European plaice measure 7-12 cm. During winter, they move to deeper waters, and growth is limited. At night, growing European plaice are usually foraging, while during the day, they bury themselves in the substrate. (Warnar, et al., 2012).

COMMON DAB *(LIMANDA LIMANDA)*

The common dab *(Limanda limanda)* is a righteye flounder with a small mouth and distinctive, marked curve over the pectoral fin on the lateral line. The dab resides on sandy and soft bottom areas at depths up to 150 meters (Muus & Nielsen, 2006). The maximum size is up to 40 cm, weighing around 1 kg. However, the most common sizes are rarely above 30 cm. The common dab is one of the demersal species in the North Sea with the highest densities (number per unit area). It has a large distribution in the southern part of the North Sea. The common dab is a demersal fish, commonly found on sandy bottoms but also occurring in gravel, shell gravel, clay, mud, and mixed substrates. These fish are often abundant in areas with strong water flow. While they tolerate brackish water, they typically avoid the most brackish areas (Carl & Munk, 2019). The pelagic larvae primarily feed on small crustaceans, especially water fleas. However, once they settle on the seabed, their diet becomes more diverse, reflecting the locally abundant food sources (Wheeler, 1969; Hinz, et al., 2005). Different dietary studies reveal varying preferences, and there is significant variation throughout the year (Lande, 1976). Their diet includes benthic organisms such as mollusks (mostly mussels), worms, crustaceans, and echinoderms (such as brittle stars). Additionally, they consume small fish, like sticklebacks, herring fry, and sprat (Bagge, 1981).

SOLENETTE *(BUGLOSSIDUM LUTEUM)*

The Solenette *(Bugglossidum Luteum)* is a type of flatfish which has a rounded head and eyes on the right side. The solenette is recognized by every 4th-7th ray of the dorsal and anal fins being black, its small size (maximum length 13 cm) and low-slung semi-circular mouth. It resides on sandy bottoms and is very common in the southern part of the North Sea and in the English Channel (Muus & Nielsen, 2006). In the southern part of the North Sea, where the species is abundant, it is considered a competitor for more valuable species, such as the common sole (Carl & Møller, 2019). The solenette can become quite old. Studies have shown a maximum age of 14 years in the North Sea and 16 years off the coast of Ireland. Females live longer than males, resulting in an overrepresentation of females in catches (Carl & Møller, 2019). The species is rather sedentary and does not undertake actual migrations (Wheeler, 1969). The juveniles are found in the same places as the adults. The solenette tolerates varying salinity, but it is not found in true brackish water, where the common sole is more frequent. The solenette is an opportunistic predatory fish that feeds on small benthic invertebrates and fish fry. Some studies have shown a broad dietary range, while others indicate a more specific diet, likely reflecting local conditions. Crustaceans (such as copepods and amphipods) and small fish are among its prey items (Carl & Møller, 2019).

SANDEEL *(AMMODYTES MARINUS R. AND AMMODYTES TOBIANUS L)*

Sandeel (*Ammodytes marinus and Ammodytes tobianus)* caught in the commercial fisheries consists of two separate species, which are usually not differentiated in the landings. The species are lesser sand-eel (*Ammodytes marinus*) and small sandeel (*Ammodytes tobianus*). The lesser sandeel is usually found further offshore compared to the small sandeel. Both species are long and slender fish of up to 20-25 cm long and are the dominating fish species in the North Sea area between 10 and 150 m depth (Muus & Nielsen, 2006). The fish spend most of the time at low light intensities (night and winter) buried in the sandy substrate. During feeding, which is correlated with the tidal current, they form massive schools in the water masses. The sandeel feeds on pelagic plankton.

4.2.2 SPAWNING AND NURSERY AREAS

Existing literature suggests that NSI.1 is utilized by various fish species for spawning and as a nursery area for juveniles. In the following sections, the utilization of the area for each relevant species is described.

ATLANTIC COD

Typically, cod spawn from January to May, and their eggs drift with the water currents in the pelagic zone. Juvenile cod use hard bottom areas as nursery grounds, where they feed on small crustaceans. Over time, their diet gradually shifts toward piscivory. According to existing literature, NSI.1 serves as a general spawning ground for cod rather than a specifically significant spawning site (Worsøe, et al., 2002) (Figure 4-2).

The Atlantic cod spawn in pairs, belly to belly, freely in the water. This usually occurs at depths of 10-100 meters. (Wheeler, 1969); (Curry-Lindahl, 1985). The eggs, which have a diameter of 1.16-1.89 mm (Ehrenbaum, 1905-1909) are pelagic and float to the surface within a few hours. Their buoyancy depends significantly on the salinity of the water, with the largest eggs having the lowest density in low-salinity areas. After spawning, the eggs rise toward the surface, where they remain until hatching, typically within 2-4 weeks. The survival of these eggs depends on factors such as oxygen levels, salinity, and temperature in the water column.

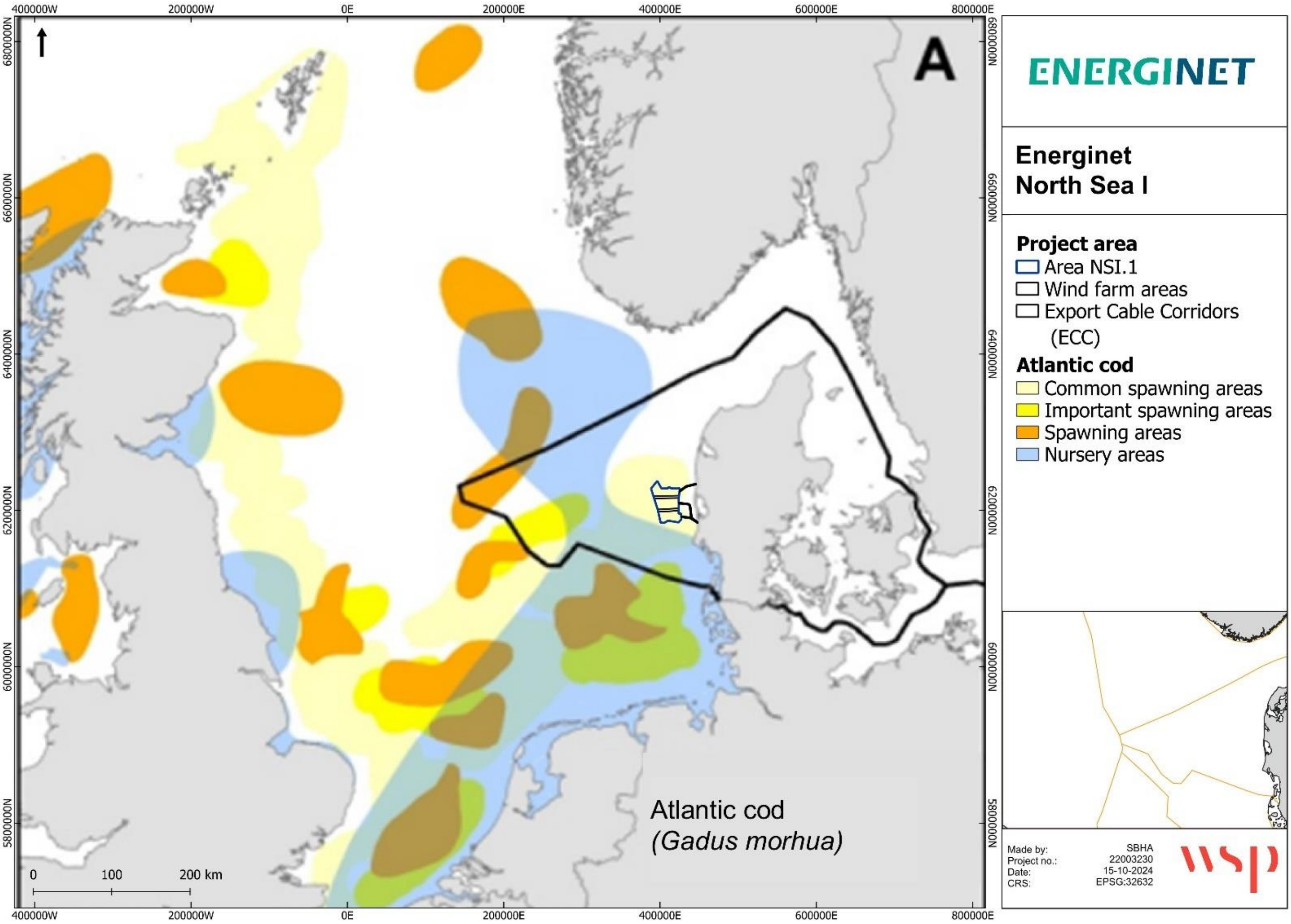

Figure 4-2 Atlantic cod *(Gadus morhua)*. Known spawning and nursery areas in the North Sea and Skagerrak. A) Light yellow: common spawning areas, yellow: important spawning areas (according to (Worsøe, et al., 2002). Orange: spawning areas (according to (Coull, et al., 1998). Blue: nursery areas according to (Coull, et al., 1998). The figure is modified from (Warnar, et al., 2012).

ATLANTIC HERRING *(CLUPEA HARENGUS)*

In Danish waters, the Atlantic herring is naturally divided into smaller populations that vary morphologically and have different spawning seasons, migration routes, way of life and growth. The Atlantic herring is a demersal spawner, and the eggs are attached to hard substrate or vegetation in relatively shallow areas (Pihl & Wennhage, 2002).

In the North Sea, there are several areas that meet the Atlantic herring's requirements for spawning grounds. As a result, there are many well-known spawning areas in the North Sea (Figure 4-3). During their first winter, the autumn- and winter-spawned herring larvae are carried by currents from the English coast across the North Sea (Knijn, et al., 1993). As a result, the most important nursery areas are located in the southern and eastern parts of the North Sea, including the entire Jutland west coast within the Danish Exclusive Economic Zone (EEZ).

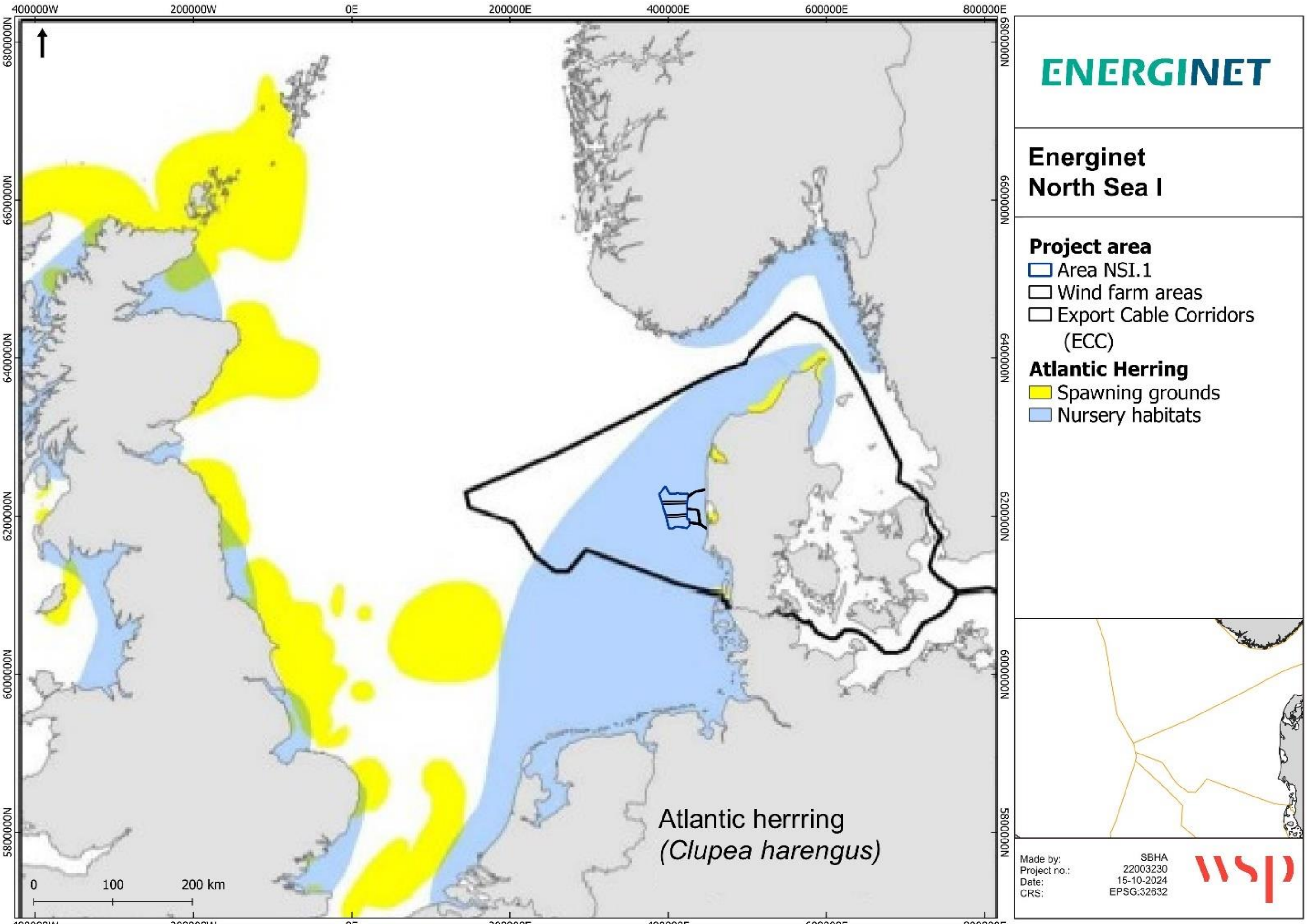

Figure 4-3 Herring *(Clupea harengus).* Known spawning and nursery areas in the North Sea and Skagerrak. Yellow: spawning grounds, blue: nursery habitats (according to (Worsøe, et al., 2002), (Coull, et al., 1998), DTU Aqua's summer acoustic survey). These areas are crucial for the reproduction and early life stages of herring and other marine species. The figure is modified from (Warnar, et al., 2012).

EUROPEAN PLAICE *(PLEURONECTES PLATESSA)*

The European plaice spawns from December to May (Munk & Nielsen, 2005); (Coull, et al., 1998). The plaice spawn's pelagic eggs that can be found in large areas, especially in the southern and central North Sea, as well as east of England and Scotland (Munk, et al., 2009); (ICES, 2007-2011). Depending on their size, females can lay up to 500,000 eggs in the open water (pelagic). The European plaice spawns in significant parts of the Danish EEZ in the North Sea. Following spawning, the eggs and potentially hatched larvae drift with the current toward coastal nursery areas (Knijn, et al., 1993); (Houghton & Harding, 1976); (Nielsen, et al., 1998). These nursery habitats are influenced by factors such as bottom composition, salinity, temperature, and water flow conditions (Poxton & Nasir, 1985). While similar areas exist along the eastern coasts of England and Scotland, as well as in the German Bight, the most significant ones are located in the Wadden Sea (Knijn, et al., 1993) (Hopkins, 1986) (Kuipers, 1977).

The pelagic eggs have a certain buoyancy, and if the salinity is too low, the eggs sink into areas with insufficient oxygen, resulting in their demise. The larvae drift with the water current into shallow softbottom sheltered areas rich in food resources known as nursery areas. The primary nursery area for European plaice in the Danish EEZ, lies off the east coast of Jutland, although smaller nursery areas exist along the Danish, Swedish, and German coastlines (Figure 4-4) (Coull, et al., 1998); (HELCOM, 2021). After 1-2 months, the European plaice larvae begin to change shape. One eye migrates to the upper side of the head, and the fish begins to swim with its left side downward. The European plaice now transform into flatfish, adapted to live and hide on the soft seabed. During winter, juveniles migrate to deeper waters, returning to shallows in spring to feed and grow. As fish mature, their winter migrations become deeper until they eventually reach spawning sites (Warnar, et al., 2012)

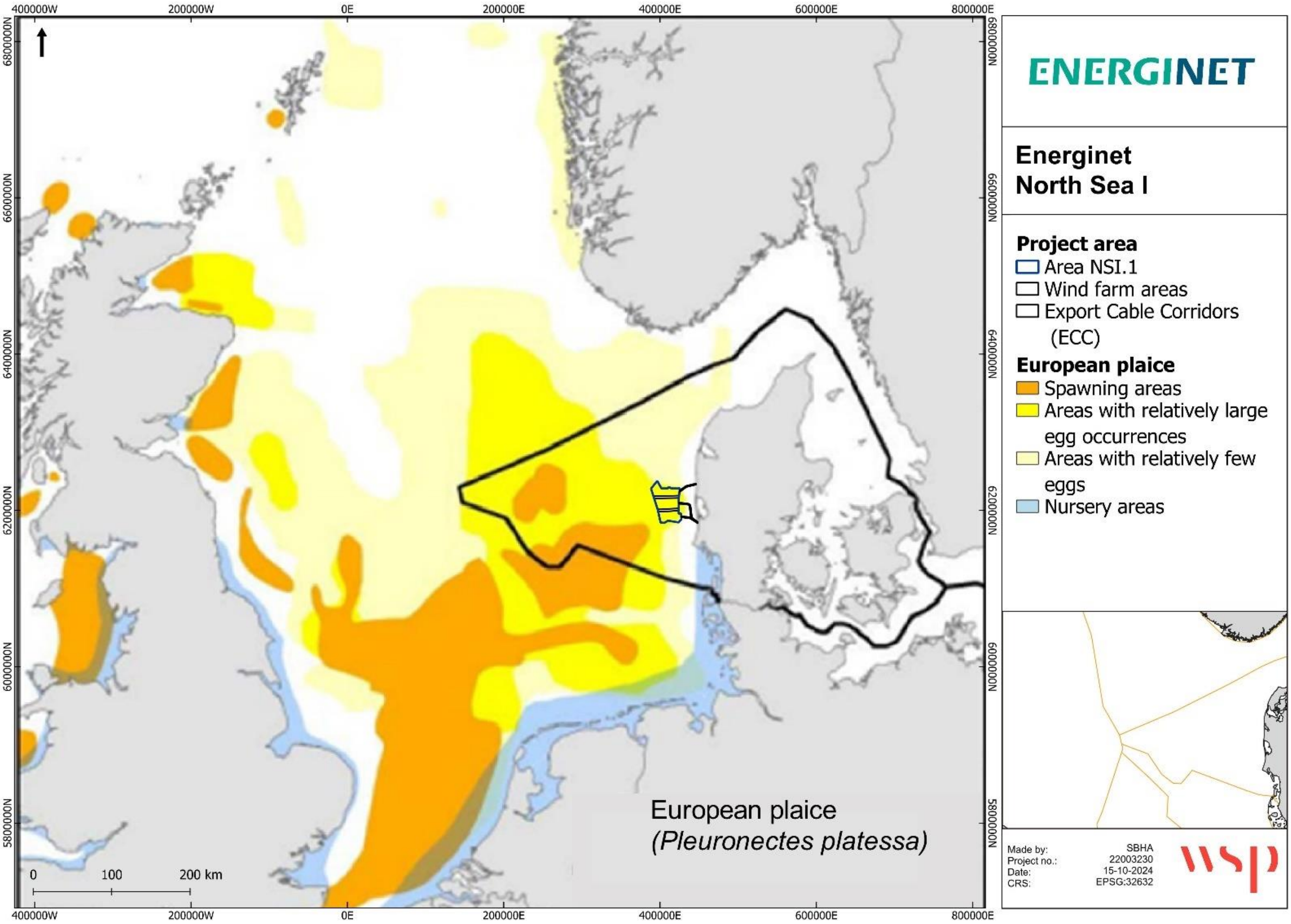

Figure 4-4 The European plaice (Pleuronectes platessa). Known spawning and nursery areas in the North Sea. Orange: spawning areas (according to (Worsøe, et al., 2002), (Coull, et al., 1998). Yellow: areas with relatively large egg occurrences, light yellow: areas with relatively few eggs (international ichthyoplankton survey 2004 - according to (Munk, et al., 2009), (ICES, 2007-2011)). Blue: nursery areas (according to (Worsøe, et al., 2002) (Coull, et al., 1998) (Warnar, et al., 2012). Figure is modified from (Warnar, et al., 2012) with the illustration of pre-investigation area and cable corridors of NSI.1 (black drawing).

COMMON DAB *(LIMANDA LIMANDA)*

Spawning occurs in the entire North Sea throughout January-August. In the North Sea the spawning takes place in April-June near the bottom in 20-40 meters depth. The eggs are pelagic and hatch within 3-12 days, depending on the temperature. The larvae also remain pelagic until they reach a length of approximately 14 mm, at which point they change shape and move toward the seabed at depths ranging from 6 to 70 meters. The diet consists of worms, crustaceans, bivalves and smaller fish such as gobies and young sand-eels (Bagge, 1981).

SOLENETTE *(BUGLOSSIDUM LUTEUM)*

The solenette become sexually mature when males measure 6-7 cm and females measure 7-10 cm, usually at around three years of age. The spawning time depends on the temperature in the North Sea, and they spawn from July to August. (Quéro, et al., 1986). The eggs are pelagic and measure 0.69-0.94 mm in diameter. They hatch after 5-6 days, and the pelagic larvae measure 1.83-2.29 mm (Ehrenbaum, 1905-1909). Once they reach a length of 9-20 mm, their metamorphosis is complete, and the young fish become benthic, just like the adults (Carl & Møller, 2019). There are no specific breeding grounds for the solenette, as they grow up and breed in the same areas.

SANDEEL *(AMMODYTES MARINUS R. AND AMMODYTES TOBIANUS L)*

The sandeel spawns during a very short period in December and January (Winslade, 1974); (Macer, 1966); (Gauld & Hutcheon, 1990). Alongside the sandeel, there are three other confirmed sandeel species in the North Sea: the lesser sandeel *(Ammodytes* tobianus), the lancelet sandeel *(Hyperoplus lanceolatus),* and the naked sandeel *(Gymnammodytes semisquamatus).* (Warnar, 2011). The spawning period varies for these mentioned species. The lesser sandeel spawns during two separate short periods: one in March/April and another in September (Russell, 1976). The lancelet sandeel has a somewhat longer spawning period, extending from April to August (Macer, 1966). There is limited knowledge about the spawning period of the naked sandeel, but it is assumed to spawn during summer (Whitehead, et al., 1986).

The sandeel spawns on the seabed, and its eggs adhere to the sediment where they hatch (Bowman, 1914; Winslade, 1971). During spawning, they are only active for a brief period before burying themselves in the sand again. All four species occur only in very well-defined areas because they have specific habitat requirements. The demersal habitats and spawning areas of the sandeel are found where the seabed consists of coarse sand with low silt content and strong currents, at depths of approximately 80 meters—specifically, on underwater banks (Macer, 1966; Winslade, 1974; Wright, et al., 1998; Proctor, et al., 1998; Jensen, 2001; Wright, et al., 2000). In addition to the Fisher Bank, Dogger Bank, and other banks, there are also ecologically important habitats for the sand eel along Scotland's east coast, as well as around Orkney and Shetland (Macer, 1966; Gauld & Hutcheon, 1990; Frederiksen, et al., 2006; Jensen, et al., 2011). The habitats and spawning areas of the lesser sand eel are found closer to the coast (within 30 meters) on sandy bottoms (Wheeler, 1969). There is limited knowledge about the spawning areas of the other two species. Sandeel habitats overlap with NSI.1 based on mapping of commercial fisheries for sandeel (Figure 4-5).

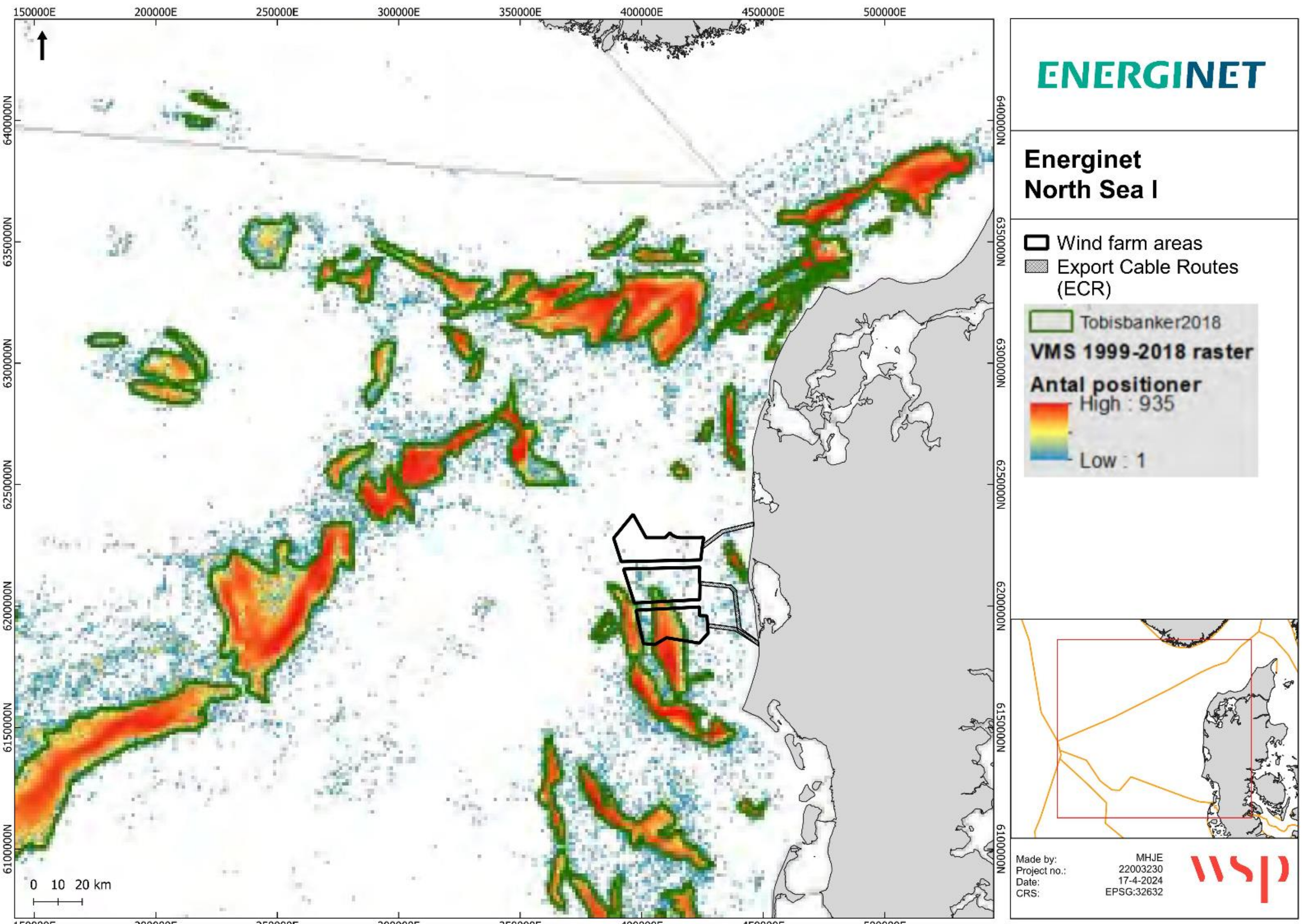

Figure 4-5 Sand eel fishing grounds digitalised from VMS data collected in 2018 (green lines) compared with sand eel fishing grounds registered in 1999-2018 (red: high intensity fishing ground, blue: low intensity. Source: (Deurs, 2019). Modified with the illustration of pre-investigation area and cable corridors of NSI.1 (black drawing).

SOLE *(SOLEA SOLEA L.)*

There are different observations regarding the spawning period of common sole in the North Sea. While (Munk & Nielsen, 2005) describe spawning occurring from April to September, other sources indicate that spawning takes place from March to May (Coull, et al., 1998) and that peak spawning activity occurs in April–May (Worsøe, et al., 2002). Age and size at sexual maturity vary from place to place, but males typically mature earlier than females. Sexual maturity does not seem to be directly dependent on the fish's growth but rather on a combination of temperature and location. In colder and more northern parts of the distribution area, soles become sexually mature at a smaller size than in warmer and more southern areas. In the North Sea, common sole become sexually mature at the age of 2-3 years, and by 4 years old, 90-100% are mature (Rijnsdorp & Beek, 1991). Typically, this occurs at a length of 23-25 cm. (Boje & Carl, 2020). The eggs and larvae drift with the current until they reach the nursery grounds in shallow sandy areas where they grow until winter, where they swim to deeper and warmer waters. The spawning area for common sole is located along the coastline of the Wadden Sea and into the English Channel. The spawning area seems to be located just on the edge of the pre-investigation area of NSI.1, however, spawning sole may also occur within NSI.1 (Figure 4-6).

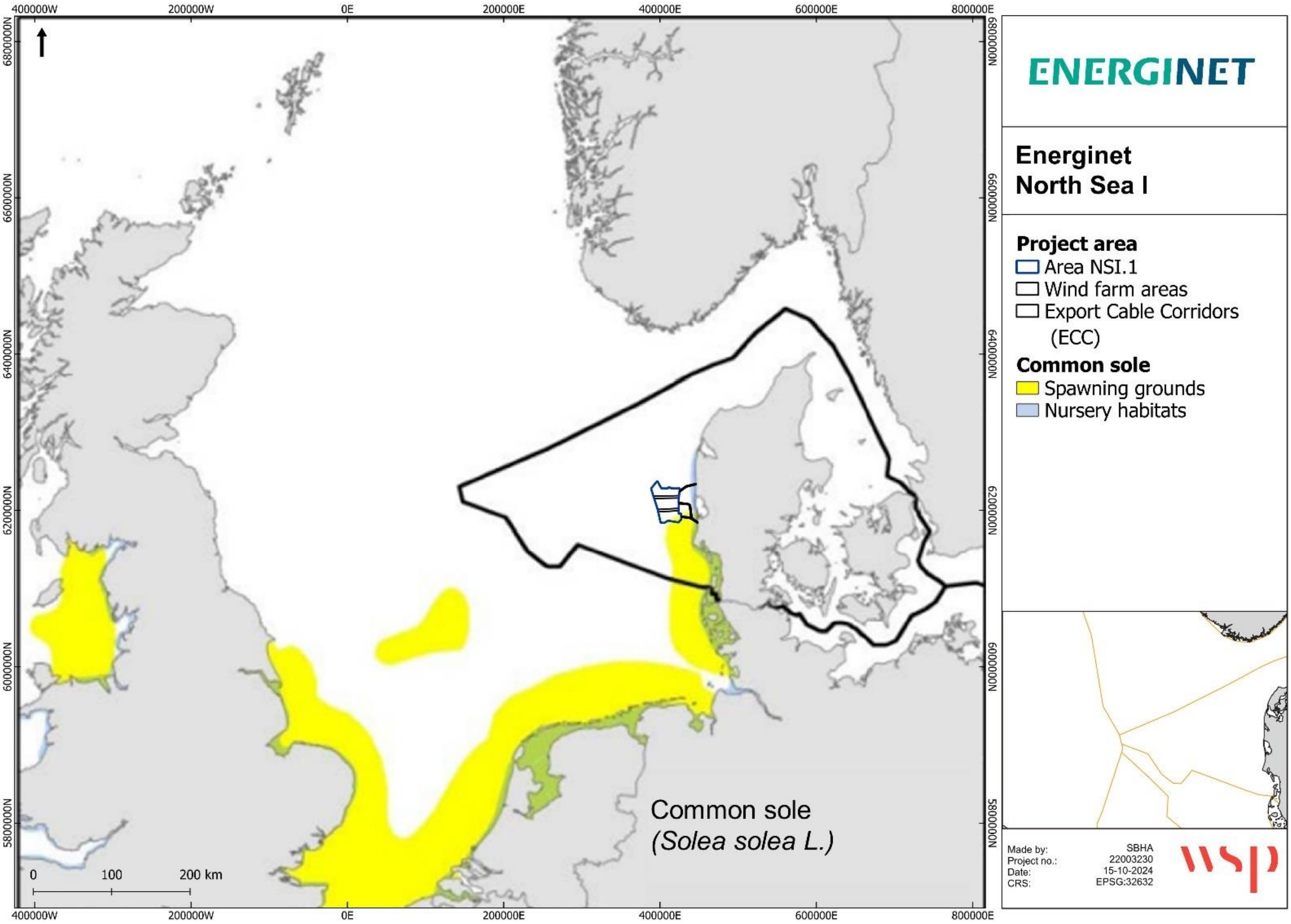

Figure 4-6: Known spawning and nursery areas for common sole in the North Sea. These areas are crucial for the reproduction and early life stages of various marine species. The yellow regions represent spawning grounds, while the blue areas indicate nursery habitats. Researchers have identified these locations based on studies by (Worsøe, et al., 2002) and (Coull, et al., 1998) (Warnar, et al., 2012). The figure is modified from (Warnar, et al., 2012) with the illustration of pre-investigation area and cable corridors of NSI.1 (black drawing).

4.2.3 PROTECTED FISH SPECIES AND HABITATS

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

The species on Annex II are attached with such strict regulations, that habitats have been appointed where the species are protected, and these sites must be managed in accordance with the ecological needs of the species. Species on Annex IV are covered by a strict regime, and they must be protected across their entire natural range within the EU, both within and outside

Natura 2000 classified sites. For the species listed on Annex V, the member states must ensure that any exploitation of the areas complies with a favourable conservation status for the listed species.

PROTECTED FISH SPECIES

Based on the Fiskeatlas database, four protected fish species listed in Annex II in the Habitats Directive, have been registered in NSI.1, including European sturgeon, twaite shad, river lamprey and sea lamprey (Table 4-3). European sturgeon is also protected under Annex IV in the Habitats directive. Annex V in the Habitats directive includes River lamprey and twaite shad, both registered in NSI.1. Of the four species, river lamprey and twaite shad are listed as Least Concern (LC) on the Danish IUCN Red List, which was last updated in Denmark in 2019 (Carl & Møller, 2019). The European sturgeon is listed as Not Applicable (NA) and sea lamprey is Data Deficient (DD). The Fiskeatlas database only holds information on presence/absence of fish species, so it is not possible to estimate the abundance or number of individuals observed pr. recording (Fiskeatlas, 2024).

Table 4-3. List of Danish marine fish species listed in the Habitats Directive Annex II, IV and X or on the IUCN's Red List (Carl & Møller, 2019), DD = Data Deficient; LC = Least Concern; NA = Not Applicable. *Fiskeatlas registrations in NSI.1 (Fiskeatlas, 2024).

Species	Latin name	Habitats Directive			IUCN Red List	Registered in the pre-investigation area*
		II	IV	V		
European sturgeon	*Acipenser sturio*	x	x		NA	x
River lamprey	*Lampetra fluviatilis*	x		x	LC	x
Sea lamprey	*Petromyzon marinus*	x			DD	x
Twaite shad	*Alosa fallax*	x		x	LC	x

The European sturgeon has been registered in the all the sub-areas within project area. Until 1950s, the European sturgeon was a relatively frequent visitor in Danish waters. However, overfishing and habitat destruction has decreased the populations. The observations of the critically endangered sturgeon in NSI.1 are all believed to originate from reared and released individuals (pers. comm. Henrik Carl, Fiskeatlas). Currently, attempts to restore the natural population of sturgeons are taking place in German, French and Dutch rivers (Kirschbaum, 2011; Brevé, 2018) and it is believed that few of the sturgeons have travelled from their release sites to Danish waters to forage. The largest threat to sturgeons is bycatch in the commercial fishery and loss of habitat in the rivers, in which they spawn. The sturgeon does not spawn in Denmark and never has (Møller & Carl, 2019).

The sea lamprey has been registered in NSI.1 ECC. The species may spawn in the Danish rivers, especially in rivers with outlet on the west coast of Jutland (Møller & Carl, 2019). However, hardly any data exist concerning the viability of the offspring. Sea lamprey is known to spawn in Ribe river each year, but no offspring has ever been detected. In the North Sea, the species is occasionally observed, but mostly in the eastern parts of the Danish waters.

The river lamprey has been registered within the ECC area of NSI-1. The species has, over the past years, gradually increased in numbers in the coastal areas of the North Sea, both in the Danish regions but also in other countries in western Europe (Møller & Carl, 2019). The increase is most likely due to improvement in rivers with less pollution, and restoration of lost habitats.

The twaite shad has been registered in the two sub-areas (A2 and A3) in NSI.1. The species is regularly seen along Danish coasts which seem to make up important habitats (Møller & Carl, 2019). Twaite shad spawns in large river mouths but not in Danish rivers (Muus & Nielsen, 2006) (Møller & Carl, 2019). Until the 1990s, the species was decreasing in population, but due to clean up and habitat restoration in rivers utilised for spawning for this species, the population now seem to increase in both the North Sea and the Baltic Sea.

PROTECTED HABITATS

Local Natura 2000 sites include no. 220 Sandbanks off Thorsminde and no. 246 Southern North Sea. Area no. 220 only include the protection of Sandbanks (1110) and Reefs (1170). Area no. 246 is designated due to Sandbanks (1110) as well as three species of marine mammals and three species of birds. There are no fish species that constitutes the reason for designation.

5 SURVEY DATA

Presented below are data gathered from the fish surveys carried out in NSI.1 during the spring and autumn surveys. The data includes information on abiotic and biological parameters. Abiotic conditions include CTDO-measurements, and biological parameters include information on fish fauna and biology. Indications of fish utilizing NSI.1 as spawning or nursery areas are described in chapter 4.2.2.

5.1 ABIOTIC DATA

Measurements of conductivity (salinity), temperature, depth, and oxygen (CTDO) were conducted in both the spring and autumn survey. The measurements were carried out both at surface level (1 m depth) and at the bottom/near the bottom (maximum depth of approx. 20 m). The temperature was generally lower in the spring survey (8-12 °C) compared to the autumn survey (14-15 °C), due to temperatures generally being lower during winter and gradually increasing during spring and summer (Table 5-1).

Salinity measurements showed more similar values, ranging from 28 to 34 PSU in spring and 31-34 in autumn (Table 5-1).

Oxygen levels were slightly higher in spring compared to autumn (Table 5-1). In both spring and autumn, the oxygen levels showed values within regular levels. This is supported by the fact that no oxygen deficiency was registered in the 2023 NOVANA data in the North Sea (Hansen & Rytter, 2023).

Table 5-1. Range of oxygen, salinity, temperature, and depth at sea surface, survey data for autumn 2023 and spring 2024

	Oxygen (mg, L)	Salinity (PSU)	Temperature (°C)	Depth, m
Spring	5.7-10.9	28.4-34.4	8.7-12.1	1.0-19.3
Autumn	7.3-7.9	30.9-33.7	14.0-14.9	1.0-20.0

5.2 FISH DATA

In the following sections, a baseline of the fish distribution in NSI.1 is presented, based on catches from the spring and autumn surveys. The surveys were conducted utilizing three gear types: beam trawl, multimesh gillnet and trammel net.

Most fish were caught in the beam trawl, and benthic and demersal fish species comprised most of these catches. However, a few pelagic species were registered in the surveys, based on catches from multimesh gillnets. The dominating fish species caught in the present survey are described in more detail in section 4.2.1 The description includes key fish species along with a few species of economic value. Species caught in low numbers were mainly of less ecological importance or presumably just passing by the area (e.g. some pelagic species), thus, these species were not described or analyzed in further detail.

Regarding future assessment of potential impact on fish and fish populations from the NSI.1 , it is expected that benthic and demersal species may experience the largest impact because of the footprint of wind turbines on the seafloor. Therefore, it is especially important to map the distribution of benthic and demersal species in the present baseline.

5.2.1 OVERALL CATCHES

A total of 11,505 fish were caught – 6,951 in spring and 4,554 in autumn, representing 28 different fish species, a few fish only determined to family level. In spring, a total of 20 species were caught, and in autumn 25 species (Table 5-2 and Table 5-3). The spring catches amounted to 343 kg, and the autumn catches to 221 kg – a total of 564 kg.

The spring catches in beam trawl, gillnets and trammel nets was dominated by flatfish, which comprised 90 % of the total catch, and comprising eight out of 20 species. The three most abundant species in the spring catches were European plaice, common dab and solenette (Table 5-2), comprising 34 %, 32 % and 22 % of the total catch, respectively. The remaining species comprised 2 % or less per species of the catch, in terms of abundance. In terms of weight, European plaice accounted for 49 % of the landings, common dab 39 %, and solenette merely 4 %, due to its modest size. The remaining species comprised 2 % or less per species with regards to the weight.

The autumn catches in beam trawl, multimesh gillnets and trammel nets consisted mainly of flatfish, which comprised 84 % of the catch, representing eight of the 25 different fish species (Table 5-3). The dominant species in the autumn catches were Solenette and Common dab (Table 5-3), making up 33 % of the catch each in terms of number. European plaice and Whiting each accounted for 15 % and 9 % of the total number of fish landed in the autumn catches. In terms of weight, Common dab and European plaice also comprised most of the catches with 49 % and 20 % of the total weight of the catch. Conversely, Solenette only accounted for 8 % of the total landed weight due to the modest size of this species. Whiting was relatively abundant in terms of biomass, accounting for 10 % of the total landed weight.

Most fish were caught in the beam trawl as this was the fishing gear type that had the highest fishing intensity in this study with a total of 26 stations pr. survey compared to 16 multimesh gillnet stations and seven trammel net stations. For two surveys, this totals 52 beam trawl stations, 32 multimesh gillnet stations and 14 trammel net stations. Overall, beam trawl accounted for 94 % of all fish caught in the present study, while multimesh gillnet accounted for 5 % and Trammel net 1 %.

Table 5-2. Fish catches from the spring survey in beam trawl, multimesh gillnet, and trammel net.

SPECIES	LATIN NAMES	BEAM TRAWL	MULTIMESH GILLNET	TRAMMEL NET	TOTAL
Atlantic cod	*Gadus morhua*	5			5
Atlantic herring	*Clupea harengus*	20			20
Common dab	*Limanda limanda*	2140	77	26	2243
Common dragonet	*Callionymus lyra*	165	2		167
Common sole	*Solea solea*	6	10		16
Dragonet sp.	*Callionymus sp.*	32			32
European flounder	*Platichthys flesus*	8			8
European plaice	*Pleuronectes platessa*	2319	24	6	2349
Goby sp.	*Pomatoschistus sp.*	23	1		24
Greater weever	*Trachinus draco*	25	1		26
Grey gurnard	*Eutrigla gurnardus*	106	1		107
Haddock	*Melanogrammus aeglefinus*	60			60
Hooknose	*Agonus cataphractus*	140	17		157
Lemon sole	*Microstomus kitt*	5			5
Mediterranean scaldfish	*Arnoglossus laterna*	126			126
Pholis gunnellus	*Spinachia spinachia*	1			1
Sand eel sp.	*Myoxocephalus scorpius*	17	26		43
Shorthorn sculpin	*Sprattus sprattus*	10			10
Solenette	*Buglossidium luteum*	1453	44		1497
Sprat/herring	*Clupeidae sp.*	14			14
Three-spined stickleback	*Gasterosteus aculeatus*	2			2
Tub gurnard	*Chelidonichthys lucerna*	2			2
Turbot	*Scopthalmus maximus*	2	1	4	7
Whiting	*Merlangius merlangus*	20	1	6	27
Total		**6703**	**206**	**42**	**6951**

Table 5-3. Fish catches from the autumn survey in beam trawl, multimesh gillnet, and trammel net.

SPECIES	LATIN NAMES	BEAM TRAWL	MULTIMESH GILLNET	TRAMMEL NET	TOTAL
Atlantic cod	*Gadus morhua*	6	3	4	13
Atlantic herring	*Clupea harengus*	6	6		12
Atlantic horse mackerel	*Trachurus trachurus*	1			1
Atlantic mackerel	*Scomber scombrus*		5		5
Common dab	*Limanda limanda*	1297	164	31	1492
Common dragonet	*Callionymus lyra*	40	10		50
Common sole	*Solea solea*	14	7		21
Common/sand goby	*Pomatoschistus sp.*	23	1		24
Eelpout	*Zoarces viviparus*	2			2
European flounder	*Platichthys flesus*	8			8
European plaice	*Pleuronectes platessa*	644	15	8	667
Goby sp.	*Pomatoschistus sp.*	10			10
Great sand eel	*Hyperoplus lanceolatus*	1	2		3
Greater weever	*Trachinus draco*	4			4
Grey gurnard	*Eutrigla gurnardus*	50	6		56
Gurnard sp.	*Eutrigla sp.*		1		1
Haddock	*Melanogrammus aeglefinus*	1			1
Hooknose	*Agonus cataphractus*	85	21		106
Lemon sole	*Microstomus kitt*	1			1
Lesser weever	*Echiichthys vipera*	1			1
Mediterranean scaldfish	*Arnoglossus laterna*	96	3		99
Nilsson's pipefish	*Syngnathus rostellatus*	1			1
Pouting	*Trisopterus luscus*		1		1
Reticulated dragonet	*Callionymus reticulatus*	1			1
Sand eel sp.	*Ammodytidae sp.*	1	1		2
Shorthorn sculpin	*Myoxocephalus scorpius*	14	10		24
Solenette	*Buglossidium luteum*	1501	16		1517
Sprat/herring	*Clupeidae sp.*		1		1
Turbot	*Scopthalmus maximus*	2	1	1	4
Whiting	*Merlangius merlangus*	283	136	7	426
Total		**4093**	**410**	**51**	**4554**

5.2.2 BEAM TRAWL

In beam trawl, a total of 10.745 fish were caught, adding up to a total of 493 kg of fish in this study. The variation in fish abundance between beam trawl stations was greater in spring with an average 22 fish pr. station. To correct for any differences in trawl lengths due to water current and wind during the trawl hauls, the catch was converted into Catch Per Unit Effort (CPUE) of 1,000 m^2. In spring, the abundance of fish ranged from 4.5 to 72 fish pr. 1,000 m^2 for the individual stations with an average of 22.2 fish, while autumn fish abundance was 14.3 fish on average with a range from 0.2 to 38.4 fish pr. station. In terms of biomass, the average biomass pr. station caught in beam trawl was almost twice as high for the spring survey (1059 g pr 1000 m^2) compared to autumn catches (607.1 g pr. 1,000 m^2).

SPRING

ABUNDANCE

In the spring survey, a total of 6652 fish were caught. European plaice, Common dab and Solenette were the three most abundant species accounting for 34 %, 32 % and 21 % of the catches, respectively (Table 5-4). The fourth most abundant fish caught in the spring survey was Common dragonet which comprised only 2 % of the catches. In comparison, the remaining species were caught in very low numbers.

Similar to The Strategic Environmental Assessment (SEA) of Thor OWF in the North Sea and ENOE OWF in the Baltic Sea, the fish density was divided into three categories: high, medium and low density. By using the same sampling methods and categories, it is possible to compare results between projects. High density was defined as > 11 fish pr. 1000 m^2, medium density as 6-11 fish pr. 1000 m^2, and low density as < 6 fish pr. 1000 m^2. This density approach was suitable for Thor OWF and ENOE OWF, however in the present study, the density of fish appears to be quite high compared to the other two studies.

Station BT09, in sub-area A2, was the beam trawl station with the highest abundance of fish, with 72 fish pr. 1,000 m^2 (Table 5-4) (Figure 5-1). This abundance was 16 times higher than the one found at station BT01, with only 4.5 fish pr. 1,000 m^2. Overall, 19 stations had a high density of fish, four stations had a medium density of fish, and an additional three stations had low density of fish. The stations with high density were primarily concentrated in the northern and central part of NSI.1, i.e. A3 and A2, as well as the southeastern part of NSI.1, which was the muddy sand area in ECC1 and A1. Stations with the lowest density were scattered without any tendencies (Table 5-4).

Table 5-4. The total fish abundance from beam trawl catches in NSI.1 spring survey 2024. The catch has been converted to Catch Per Unit Effort (CPUE = 1,000 m^2).

No. of fish pr. 1000 m^2	BT01	BT02	BT03	BT04	BT05	BT06	BT07	BT08	BT09	BT10	BT11	BT12	BT13	BT14	BT15	BT16	BT17	BT18	BT19	BT20	BT21	BT22	BT23	BT24	BT25	BT26	Total
Atlantic cod						0,1						0,1									0,3						**0,4**
Atlantic herring	0,1		0,2	0,1	0,1				0,6	0,1			0,1			0,2			0,1		0,2						**1,7**
Common dab	1,0	1,5	3,8	3,5	18,4	13,0	9,8	2,5	21,8	2,1	14,2	6,5	1,9	7,1	4,3	3,2	5,8	6,1	10,2	3,5	10,9	0,7	6,4	2,4	1,2	10,5	**172,4**
Common dragonet		0,1	0,7	0,1	0,3	0,6	0,1	0,1	0,3	0,2		0,2	0,1	0,2	0,2	1,7	0,3	2,3	3,2	0,4	0,6	0,2	1,0	0,1	0,1	0,3	**13,5**
Common sole	0,1				0,2		0,1																		0,1		**0,4**
European flounder													0,1	0,1			0,1					0,1	0,2	0,2			**0,7**
European plaice	3,1	6,0	5,6	9,5	10,0	11,8	9,6	10,0	33,9	4,5	7,1	32,3	4,2	4,2	3,5	3,4	4,7	3,0	2,2	1,3	5,7	2,5	1,1	1,4	1,0	5,7	**187,2**
Goby sp.		0,2			0,1	0,3	0,2		0,3			0,2	0,1	0,1							0,5						**1,9**
Greater weever	0,2	0,1	0,1				0,2			0,7												0,2	0,1	0,1	0,4		**2,0**
Grey gurnard		0,1	0,2	0,8	0,7	0,9	0,3	0,2	0,1	0,4		0,2	0,2	0,2	0,1	0,6	0,8	1,0	0,9	0,1	0,3	0,1	0,1			0,5	**8,7**
Haddock		0,1		1,6	1,6	0,7			0,7		0,1										0,1						**4,7**
Hooknose		0,1	0,2	0,3	0,7	0,4	0,3	0,3		0,5		0,5		2,8	1,2	0,4	0,3	0,2	1,4	0,1	0,7	0,1	0,1	0,2	0,1		**10,8**
Lemon sole					0,4																						**0,4**
Mediterranean scaldfish		0,6	0,4	0,7	1,1		0,4		0,8	0,5	0,2	0,2	0,4	0,3	0,2	0,5	1,0	0,3	0,2		0,6	1,0	0,3		0,3	0,2	**10,4**
Pholis gunnellus														0,1													**0,1**
Sandeel sp.	0,1	0,1								0,1		0,1		0,1		0,1						0,2	0,2	0,1	0,4		**1,2**
Shorthorn sculpin				0,3	0,3	0,1							0,1					0,1									**0,8**
Solenette		3,0	9,0	9,3	11,6	5,5	7,4		13,6	1,7	1,6	6,3	0,8	3,2	8,6	4,9	3,7	4,3	3,4	0,6	3,5	6,7	1,0	0,2	1,3	2,8	**113,8**
Sprat/herring									0,1									0,2				0,1		0,5	0,2	0,1	**1,1**
Three-spined stickleback																			0,2								**0,2**
Tub gurnard																									0,1		**0,1**
Turbot																									0,1		**0,1**
Whiting			0,1	0,3	0,1	0,2	0,2			0,1	0,1	0,2					0,1	0,1		0,1			0,1			0,1	**1,6**
Dragonet sp									0,1						1,2		1,0							0,1			**2,4**
Gadidae				0,1																							**0,1**
Total	**4,5**	**11,8**	**20,3**	**26,7**	**45,5**	**33,4**	**28,7**	**13,1**	**72,0**	**10,8**	**23,3**	**46,8**	**7,9**	**18,3**	**19,4**	**14,9**	**17,9**	**17,5**	**21,8**	**6,0**	**23,2**	**11,8**	**10,4**	**5,1**	**5,2**	**20,2**	**536,7**

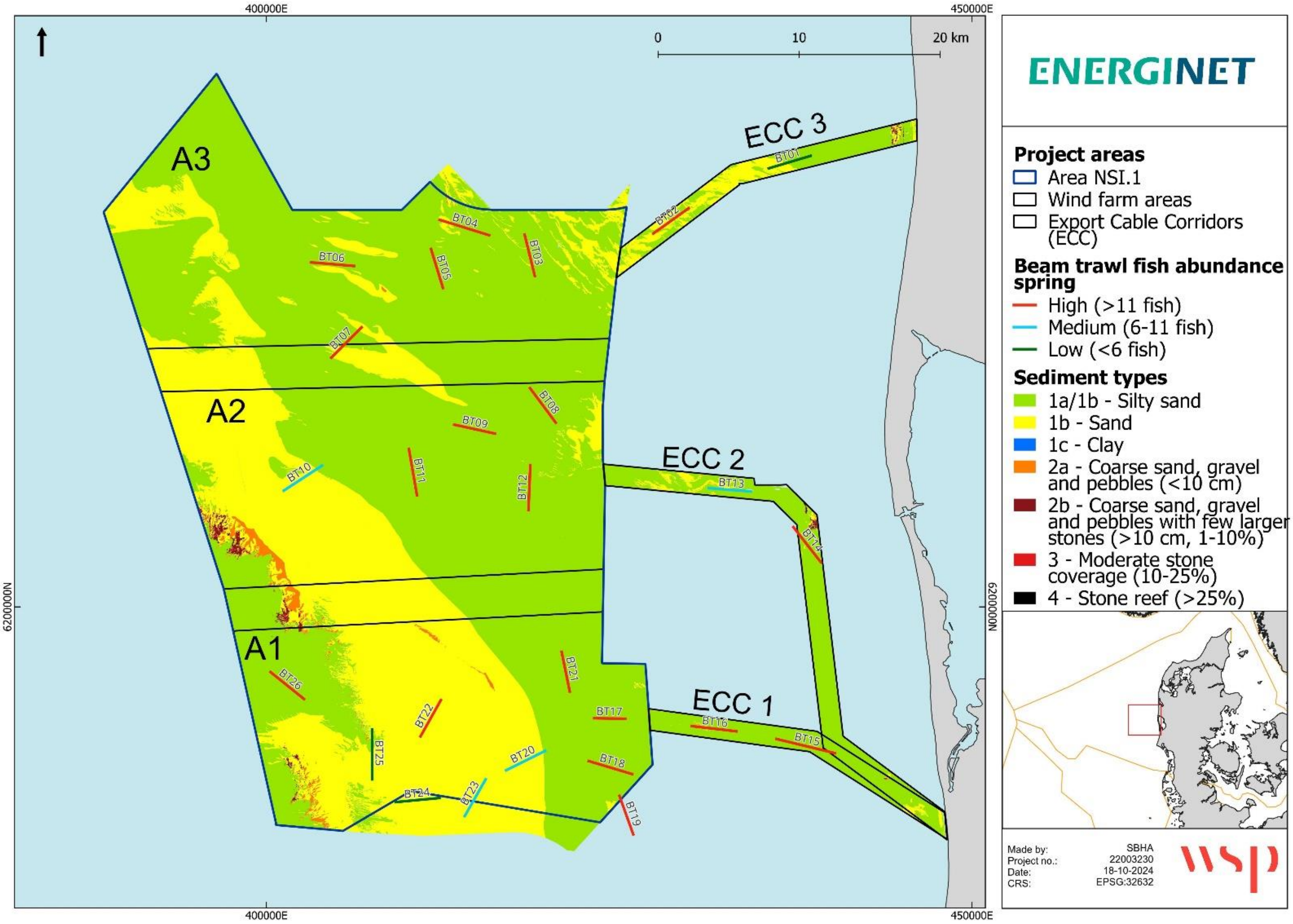

Figure 5-1. The fish density from beam trawl catches in NSI.1 spring survey 2024. CPUE = no. of fish pr. 1000 m^2.

BIOMASS

In the spring survey, nearly 318 kg of fish were caught in beam trawl. European plaice comprised 51 % of the total biomass, while common dab accounted for 38 %. Solenette only made up 4 % of the total catches, and very low biomasses was observed for the remaining species caught in the spring survey.

The biomass of spring catches was converted into CPUE per 1,000 m^2 (Table 5-5). As for density, BT09 was the station with the highest biomass pr. 1000 m^2, amounting 4,024 kg of fish. BT12 also showed quite high biomasses with approx. 2.5 kg of fish pr. 1000 m^2.

The station with the lowest fish biomass was BT25 with merely 195 g of fish pr. 1000 m^2. This was 20 times lower compared to station BT09. The average biomass for all beam trawl stations were 1,059 g of fish pr. 1000 m^2.

The fish biomass pr. 1000 m^2 was divided into three categories, as in Thor OWF and ENOE OWF investigations, with high biomasses defined as > 500 g fish pr. 1000 m^2, medium biomass as 250-500 g fish pr. 1000 m^2, and low biomass as <250 g fish pr. 1000 m^2. A total of 20 stations showed high biomasses, five stations medium biomasses, and one had low biomass (BT25) (Figure 5-2). The low-medium biomass stations were primarily located in the central part of A1.

Table 5-5. The total fish biomass from beam trawl catches in NSI.1 spring survey 2024. The catch has been converted to CPUE = 1,000 m².

Gram fish pr. 1000 m^2	BT01	BT02	BT03	BT04	BT05	BT06	BT07	BT08	BT09	BT10	BT11	BT12	BT13	BT14	BT15	BT16	BT17	BT18	BT19	BT20	BT21	BT22	BT23	BT24	BT25	BT26	Total
Atlantic cod						0						0									1						**2**
Atlantic herring			5	1					7	1			0			0			0		3						**18**
Common dab	69	93	198	167	829	633	483		1.152	123	665	404	146	564	283	243	395	406	643	325	688	53	408	180	99	545	**9.797**
Common dragonet		2	22	1	4	21		2	10	12		5	3	8	5	3	7	17	11	0	21	0	9	2	0	12	**178**
Common sole					4																				1		**5**
European flounder													13	18								21	44	35			**132**
European plaice	311	460	368	680	860	841	609	877	2.607	279	471	2.037	293	405	96	245	255	120	122	56	374	132	73	77	61	336	**13.046**
Goby sp.		1			0	2	1		1			1	0	0							2						**9**
Greater weever		2	3				26			23													1	2	13		**70**
Grey gurnard		12	27	51	62	49	16	8		31		22		17	11	25	55	70	39	2	28	1	1			13	**542**
Haddock		0		240	24	93			115		9																**481**
Hooknose		2	6	7	8	4	7	6		8		12		50	16	7	4	3	27	2	14	2	1	3	2		**189**
Lemon sole					67																						**67**
Mediterranean scaldfish		11	6	9	16		5		10	7	4	7	7	5	2	6	15	7	4		6	11	5		4	2	**148**
Pholis gunnellus														4													**4**
Sandeel sp.		1								2		2		2									3	3	7		**20**
Shorthorn sculpin				24	21	16							17					3									**80**
Solenette		27	66	68	95	41	60		123	14	14	55	9	32	93		37	37	32	3	33	40	10	2	2	25	**917**
Sprat/herring									0									5				0		0	0	0	**6**
Three-spined stickleback																			0								**0**
Tub gurnard																									5		**5**
Turbot																											**-**
Whiting				14	4	7	14			3		7						5					2			5	**61**
Dragonet sp															2		1							0			**3**
Gadidae				0																							**0**
Total	**379**	**611**	**702**	**1.262**	**1.994**	**1.706**	**1.220**	**892**	**4.024**	**501**	**1.163**	**2.551**	**488**	**1.106**	**507**	**529**	**770**	**674**	**878**	**389**	**1.171**	**262**	**557**	**305**	**195**	**940**	**25.778**

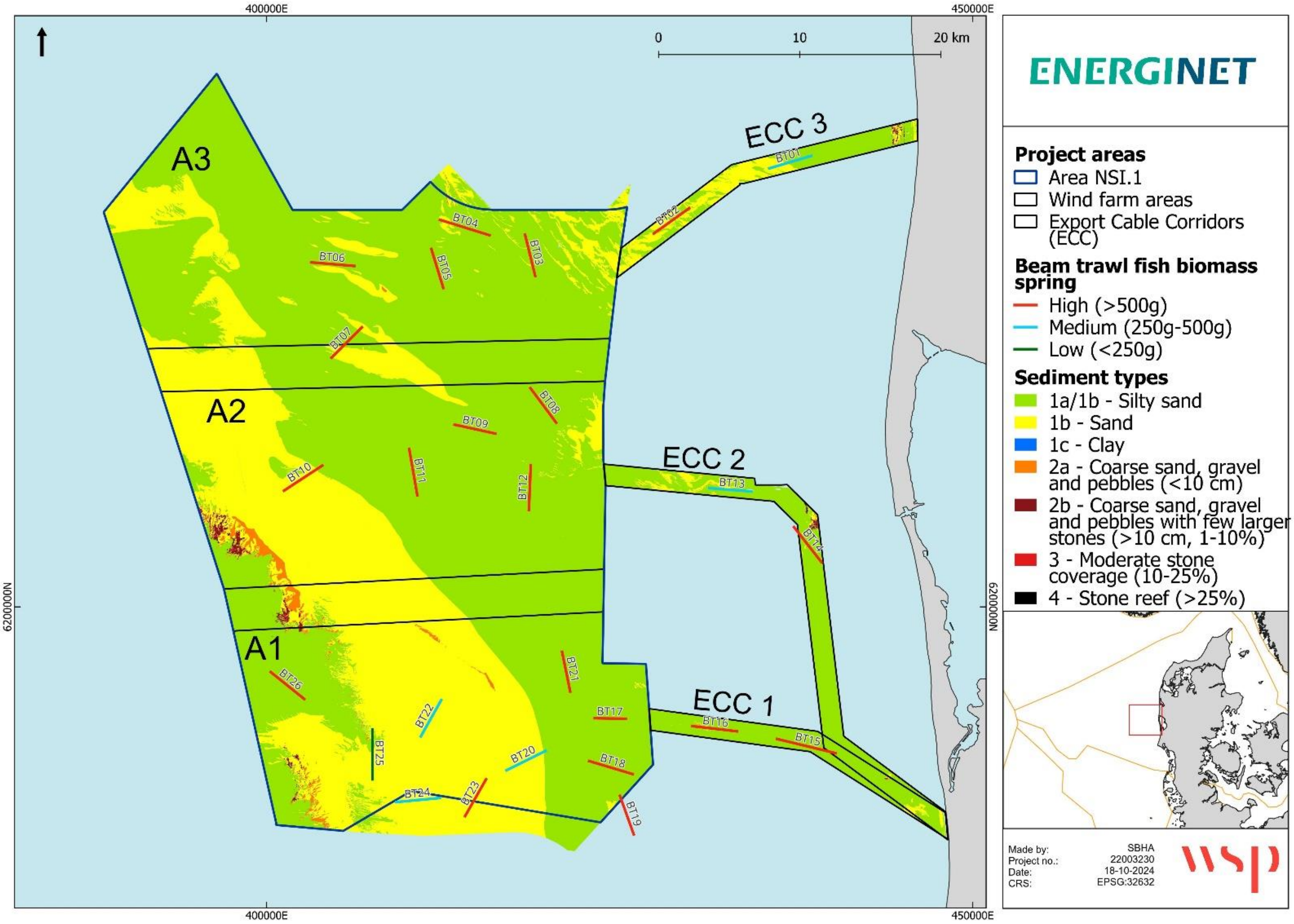

Figure 5-2. The fish biomass from beam trawl catches in NSI.1 spring survey 2024. CPUE = gram fish pr. 1000 m².

AUTUMN

ABUNDANCE

In the autumn survey, a total of 4093 fish were caught in beam trawl. The three most abundant fish caught in beam trawl were solenette, common dab and European plaice, which comprised 37 %, 32 % and 16 %, respectively. Whiting was the fourth most abundant fish species caught in beam trawl in the autumn survey, which accounted for 7 % of the landings. In comparison, the remaining fish species were caught in very low numbers (2 % or less for each species). Common dab was caught on all stations except one, while European plaice and solenette were caught on 24 of 26 stations.

The beam trawl catches were converted into CPUE of 1000 m^2 to consider the different trawl lengths. The catch sizes varied between <1 fish and up to 38 fish per 1000 m^2 with an average of 14 fish pr. 1000 m^2 (Table 5-6). Station BT26 and BT04 had a density of fish of 38 fish pr. 1000 m^2 and were located in the southwestern part of the area (A1) and the northern part of NSI.1 (A3), respectively (Figure 5-3). This was more than 100 times the fish abundance on station BT13, at which <1 fish per 1000 m^2 was caught.

Dividing the fish density into three categories (as previously described): high, medium, and low - 16 stations had a high density of fish. In addition, five stations had medium density, and five had a low density. A tendency towards high fish densities at stations located in the north and western part of NSI.1 was evident, while stations with low fish density were located in the south and eastern part of NSI.1.

Table 5-6. The total fish abundance in NSI.1 from the autumn survey 2023 caught with beam trawl. The catch has been converted to Catch Per Unit Effort (CPUE = 1,000 m²).

No. fish pr. 1000m^2	BT01	BT02	BT03	BT04	BT05	BT06	BT07	BT08	BT09	BT10	BT11	BT12	BT13	BT14	BT15	BT16	BT17	BT18	BT19	BT20	BT21	BT22	BT23	BT24	BT25	BT26	Total
Atlantic cod				0,1				0,1				0,1		0,1	0,2												0,5
Atlantic herring			0,1							0,2	0,2																0,5
Atlantic horse mackerel											0,1																0,1
Common dab	1,6	1,8	2,1	9,9	7,9	4,7	8,5	3,3	1,1	5,4	6,4	4,5	0,1		2,2	1,9	5,3	4,8	4,2	3,6	0,5	4,5	8,4	5,3	3,6	16,4	118,1
Common dragonet			0,1	0,4	0,5	0,1	0,3				0,2	0,1		0,1	0,2	0,1	0,1	0,1	0,1			0,2	0,2	0,2	0,1	0,7	3,7
Common sole	0,1	0,1	0,2												0,2		0,1	0,2	0,2				0,2		0,1		1,2
Common/sand goby																	1,0	0,2								1,1	2,3
Eelpout																			0,1		0,1						0,2
European flounder														0,1		0,2			0,3	0,1			0,1				0,7
European plaice	1,7	2,7	3,3	9,9	6,0	1,8	3,1	2,7	0,3	0,6	2,0	0,1		1,0	5,0	1,2	2,1	1,9	1,7	0,5		1,6	0,2	1,0	0,6	8,2	59,3
Goby sp.					0,1		0,2										0,1		0,4				0,1				0,9
Great sandeel															0,1												0,1
Greater weever							0,1			0,2																	0,3
Grey gurnard		0,1	0,5	1,1	0,5	0,1	0,6	0,1		0,7	0,6	0,1										0,1	0,1		0,1		4,6
Haddock																						0,1					0,1
Hooknose	0,1	0,1	0,1	0,4	0,1	0,1		0,4	0,1		0,1	0,1			0,5	0,2	0,8	0,8	2,2			0,4	0,6	0,3		0,5	7,7
Lemon sole																			0,1								0,1
Lesser weever																									0,1		0,1
Mediterranean scaldfish		0,3	0,2	0,9	0,5	0,3	0,3		0,2	0,2	0,1	0,1		0,1	0,8	0,2	1,3	0,6	0,3			0,8		0,3	0,3	1,2	8,7
Nilsson's pipefish																								0,1			0,1
Reticulated dragonet																		0,1									0,1
Sandeel										0,1																	0,1
Shorthorn sculpin	0,1		0,1		0,2						0,1				0,1		0,3	0,3	0,1			0,1					1,2
Solenette	4,5	6,9	6,8	12,6	8,8	10,1	8,3	3,7	9,6			3,2	0,1	0,3	8,6	1,2	8,3	8,4	10,6	0,2	0,3	5,0	3,2	2,6	1,4	9,6	134,4
Turbot										0,1												0,1					0,2
Whiting	1,6	2,3	0,3	3,0	0,9		0,8	0,9	0,2	0,7	1,1	0,5		0,1	1,5	0,5	1,1	0,4	0,9	0,1	0,1	2,1	1,9	2,6	1,0	0,8	25,5
Total	9,7	14,2	13,8	38,3	25,6	17,0	22,3	11,2	11,5	8,1	10,8	8,7	0,2	1,8	19,3	5,5	20,4	17,8	21,0	4,5	1,0	15,0	15,0	12,3	7,2	38,4	370,5

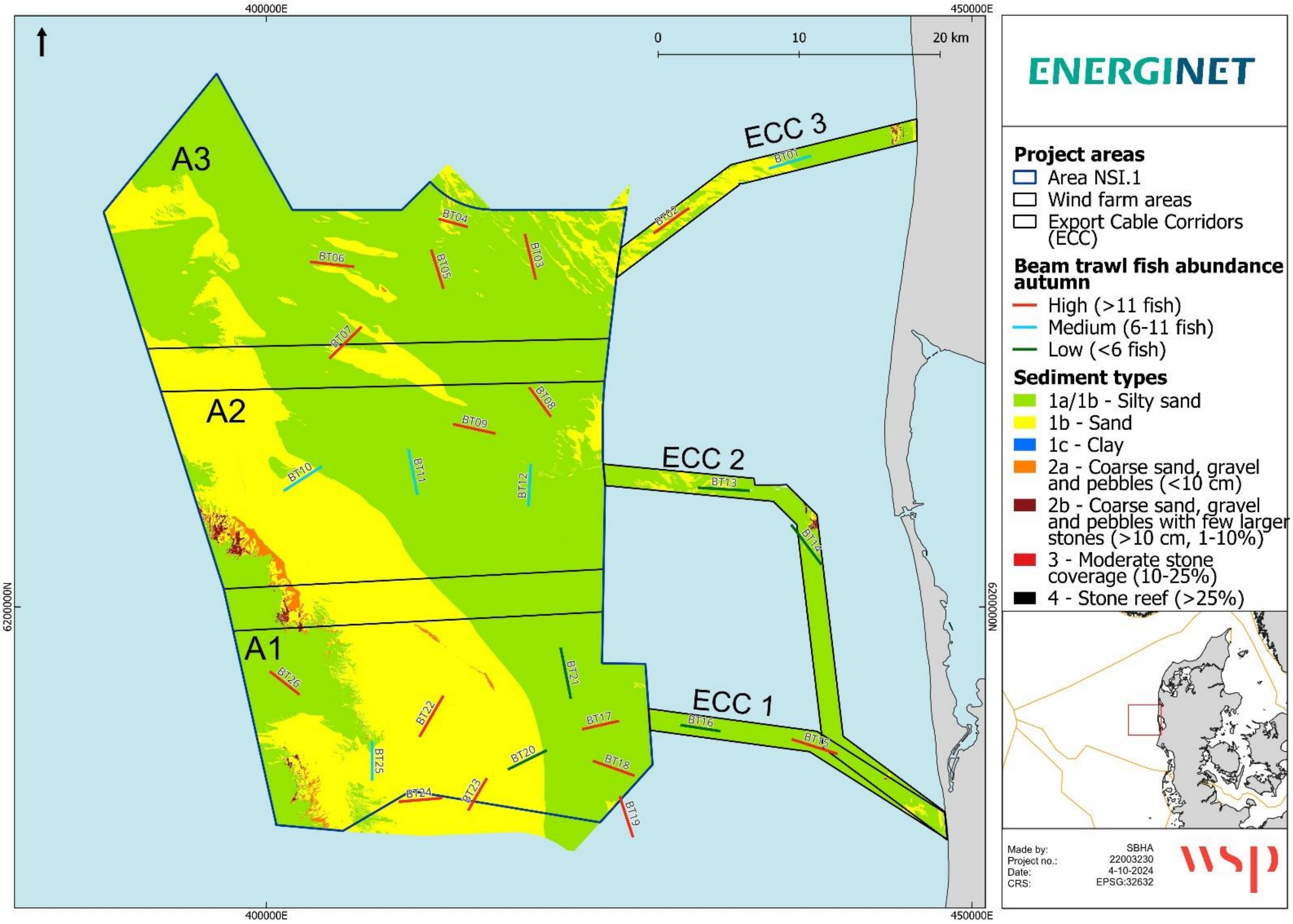

Figure 5-3. The fish abundance in CPUE 1,000 m² for each sampled station in the autumn survey.

BIOMASS

A total of 175 kg of fish were caught in the autumn survey. Common dab, European plaice, solenette, and whiting were the four most frequently occurring species across all stations.

Station BT04 and BT26 showed the highest biomass with approx. 1,600 and 1,400 g of fish pr. 1000 m^2 (Figure 5-7). The lowest biomass was observed at station BT13 with only 18 g fish pr. 1000 m^2. This was nearly 90 times lower than BT04.

When dividing the fish biomass into three categories: high, medium, and low - 15 stations had a high biomass of fish. In addition, seven stations had medium biomass, and four had low biomass. There were no clear tendencies in regard to areas/depths with high/low biomasses.

Table 5-7. The total fish biomass from beam trawl catches in NSI.1 autumn survey 2023. The catch has been converted to CPUE = 1,000 m².

Gram fish pr. 1000 m^2	BT01	BT02	BT03	BT04	BT05	BT06	BT07	BT08	BT09	BT10	BT11	BT12	BT13	BT14	BT15	BT16	BT17	BT18	BT19	BT20	BT21	BT22	BT23	BT24	BT25	BT26	Total
Atlantic cod				132,6				2,1				0,4		1,5	55,1												**191,7**
Atlantic herring										7,4	11,9																**19,3**
Atlantic horse mackerel											0,4																**0,4**
Common dab	214,9	186,4	132,8	623,6	390,3	263,8	463,3	186,1	70,0	410,3	445,9	388,1	14,3		188,7	102,5	364,8	293,8	269,8	344,8	41,7	383,7	589,4	537,5	248,2	771,2	**7.926,1**
Common dragonet				7,6	9,2	0,9	9,9				7,2	0,9			5,4	4,6	0,2	3,4	4,3			5,9	5,6	1,7	0,4	17,9	**84,9**
Common sole	11,1	5,1	11,1												38,5		6,0	38,8	21,7				1,0		1,8		**135,1**
Common/sand goby																	0,4	0,1								0,6	**1,2**
Eelpout																			1,7		1,4						**3,1**
European flounder														16,3		53,6			53,8	11,2			10,1				**144,9**
European plaice	214,9	178,0	173,3	498,0	387,8	113,9	249,0	226,9	17,1	27,1	128,0	2,8		55,4	244,2	78,5	176,8	151,4	131,8	11,2		96,3	10,1	41,1	84,7	432,9	**3.731,0**
Goby sp.					0,0		0,1										0,1		0,2				0,1				**0,5**
Great sandeel															0,4												**0,4**
Greater weever							5,8			8,2																	**14,0**
Grey gurnard		4,2	42,9	78,3	20,2	2,9	46,8	7,2		50,9	40,5	4,4										15,7	4,0		4,8		**323,0**
Haddock																						37,6					**37,6**
Hooknose	0,9	0,8	1,6	3,8	0,5	2,1		5,2	1,7		2,0	0,9			7,7	3,7	6,6	4,3	22,4			3,9	9,6	4,3		3,9	**85,8**
Lemon sole																			6,1								**6,1**
Lesser weever																									4,8		**4,8**
Mediterranean scaldfish		1,7	2,7	5,7	5,5	1,7	7,5		4,3	0,8	2,3	0,9		0,4	11,6	1,8	13,6	4,7	1,5			7,8		3,2	2,7	8,1	**88,4**
Nilsson's pipefish																								0,3			**0,3**
Reticulated dragonet																		0,4									**0,4**
Sandeel										0,8																	**0,8**
Shorthorn sculpin	17,1				53,1						9,5				7,7		31,9	21,9	13,9			5,9					**161,1**
Solenette	39,3	60,8	46,9	92,5	148,1	67,5	100,9	31,9	19,3			28,1	3,6	3,7	188,7	12,9	235,3	149,3	189,0	0,5	2,1	27,7	15,3	11,4	11,9	152,6	**1.639,4**
Turbot										13,1												19,6					**32,7**
Whiting	128,2	101,7	12,7	165,5	31,1		41,9	30,9	12,8	32,8	48,5	17,6		7,4	64,7	20,3	49,9	20,2	33,0	3,4	8,5	70,5	71,7	106,2	50,0	21,9	**1.151,5**
Total	**626,4**	**538,8**	**424,1**	**1.607,5**	**1.045,7**	**452,8**	**925,2**	**490,3**	**125,1**	**551,5**	**696,2**	**444,1**	**17,9**	**84,6**	**812,6**	**278,1**	**885,5**	**688,5**	**749,3**	**371,1**	**53,7**	**674,5**	**716,9**	**705,8**	**409,2**	**1.409,2**	**15.784,6**

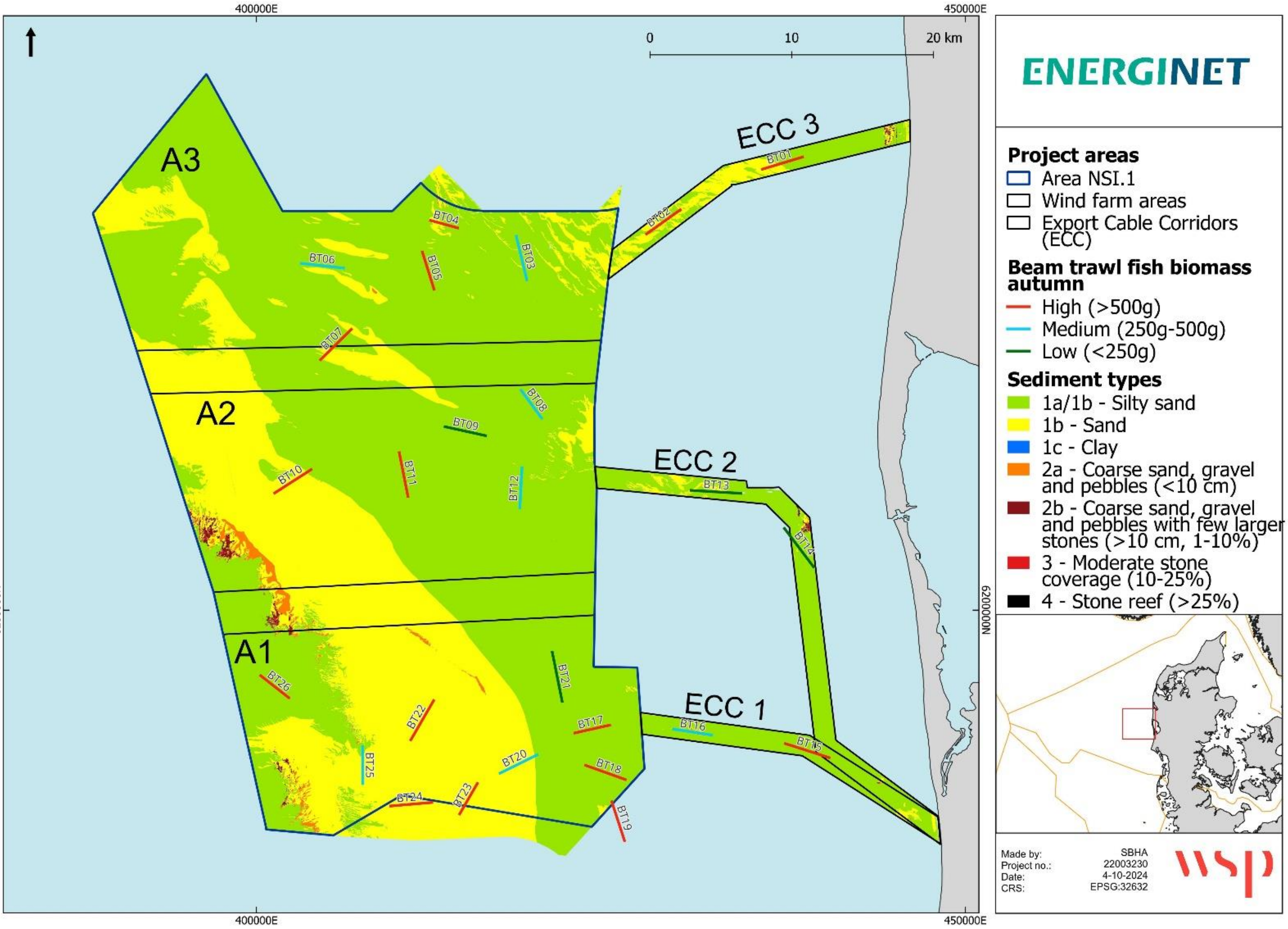

Figure 5-4. Biomass of fish caught in beam trawl in CPUE 1,000 m² for each sampled station in the autumn survey of NSI.1.

5.2.3 MULTIMESH GILLNETS

In the multimesh gillnets, a total of 655 fish were caught, with 245 fish caught in spring and 410 fish caught in autumn in this study. The spring and autumn catches in multimesh gillnet were dominated by common dab. In terms of weight a total of 49,2 kg of fish were caught in multimesh gillnet, with 16,01 kg caught in spring and 33,2 kg caught in autumn.

SPRING

ABUNDANCE

In the spring survey, common dab and solenette dominated the multimesh gillnets catches, followed by sandeel and European plaice (Table 5-8). The catch was converted into Catch Per Unit Effort (CPUE) to analyse the catch according to the fishing effort i.e., fish caught per net per day. The quantity of fish varied from 0-54 individuals in multimesh gillnet per net per day across the stations. Station MN14 showed the highest catch value, with a total of 54 fish per net per day. Common dab constituted 46 % hereof and solnette accounted for 33 %.

When divided into three categories of density, eight of the 16 stations had a high density of fish. Three of the stations had a medium density of fish, while the remaining had low density (Figure 5-5).

Table 5-8. Total catches in multimesh gillnets in spring survey 2024 in NSI.1. The CPUE is number of fish per net per day.

Fish pr. net pr. day	MN01	MN02	MN03	MN04	MN05	MN06	MN07	MN08	MN09	MN10	MN11	MN12	MN13	MN14	MN15	MN16	Total
Common dab	7		1	5	17	13	2	4	1		4	11	1	25	4		95
Common dragonet												1		1			2
Common sole	2				1	1					3	2	1		1		11
European plaice	5		4	1	2	4		4				1	1	1	1		24
Goby sp.															1		1
Greater weever										1							1
Grey gurnard						1											1
Hooknose			2	1							2	1		9	4		19
Sandeel sp.					1	19		7									27
Solenette	2		6	3	6	1		1		3	2	13	3	18	3		61
Turbot										1							1
Whiting								1									1
Total	**16**	**0**	**13**	**10**	**27**	**39**	**2**	**17**	**1**	**5**	**11**	**29**	**6**	**54**	**14**	**0**	**245**

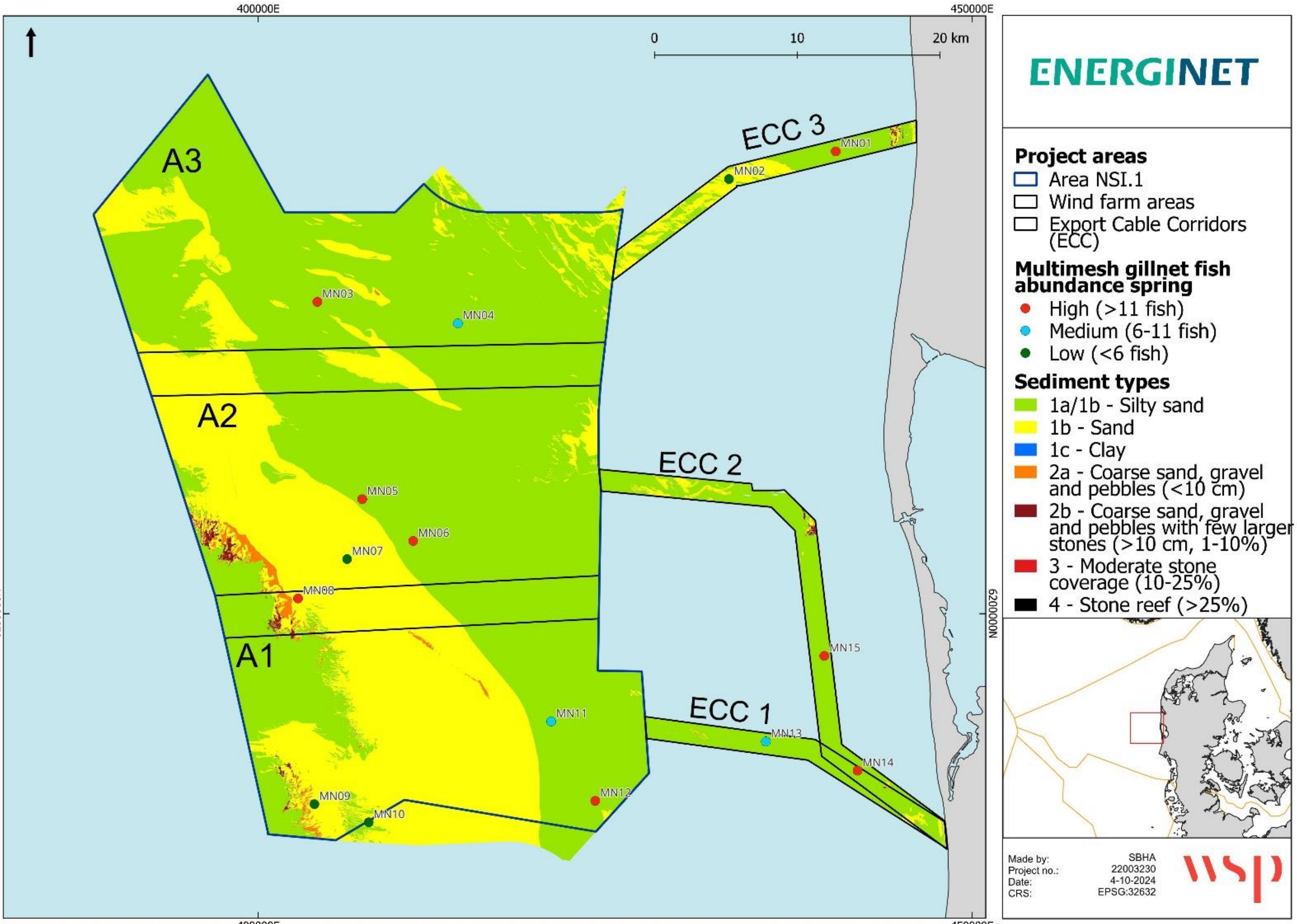

Figure 5-5. The fish density from catches with multimesh gillnets in NSI.1 spring survey 2024.

BIOMASS

The biomass was converted into Catch Per Unit Effort (CPUE) gram per net per day, to calculate the fishing effort and total fish biomass caught at each station. The total fish biomass caught in nets varied from 0 gram to 3,376 gram per net per day across the stations (Table 5-9). The dominating species was common dab constituting 59 % of the total catch and European plaice with 21 %. MN14 was the station with the highest biomass, consisting of mainly common dab (88 %), followed by a hooknose and solenette 5% and 4 %, respectively. Divided into three categories: high, medium, and low - 10 stations showed a high biomass, while one stations had a medium biomass, and the remaining five stations had a low biomass (Figure 5-6).

Table 5-9. The total biomass of fish caught in multimesh gillnets in spring survey 2024 in NSI.1. The CPUE is gram per net per day.

Gram fish pr. net pr. day	MN01	MN02	MN03	MN04	MN05	MN06	MN07	MN08	MN09	MN10	MN11	MN12	MN13	MN14	MN15	Total
Common dab	670			530	1300	920	220	490	160		300	1150	70	2980	640	**9430**
Common dragonet												45		50		**95**
Common sole	430				120	130						190	40		40	**950**
European plaice	950		1030	110	120	140		520					60	10	500	**3440**
Goby sp.															5	**5**
Greater weever										60						**60**
Grey gurnard						120										**120**
Hooknose			65	40							30	20		180	200	**535**
Sandeel sp.					15	160		80								**255**
Solenette	10		40		45	10				26	8	115	70	156	100	**580**
Turbot										500						**500**
Whiting								38								**38**
Total	**2060**	**0**	**1135**	**680**	**1600**	**1480**	**220**	**1128**	**160**	**586**	**338**	**1520**	**240**	**3376**	**1485**	**16008**

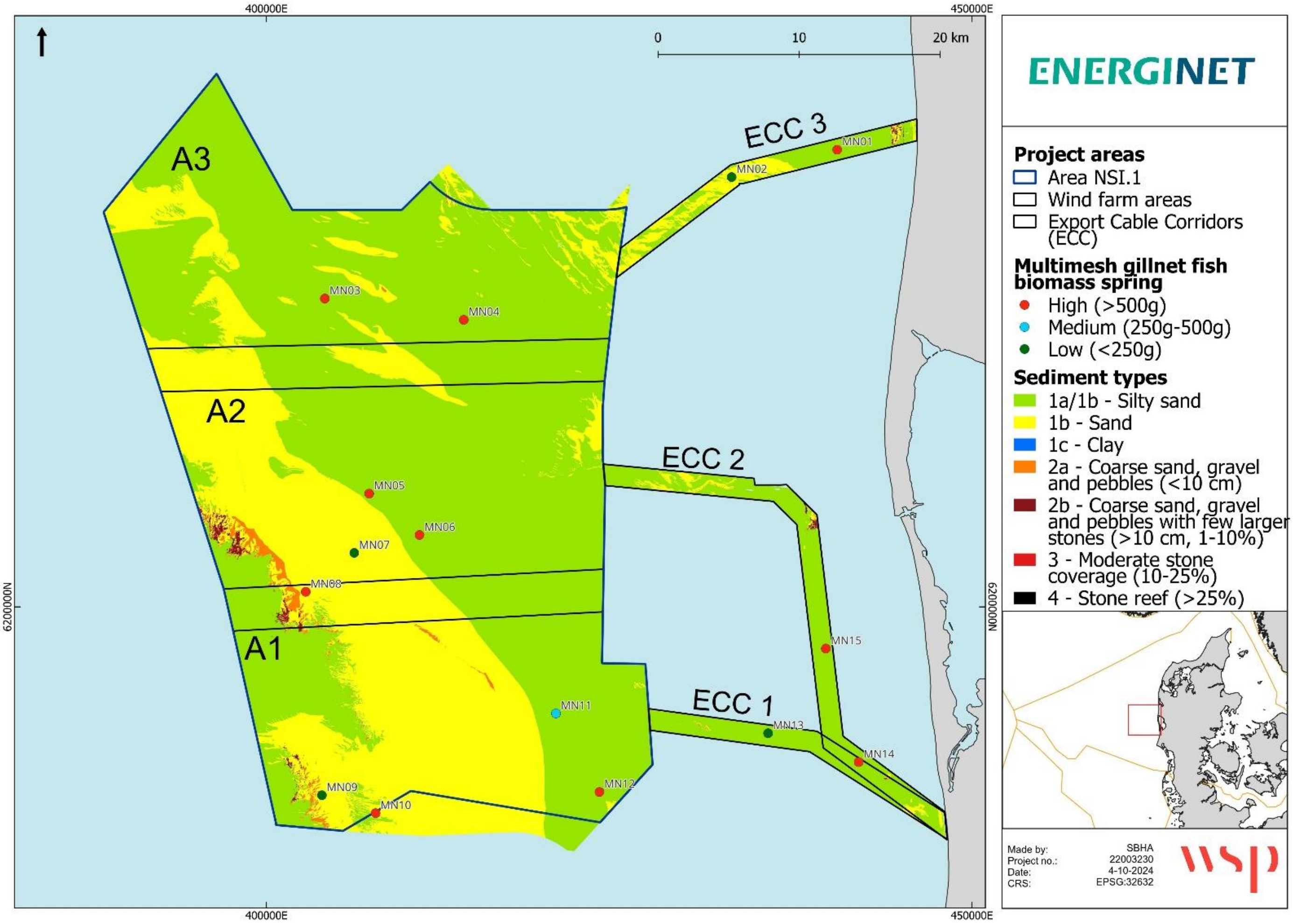

Figure 5-6. The biomass from multimesh gillnets catches in NSI.1 spring survey 2024.

AUTUMN

ABUNDANCE

A total of 410 fish were caught in multimesh gillnet in the autumn survey. The catches were dominated by common dab and whiting, which comprised 40 % and 33 %, respectively. In the autumn survey, the fish density from catches with multimesh gillnets varied from 0-83 fish per net per day (Table 5-10). The highest fish abundance was observed at station MN05 on silty sand sediment in the A2 sub-area, while no fish were caught at station MN06, also on silty sand sediment in the A2 sub-area.

Dividing the stations into three categories: high, medium and low density of fish - 15 of the 16 stations had a high density of fish, while the last station (MN06 where no fish were caught) had a low density of fish (Figure 5-7).

Table 5-10. The total fish abundance from catches with multimesh gillnets in NSI.1 autumn survey 2023. The catch has been converted to Catch Per Unit Effort (abundance of fish per net per day).

Species	MN01	MN02	MN03	MN04	MN05	MN06	MN07	MN08	MN09	MN10	MN11	MN12	MN13	MN14	MN15	MN16	Total
Atlantic cod								2				1					3
Atlantic herring	1		1		4												6
Atlantic mackerel								2	3								5
Common dab	3	6	10	10	49		17	6	7	8	20	14	5	2	6	1	164
Common dragonet			1		6			2							1		10
Common sole					2		2				1	1	1				7
Common/sand goby										1							1
European plaice	2						2	4	2		1	1	1	2			15
Great sandeel		2															2
Grey gurnard			1	3			1								1		6
Gurnard							1										1
Hooknose	3	1						2	2			1	6		2	4	21
Mediterranean scaldfish					1		2										3
Pouting					1												1
Sandeel										1							1
Shorthorn sculpin	1			1					1		2			4	1		10
Solenette	2	1		2	6		2							1	1	1	16
Sprat/herring									1								1
Turbot											1						1
Whiting	11	5	9	11	14		8	4	11	7		2	6	17	16	15	136
Total	23	15	22	27	83		35	22	27	17	25	20	19	26	28	21	410

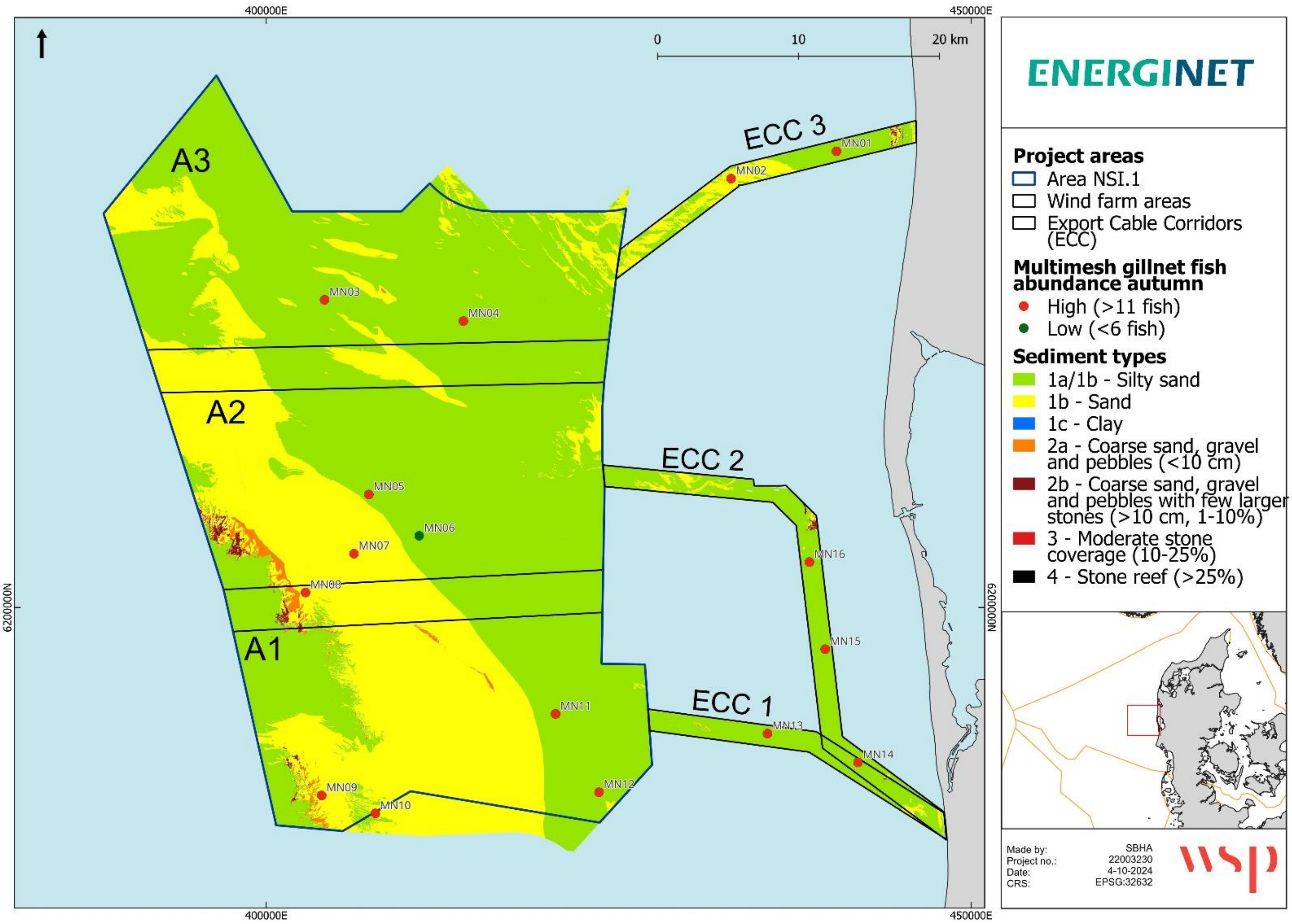

Figure 5-7. The fish abundance in CPUE number of fish per net per day for each sampled station in the autumn survey 2023.

BIOMASS

In the autumn survey, the total biomass caught in multimesh gillnets amounted to 33.2 kg of fish (Table 5-11). Common dab accounted for 43 % of the total catches with 14.4 kg, while whiting comprised an additional 26 % with 8.7 kg. The remaining fish showed very low biomass values.

The biomass varied between 0- and 5,760-gram fish pr. Station, and the highest biomass was observed at station MN05 in the A2 sub-area. Also, MN11 with 4,640 g and MN08 with 3,410 grams of fish had a high biomass of fish.

Table 5-11. The total biomass of fish caught in multimesh gillnets in autumn survey 2023. The CPUE is gram per net per day.

m fish pr. 1000 m^2	MN01	MN02	MN03	MN04	MN05	MN06	MN07	MN08	MN09	MN10	MN11	MN12	MN13	MN14	MN15	MN16	Total
Atlantic cod								360				40					400
Atlantic herring	120		65		210												395
Atlantic mackerel								960	400								1.360
Common dab	270	450	810	720	4.440		1.060	930	640	950	1.900	1.200		300	610	120	14.400
Common dragonet			55		60										30		145
Common sole					220		30				80	20	200				550
Common/sand goby										1							1
European plaice	120						240	840	300		40	30	70	190			1.830
Great sandeel		8															8
Grey gurnard			60	570			190								150		970
Gurnard							190										190
Hooknose	65	10						30	210			10	100		40	80	545
Mediterranean scaldfish					10		30										40
Pouting					80												80
Sandeel										5							5
Shorthorn sculpin	100			40					50		220			310	180		900
Solenette	5	2		30	100		40							20	10	30	237
Sprat/herring																	
Turbot											2.400						2.400
Whiting	990	350	710	610	640		460	290	910	490		200	330	980	890	890	8.740
Total	1.670	820	1.700	1.970	5.760		2.240	3.410	2.510	1.446	4.640	1.500	700	1.800	1.910	1.120	33.196

When divided into the three categories of high, medium and low biomass, only MN06 was low, while the rest was categorized as high biomass pr. station (Table 5-8).

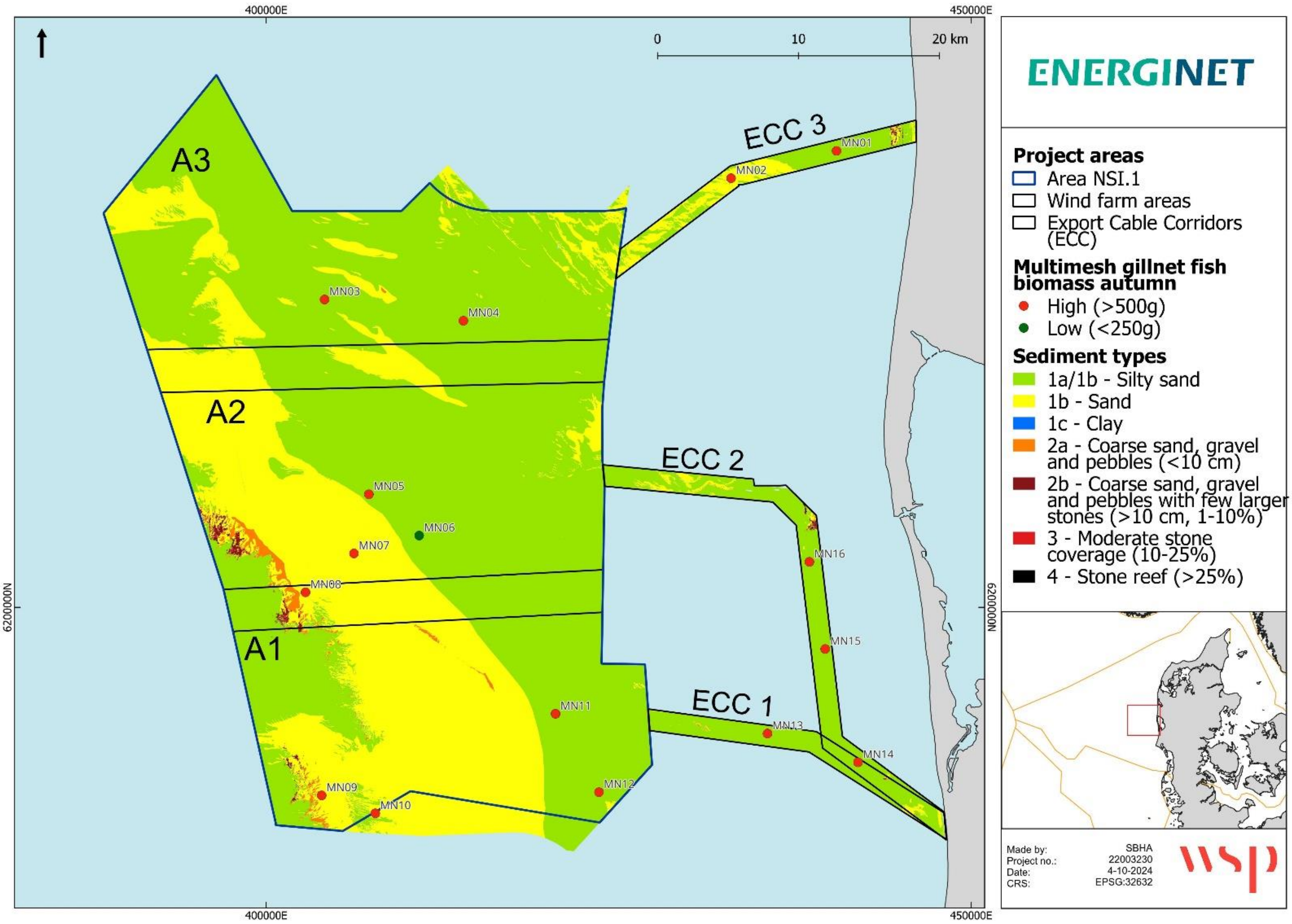

Figure 5-8. Fish biomass in CPUE gram fish per net per day for each sampled multimesh gillnet station in the autumn survey 2023.

5.2.4 TRAMMEL NETS

As for the multimesh gillnet, the spring and autumn catches in trammel net were dominated by common dab. A total of 105 fish were caught in the trammel nets with approximately 50% caught in spring and autumn, respectively. In terms of weight a total of 22.2 kg of fish were caught in trammel net, with 9.1 kg caught in spring and 13.1 kg caught in autumn. Compared to the other fishing methods utilized in this study, few fish species and individuals was caught using trammel nets.

SPRING

ABUNDANCE

In the spring survey, common dab dominated the catch in trammel nets. The total catch varied from 3-17 fish across stations Station TN07 was the trammel net station with the highest abundance of fish, with 17 fish per net per day (Table 5-12).

Table 5-12 Total catches in trammel nets in spring survey 2024 in NSI.1. The CPUE is number of fish per net per day.

Fish pr. net pr. day	TN01	TN02	TN03	TN04	TN05	TN06	TN07	Total
Common dab	9	3	3		8	3	12	38
European plaice		2		1			3	6
Turbot				2			2	4
Whiting	2	1			2	1		6
Total	**11**	**6**	**3**	**3**	**10**	**4**	**17**	**54**

Dividing the stations into high, medium, and low density of fish - one station showed a high density of fish (TN07), while three stations had a medium density, and three stations had low densities (Figure 5-9).

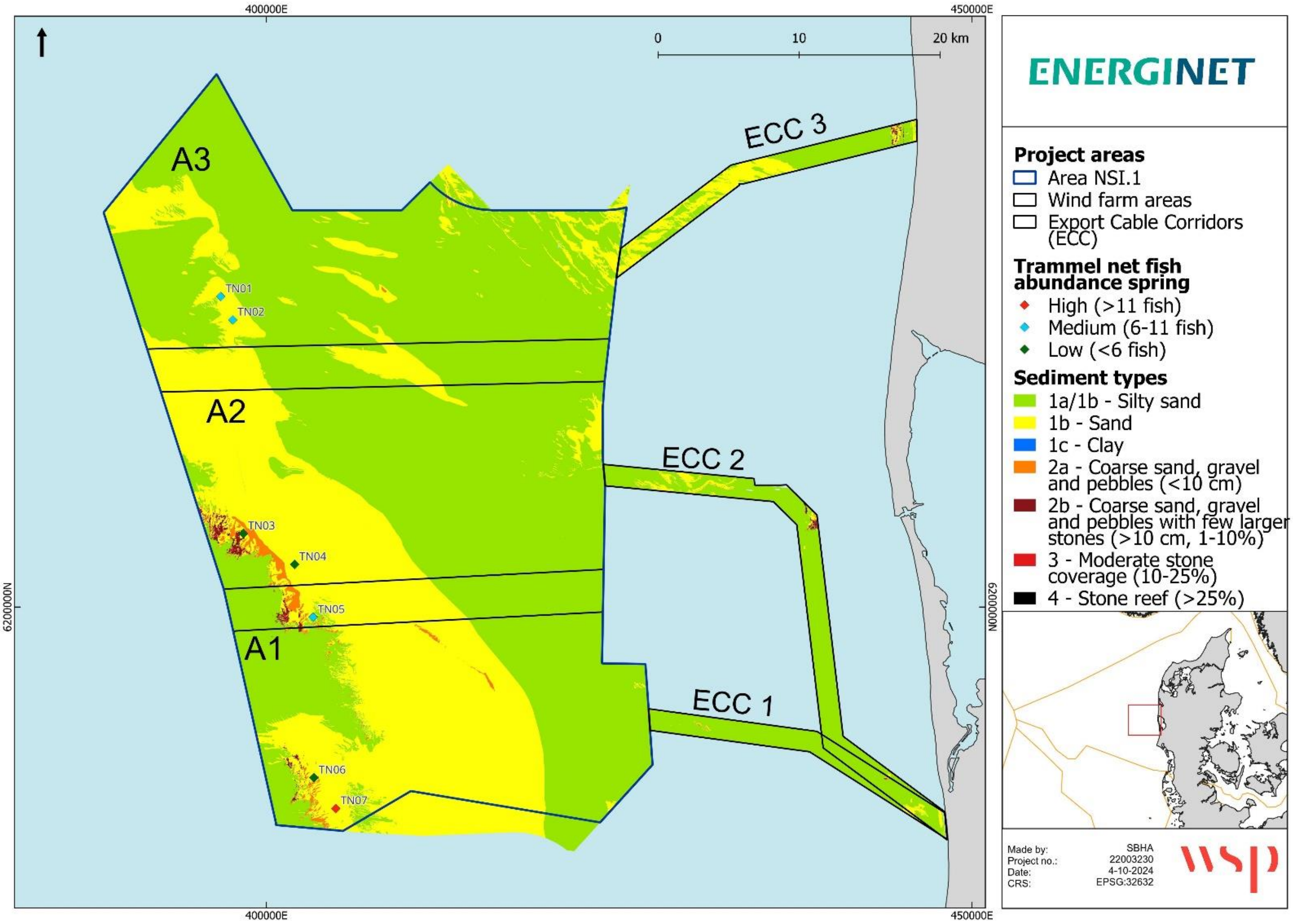

Figure 5-9 The fish density from catches with trammel net in NSI.1 spring survey 2024.

BIOMASS

The total biomass of fish caught in trammel nets in the spring survey was 9,094 g (Table 5-13). Common dab dominated with 59 %, while European plaice made up 22 % of the overall spring catches in the spring survey. Witing and turbot comprised 11 % and 8 %, respectively. The highest biomass was caught at station TN07, with 2,750 g, while the lowest biomass originated from TN06 with just 460 g fish.

Dividing the of the biomass pr. station into high, medium or low biomasses can be observed in Figure 5-10.

Table 5-13 The total biomass of fish caught in trammel nets in spring survey 2024 in NSI.1. The CPUE is gram per net per day.

Gram fish pr. net pr. day	TN01	TN02	TN03	TN04	TN05	TN06	TN07	Total
Common dab	1600	600	470		430	390	1850	**5340**
European plaice		720		380			900	**2000**
Turbot				760				**760**
Whiting	588	135			201	70		**994**
Total	**2188**	**1455**	**470**	**1140**	**631**	**460**	**2750**	**9094**

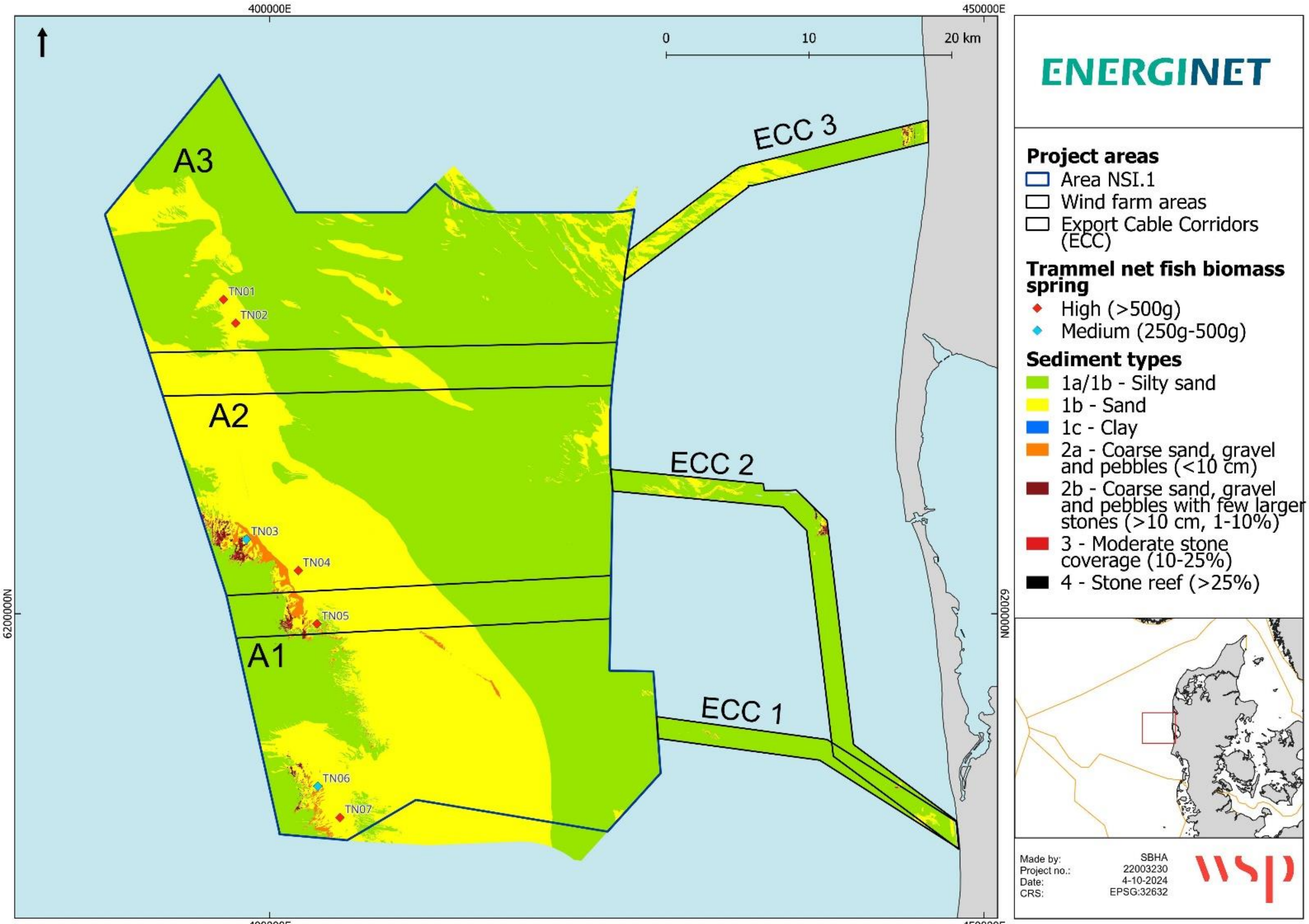

Figure 5-10 The biomass from multimesh gillnets and trammel nets catches in NSI.1 spring survey 2023.

AUTUMN

ABUNDANCE

In the autumn survey, trammel net catches show fish abundance ranging from 0 to 14 fish per net per day with a total of 51 individuals (Table 5-14). The highest fish abundance was observed at station TN04, while no fish was caught at station TN05. In general, few individuals and few different fish species were caught across the stations. Common dab was caught at 6 out of 7 stations and comprised 61 % of the total catches in trammel net in spring.

The division of the abundance pr. station into high, medium, or low biomasses can be observed in Figure 5-11.

Table 5-14 The total fish abundance from catches with trammel nets in NSI.1 autumn survey 2023.

No. fish pr. net pr. day	TN01	TN02	TN03	TN04	TN05	TN06	TN07	Total
Atlantic cod	2	2						4
Common dab	2	8	2	8		6	5	31
European plaice	2			6				8
Turbot						1		1
Whiting	5	2						7
Total	**11**	**12**	**2**	**14**		**7**	**5**	**51**

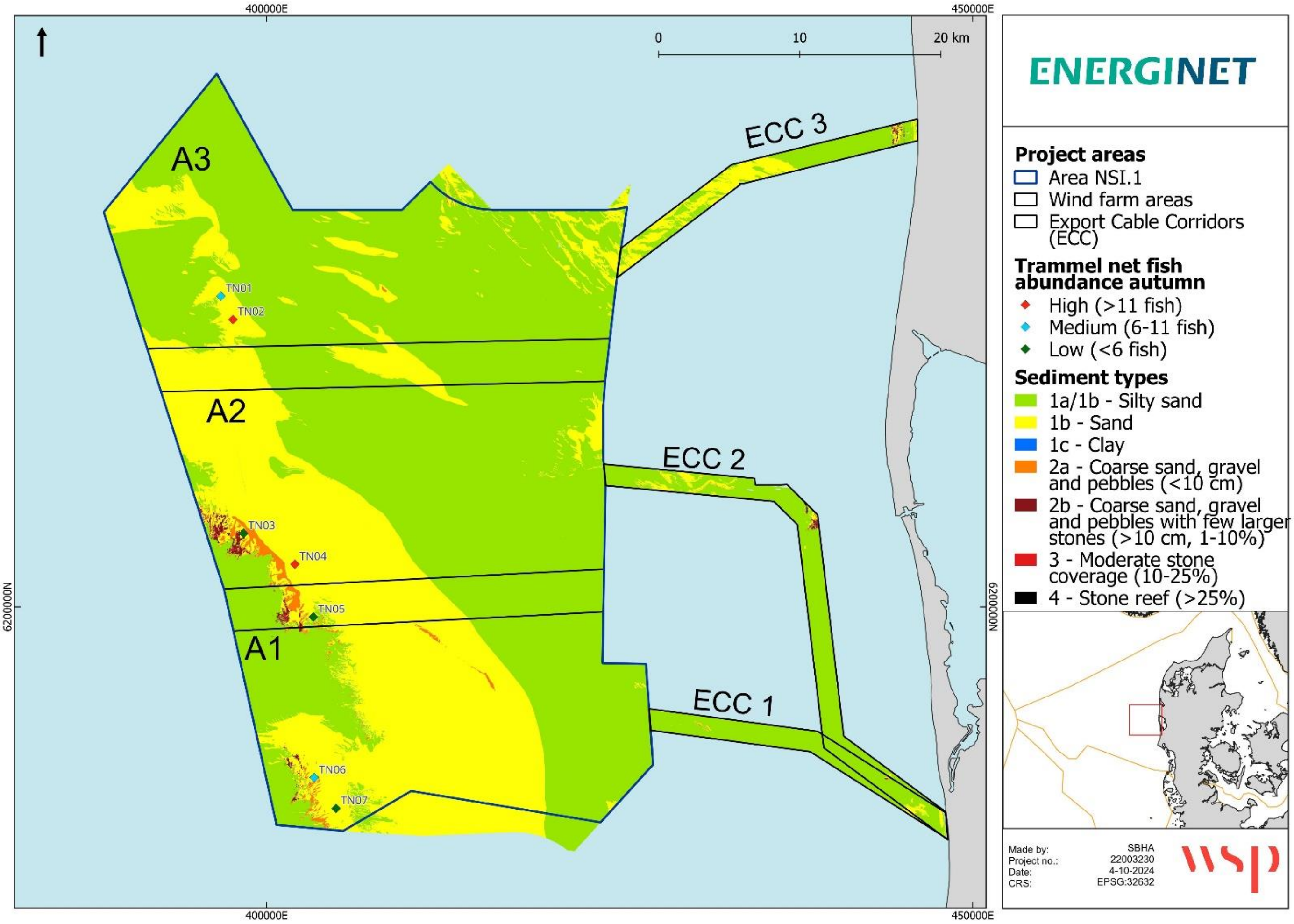

Figure 5-11. The fish abundance in CPUE number of fish per net per day for each sampled station in the autumn survey.

BIOMASS

In the autumn survey, trammel net catches show fish biomasses ranging from 950 g to 5,900 g pr net pr day, with a total biomass of 13,140 g pr net pr day (Table 5-15). The highest fish biomass was observed at station TN01, while no fish was caught at station TN05. In general, few different fish species were caught across the stations. Atlantic cod had the highest individual biomass comprising 39 % of the catches very closely followed by common dab with 37 % of the catches. European plaice accounted for 13 % of the total landings.

Table 5-15. The total biomass of fish caught in trammel nets in autumn survey 2023. The CPUE is gram per net per day.

Gram fish pr. net pr. day	TN01	TN02	TN03	TN04	TN05	TN06	TN07	Total
Atlantic cod	4400	660						5060
Common dab	340	1040	380	1420		780	950	4910
European plaice	480			1200				1680
Turbot						630		630
Whiting	680	180						860
Total	**5900**	**1880**	**380**	**2620**		**1410**	**950**	**13140**

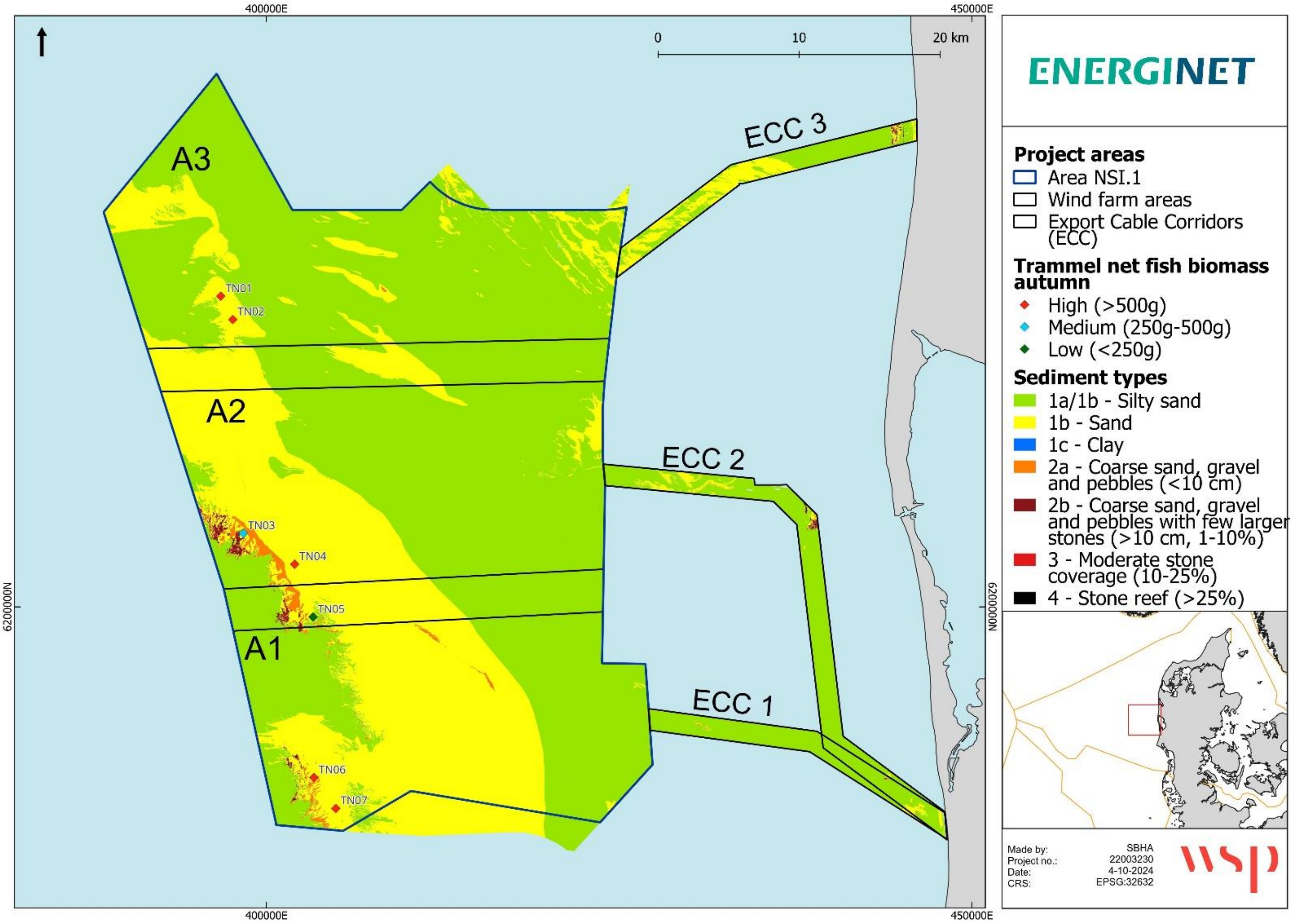

Figure 5-12. Fish biomass in CPUE gram fish per net per day for each sampled trammel net station in the autumn survey 2023.

6 SPAWNING AREA

Below, existing literature on spawning behaviour for the fish described in detail in section 4.2.2 Spawning and nursery areas, and observations on fish maturity stages from this present study, is summarized. Common dab, solenette, and sand eel spawn in the same areas as the adult population occur, thus no specific spawning area exists for these species. Therefore, it was likely that these species would spawn in the NSI.1, as especially common dab and solenette were abundant in the present fish catches. Common sole has a known spawning area just south of NSI.1 and along the coastline of the Wadden Sea, so this species was also expected to spawn in NSI.1. NSI.1 area is of less importance as spawning area for cod, as more important spawning areas occur in the deeper parts of the North Sea.

In the present fish surveys, very few individuals were physiologically ready to spawn. A total of two turbots (one male and one female) and six common dab (one female and the remaining males), caught in the spring survey, were physiologically ready to spawn. Common dab and solenette usually spawn from April to June and from March to July, respectively, thus, May – at which point the spring survey was conducted – should be within the prime spawning period for both species (Table 6-1). The few spawning individuals observed indicate that NSI.1 has limited function as spawning area.

Many of the common dab and solenette individuals caught were just on the edge of spawning in the spring survey, as the females had visible egg cells in the gonads, but the eggs were still small and scattered. For common dab, 73% of the individuals were ripening, and for solenette the percentage of ripening individuals were 84% in the spring survey (Figure 6-1). When actively spawning, all egg cells should be enlarged (water filled) and the eggs protrude from the vent when pressure is put on the fish abdomen. The gender ratio for solenette was especially high for females in the spring survey, females constituting 72%. The solenette can grow quite old (14-16 years) and the females usually grow older than the males (Carl & Møller, 2019). Therefore, the ratio of females is usually higher than males in the North Sea.

Table 6-1. Spawning time and strategy for most abundant fish caught in the fish survey here and other relevant fish species. Source (Muus & Nielsen, 2006), (Worsøe, et al., 2002), (Warnar, et al., 2012) (Munk, et al., 2019), (Møller, et al., 2019), (Møller, et al., 2019)

Common name	Spawning time												Spawning stategy
	J	F	M	A	M	J	J	A	S	O	N	D	
Atlantic cod	x	x	x	x	x								Pelagic
Common dab				x	x	x							Pelagic
Common dragonet				x	x	x	x	x					Pelagic
Common sole				x	x	x							Pelagic
European plaice	x	x	x	x								x	Pelagic
Great sandeel				x	x	x	x	x					Benthic
Grey gurnard				x	x	x	x	x					Pelagic
Haddock			x	x	x	x							Pelagic
Hooknose	x	x	x	x									Benthic
Lesser sand eel	x											x	Benthic
Mediterranean scaldfish					x	x	x	x					Pelagic
Small sand eel	x	x											Benthic
Solenette			x	x	x	x	x						Pelagic
Whiting		x	x	x	x	x							Pelagic

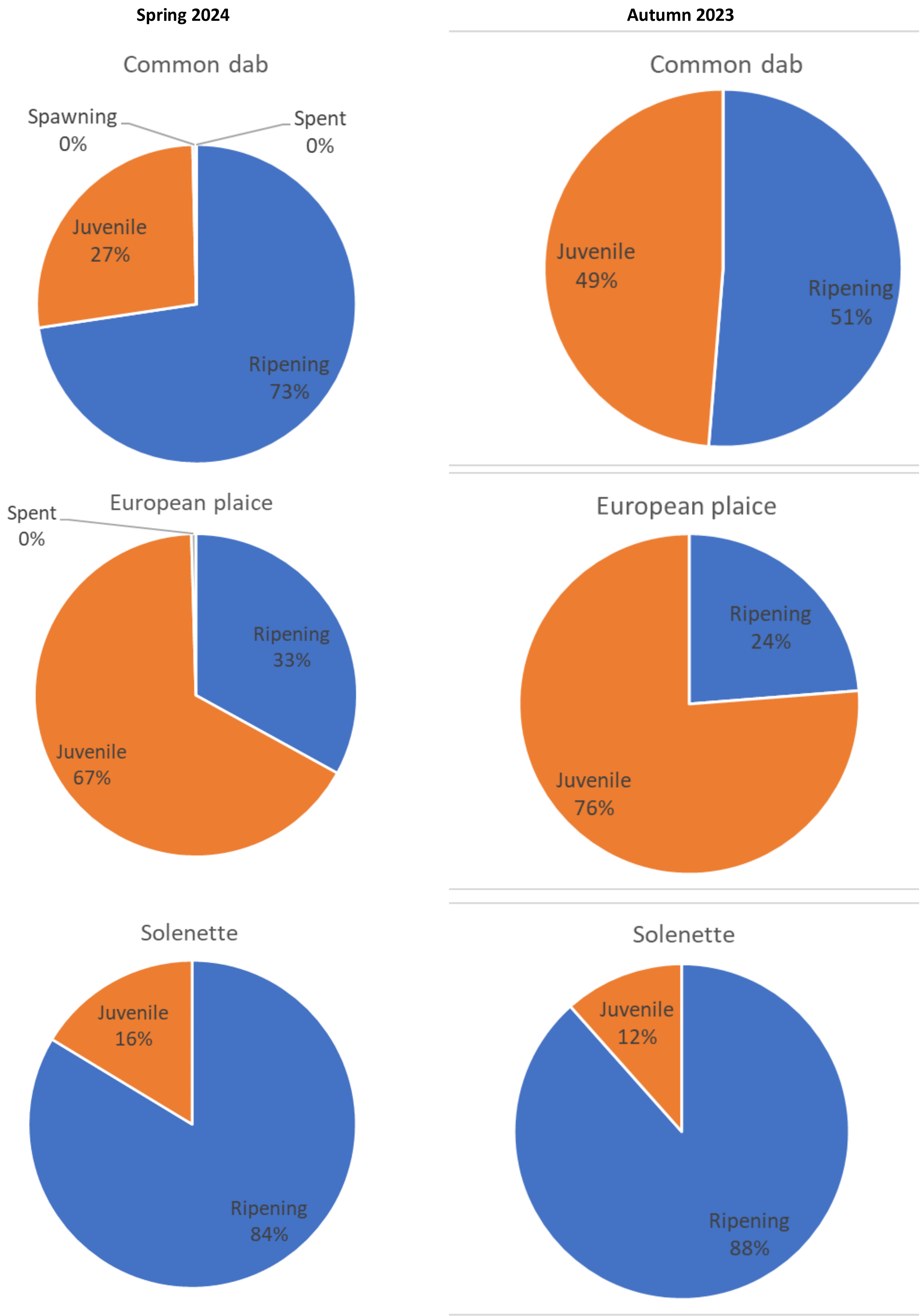

Figure 6-1. Maturity of the three most abundant species caught in spring and autumn survey; common dab, European plaice, and solenette.

7 SIZE DISTRIBUTION AND NURSERY AREA

When analysing the length of individuals in a fish population, it is possible to find and track individuals of same length and, thus, roughly the same age. Usually, when the dataset is large enough, each year class or cohort can be seen as peaks of individuals when mapping them based on size (such as in Figure 7-1). The cohorts can then be tracked year by year as they grow.

In this chapter, the length of the fish caught in the spring and autumn surveys were used to evaluate if NSI.1 was utilized as nursery area for juvenile fish. The size distribution was analysed for the three most abundant fish species – the European plaice, common dab and solenette, for both the spring and autumn survey.

7.1 EUROPEAN PLAICE

In the spring survey, a total of 2,349 European plaice where caught, however due to subsampling, length measurements were only conducted for 1603 European plaice. As the subsamples were based on a representative size range of the total batch of European plaice, it is expected that the size distribution would have been very similar if all European plaice had been sized. The size of the European plaice ranged from 4 cm to 43 cm in length (Figure 7-1). A total of 491 European plaice were 15 cm or below, indicating that they were juveniles from last year or the year before (i.e. 1–2-year-old individuals).

Despite the very large quantity of European plaice caught in the spring survey, it was difficult to distinguish any proper cohorts. A peak is visible around 12 cm, which may be 2-year-old individuals (Muus & Nielsen, 2006). There is a larger peak at 15-18 cm and according to size-at-age literature, this cohort was approximately 3-year-olds. Two individuals of 40 cm or more were both females, which was to be expected as the female European plaice are usually larger than the males.

In the autumn catches, a total of 667 European plaice were caught, and they were all measured to size. Merely eight individuals were of 10 cm or below (Figure 7-1). A cohort peak was observed around 14-16 cm of length, and according to size-at-age literature, this cohort was approximately 3-year-olds. The autumn survey was carried out in 2023, while the spring survey took place in 2024. Therefore, the cohort of 14-16 cm in autumn is believed to be the same cohort of 15-18 cm the following spring, as the fish grow slowly during winter compared to summer.

The European plaice utilizes shallow, sheltered, and sandy areas as nursery areas after settling (Poxton & Nasir, 1985), and NSI.1 does not fit the profile for such a nursery area, as the area is neither shallow nor sheltered. However, juvenile plaice migrate into deeper waters in winter, when temperatures drop. When water temperatures increase over late spring and early summer, they migrate back into shallower nursery areas.

7.2 COMMON DAB

In the spring survey, the number of common dab amounted to 2243. Due to the large quantity, subsamples that were representative of the overall size range of common dab were selected on some stations, where the catches were especially large (100+ fish). Therefore, a total of 1896 common dab were measured. The size range in the spring survey was between 6 cm and 32 cm in length – common dab of more than 30 cm is rarely seen (Figure 7-1) (Carl & Munk, 2019). Relatively few juveniles (13 individuals of 7 cm or smaller) were observed in NSI.1, compared to the larger individuals. According to size-at-age literature these individuals were 1 year, or younger. Dab settles at 10-20 m depth, but the range may be as large as 6-70 m depth. So, a proper nursery area may not be found for this species. Considering the above factors, it seems unlikely that NSI.1 area is important for juvenile common dab.

The size distribution of common dab shows a substantially larger cohort from 14 cm to approximately 22 cm, where the cohort gradually is reduced in size. The large "peak" or bulk of the catches probably represent larger year classes of between 2–4-year-old common dab. According to existing literature, growth slows down after 20 cm, and hereafter common dab only grow approximately 1-2 cm pr. year (ICES, 2018a; ICES, 2018b).

In autumn catches, a total of 1492 common dab was caught, and they were all measured to size. The size range of common dab caught in the autumn survey was between 4 cm and 30 cm (Figure 7-1). Of these, 37 were 7 cm or less, meaning that they were approximately 1 year or less. A larger cohort was observed from approximately 12 cm in length in the autumn survey. This is probably the same cohort observed in the following spring from approximately 13 cm, as the common dab grows very slowly over winter.

7.3 SOLENETTE

A total of 1497 solenettes were caught in the spring catches, which were all measured to size. The size range was between 4 cm and 12,5 cm (Figure 7-1). According to size at age literature, solenettes grow approximately 4 cm within the first year and reach a length of 7 cm after two years. This indicates that solenettes utilize the NSI.1 area both as juveniles of approximately 1 year, as well as adults of approximately 10-14 years old. According to literature, the juveniles do not have a nursery area that is separated from where the adults occur. Instead, the juveniles coexist alongside the adult individuals of solenette (Wheeler, 1969). Therefore, it can be concluded that solenettes utilize the NSI.1 area as a nursery area.

Although a relatively large number of solenettes were caught in the spring survey, it is difficult to distinguish actual peaks or cohorts. The species has a very limited size even as adults, and the size distribution of solenette seem more to demonstrate a normal distribution of sizes rather than individual cohorts. Possible cohorts may cause the peaks at 8, 9, 10 and 11 cm, which probably indicate fish one year apart in age, as the fish grown approximately 1 cm pr. year.

In the autumn survey, 1517 solenettes were caught, and all measured to size. The length of the solenettes ranged from 5.5 cm to 13 cm (Figure 7-1). Again, it is evident from the data collected here that all sizes of solenette are represented in the NSI.1 area. As the autumn in 2023 survey took place prior to the spring survey in 2024, it is likely that the peaks of solenette of 7.5 cm and 8.5 cm, respectively, in the autumn survey are the same cohorts that have grown into 8 and 9 in the spring survey.

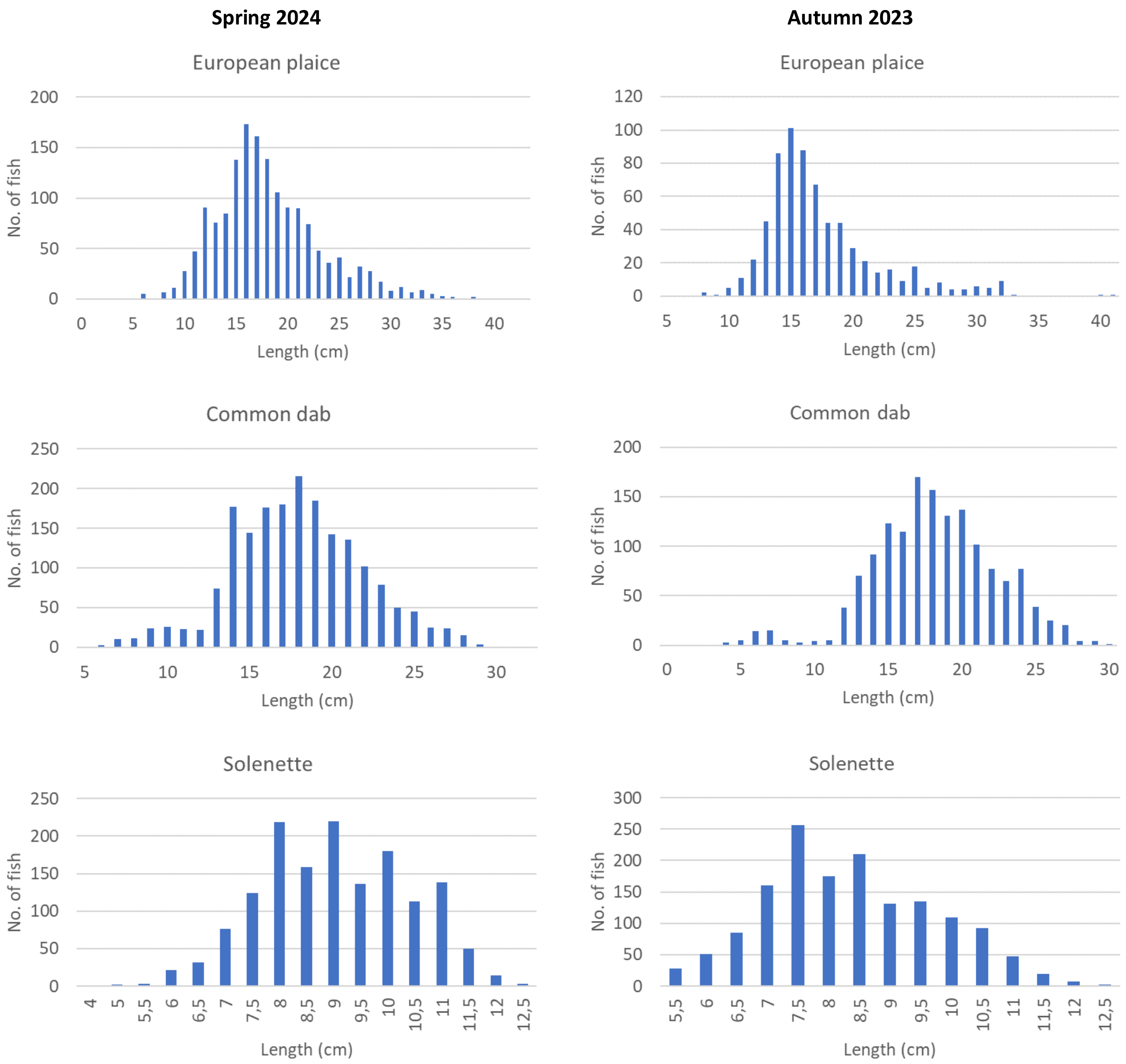

Figure 7-1 The size distribution of the three most abundant fish species in the beam trawl, multi net and trammel net catches in autumn 2023 and spring 2024. Please note the differences in abundances between graphs.

8 SPECIES DIVERSITY AND EVENNESS

The Shannon Wiener index was used to measure the diversity of fish species and the community structure in NSI.1 based on beam trawl, multimesh gillnets and trammel nets. The index considers the number of species living in the area and how dominating each species is. A low Shannon Wiener index indicates a low number of species and/or strong dominance of one or a few species. On the other hand, a high Shannon Wiener index indicates a high species richness with great evenness between species. The index value rarely exceeds 4.

The Evenness index is an estimate of how even the individuals are distributed between species. The values may range between 0 and 1. If values are low (near 0), it indicates that one or few species dominate the community, and if values are high (near 1), a more even distribution of individuals between species occurs.

An evaluation of the fish species diversity and evenness is presented below based on the Shannon Wiener index and Evenness index.

8.1 BEAM TRAWL

The biodiversity of fish was divided into three categories as in Thor OWF and ENOE OWF with high biodiversity being > 11 species pr. station, medium biodiversity was 10-11 species pr. station and low biodiversity was < 10 species. For the spring survey in this study, the number of fish species caught per station with beam trawl varied from five to 14 species with an average of 9.8 species (Table 8-1). Most stations had a medium score on biodiversity, while three stations had a high biodiversity and eight had a low score (Figure 8-1). No clear tendencies could be observed with regards to areas, sediment types or depths having high or low biodiversity scores.

For the autumn survey, the range was similar although with lower numbers; two to 12 species. However, the average number of species per station was slightly lower for the autumn catches, with an average of 8.1 species. The station with the highest number of species observed was BT19 and the lowest number on BT13 (Figure 8-2). Most stations (17 stations) had low biodiversity, while 8 had medium diversity and 1 had high biodiversity. No clear tendencies could be observed, however, most stations in the shallow ECCs had low biodiversity.

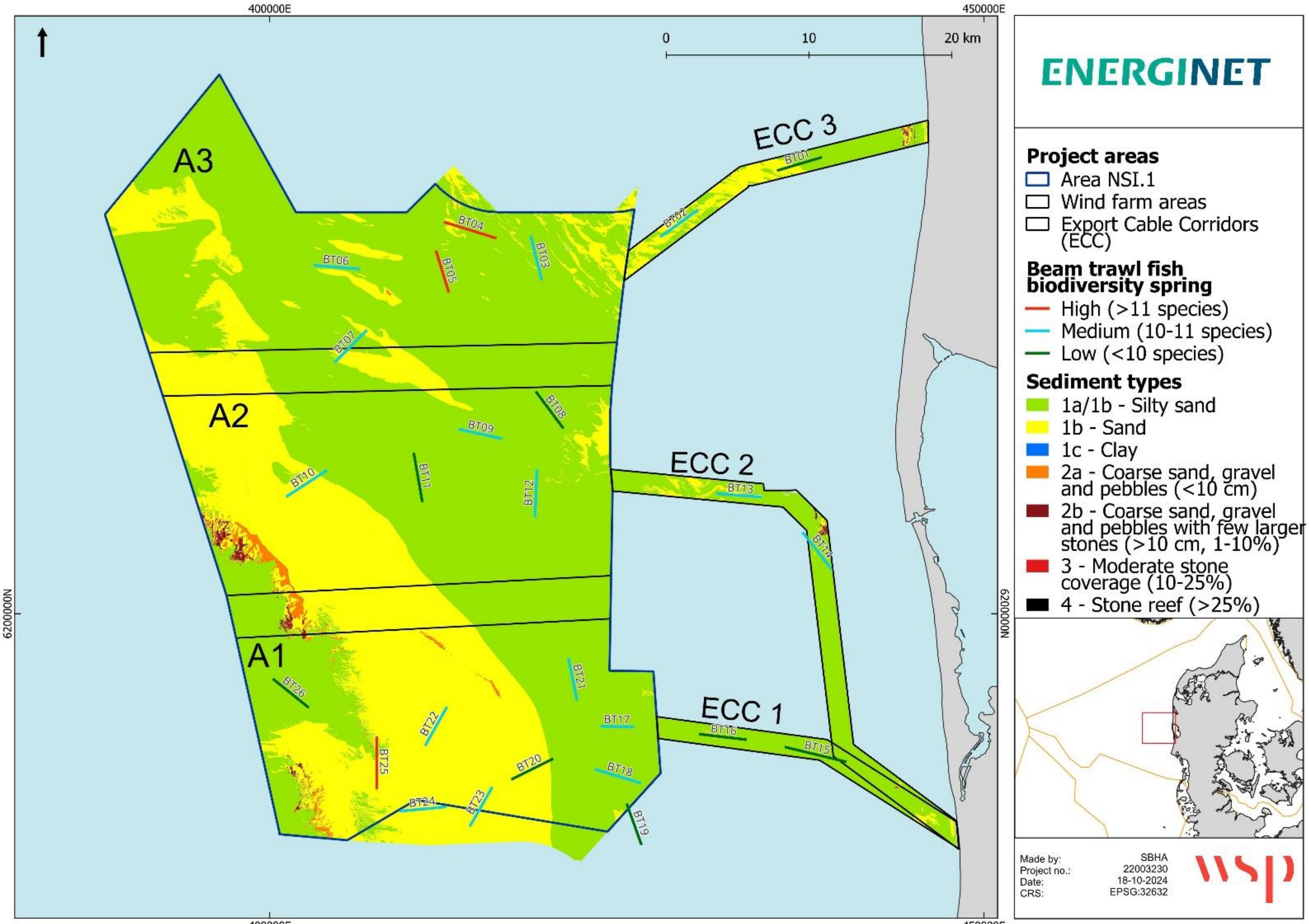

Figure 8-1 The biodiversity (number of species) on beam trawl stations in NSI.1 spring survey 2024.

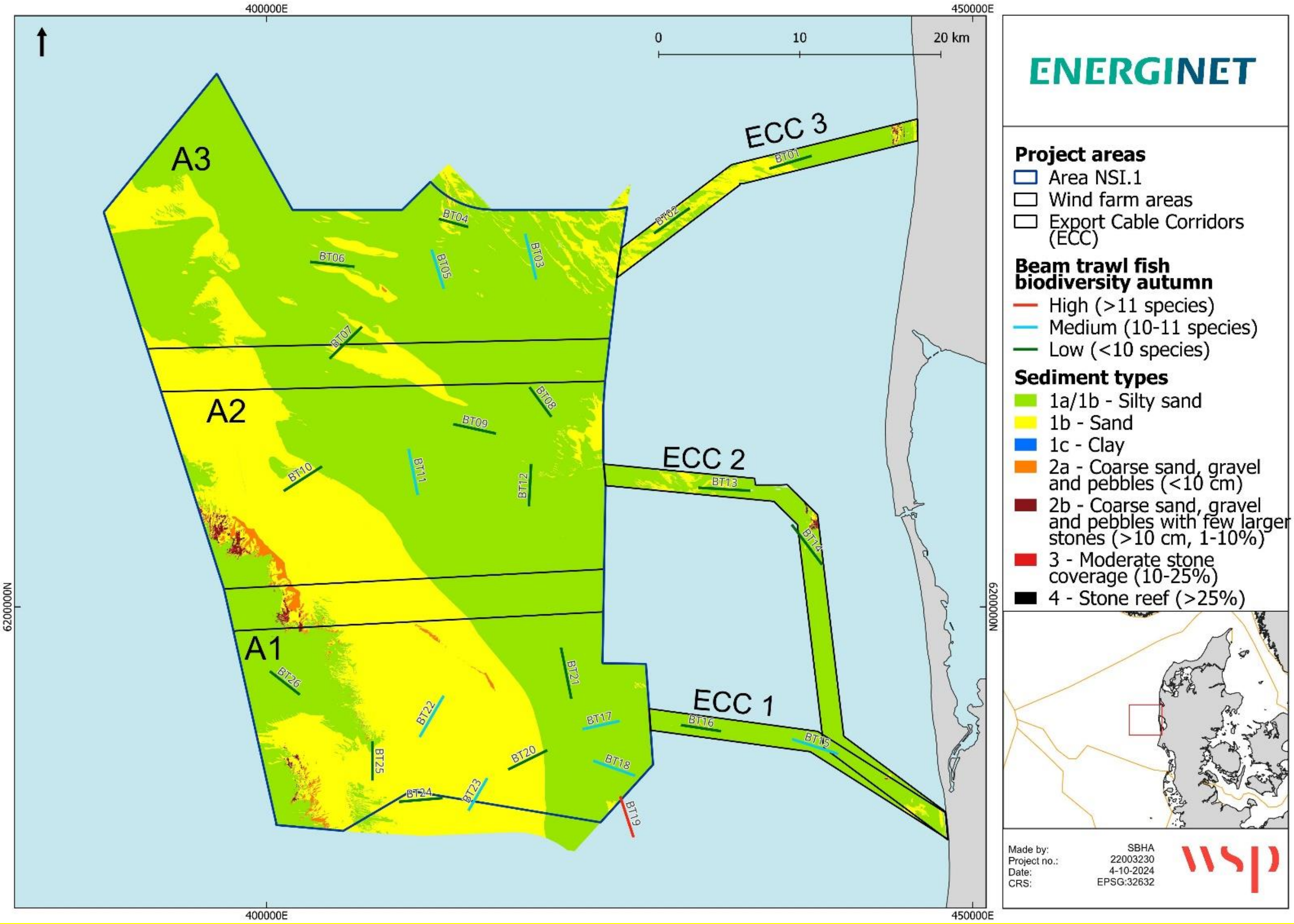

Figure 8-2 The biodiversity (number of species) on beam trawl stations in NSI.1 OWF autumn survey.

Shannon-Wiener Index values generally vary between 1.5 and 4 in most ecological studies and the index is rarely greater than 4. In the present study, the Shannon Wiener index for the beam trawl sampled stations ranged from 0.7 to 2.0 in the spring survey, with an average of 1.4 within NSI.1. For the autumn survey, the index ranged from 0.6 to 1.7 with an average of 1.3, which was slightly lower than in the spring (Table 8-1). The relatively low values indicate a low number of species caught on beam trawl stations, which may indicate an ecosystem in ecological instability or disturbance. However, it in this case this is the consequence of a few species dominating the catches (i.e. common dab, European plaice, solenette). These species are well adapted to the physical environment of the North Sea and the vast sandy and/or silty sand banks of the area.

The stations with high Shannon Wiener index varied somewhat between spring and autumn. In autumn, stations with low Shannon Wiener index were generally located in the central and northern part of the NSI.1 and ECC where the sediment types generally were very similar (sand and silty sand) (Figure 8-2). Stations with high to medium Shannon Wiener index were, on the other hand, primarily located in the southern part of the NSI.1 where sediment types were more varied. However, in spring, this pattern was less pronounced (Figure 8-1).

The Evenness index ranges between 0-1, where numbers close to 1 indicate a high evenness and numbers close to 0 indicate that some species dominate in abundance. For the present study, the Evenness index calculated for NSI.1 in spring ranged between 0.14 and 0.48 with an average of 0.26 (Table 8-1). For the autumn survey, the Evenness index ranged from 0.17 to 0.92 with BT13 and BT21 markedly higher than the rest of the stations. The high Evenness index indicates evenness in abundance between species and that most species were caught in relative comparable numbers. This was in fact the case. In BT13 in the autumn survey, merely 0,2 fish were caught pr. 1000 m^2 and only two different species were caught here. For BT21 four different species were caught in in relatively even abundances, but catches were very low with only 1 fish pr. 1000 m^2. The average Evenness index for the autumn catches was 0.32 which was similar to the index level for spring catches in beam trawl. So, on average, the species caught in the spring and autumn survey were equally distributed between species in the two surveys. No clear picture was found with regards to high or low Evenness index on the various sediment types.

To summarize, the Shannon Wiener index calculated for NSI.1 show low values, indicating a low species diversity. Similarly, low levels of Evenness indicates that a few species dominate the catches. No pattern is clear concerning the Shannon Wiener and Evenness index. The index may be low in spring and high for the autumn catches at the same station. Another survey in the Thor OWF technical report, which used the same beam trawl method, found an average number of species between 10 species in spring and 11 in autumn (Rambøll & WSP, 2021). In Thor study, the Shannon Wiener index showed an average of 1.6 in spring and 1.5 in autumn with an average Evenness index of 0.5 for both seasons. Compared to the present study of NSI.1, the average number of species, the Shannon Wiener index and the Evenness index were all slightly higher in the Thor study. The results can most likely be explained by a higher heterogeneity in sediment types in the Thor area compared to the NSI.1, as higher habitat complexity attracts a larger span of fish species.

Table 8-1 Number of species, Shannon Wiener index and evenness index for all beam trawl stations based on abundance.

	Spring			Autumn		
	No. of species	Shannon Wiener	Evenness	No. of species	Shannon Wiener	Evenness
BT 01	6	0.94	0.29	7	1.38	0.23
BT 02	11	1.38	0.24	8	1.39	0.21
BT 03	10	1.41	0.23	11	1.42	0.25
BT 04	12	1.58	0.22	9	1.57	0.24
BT 05	14	1.55	0.20	9	1.48	0.25
BT 06	11	1.43	0.20	7	1.04	0.17
BT 07	11	1.39	0.20	8	1.37	0.25
BT 08	5	0.70	0.19	7	1.48	0.28
BT 09	11	1.23	0.14	6	0.64	0.24
BT 10	11	1.74	0.33	8	1.19	0.38
BT 11	6	0.94	0.16	10	1.30	0.27
BT 12	11	0.99	0.16	9	1.16	0.25
BT 13	10	1.39	0.30	2	0.64	0.92
BT 14	11	1.56	0.20	7	1.35	0.54
BT 15	8	1.48	0.26	11	1.55	0.24
BT 16	9	1.69	0.31	8	1.66	0.47
BT 17	10	1.72	0.32	9	1.55	0.27
BT 18	10	1.67	0.24	10	1.45	0.26
BT 19	9	1.57	0.26	12	1.49	0.23
BT 20	7	1.23	0.30	5	0.70	0.30
BT 21	11	1.52	0.29	4	1.17	0.69
BT 22	11	1.35	0.28	11	1.66	0.23
BT 23	11	1.36	0.30	9	1.29	0.26
BT 24	10	1.55	0.40	8	1.48	0.30
BT 25	12	2.02	0.48	9	1.50	0.34
BT 26	8	1.23	0.20	7	1.37	0.32
Average	9.85	1.41	0.26	8.12	1.32	0.32

8.2 MULTIMESH GILLNETS

The number of species caught in multimesh gillnets ranged from 1 to 6 species, averaging 3.6 species in the spring survey (Table 8-2). The number of species were lower in the autumn survey where 0 to 7 averaging 1.2 species were caught. Compared to the beam trawl stations, this is a much lower number of species caught, although the multimeshed gillnets are designed to catch several different species. When the biodiversity of fish was divided into three categories, high, medium and low, all multimesh gillnet stations showed low values. Therefore, no maps are presented for this gear type.

The Shannon Wiener index ranged between 0 and 1.6 with an average of 0.9 for the spring survey (Table 8-2). For the autumn survey, the Shannon Wiener index varied from 0 to 1.6 with an average of 1.2. The relatively low values indicate a low number of species and/or that a few species dominate the catches.

The average Evenness for the spring survey was 0.9, ranging from 0.3 to 1 (Table 8-2). For the autumn survey the average was 0.5 and values varied between 0.37 and 1. The high numbers indicate that most individual belonged to one or a few species and that one or a few species dominated the catches.

To summarize, the results found for Shannon Wiener and Evenness indicated that very few species were caught in the multimesh gillnets and that one or a few species dominated in terms of individuals. In other words, most species occurred in very low numbers, while a few species dominated.

Table 8-2 Number of species, Shannon Wiener (biodiversity) and evenness index for all Multimesh gillnet stations based on abundance.

	Spring			Autumn		
	No. of species	**Shannon Wiener**	**Evenness**	**No. of species**	**Shannon Wiener**	**Evenness**
MG 01	4	1.25	0.81	7	1.58	0.67
MG 02	N/A	N/A	N/A	5	1.36	0.66
MG 03	4	1.20	0.72	5	1.15	0.44
MG 04	4	1.17	0.71	5	1.29	0.55
MG 05	5	1.06	0.44	8	1.33	0.37
MG 06	6	1.23	0.79	0	0.00	0.00
MG 07	1	0.00	1.00	7	1.46	0.56
MG 08	5	1.38	0.64	7	1.85	0.88
MG 09	1	0.00	1.00	6	1.49	0.63
MG 10	3	0.95	0.83	2	0.69	1.00
MG 11	4	1.34	0.95	5	0.77	0.41
MG 12	6	1.26	0.43	6	1.08	0.52
MG 13	4	1.24	0.86	5	1.39	0.60
MG 14	5	1.17	0.30	5	1.09	0.52
MG 15	6	1.61	0.74	7	1.31	0.48
MG 16	N/A	N/A	N/A	4	0.85	0.43
Average	3.63	0.92	0.76	5.25	1.17	0.54

8.3 TRAMMEL NETS

The number of species caught in trammel nets ranged from 1 to 3 species in the spring and autumn survey, which is even lower than for multimesh gillnets (Table 8-3). When the biodiversity of each trammel net station is divided into three categories, high, medium and low, all stations were categorized as low. Therefore, no maps are presented for this gear type.

The Shannon Wiener index ranged between 0 and 1 with an average of 0.7 for the spring survey (Table 8-3). For the autumn survey, the Shannon Wiener index varied from 0 to 1.3 with an average of 0.5. The low values indicate a low number of species and/or that a few species dominate the catches.

The average Evenness for the spring survey was 0.7, ranging from 0.3 to 1 (Table 8-3). For the autumn survey the average was 0.9 and values varied between 0.6 and 1. The high numbers indicate that most individuals belonged to one or a few species and that one or a few species dominated the catches.

To summarize, the results found for Shannon Wiener and Evenness indicated that very few species were caught in the trammel nets and that one or a few species dominated in terms of individuals. In other words, most species occurred in very low numbers, while a few species dominated.

Table 8-3 Number of species, Shannon Wiener (biodiversity) and evenness index for all trammel net stations based on abundance. * Fished with beam trawl before this substrate was avoided with dredging gear and the station was instead sampled with trammel net.

	Spring			Autumn		
	No. of species	**Shannon Wiener**	**Evenness**	**No. of species**	**Shannon Wiener**	**Evenness**
TN01	**2**	**0.47**	**0.67**	**4**	**1.29**	**0.90**
TN02	**3**	**1.01**	**0.87**	**3**	**0.87**	**0.74**
TN03	**1**	**0.00**	**1.00**	**1**	**0.00**	**1.00**
TN04	**2**	**0.64**	**0.92**	**2**	**0.68**	**0.99**
TN05	**2**	**0.50**	**0.25**	**N/A**	**N/A**	**N/A**
TN06	**2**	**0.56**	**0.81**	**2**	**0.41**	**0.57**
TN07	**3**	**0.80**	**0.66**	**1**	**0.00**	**1.00**
Average	**2.14**	**0.57**	**0.74**	**1.86**	**0.46**	**0.89**

9 FEEDING AREAS

This chapter provides an overview of the distribution of relevant food organisms for fish in NSI.1. Fish do naturally spread out according to the quality of the habitat, which includes the availability of food items. Therefore, it is relevant to evaluate the availability of the various food resources for fish - which was mapped in the benthic baseline report (WSP, 2024).

The sediment type is determining for the species composition. The difference in taxa between the subareas (A1-3 and ECC1-3) should not be over-emphasised, except when based on differences in sediment types within the subareas since the species composition in the sediment types is not different between the two pre-investigation areas (WSP, 2024).

In general, the fauna coverage was high in the ECC areas near the coastline. In addition, high fauna coverage was observed in the northwestern part of NSI.1 (Figure 9-1). The most abundant infauna species were horseshoe worm (*Phoronis* sp.), the bristle worm species *Magelona mirabilis*, the tube worm *Owenia fusiformis,* sea potato (*Echinocardium cordatum*) and the sand burrowing brittle star (*Acrocnida brachiata*). The fauna coverage for Phoronids, Lanice, brittle star and sea potato can be seen below in (Figure 9-2).

Accordingly, the dominating species from visual verification (ROV) was horseshoe worm (*Phoronis* sp.), followed by the tube living bristle worm *Lanice conchilega*, sea potato (*Echinocardium* spp.), and bristle stars (*Ophiura* sp.), the bivalve mollusc bean-like tellin (*Fabulina fabula*), and the bristle worm species *Protodorvillea kefersteini.*

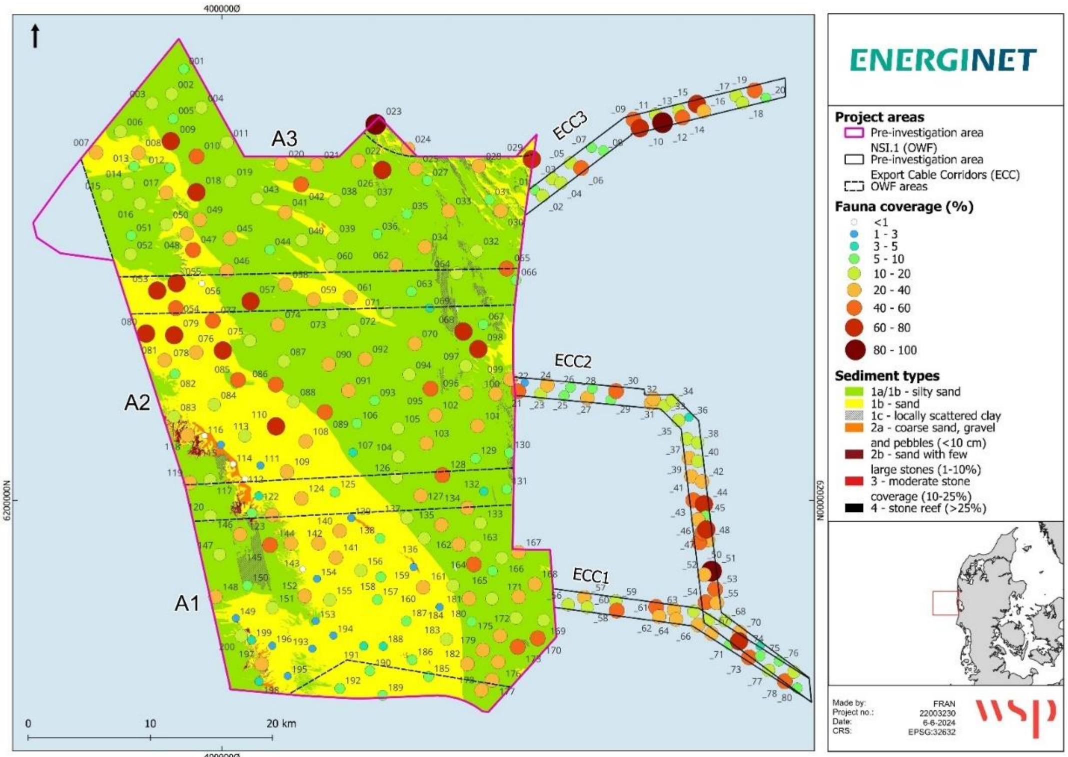

Figure 9-1. Map of area coverage (%) of total benthic fauna observed on ROV video in the two pre-investigation areas for the NSI.1 (NSI.1-OWF) and export cable corridors (NSI.1-ECC) made from June 2023 data. Note that area coverage is given as a range in % at each ROV station in the logbook (see Appendix 3B). As it is not possible to make this figure with the same variance in ranges as in the logbook, the maximum coverage % for the range is used in this figure. ROV station number is given in the figure. Prefix of ROV stations is OWF_ROV_ and ECC_ROV_. Background is the sediment type map from this baseline study. Source: (WSP, 2024).

In terms of biomass in dry weight, Echnoidea dominated the infauna both in the OWF and ECC area (Figure 9-3). This result is caused by the high degree of exoskeleton for this group of fauna. Other dominating groups of infauna included bivalves and Phoronida.

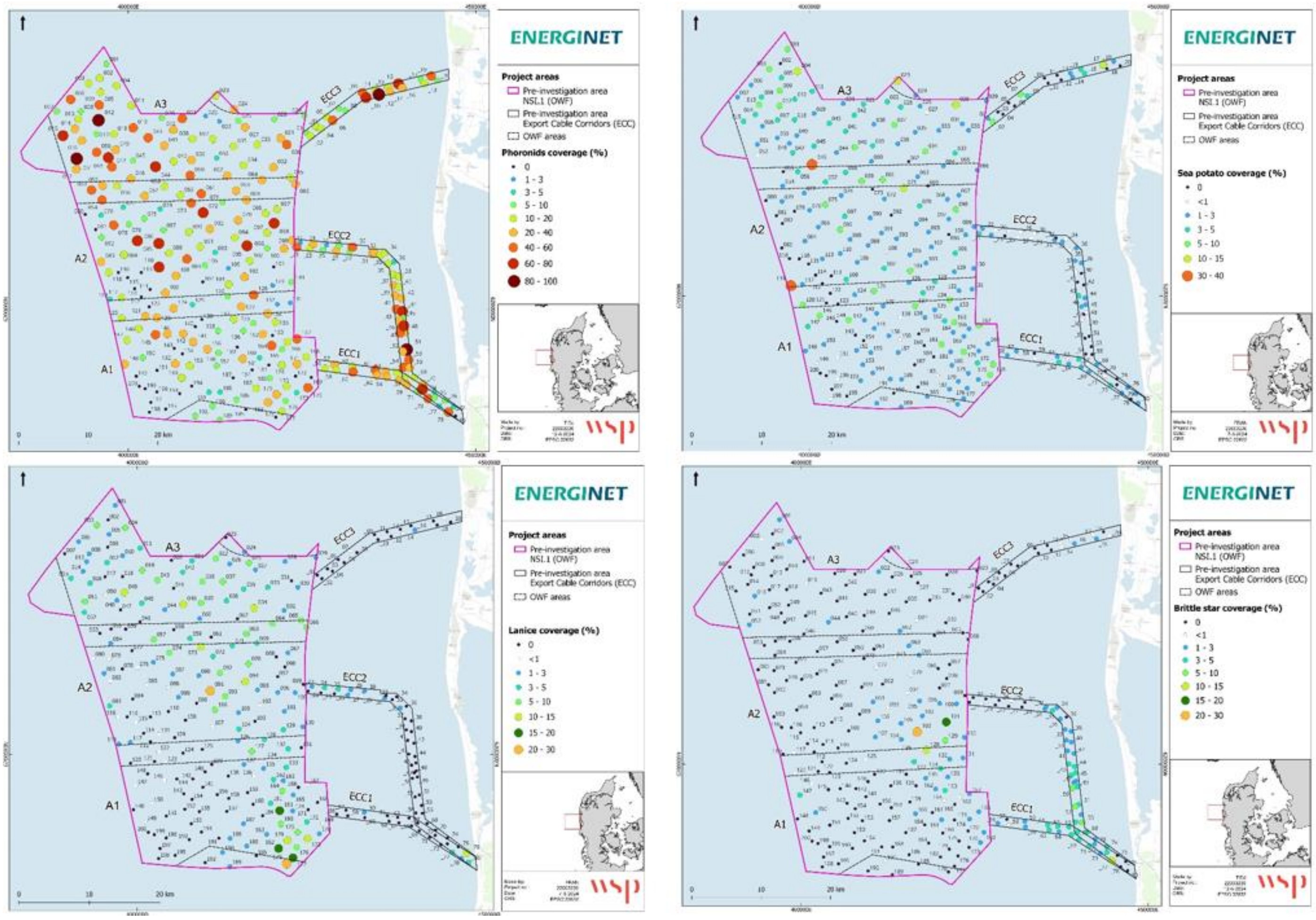

Figure 9-2. Area coverage (%) for the dominating species (Phoronids, sea potato, brittle stars and the bristle worm *Lanice conchilega*) in the two pre-investigation areas for the NSI.1-OWF and export cable corridors (NSI.1-ECC). Data from June 2023 is used. Note that area coverage is given as a range in % at each ROV station in the logbook (see Appendix 3B). As it is not possible to make this figure with the same variance in ranges as in the logbook, the maximum coverage % for the range is used to determine the range used in this figure. Source: (WSP, 2024).

Class distribution (%) of infauna abundance was very similar between the two pre-investigation areas, where Phoronida (taxonomic level is phylum, not class) dominated the abundance, contributing 65 % and 62 % in NSI.1-OWF and NSI.1-ECC, respectively (Figure 9-3). The second most abundant class was Polychaeta (22 % and 23 % in NSI.1-OWF and NSI.1-ECC, respectively), followed by Bivalvia, contributing 5 % and 6 % of the total infauna class abundance in NSI.1-OWF and NSI.1-ECC, respectively (WSP, 2024).

As for the abundance, the infauna class distribution of biomass (%) was similar between the two pre-investigation areas, where Echinoidea (Echinoderms) dominated with contributions of 50 % and 59 % in NSI.1-OWF and NSI.1-ECC, respectively (Figure 9-3). In NSI.1-OWF, Phoronida and Bivalvia contributed 22 % and 17 %, respectively, and in NSI.1-ECC, Bivalvia and Phoronida contributed 19 % and 17 %, respectively. The remaining classes contributed together 11 % and 5 % of the total infauna biomass in NSI.1-OWF and NSI.1-ECC, respectively, where Polychaeta had higher contribution in NSI.1-OWF (5 %) compared to NSI.1-ECC (1 %) (WSP, 2024). Infauna class distribution in the two pre-investigation areas was similar to class distribution reported for Thor OWF (Energinet, 2021).

The dominant fish species observed in the NSI.1 were flatfish, specifically European plaice, common dab, and solenette, which primarily feed on prey in or on the sediment. Generally, flatfish feed on small mussels and worms. Based on the results on infauna observed in NSI.1, the food availability for especially benthic fish seems to be abundant, which helps to explain the high abundance of fish observed in the area.

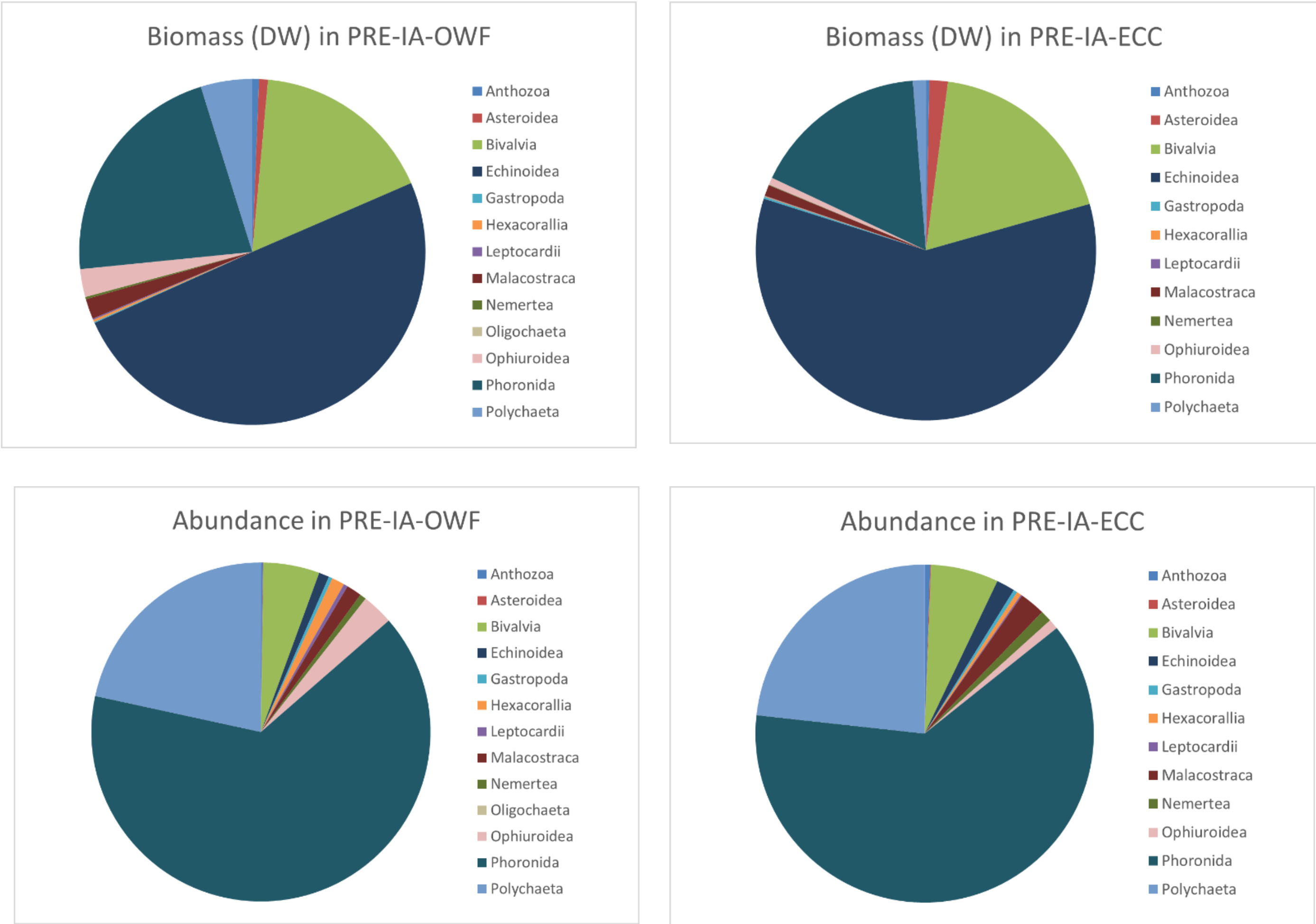

Figure 9-3 The biomass in dry weight and abundance in the pre-investigation area of NSI.1 OWF and ECC. Source: (Energinet, 2024): (WSP, 2024).

10 CONCLUSION

The baseline study is based on a combination of existing literature and thorough investigations of the distribution of fish in of NSI.1. Two fish surveys were conducted in autumn 2023 and spring 2024, respectively, and sampling gear included beam trawl and multimesh gillnets. In areas of hard bottom, trammel net substituted beam trawl to avoid risks of damages to vessel and gear.

According to the data extraction from the database, Fiskeatlas, of fish distribution in Danish waters, 156 different fish species have been observed over the past 100 years in the North Sea. In NSI.1, a total of 71 different fish species have been observed and registered in the Fiskeatlas database. In the OWF area 67 fish species have been registered, and especially in NSI.1-A3, the number of species were high with 56 species. In NSI.1-A2 and NSI.1-A1, a total of 47 and 31 species have been registered over time. A total of 35 different fish species have been registered in the NSI.1-ECC. The observed species include numerous observations of common and economically important species such as Atlantic cod, Atlantic herring, European sprat, whiting and the flatfish species common dab, European plaice, turbot, and European flounder. Also protected species have been observed in NSI.1, including European sturgeon, twaite shad as well as river and sea lamprey.

In the fish survey conducted in this study, a total of 28 different fish species were caught in beam trawl, multimesh gillnet and trammel net. Additionally, a few fish were only identified to family due to crabs having partially eaten the fish (e.g. sprat/herring, sandeel and gobies). In spring 6,951 fish were caught and in autumn 4,554 fish were caught, which combined is 11,505 fish caught in the present study. In terms of biomass, 554 kg fish were caught with 343 kg caught in spring and 221 kg in autumn, respectively.

The majority of landings were flatfish, as flatfish constituted 90 % of the landings in spring catches for all gear types, while flatfish comprised 84 % of the landings in autumn. Especially common dab, European plaice and solenette dominated the catches. This is in accordance with existing literature, stating that common dab is the most abundant species in the North Sea and that solenette – despite its small size (maximum 13 cm) – in some areas of the southern North Sea are so numerous, that it competes for food with common sole. The observed community structure and fish distribution is very common for the North Sea, and most fish species are widely distributed.

This study applied the same types fishing gear (identical beam trawl) and method (speed and duration) as in the Thor fish survey, and therefore it is possible to compare the results. In the Thor pre-investigation area, the abundance of fish pr. 1000 m^2 caught in beam trawl were between 3 and 17 fish for both spring and autumn. For the present study the abundance of fish ranged from 4-72 fish in spring and 1-38 fish pr. 1000 m^2. In addition, the number of beam trawl stations with a high abundance of fish (> 11 fish pr. 1000 m^2) was higher for the present study compared to the fish surveys carried out in the Thor pre-investigation area. In terms of biomass, the results were relatively similar for autumn between the Thor and NSI.1 area; with 257-1368 g of fish pr. 1000 m^2 in the Thor pre-investigation area and 18-1600 g. fish pr. 1000 m^2 in the present study. However, for the spring surveys, the biomass was higher for the NSI.1 area with 195-4024 g fish pr. 1000 m^2 compared to Thor landing 134-736 g of fish for the same area. In short, the abundance and biomass of fish caught in the present study, were higher than those found in the Thor OWF.

The number of fish species caught per station varied from 0 to 12 species for both spring and autumn. The number of species were generally higher in beam trawl compared to multimesh gillnets and trammel net. Compared to the baseline for Thor OWF, the average number of species pr. station were higher in Thor OWF than in the present study. This may be explained by the heterogeneity of the sediment in the Thor OWF area, while the sediments found in the NSI.1 were dominated by large sandy areas. The more divers habitat that are present in an area, the more species are expected. In addition, Thor OWF area had areas of hard substrate, which is known to be one of the habitats hosting the largest biodiversity in Danish marine habitats.

The Shannon Wiener and Evenness index values were generally quite low in this study. Low index values indicate low evenness between species and that few species dominate the catches. This was true, as three species of flatfish generally dominated all landings: common dab, European plaice and solenette.

In the fish surveys conducted here, very few individuals physiologically ready to spawn were caught in NSI.1. A total of two turbot (one male and one female) and six common dab (one female and the rest males) were physiologically ready to spawn. Common dab and solenette, are known to spawn from April to June and March to July, respectively, so May should be within the prime spawning season for these two species. The few spawning individuals indicate that NSI.1 has limited function as spawning area. According to existing literature, Atlantic cod has a general spawning ground along the west coast of Jutland, but more important spawning areas in the Wadden Sea and further west on the edge of the Danish EEZ.

Plaice eggs regularly occur in the project area, but spawning occur further west and especially in the southern North Sea and into the English Channel. Nursery areas for plaice are located along the entire coastline of the Wadden Sea.

Solenette and common dab do not have distinct spawning and nursery areas. They spawn in their entire span of occurrence, and juveniles grow up in the same areas as the adult population occurs. Very few juvenile common dab were caught in NSI.1, suggesting that even though juveniles could be expected in the area, for some reason they prefer other areas. And NSI.1 may not function as nursery area for common dab.

To summarize, the fish distribution and community structure observed in the present study, are very common for large sandy areas that are characteristic of the North Sea. The fish community is dominated by flatfish and the community may even be described as a *Pleuronectes platessa* and *Limanda limanda* community, due to the domination of these two fish species in the silty sandy areas of NSI.1. Flatfish are generally resilient and well adapted to the physical disturbance and changing environment in the North Sea.

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APPENDIX 1

BIODIVERSITY AND EVENNESS BETWEEN SPECIES

Fish fauna was analysed for species richness, Shannon-Wiener Index and Pilou’s Evenness index. Each method is described in further detail below.

SPECIES RICHNESS

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

SHANNON-WIENER INDEX

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

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

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

PIELOU´S EVENNESS INDEX

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

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

H’ is the number derived from the Shannon diversity index and H’max is the maximum possible value of H’ where:

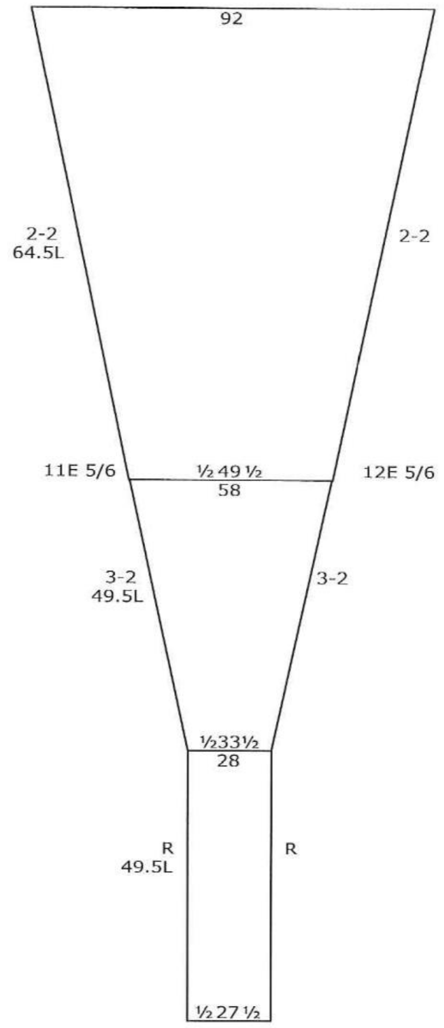
$$H'_{max} = \ln S$$

APPENDIX 2

TRAWL SPECIFICATIONS

Overpanel

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



Skovn Bomtrawl

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

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

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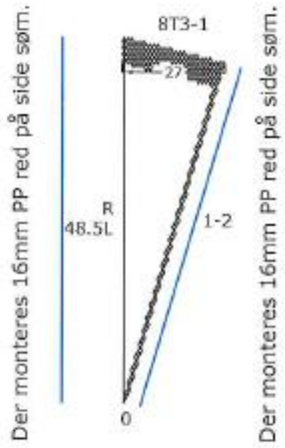
Sidepanel

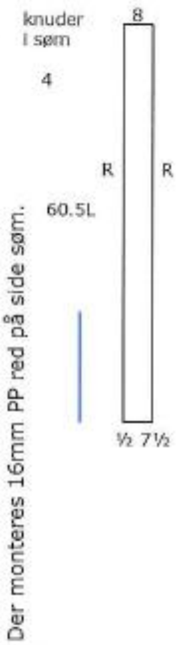
Bryst reb i 12mm Nylon reb.

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



Plade til Underpanel

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



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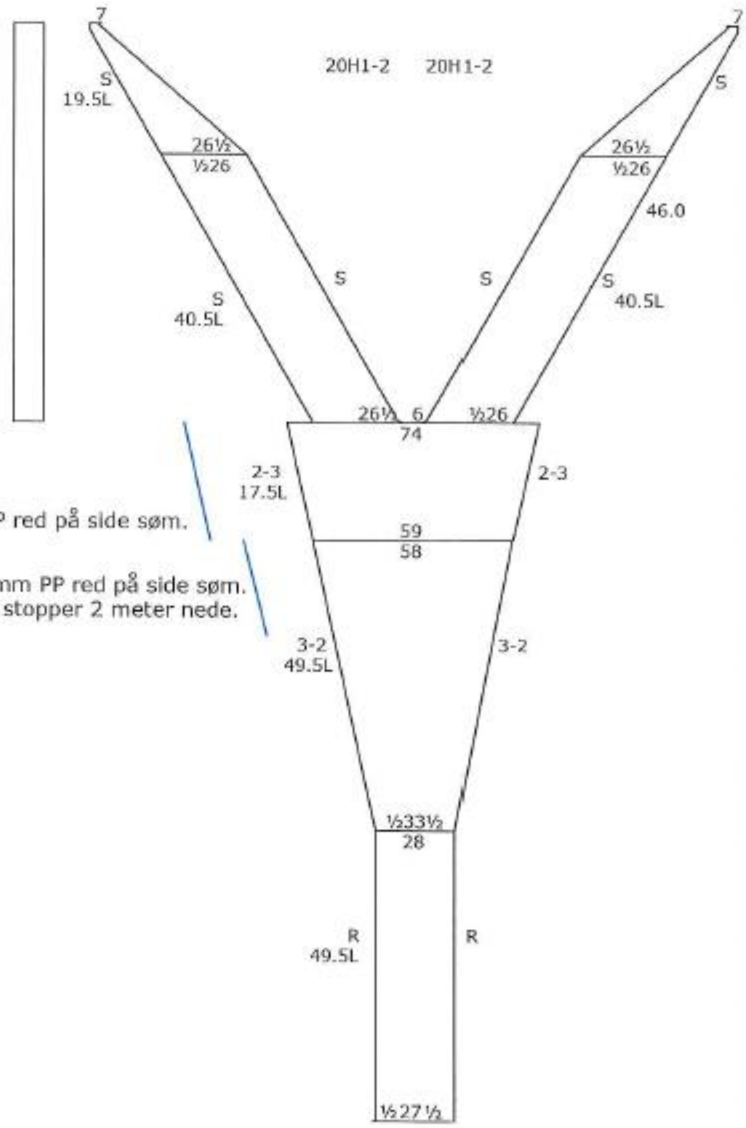
Underpanel

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



Der monteres 16mm PP red på side søm.

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

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