ENERGINET

MARINE ENVIRONMENTAL STUDIES – NORTH SEA I

TECHNICAL REPORT FOR BENTHIC ECOLOGY

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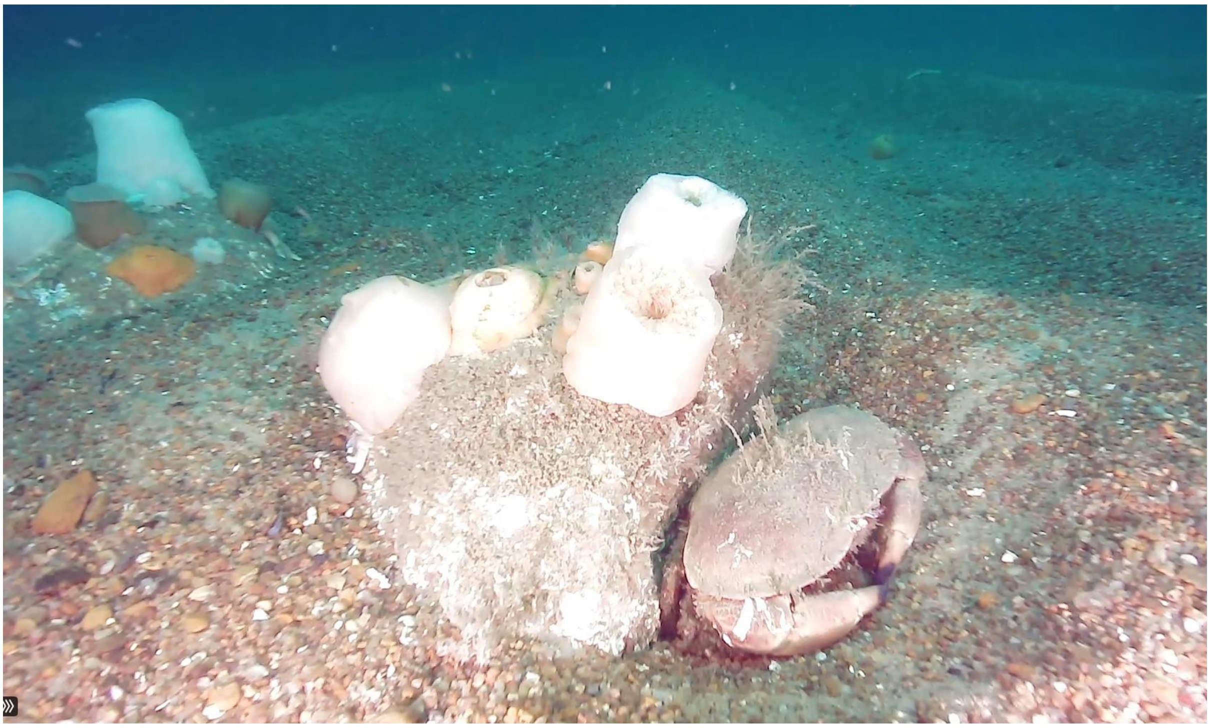

Photo from ROV station OWF_ROV_199

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CONTENTS

Abbreviation	Explanation
A1-3	Subdivision of the North Sea I.1 area into three subareas (OWF areas) separated by shipping corridors (SC)
AMBI index	AZTI Marine Biotic Index (AMBI), was designed to establish the ecological quality of European coasts. The index examines the response of soft-bottom benthic communities to natural and man-induced disturbances in coastal and estuarine environments.
ANOSIM	Analysis of Similarity, statistical analysis
Baseline study	Maps the situation before a project is implemented and is used as basis for the impact assessment of a project (EIA)
Baseline report	Report for the baseline study also called a technical report
CTDO	Conductivity-Temperature-Depth-Oxygen (Optical)
DEA	Danish Energy Agency (Energistyrelsen, ENS)
DKI	The Danish Quality Index for benthic infauna used for assessment of infauna condition
DW	Dry weight
ECC	Export cable corridors
ECC1-3	Three export cable corridors (ECC1-3) from land to the three OWF areas (A1-3)
ECR	= ECC, old name changed after sampling
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency (Miljøstyrelsen, MST)
GSA	Grain size analysis
Habitat	The array of conditions defining the natural environment in which flora and fauna lives, such as sediment type, grain size, complexity, salinity, oxygen conditions etc.
HAPS	Sediment core sampler. Samples a cylinder of sediment in soft to loose seabed sediments. Sampling is not possible on hard, stony bottom
Landfall	Where the cable transfers from sea to land
LARS	Launch and Recovery Systems
LOI	Loss of ignition
OWF	Offshore Wind Farm
OWF area	Offshore Wind Farm area (A1-3)
MES	Marine Environmental Surveys/Studies
Nature type	= benthic community. A nature type is the biological, benthic community living on a sediment type observed by ROV. The map of benthic communities/nature types is made from the sediment map overlayed by the observed benthic species observed on the ROV video for each sediment type
NOVANA	The Danish national surveillance program for the aquatic environment and nature (NOVANA)
NSI.1	North Sea I.1. The name of the offshore wind farm area (OWF) including all three subareas (A1-3) and the shipping corridors in between the three subareas (= NSI.1-OWF)
Pre-investigation area	Areas wherein the two benthic surveys have been conducted. The pre-investigation area is divided into two areas. 1. The pre-investigation area are the three wind farm areas (OWF-A1, OWF-A2 and OWF-A3) and the shipping corridors between the three OWF areas (NSI.1-OWF) 2. The pre-investigation area for the three export cable corridors (ECC1, ECC2 and ECC3) (NSI.1-ECC)
NSI.1-OWF	The pre-investigation area for the three wind farm areas (A1-3) and the shipping corridors in between
NSI.1--ECC	The pre-investigation area for the three export cable corridors (ECC1, ECC2 and ECC3)
psu	Practical salinity unit
ROV	Remotely Operated Underwater Vehicle
RBMP	River Basin Management Plan
SC	Shipping corridors in between the OWF areas A1-3
Shannon-Wiener index	The Shannon-Wiener Index gives a measure of the diversity of species in a community
SIMPER analysis	Similarity Percentage Analysis
SSS	Side scan sonar
Subareas	The pre-investigation area for NSI.1 OWF is subdivided into three subareas OWF area A1-3, and the pre-investigation area for the export cable corridors consists of three subareas = ECC1-3
TOC	Total Organic carbon given as % of DW
WFD	Danish Water Framework Directive
WW	Wet weight
WP	Work Package

1 SUMMARY

INTRODUCTION

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.

In order 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 (from now on NSI.1) has a total area of 1.400 km^2, which is divided into three sub-areas (From now on OWF area A1, A2 and A3) planned for offshore wind farms (see Figure 1-1). The NSI.1 is located 20-80 km off the coast of West Jutland and from each of the three subareas, there will be corridors for export cables connecting the offshore wind farms to the onshore grid (ECC1-3).

PROJECT AREA

This baseline study for the North Sea I.1 offshore windfarm area (OWF) was conducted in two pre-investigation areas – one for the NSI.1 OWF area (NSI.1-OWF) and one for the three export cable corridors (NSI.1-ECC). Furthermore, the pre-investigation area for NSI.1 included three OWF subareas called OWF area A1-3. The pre-investigation areas for the three cable corridors (NSI.1-ECC) included three export cable corridors called ECC1-3. Area definitions are given in Figure 1-1 below.

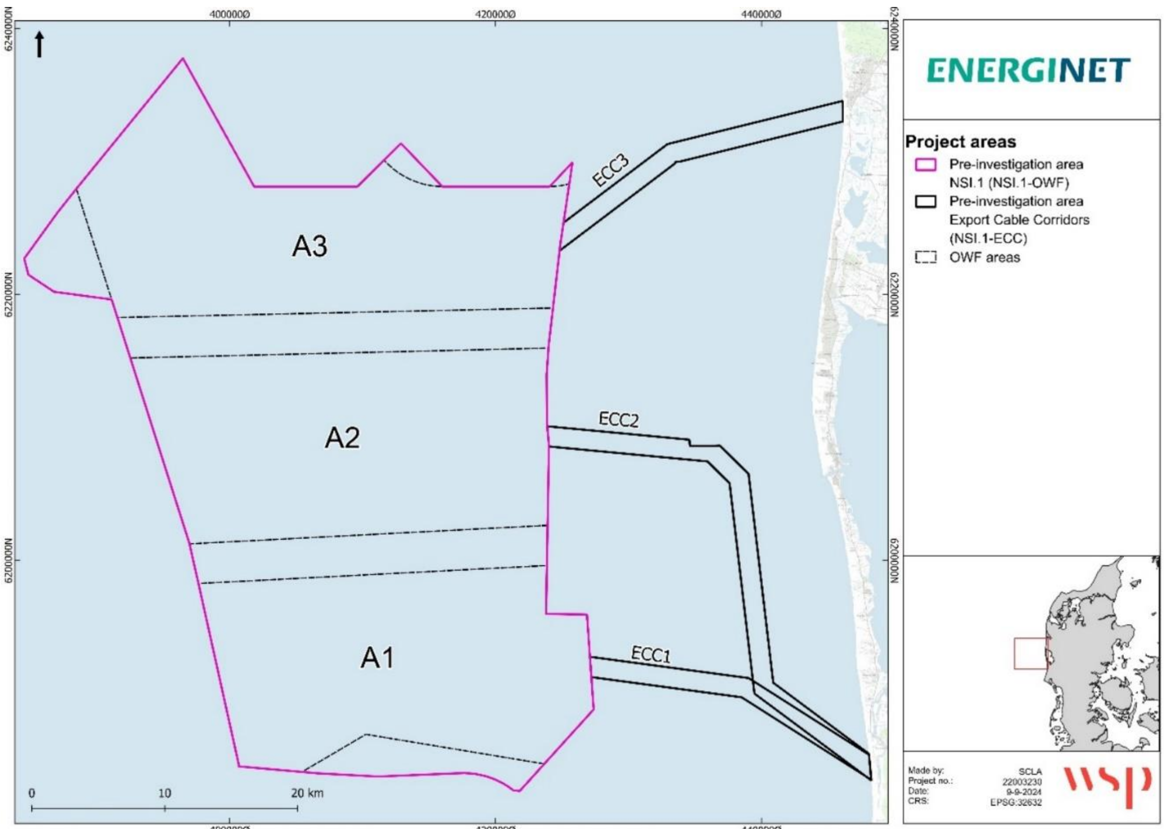


Figure 1-1. Area definitions for the North Sea I.1 baseline study for benthic ecology.

METHODOLOGY

Two surveys were conducted in the two pre-investigation areas for North Sea I.1 in this baseline study: one survey was conducted in May and one in June of 2023. In total, 892 stations were sampled within the pre-investigation areas. Sampling activities at the stations included collection of ROV video of the seabed; CTDO-profiles to measure temperature, salinity, and oxygen in the water column; HAPS sediment cores for grain size analysis, chemical analysis of pollutants and characterization of infauna. Furthermore, sediment types and benthic communities were mapped in the two pre-investigation areas based on side scan sonar data collected during the geophysical surveys in April to September 2023, and visual verification of the seabed from video recording of the seabed at the ROV stations collected during the two surveys.

EXISTING DATA

Existing data presented in this baseline report are based on various sources: the geophysical surveys of NSI.1, the Danish environmental monitoring program i.e. the NOVANA program (TOC, nutrients, pollutants, Eelgrass, macroalgae and infauna stations), the Danish Environmental Portal and data from local OWFs and projects: Thor OWF, Vesterhav Syd OWF, Vesterhav Nord OWF and Horns Rev III OWF, the EIA report of coastal nourishment (0-8 m depth) along the West Coast of Denmark from Nymindegab to Lodbjerg and sand extraction site 578-AA Husby Klit. Survey data were compared to existing data from the area when available and relevant.

Results from the surveys for the relevant parameters are presented in the following:

ABIOTIC DATA

CTDO profiles of salinity, temperature, and oxygen concentrations in mg/l and % saturation down through the water column were sampled both in May 2023 at infauna stations and in June 2023 in the two pre-investigation areas. Comparing May and June CTDO-profiles showed a generally well mixed water column and a few stations with weak stratification in May. In June, a stratified water column was observed, except for the shallowest stations close to the coast where wave action continuously mixes the water column. The CTDO profiles in June showed that the water column was generally stratified with two separate water masses with different salinities and temperature and a mixing zone in between the two water masses, in which temperature and salinity changes rapidly. This is referred to as a thermocline for temperature and halocline for salinity. The thermocline is observed between 9-15 meters of depth and the halocline is observed between 9-14 meters of depth at CTDO station OWF_41. Stratification of the water column is only a problem for benthic flora and fauna if it hinders the diffusion of oxygen to the seabed and thereby causes oxygen deficiency. However, bottom oxygen conditions (approximately 1 m above seabed) were good at all stations in both May and June (i.e. >6.6 mg O_2/l). Moderate oxygen deficiency (2-4 mg O_2/l) and severe oxygen deficiency (<2 mg O_2/l) were not observed at the seabed at any of the sampled CTDO stations in May or June.

In conclusion, quite similar conditions were observed in the three OWF areas (A1-3) and in the three export cable corridors (ECC1-3) with small differences generally related to depth. In general, the three OWF areas (A1-3) and export cable corridors (ECC1-3) showed increasing salinity and decreasing temperature and oxygenation in a north-going direction. However, the differences are small and are not observed as differences in the benthic communities.

SEDIMENT TYPES

The overall area coverage of the seven observed sediment types in the two pre-investigation areas is presented in Figure 1-2. In general, sediment type 1a/1b – “silty sand” and sediment type 1b – “sand” dominated the seabed in both pre-investigation areas and all other sediment types covered less than 1.2 % of the areas.

OWF areas A2 and A3 were dominated by sediment type 1a/1b “silty sand”, with 65 % and 86 % area coverage, respectively, whereas OWF area A1 had 49 % of “silty sand” and 50 % of “sand”. Sediment type 1b – sand, covered 33 % and 15 % in A2 and A3, respectively. All other mapped sediment types constituted 1.2 % or less of the three OWF areas (A1-3). Sediment types with large stones (2b, 3 and 4) were very scarce in both A1 and A2 (≤0.5 %) and very rare in A3 (≤0.0001 %) (see Table 5-3). The sediment type map in Figure 1-2 shows, that the stony sediment types with small stones (pebbles) (<10 cm; sediment type 2a) or large stones (>10 cm; sediment type 2b, 3 and 4) were present mainly in the southwestern part of both OWF area A1 and A2. All three cable corridors (ECC1-3) were dominated by sediment type 1a/1b – "silty sand" with area coverage ranging from 58-96 % (Table 5-3). Sediment type 1b – "sand" covered from 4-41 % and all other sediment types covered less than 0.8 %.

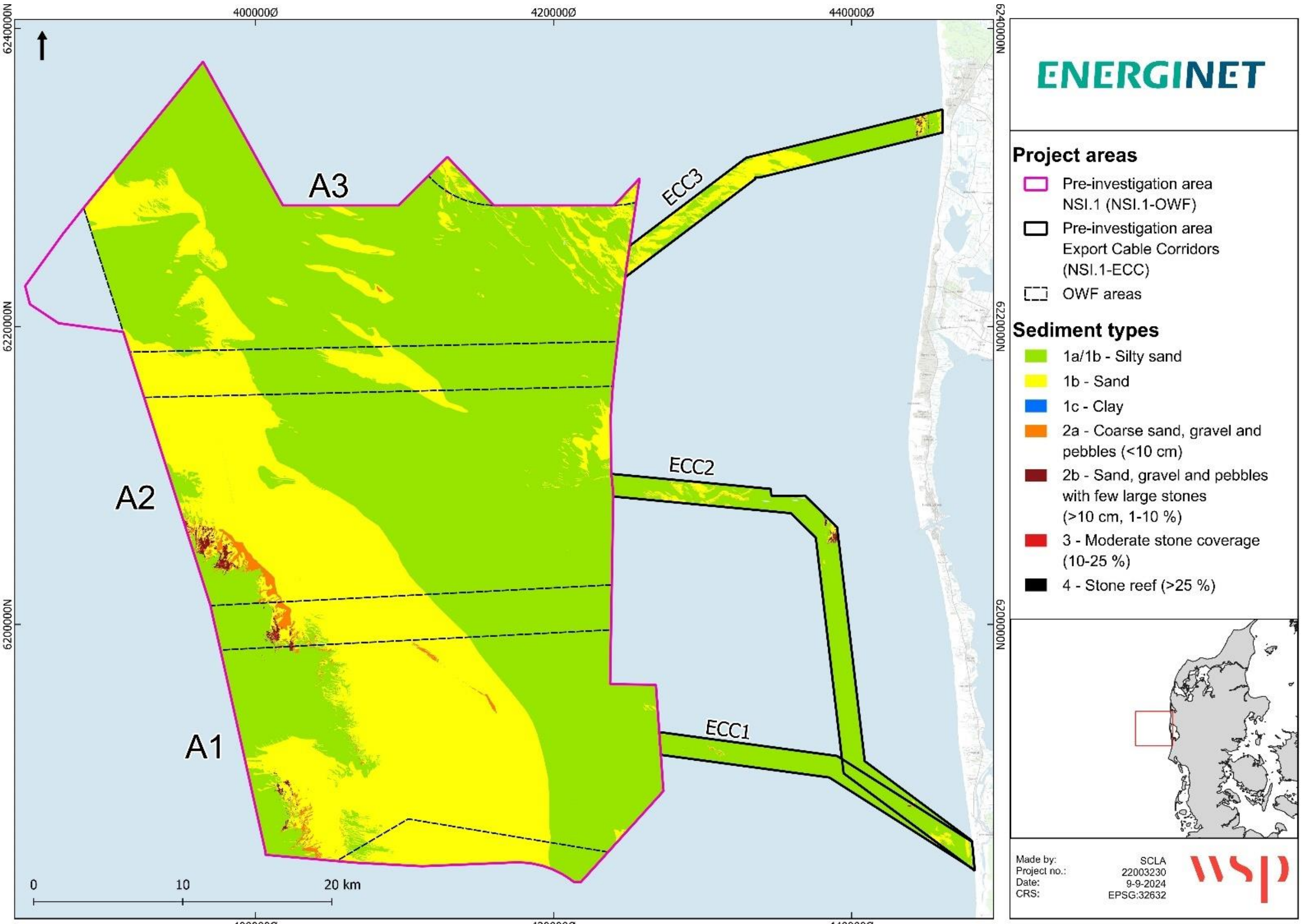


Figure 1-2. Sediment type map for the seabed (surface layer) in the two pre-investigation areas and subareas (three OWF areas (A1-3) and three export cable corridors (ECC1-3)).

PHYSICAL PARAMETERS (GRAIN SIZE/TOC)

Grain size: All HAPS samples analysed for grain size in this study were dominated by "sand", indicating that the two pre-investigation areas - and therefore also the subareas (OWF area A1-3 and ECC1-3) were very similar. Comparing the uniformity coefficient (Cu) = d60/d10 between the two pre-investigation areas shows that the particle sizes in the sediment were generally very uniform with a Cu<4. Only one sample in ECC3 at 22.6 m depth, had a Cu of 4.88 (ECC_GSA_A10_02), which is still below a Cu of 6 (threshold for low uniformity), indicating relatively uniform particle sizes at this station also.

The sediment type map in Figure 1-2 indicates, that a large part of the seabed consists of "silty sand" areas (sediment type 1a/1b), which consists of sand with a thin layer of silt covering the surface, which is mixed down into the upper few cm of the sediment. The dominance of "sand" (sediment type 1b) in the grain size analyses is explained by these samples being analysed as a mix of the upper 0-20 cm of the HAPS core sample, which is mainly sand, since the silt in this study is present mainly in the upper few centimeters of the sediment. It is therefore not possible, in this baseline study, to directly compare the sediment type map with the grain size analyses. The silt covering large parts of the sandy seabed in the two pre-investigation areas, likely originates from outflow from local fjords, the Wadden Sea and German river outlets. This input likely to varies greatly with weather, currents and between years.

TOC: TOC concentrations were very low and ranged from 0.03 to 0.32 % TS for all samples from both pre-investigation areas. The TOC concentrations for the pre-investigation area of NSI.1 OWF (OWF areas A1-3) ranged from 0.10 to 0.24 % TS and from <0.1 to

0.32 % TS for the pre-investigation area of the export cable corridors (ECC1-3). Overall, the two pre-investigation areas had very low and similar TOC concentrations. Similarly, TOC was very low and with very small and insignificant differences when comparing the three OWF areas (A1-3) and the three export cable corridors ECC1-3. The similarity in TOC between stations in this study is caused by the highly dynamic seabed and the continuous mixing of the seabed in the North Sea.

NUTRIENTS

Nutrients were not sampled and analysed in this study but are presented based on existing data from the surrounding NOVANA stations. Total nitrogen (TN) concentrations ranged between 50-2307.6 µg/l at the six NOVANA stations and total phosphorous (TP) concentrations ranged between 3-340 µg/l. The highest concentrations of TN and TP was measured at the station closest to the coast (91300001 – Vesterhavet), which is to be expected as the nutrient concentration is generally higher near the coast, due to e.g. run-off from land. There are no threshold values for total nitrogen (TN) or phosphorous (TP) but comparing with measurements in the open inner Danish waters, the concentrations in the pre-investigation areas Table 4-5 are generally low and comparable to what is normally measured in the North Sea.

POLLUTANTS

Pollutants measured in the sediment samples from the Chemical HAPS stations were assessed for exceedances of relevant threshold values as listed below. Concentrations of pollutants below threshold values are considered not to cause harm to the marine environment.

Chemical parameters analysed:	**Applied threshold values, which are prioritized in the following order:**
• Total Organic Carbon (TOC) by Loss of Ignition (LOI) • Heavy metals (10): Arsenic (As), lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), silver (Ag), vanadium (V) and zinc (Zn) • PAH compounds (20): Naphthalene, acenaphthylene, acenaphthene, fluoren, phenanthrene, anthracene, fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(b+j+k)fluoranthene, benzo(e)pyrene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene, benzo(g,h,i)perylene, 1-methylnaphthalene, 2-methylnaphthalene, dimethylnaphthalene, trimethylnaphthalene • Phenols (2): nonylphenols and 4-tert-octylphenol • Phthalate (3): Benzyl butyl phtalate (BBP), bis(2-ethylhexyl) adipate (DEHA) and Bis(2-ethylhexyl) phthalate (DEHP)	1) NEQS: National Environmental Quality Standards, Danish EPA 2) NQC: National Quality Criteria, Danish EPA 3) EAC: The Environmental Assessment Criteria, OSPAR 4) ERL: Effect Range Low, US EPA

The sampling stations were divided into two groups, related to which laboratory analysed the samples for pollutants, i.e. Eurofins (EF, 15 stations) and Aarhus University (AU, 14 stations) (see Figure 3-5). At the EF-stations, the samples were analyzed for heavy metals (8 different pollutants) and PAH's (20 different pollutants). The AU-stations were analyzed for phenols (2 different pollutants), phthalates (3 different pollutants) and TOC. In total, the concentrations of 35 pollutants were measured and a total of 29 stations/samples were analysed for pollutant concentrations, 10 in the pre-investigation area for NSI.1-OWF and 19 in the pre-investigation area for the cable corridors (NSI.1-ECC). In the following, the four methylnaphthalenes are considered as one compound, as the threshold value is for the sum of these four individual compounds.

Exceedances of applied threshold values were observed for 8 pollutants (heavy metals (1), PAH-compounds (5) and phenols (2)). As the only pollutant, the heavy metal arsenic, exceeded the threshold values at all measured stations. The PAH-compounds that exceeded threshold values were anthracene, benz(a)anthracene, chrysene, naphthalene and methylnaphthalenes (sum). Anthracene, methylnaphthalenes (sum), chrysene and benz(a)anthracene either exceeded thresholds or were below detection limits at all measured stations in all OWF- and ECC areas. Naphthalene exceeded the threshold value at one station in OWF area A2 as well as in ECC2 (at 13 % of all measured stations). For the two phenols; nonylphenols (sum) exceeded the threshold at one or more stations in OWF area A1, A3, in ECC2 and ECC3 (57 % of all measured stations), and 4-tert-octylphenol exceeded the threshold at one or more stations in all OWF areas (A1-3) and in ECC2 and ECC3 (71 % of all measured stations). Exceedances of applied threshold values for PAH's and phenols were observed due to very low TOC content in the sediment (between 0.03 to 0.32 %), as the thresholds are calculated from the TOC content of the sediment. The threshold values are calculated from the TOC concentration in the sediment, and low TOC results in correspondingly low threshold values and correspondingly more exceedances of the threshold values or threshold values below detection limit. This calculation method makes it difficult not to exceed threshold values in marine areas with very low TOC content, as is the case for the North Sea.

The highest pollutant concentrations were found in the two export cable corridors EEC2 and ECC3, where the sediment type in the HAPS samples was "silt", and a relationship between the sediment type and pollutant concentration was observed for some of the pollutants. However, no correlation between station depth or analysis depth in the HAPS sediment core (0-2 cm contra 0-20 cm sediment of the HAPS core sample) was observed.

Furthermore, due to very low TOC contents (between 0.03 to 0.32 %), the estimated threshold for several of the pollutants based on the TOC measurements, was very low and often below the detection limit for the laboratory analysis. This makes it difficult not to exceed threshold values in marine areas with very low TOC content, as is the case for the North Sea. It is debatable whether this method is most appropriate, and exceedances of the pollutants were therefore compared with threshold values, where a TOC of 5 % was applied, as described in the Danish consolidation act BEK. no. 796 of 13/06/2023. When applying a TOC of 5 %, only methylnaphthalenes (sum) and arsenic (the threshold is not calculated based on TOC) exceeded the threshold values in the three ECC areas. Within the three OWF areas (A1-3) only four pollutants (including arsenic) exceeded the threshold values, compared to the eight pollutants, when using the low average TOC of 0.17 %.

BENTHIC COMMUNITIES (NATURE TYPES)

The benthic community/nature type describes the distribution of benthic flora and fauna communities in an area. The nature type is determined by combining the observed sediment types with the associated benthic flora and fauna communities observed at the ROV stations. E.g. sediment type 1b – "sand", becomes nature type 1b - "Sand-bottom community" and changes from relating to the sediment type (geology), to relating to the benthic flora and fauna organisms present in the nature type (biology).

Four different benthic communities/nature types were observed in the two pre-investigation areas and they are listed in Table 1-1 and Table 1-2 below. Table 1-1 shows the area coverage of the benthic communities in the two pre-investigation areas and related subareas (OWF area A1-3 and ECC1-3) in km^2 and in %.

Table 1-1. Area coverage of the benthic communities (nature types) given in percent and in km² in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) and subareas (OWF area A1-3 and ECC1-3). Substrate type 1c is included in nature type 1a/1b.

Benthic communities (Nature type)/ Areas	Soft-bottom (1a/1b)	Sand (1b)	Mixed (2a + 2b)	Hard-bottom (3 + 4)
Pre-investigation area for NSI.1 OWF (NSI.1-OWF)	901.9 km^2 65 %	472.1 km^2 34 %	12.9 km^2 0.9 %	0.4 km^2 0.03 %
A1	178.9 km^2 49 %	183.5 km^2 50 %	3.6 km^2 1.0 %	0.03 km^2 0.007 %
A2	260.6 km^2 65 %	133.4 km^2 33 %	6.5 km^2 1.6 %	0.2 km^2 0.06 %
A3	342.1 km^2 86 %	58 km^2 15 %	0.1 km^2 0.04 %	0.0008 km^2 0.0002 %
Pre-investigation area for export cable corridors (NSI.1-ECC)	98.02 km^2 83 %	19.1 km^2 16 %	0.8 km^2 0.7 %	0.3 km^2 0.2 %
ECC1	32.6 km^2 96 %	1.3 km^2 4.0 %	0.1 km^2 0.4 %	0.0005 km^2 0.001 %
ECC2	55.5 km^2 92 %	4.2 km^2 7 %	0.5 km^2 0.8 %	0.1 km^2 0.2 %
ECC3	20.4 km^2 58 %	14.5 km^2 41 %	0.3 km^2 0.8 %	0.1 km^2 0.3 %

The soft-bottom- and the sand-bottom communities dominated the two pre-investigation areas and all subareas. The other benthic communities (nature types), i.e. mixed community (Nature type 2) and the hard-bottom community (Nature type 3/4), were very scarce with low coverage in both pre-investigation areas of less than 0.9 % (Table 1-1). The benthic community map in Figure 1-3 below shows that the mixed and hard-bottom communities were present in the stonier southwestern part of the pre-investigation area of NSI.1 OWF, corresponding to subareas A1 and A2 and in small patches in the three cable corridors (ECC1-3).

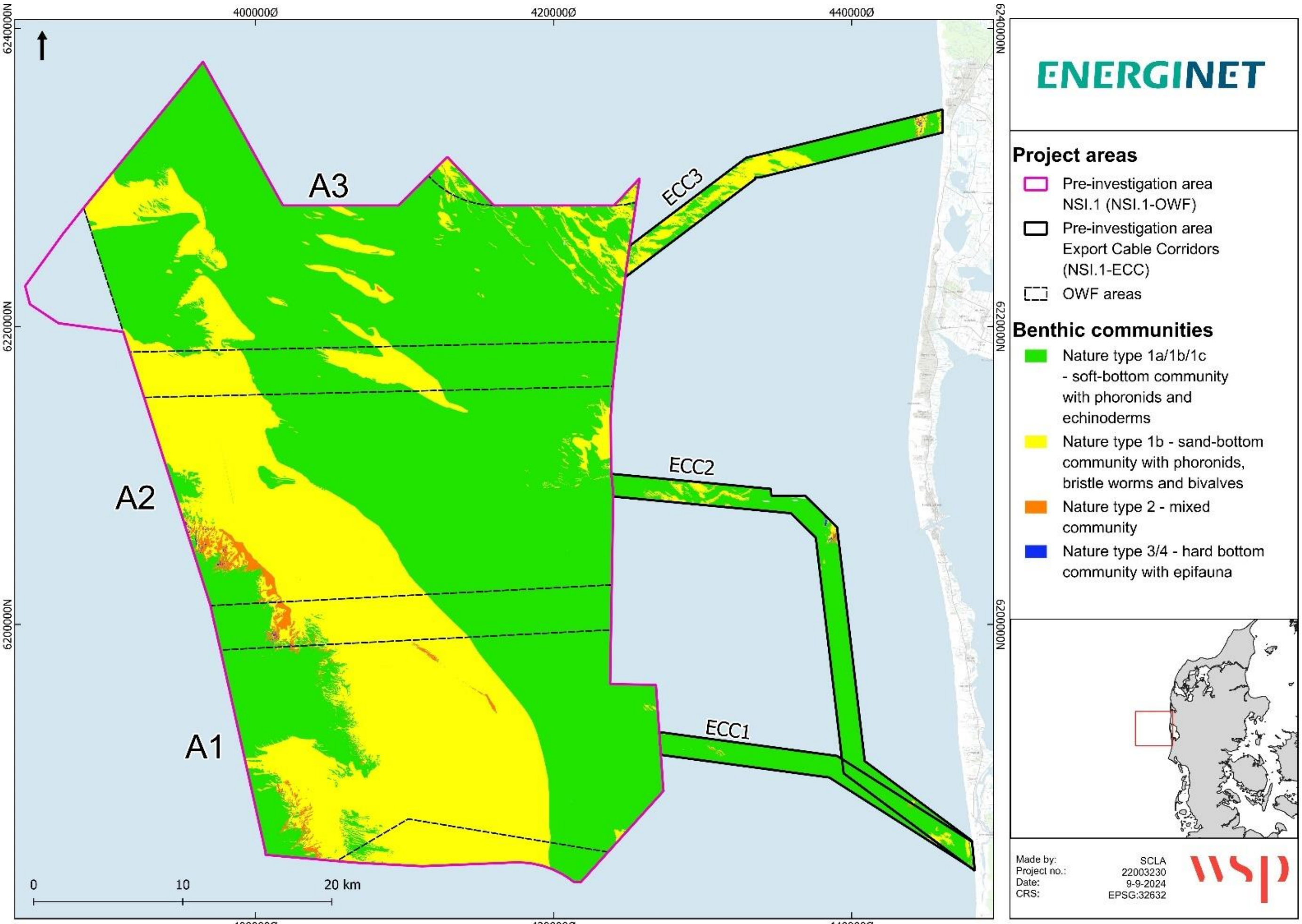


Figure 1-3. Map of the benthic communities (nature types) in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) and related subareas (OWF area A1-3 and export cable corridors ECC1-3). Based on sediment types in Figure 1-2 and observations of the associated benthic flora and fauna communities on the ROV video stations.

The dominating benthic flora and fauna species/taxa of the observed benthic communities (nature types) are listed in Table 1-2 below.

Table 1-2. Benthic communities (nature types) observed in the two pre-investigation areas and the dominating benthic flora and fauna species.

Nature type and benthic community	Dominating fauna species	Dominating flora species
Nature type 1a/1b – Soft-bottom community	Horseshoe worm (*Phoronis* sp.) Echinoderms – sea potato (*Echinocardium* spp.) and brittle star (*Ophiura* sp.) The bristle worm *Lanice conchilega*	No living benthic flora species were observed on this nature type.
Nature type 1b – Sand-bottom community	Horseshoe worm (*Phoronis* sp.) The bristle worm *Lanice conchilega* Bivalves such as common cockle (Cerastoderma sp.) razor clam (*Phaxas pellucidus*) and rayed trough-shell (*Mactra stultorum*)	Very few crust algae on single stones: red crust (*Hildenbrandia* spp.) and brown crusts
Nature type 2 – Mixed community	Mix of nature type 1b and 3/4	Minor finding of Brown crust
Nature type 3/4 – Hard-bottom community	Sea anemones (*Metridium senile, Urticina felina*), leafy bryozoans (*Flustra foliacea*), dead man´s fingers (*Alcyonium digitatum*), hydroids, calcareous tube worms (*Pomatoceros triqueter*), white weed (*Satularia cuppresina*), seasponges and tunicates sp.	Few crust algae: red crust (*Hildenbrandia* spp.) and brown crusts

BENTHIC FLORA

Benthic flora includes macroalgae and seagrasses. Only macroalgae were observed in the two pre-investigation areas, as the North Sea coast is too dynamic for seagrasses. Macroalgae were found at four ROV stations in the pre-investigation area for NSI.1 OWF and not in the export cable corridors. Observed macroalgae included only small, single specimens of red algae crusts (*Hildenbrandia* sp.) and brown crusts found at depths between 18.8-25.8 meters with very low area coverage (<1-2 %). The few observed crust algae were found in the southern OWF area A1 and in the corridor between OWF area A1 and A2. This is likely due to a very limited occurrence of crust algae in the area, and the fact that very few ROV stations were placed on seabed with large stones (>10 cm) suitable for macroalgae attachment (<0.2 % of NSI.1-OWF, Sediment type 2b, 3 and 4).

BENTHIC FAUNA

Benthic fauna refers to invertebrates associated with the seabed surface (epifauna) or living buried in the seabed (infauna).

EPIFAUNA

In total, 56 taxa of benthic fauna were observed on ROV video of the seabed in the two pre-investigation areas in this baseline study. In the pre-investigation area for the NSI.1 OWF, a total of 49 species was observed, and slightly fewer species were observed in the pre-investigation area for the export cable corridors (ECC1-3), i.e. 37 taxa. The sediment type is the key determinator for the species composition of epifauna. The species composition found in the different sediment types in this study, is not different between the two pre-investigation areas. Therefore, the total number of different taxa found in each sediment type can potentially be found on the same sediment type in all subareas of this baseline study. The difference in taxa between the subareas (A1-3 and ECC1-3) should therefore not be over-emphasised, except when based on differences in area coverage of the sediment types between the subareas. Species number was 42, 29 and 28 for OWF area A1, A2 and A3, respectively. The number of species increases with the number of sediment types observed in an area. The number of taxa observed was highest in the A1 OWF area (42 taxa), since this was the only area where sediment types with large stones (>10 cm, sediment type 2b, 3 and 4) were present on the ROV stations, and thus the only area with additional species from the hard-bottom community. The taxa number was relatively similar in the three export cable corridors (28, 31 and 24 taxa), only slightly higher in ECC2 (31 taxa), which was likely due to the presence of more stony areas in ECC2.

The same range of fauna area coverage % was observed in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC). The main reason for this was the dominance of horseshoe worm (*Phoronis* sp.), which was present with a high percent area coverage on both sediment type 1a/1b – "silty sediment" and sediment 1b – "sand", which dominate the two pre-investigation areas. Comparing the total fauna coverage in the three OWF areas (A1-A3), area coverage was generally lowest in the shallower and more dynamic A1 OWF area and within the same range for A2 and A3. Similarly, the total fauna coverage in the three export cable corridors was also within the same coverage ranges, with ECC1 being slightly lower.

The dominating species observed at the ROV stations were horseshoe worm (*Phoronis* sp., 0-90 % area coverage), the tube-living bristle worm *Lanice conchilega* (0-25 %), sea potato (*Echinocardium* spp., 0-40 %) and brittle star (*Ophiura* sp., 0-30 %) - all species feeding on silt or organisms living in the silt.

INFAUNA

In the two pre-investigation areas, a total of 11 infauna stations (6 stations in NSI.1-OWF (infauna station A_01-06) and 5 stations in NSI.1-ECC (infauna station A_07-11) were investigated for infauna. Each infauna station constituted an area of 1x1 km within which 42 HAPS samples were collected – i.e. a total of 252 and 210 infauna HAPS samples in NSI.1-OWF and NSI.1-ECC, respectively.

In total, 109 infauna species were identified in NSI.1-OWF, and the number of species found per infauna station ranged from 28-56 species. In NSI.1-ECC, a total of 93 species were found, and the number of species found per infauna station ranged from 36-51 species.

In total, 13 taxonomical classes were found in the pre-investigation area of NSI.1-OWF, and 12 classes were found in NSI.1-ECC as Oligochaeta (worms) was not found in NSI.1-ECC. In both pre-investigation areas, Polychaeta (bristle worms) was the most represented class with 45 and 39 species in NSI.1-OWF and NSI.1-ECC, respectively. Malacostraca (crustaceans) had the second highest species numbers in both areas, with 26 (OWF) and 20 species (ECC), followed by Bivalvia (molluscs) with 19 (OWF) and 17 species (ECC).

In general, there was high variation in terms of species numbers, abundances (ind./m^2), and biomasses (g DW/m^2) of infauna between the 42 samples collected at each infauna station in both pre-investigation areas. There was not always a correlation between high abundance and high biomass, and some samples/stations had high abundances but low biomass and vice versa. A high biomass but low abundance would e.g. be the case when molluscs were present. The number of species per sample varied between 0-18 in NSI.1-OWF (average of 7.4 species per sample) and ranged from 0-15 in NSI.1-ECC (average of 7.1 species per sample).

Infauna abundances at stations in NSI.1-OWF ranged from 162-6009 ind./m^2, with an overall average of 2473 ind./m^2per station, whereas abundances found at stations in NSI.1-ECC ranged from 420-3267 ind./m^2, with an overall average of 2003 ind./m^2 per station. There was a clear difference in abundance of infauna between eastern and western located stations in NSI.1-OWF, where the three eastern located stations had the highest abundances of infauna, compared to the three western located stations. Hence, the abundance at stations within each OWF subarea (A1-3) varied since each OWF subarea had one eastern and one western infauna station. The observed difference between the western and eastern stations are explained by more sandy sediment in the western part and more silty sediment in the eastern part and the cable corridors (see Figure 1-2 and statistics section below Figure 1-2).

In general, the average biomass per station was higher at stations in the pre-investigation area of NSI.1-ECC compared to NSI.1-OWF. In NSI.1-OWF, average infauna biomass at the six infauna stations ranged from 18-204 g DW/m^2 (overall average of 113 g DW/m^2) and 30-389 g WW/m^2 (overall average of 229 g WW/m^2), respectively. As for the abundance and number of species, there was in general a higher infauna biomass at the eastern located stations in NSI.1-OWF, compared to the western located stations in the area. In NSI-ECC, the average infauna biomass at the five stations ranged from 41-229 g DW/m^2 (overall average of 163 g DW/m^2) and 89-491 g WW/m^2 (overall average of 339 g WW/m^2).

Abundance and biomass were dominated by the same infauna taxonomical classes in the two pre-investigation areas, where Phoronida dominated the abundance, followed by Polychaeta and Bivalvia. In terms of biomass, Echinoderms (Echinoidea) dominated, and Phoronida and Bivalvia were present in similar numbers.

The difference in infauna species number, abundance and biomass between the infauna stations in the subareas (OWF area A1-3 and ECC1-3) were low, and lower than the natural variation observed between individual samples within each infauna station area (of 1x1 km). In general, species numbers at infauna stations were similar in OWF area A1-3 and ECC1-3. Abundance was highest in OWF area A3 and lowest in A1, while the highest abundance was found in ECC2 and lowest in ECC3. Finally, biomasses were similar for OWF area A1-2 and highest in A3 and relatively similar for the three export cable corridors (ECC1-3).

Species diversity in the pre-investigation areas was investigated by the Shannon-Wiener diversity index (H'). The average H' for NSI.1-OWF and NSI.1-ECC including all sampled stations was 1.13 ± 0.19 SE and 1.19 ± 0.17, which is lower than reported for the inner Danish waters, but within range of what has previously been reported for the North Sea (NOVANA data).

The AMBI index in NSI.1-OWF had an overall average of 1.35 (range from 1.07 to 1.86), which classifies the overall area as slightly disturbed and the infauna community as unbalanced. In NSI.1-ECC the overall average of AMBI was 1.20 (range from 0.84 to 1.39), which classifies the overall area as undisturbed and an impoverished infauna community. AMBI values in the two areas NSI.1-OWF and NSI.1-ECC are within the range of AMBI values found in other areas of the North Sea (NOVANA data).

The Danish Quality Index (DKI) can be used to assess the environmental state/condition of a marine area in accordance with EU's Water Framework Directive. DKI combines factors such as diversity (expressed as Shannon-Wiener diversity) and the sensitivity level in the infauna community (AMBI) and has a value between 0 (poor environmental status) and 1 (good environmental status). NSI.1-OWF and NSI.1-ECC had an average DKI of 0.43 ± 0.04 SE and 0.49 ± 0.03 SE, respectively, indicating "moderate ecological status" of the marine area. The average DKI values from the two areas are comparable to DKI values found for NOVANA stations in the area but lower than the DKI values reported for Thor OWF (ranging from 0.78 to 0.83) and the average DKI value for the inner Danish waters (DKI: 0.69), indicating a disturbed infauna community, likely due to the highly dynamic area with frequent resuspension and mixing of the sediment and associated fauna.

Multivariate statistic analyses were conducted to investigate infauna community structure and identifying patterns in species composition and abundances in the two pre-investigation areas. Furthermore, multivariate statistic analyses were applied to investigate whether spatial trends in infauna community structure are determined by any abiotic and/or physical factors. The multivariate statistical analyses showed, that there was a difference in infauna communities between sediment types (sand and silty sand), and that the lowest variance and most homogenous infauna species composition (abundance of each observed species was more similar between samples) was found in the samples at infauna stations located on silty sand (sediment type 1a/1b) and highest variance and highest heterogeneity between samples at stations located on sand (sediment type 1b). Furthermore, the analysis indicates that the same infauna community is present in the two pre-investigation areas, and that species abundance is determined by the distribution of silt on the seabed, which again is likely caused by weather induced pulses of organic matter originating from the Wadden Sea, local fjords and the rivers in the Southern part of the North Sea.

CONCLUSION

This baseline study is comprised by a large, comprehensive sampling program providing detailed knowledge of sediment, benthic flora and fauna in the two pre-investigation areas for NSI.1 (NSI.1-OWF) and export cable corridors (NSI-ECC) including the three OWF areas (A1-3) and three export cable corridors (ECC1-3).

The sediment types in the two pre-investigation areas are dominated by "silty sand" (sediment type 1a/1b) and "sand" (sediment type 1b), with very little area coverage of stones (<1.2%) (sediment types 2a, 2b, 3 and 4). "Silty sand" consists of sand with a surface layer of silt (few centimetres) and is more prevalent than previously found in existing studies from the area, indicating temporal and spatial variation in the silt area coverage in the area. The surface silt layer covering large parts of the sandy seabed in the two pre-investigation areas, likely originates from outflow from local fjords, the Wadden Sea and German river outlets.

Abiotic data (temperature, salinity and oxygen) showed a generally well mixed water column in May 2023, and a more stratified water column in June 2023 except for the shallowest stations close to the coast, where wave action continuously mix the water column. Good oxygen conditions for benthic flora and fauna at the seabed were found in both months (>6.6 mgO_2/l). Oxygen deficiency is very rare in the North Sea, due to the very dynamic conditions at the West coast of Jutland.

Pollutants generally adsorb to fine-grained, organic-rich material. Accordingly, the highest number of exceedances of threshold values for pollutants were observed in samples collected on organic-rich silty sand (ECC2 and ECC3) and lower exceedances were observed on sand (OWF areas A1-3 and ECC1). No relationship between pollutant concentration and sample depth was observed. Furthermore, due to very low TOC contents (between 0.03 to 0.32 %), the estimated threshold for several of the pollutants based on the TOC measurements, was very low and often below the detection limit for the laboratory analysis. This makes it difficult not to exceed threshold values in marine areas with very low TOC content, as is the case for the North Sea. It is therefore debatable whether this method of threshold calculation is most appropriate.

Observed benthic flora and fauna species and communities are all common for the North Sea and are similar to the results from other OWF areas in the Danish North Sea (Thor, Vesterhav Syd, Vesterhav Nord, Horns Rev III) regarding dominating species, benthic communities and area coverage. None of the observed species of benthic flora and fauna in the pre-investigation areas are considered threatened (Critically Endangered, Endangered or Vulnerable) according to the HELCOM red list (HELCOM, 2024a). However, the masked crab (*Corystes cassivelaunus*) is listed as Near Threatened (NT) (HELCOM, 2023b) and is commonly observed in the North Sea and was also observed in both pre-investigation areas. No evidence or indicators of biogenic reef structures from blue mussel (*Mytilus edulis*), European oyster (*Ostrea edulis*) or Sabellaria reef compositions were found.

Very few small spots of crust algae were observed in the pre-investigation area for NSI.1 (NSI.1-OWF), but none in the export cable corridors (NSI.1-ECC). The general lack of macroalgae is mainly due to large depth and resulting light limitation in the pre-investigation areas for NSI.1 (NSI.1-OWF) and in the deeper part of the export cable corridors (NSI.1-ECC). Furthermore, the seabed is very dynamic with few larger stones (>10 cm) for attachment, which cause frequent scrubbing of the stones and covering of flora and fauna with sand.

Species number and area coverage for benthic fauna (epifauna and visible infauna) at ROV stations were determined mainly by sediment type and to a lesser degree by depth. It was observed that species number and area coverage was generally lower in OWF area A1 and ECC1, likely due to a larger area coverage of sediment type 1b – “sand”, compared to a larger coverage of sediment type 1a/1b – “silty sand” in OWF areas A2 and A3. Furthermore, OWF area A1 and ECC1 were shallower compared to the other subareas, and thus more dynamic with a coarser seabed. The same species were observed in the two pre-investigation areas and similar ranges of area coverages were observed, indicating that the species originates from the same pool of larvae being transported along the West coast of Jutland.

The same trend was also observed for infauna species, abundances and biomasses, which were comparable in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC). The largest differences were seen within the NSI.1-OWF area where fewer species, lower abundances and biomasses were found in the western part of the NSI.1-OWF, compared to the eastern part. The observed differences are due to the fact, that the western part of NSI.1-OWF is dominated by “sand” and the eastern part is dominated by “silty sand” as is shown in the multivariate analysis below.

Three different indices were applied to investigate biodiversity (H’) and the quality of the marine ecosystem (AMBI and DKI) based on the composition and abundance of the infauna community in the area. Species diversity (Shannon-Wiener index, H’) was similar in both pre-investigation areas (1.13 and 1.19 in NSI.1-OWF and NSI.1-ECC, respectively) and comparable to H’ found for the closest NOVANA stations and for Thor OWF, but lower than the average H’ reported for the inner Danish waters in 2022. A lower H’ suggests an infauna community with fewer species (lower biodiversity), where some species dominate with high abundances (low evenness). The overall environmental health and quality of the marine ecosystem in the area (determined by the AMBI index) is comparable with the surrounding area. The AMBI value (1.35) in NSI.1-OWF classifies the overall area as slightly disturbed and the infauna community as unbalanced. The slightly lower AMBI (1.20) in NSI.1-ECC classifies the overall area as undisturbed and an impoverished infauna community. The Danish Quality Index (DKI) combines factors such as Shannon-Wiener diversity and AMBI, where a high value (between 0.8 and 1) indicates “good environmental status”. The average DKI in NSI.1-OWF and NSI.1-ECC was 0.43 and 0.49, respectively, indicating a “moderate ecological status” of the marine area/water body (“Vandområde ID 133: Vesterhavet, Nord” (water body North Sea)). DKI in the two pre-investigation areas were comparable to DKI values calculated for the NOVANA stations in the area but lower (i.e. lower status) than DKI reported for Thor OWF and for the inner Danish waters.

The multivariate statistical analysis showed, that there was a difference in infauna communities between sediment types (sand and silty sand), and that the lowest variance and most homogenous infauna species composition (abundance of each observed species was more similar between samples) was found in the samples at infauna stations located on silty sand and highest variance and highest heterogeneity between samples at stations located on sand. Furthermore, the analysis indicates, that the same infauna community is present in the two pre-investigation areas, and that species abundance and composition is determined by the distribution of silt on the seabed, which again is likely caused by weather induced pulses of organic matter originating from the Wadden Sea, local fjords and the rivers in the Southern part of the North Sea.

The observed benthic flora and fauna species in the two pre-investigation areas are robust species adapted to the very dynamic conditions in the North Sea. The observed benthic species are common along the West coast of Jutland and in this part of the North Sea (Køie & Kristiansen, 2023) and are expected to re-colonize a disturbed area (i.e. from digging, dredging and flushing project activities) within 2-5 years (Rambøll, 2020b; Vattenfall, 2020a; Essink, 1999; Essink et al., 1997). This is supported by experience from sand extraction areas in this part of the North Sea, that shows that re-colonization of benthic fauna and flora commences as soon as the dredging/disturbance in finished, and a full recovery is seen within a few years (Orbicon, 2014b; Orbicon, 2016).

Thus, the observed benthic communities of benthic flora and fauna in the two pre-investigation areas of North Sea I.1 are very common for the North Sea, with re-colonization times of 2-5 years after sediment disturbances and with a high recolonization potential from the surrounding similar populations and larvae drift along the West coast of Jutland.

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.

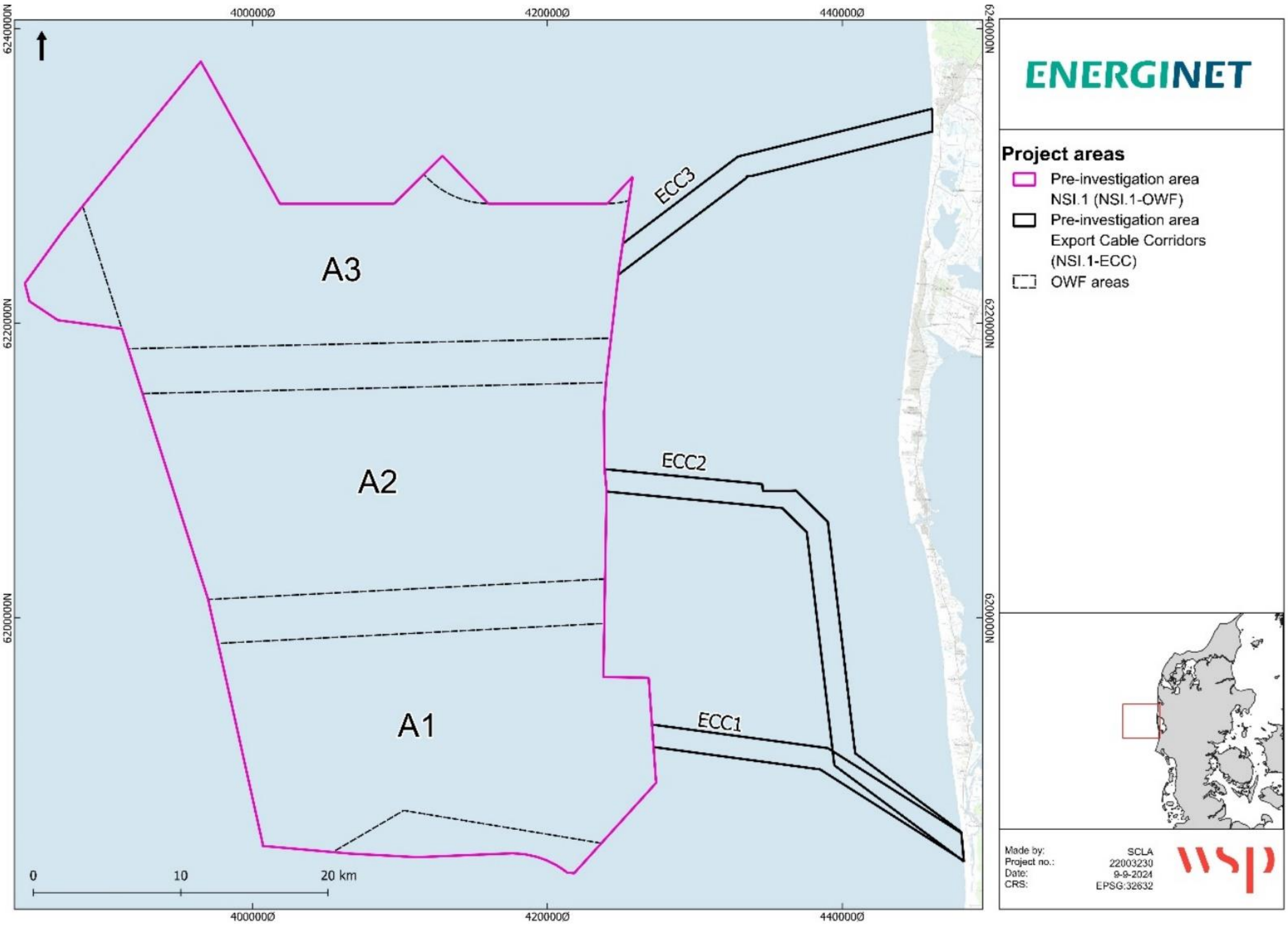


Figure 2-1. North Sea I.1 offshore wind farm area. Area definitions used in this report including the pre-investigation areas for North Sea I.1 offshore wind farm area (NSI.1) including the three OWF areas (A1-3) and the pre-investigation area for the export cable corridors (ECC1-3). Note there are two pre-investigation areas; one for the NSI.1 OWF (A1-3) and one for the three export cable corridors (ECC1-3).

In order 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 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 background report is to map and describe the benthic ecology i.e. sediment, benthic flora and benthic fauna in the pre-investigation areas and subareas (OWF area A1-3 and ECC1-3).

The geographical location of the NSI.1 area and the project areas used in this report are illustrated in Figure 2-1.

2.2 OBJECTIVE

This technical report concerns the pre-investigation area for the North Sea I.1 offshore wind farm area (NSI.1-OWF) and the pre-investigation area for the three export cable corridors (ECC1-3) (NSI.1-ECC) (see Figure 2-1). The pre-investigation area for the NSI.1 includes three offshore wind farm areas (A1-3) and the corridors in between.

This is the technical report containing the baseline study for "Benthic ecology" within the pre-investigation areas for the NSI.1 and the export cable corridors in the North Sea. "Benthic ecology" covers the relevant parameters for sediment, benthic flora and benthic fauna. This report presents both existing data and survey data for benthic ecology in the two pre-investigation areas, which will be used as a baseline study for the Environmental Impact Assessment (EIA), which will be created by the contractor of the final offshore wind farm project.

This technical report provides a description of existing data and survey data for the following parameters:

- Abiotic parameters (Depth, salinity, temperature and oxygen)
- Seabed sediment characteristics (Sediment types, grain size, TOC, nutrients (only existing data) and pollutants)
- Benthic communities
- Benthic flora (seagrasses and macroalgae)
- Benthic fauna (epifauna and infauna)

3 METHODOLOGY

In the following, the sampling program, equipment, sampling methods and data analyses are described for Benthic Ecology in the two pre-investigation areas: North Sea I.1 OWF (NSI.1-OWF) and the export cable corridors (NSI.1-ECC). Sampling overview, maps, stations and raw data are presented in the different appendices presented in the Appendices document.

3.1 SURVEY AREA

The survey area includes the pre-investigation area for the North Sea I offshore wind farm area (NSI.1-OWF), including three OWF areas (A1-3) and the corridors in between, together with the pre-investigation area for the three export cable corridors (ECC1-3) (see Figure 2-1). The sampling programme is assembled and planned to sufficiently cover and describe sediments and biological communities in all sediment types and in defined depth intervals in the two pre-investigation areas.

3.2 SAMPLING PROGRAM

The sampling program is based on current available knowledge of sediment types in the two pre-investigation areas represented by the GEUS seabed sediment map (GEUS Marta-database, see Figure 3-1) along with other public available data sources (EMODnet) and WSP's knowledge from recent surveys in an around the survey area. Stations were therefore placed according to the best existing knowledge. However, the North Sea is a very dynamic area with high sediment transport and the mapped sediment types in this study therefore differ from the GEUS map, which is discussed in the results section 5.2.1 – Sediment types.

The distribution of stations was done to cover all sediment types and depth ranges within the two pre-investigation areas, as best as possible, based on existing sediment type maps and depth maps from the area (see Figure 3-1). The sampling program for the two pre-investigation areas is described in section 3.2.2 below.

The sampling program was conducted during two marine, environmental surveys, one in May and one in June 2023, as presented in section 3.2.1 below. During each survey, different sampling activities were conducted to map and describe sediment, benthic flora and benthic fauna (including epifauna and infauna) in the two pre-investigation areas, resulting in a total of 892 samples collected for the different sampling activities. Sampling is described in detail for all subareas in section 3.2.2 below.

Side scan sonar data was used for sediment type mapping and was collected during the geophysical surveys in April to September 2023.

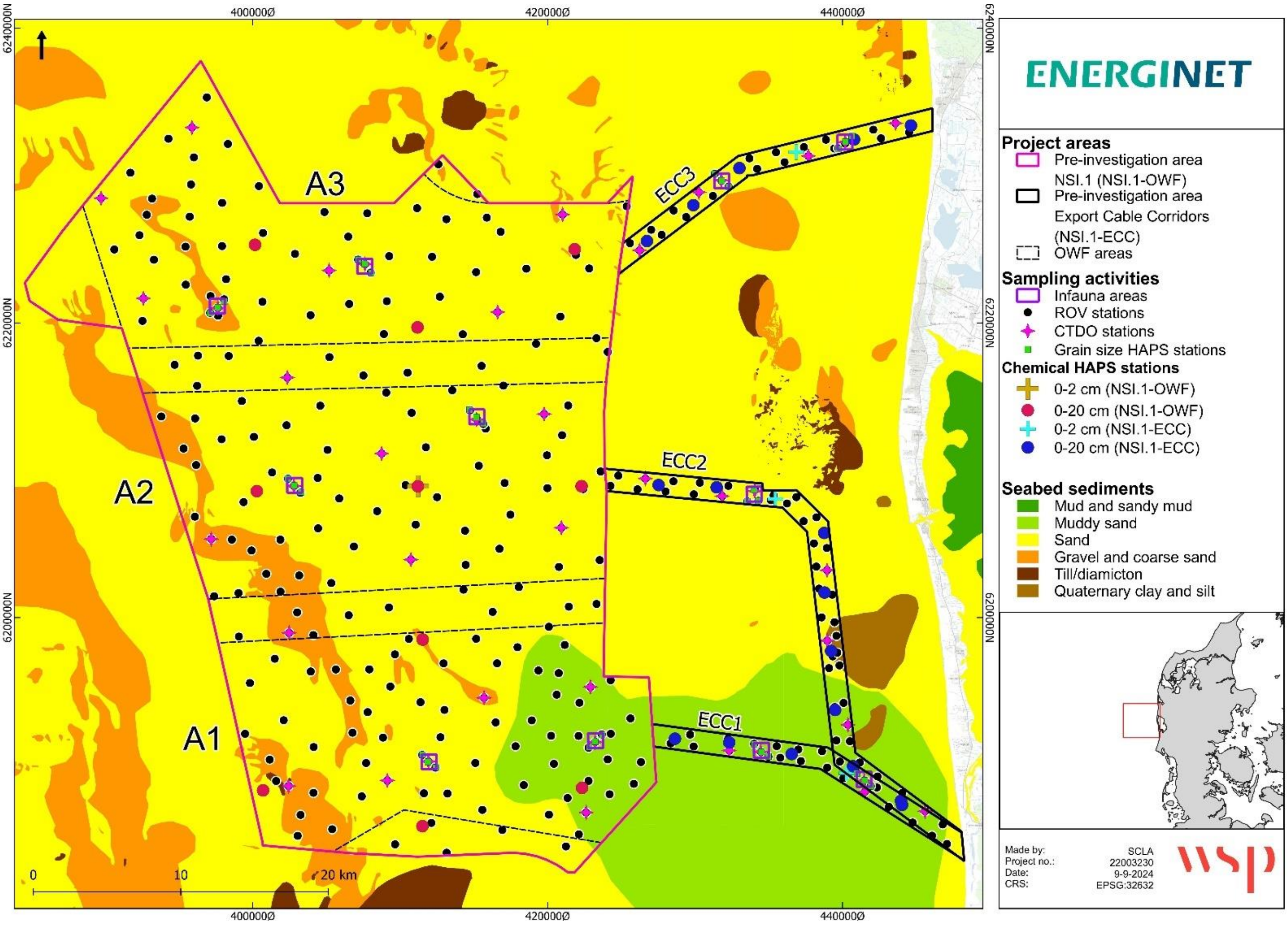


Figure 3-1. The full sampling program conducted in the pre-investigation areas for North Sea I.1 (NSI.1) including the OWF areas (A1-3) and the pre-investigation area for the export cable corridors (ECC1-3) during May and June 2023. Background map is from GEUS Marta-database.

3.2.1 SURVEYS

Two marine, environmental surveys were conducted during 2023 (Table 3-1) – one in May and one in June within the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC). Sampling overview of the different surveys and stations are presented in Table 3-1 and in full detail in Appendix 1.

Survey 1 (S1): The Infauna survey was conducted in May (11th-14th) with the vessel M/S Skoven. During this survey, infauna HAPS samples were collected at the eleven infauna stations (A_01-11) (see Figure 3-6). Each infauna station covers an area of 1x1 km within which 42 separate infauna HAPS samples were collected (Figure 3-7): three ROV stations (Figure 3-4), one CTDO profile (Figure 3-2) and three grain size HAPS samples (see Figure 3-3). Sampling of infauna was conducted in accordance with the technical requirements for soft bottom fauna sampling in the Danish NOVANA monitoring program (Hansen, L. S. and Josefson, A., 2019).

Survey 2 (S2): The Benthic survey was conducted in June (11th-19th) with the vessel M/S Skoven. During this survey, ROV stations (Figure 3-4), CTDO profiles (Figure 3-2), HAPS samples for grain size (Figure 3-3) and HAPS samples for chemical analysis of pollutants (Figure 3-5) were collected.

3.2.2 SAMPLING

Sampling activities and sampling numbers for the two surveys in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) and subareas within (A1-3 and ECC1-3) are presented in Table 3-1. Samples placed in the corridors between the OWF areas (A1-3) are not enumerated separately but are included in the numbers for the pre-investigation area of NSI.1-OWF.

Figures with sampling stations for each sampling activity are presented in Figure 3-2 to Figure 3-6: CTDO profiles, ROV stations, HAPS samples for chemical analysis, HAPS samples for grain size analysis and HAPS samples for infauna analysis. For full overview of sampled stations and samplings activities see Appendix 1.

Table 3-1. Overview of the sampling program, sampling activities and number of samples for the pre-investigation area for the North Sea I.1 OWF (including OWF areas A1-3) and the pre-investigation area for the export cable corridor area (ECC1-3). Sampling month is given in brackets in the title (May and/or June) corresponding to survey (Survey 1 and/or 2). HAPS samples for infauna were collected in May only and HAPS samples for chemical analysis were collected in June only. Note that sampling for each infauna station (A_01-11) included 42 samples (each sample = 1 HAPS sample).

Sampling activity/ Sampling area	CTDO profiles (May/June)	ROV Stations (May/June)	HAPS samples - Infauna (May/June)	HAPS samples - Grain size (May/June)	HAPS samples - Chemical analysis (May/June)
Pre-investigation area for NSI.1 OWF (NSI.1-OWF)	6/18	18/200	252 (6*42)/-	18/5	-/10
Pre-investigation area for the three export cable corridors (ECC1-3) (NSI.1-ECC)	5/12	15/80	210 (5*42)/-	15/9	-/19
Total	11/30	33/280	462 (11*42)/-	33/14	-/29

Sampling overview for the three OWF areas (A1-3) and three export cable corridors (ECC1-3), specifically, are given in Table 3-2. Note the total number of samples in ECC1 and ECC2 is given including stations in the overlapping part for both ECC1 and ECC2.

Table 3-2. Overview of the sampling program, sampling activities and number of samples specifically for the three OWF areas (A1-3) and for the three export cable corridors (ECC1-3). Sampling month is given in brackets in the title (May and/or June) corresponding to survey (Survey 1 and/or 2). HAPS samples for infauna were collected in May only and HAPS samples for chemical analysis were collected in June only. Note that sampling for each infauna station (A_01-11) included 42 samples (each sample = 1 HAPS sample).

Sampling activity/ Sampling area	CTDO profiles (May/June)	ROV stations (May/June)	HAPS samples - Infauna (May/June)	HAPS samples - Grain size (May/June)	HAPS samples - Chemical analysis (May/June)
A1	2/5	6/63	84 (2*42)/-	6/2	-/3
A2	2/5	6/55	84 (2*42)/-	6/1	-/4
A3	2/6	6/52	84 (2*42)/-	6/2	-/3
ECC1	2/3	2/25	84 (2*42)/-	6/2	-/6
ECC2	2/6	2/48	84 (2*42)/-	6/5	-/10
ECC3	2/4	3/20	84 (2*42)/-	6/4	-/9

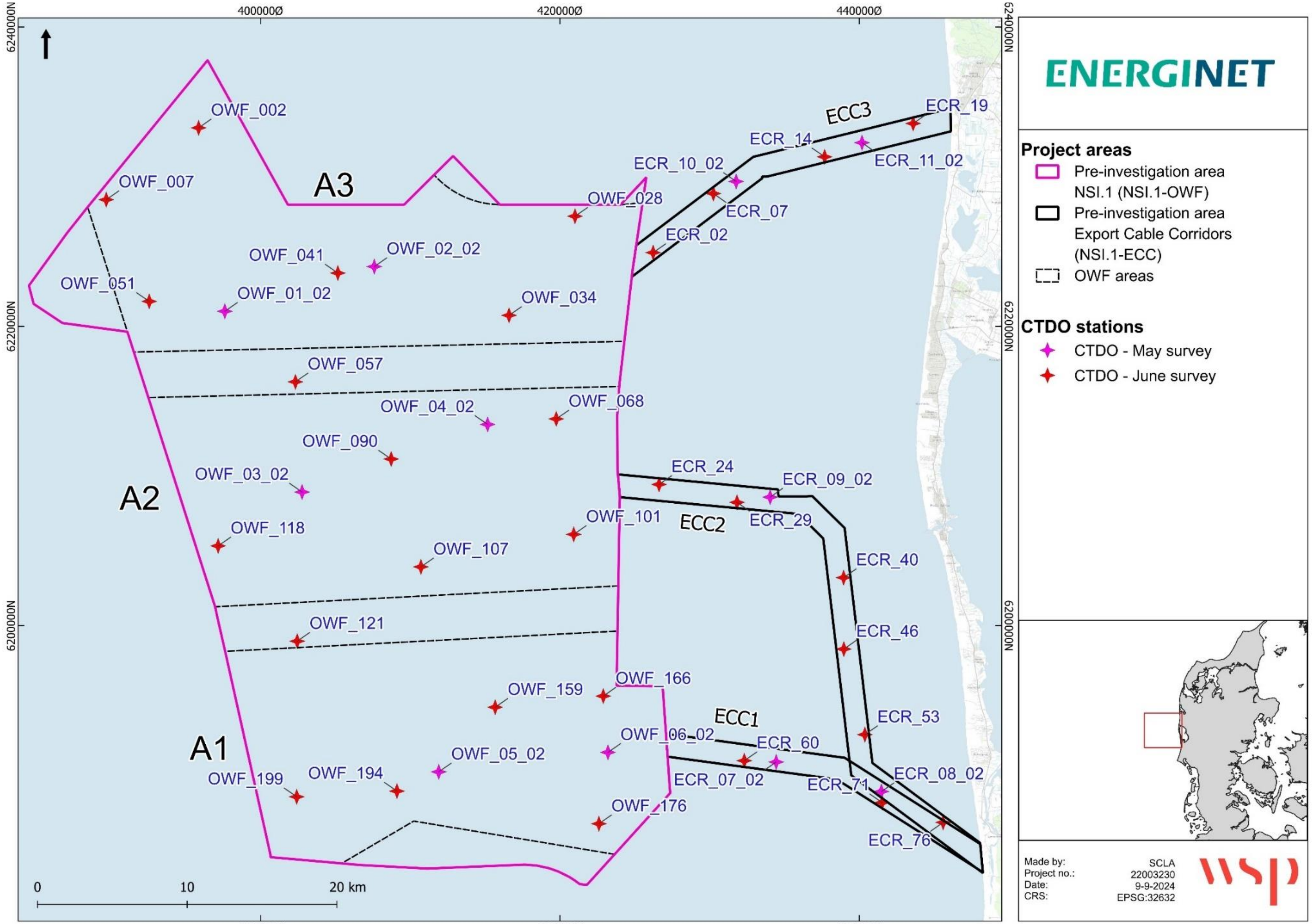


Figure 3-2. CTDO stations sampled in May 2023 and June 2023 within the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC). See raw data in Appendix 4.

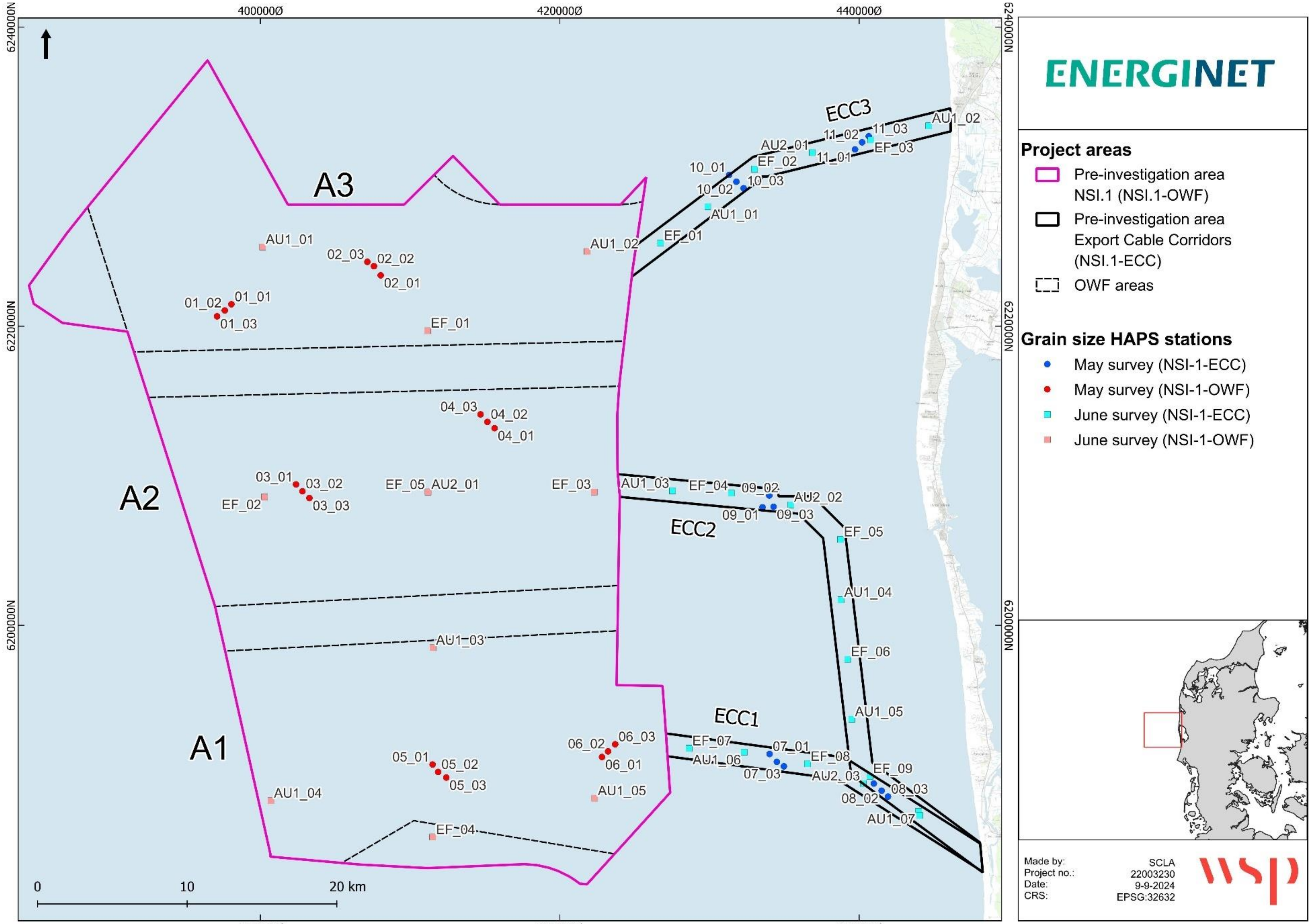


Figure 3-3. Grain size HAPS stations sampled in May 2023 (three at each infauna station) and June 2023 in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC). See raw data in Appendix 5.

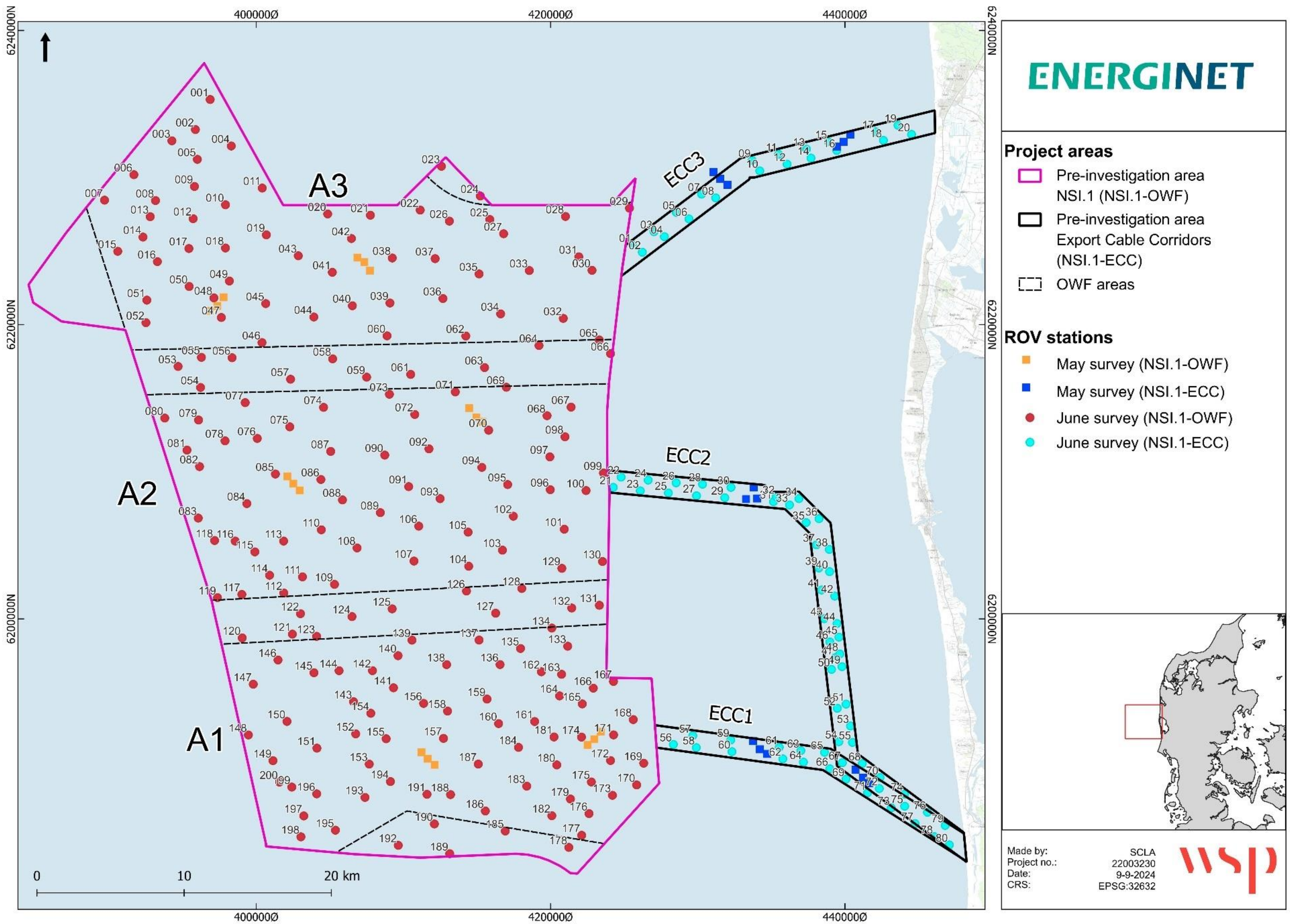


Figure 3-4. ROV stations in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) sampled in May and June 2023. At each ROV station, a video sequence of the seabed is recorded. Prefix is OWF_ROV_ in the pre-investigation area for NSI.1 and ECC_ROV_ in the pre-investigation area for export cable corridors. See data in Appendix 3A and 3B - logbooks.

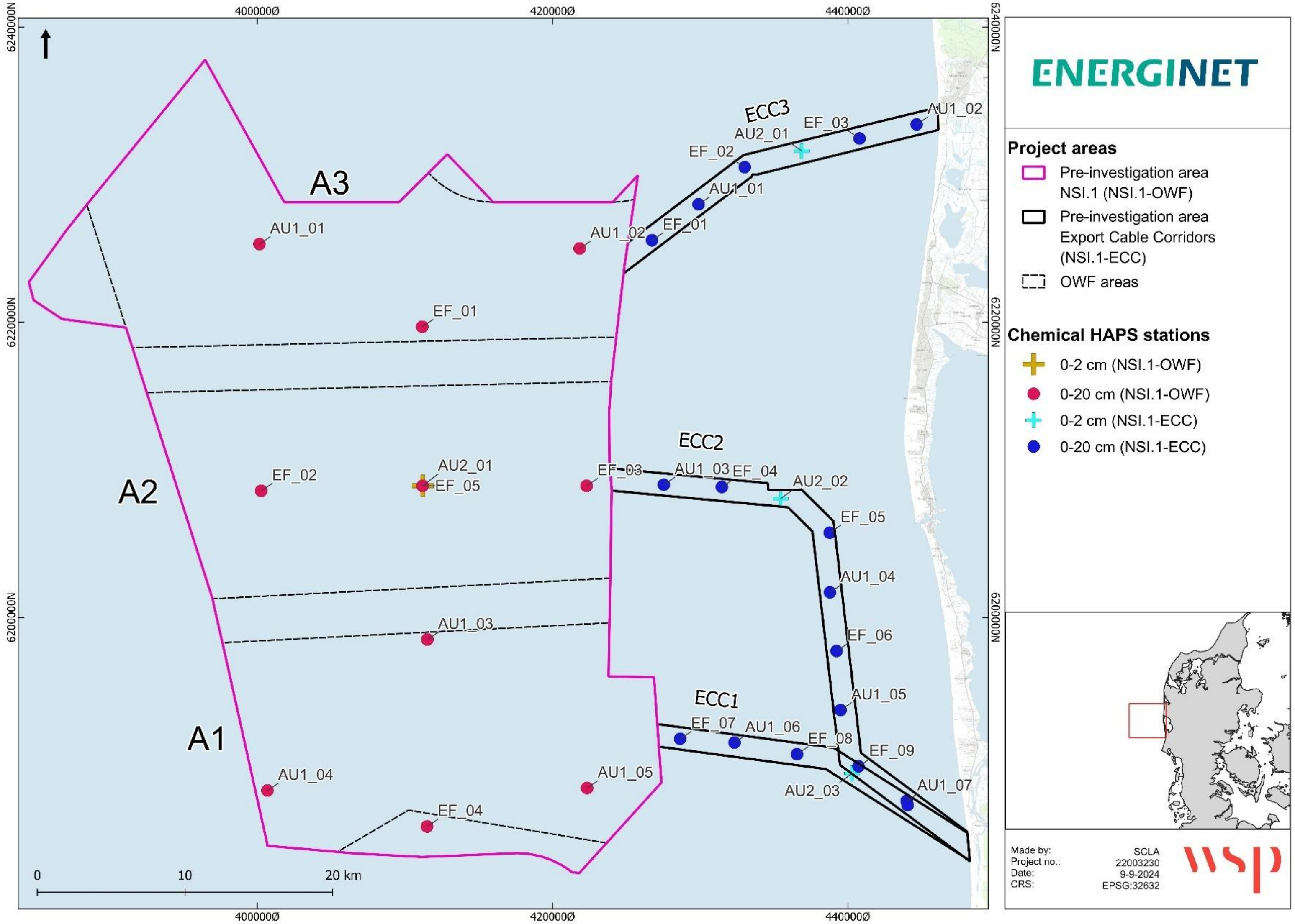


Figure 3-5. HAPS samples for chemical analysis of pollutants collected in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) in June 2023. AU and EF indicate the laboratory that have analysed the samples. AU = Aarhus University, DCE. EF = Eurofins. AU1 indicate sampling material collected from 0-20 cm depth in the HAPS core sampler. AU2 indicated surface sample of 0-2 cm depth of the HAPS core sampler sample. Prefix is OWF_MFS_ in the pre-investigation area for NSI.1 OWF and ECC_MFS_ in the pre-investigation area for the export cable corridors. See raw data in Appendix 6.

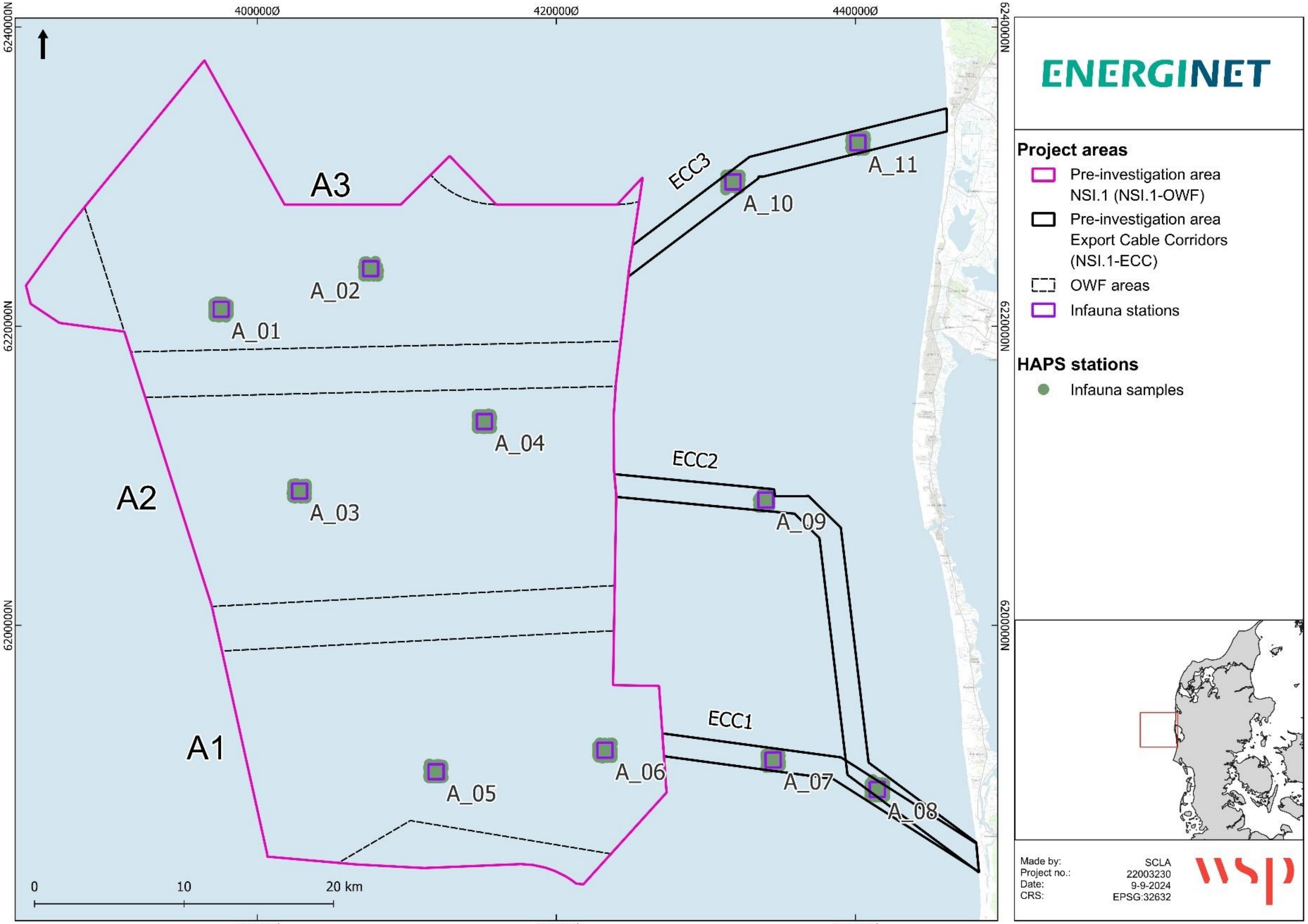


Figure 3-6. Infauna stations (A_01-11) in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) sampled in May 2023. One infauna station covers an area of 1x1 km in which 42 infauna HAPS samples were collected. See Figure 3-7 below for placement of the 42 infauna stations within infauna station area A_01 as an example. See raw data in Appendix 7.

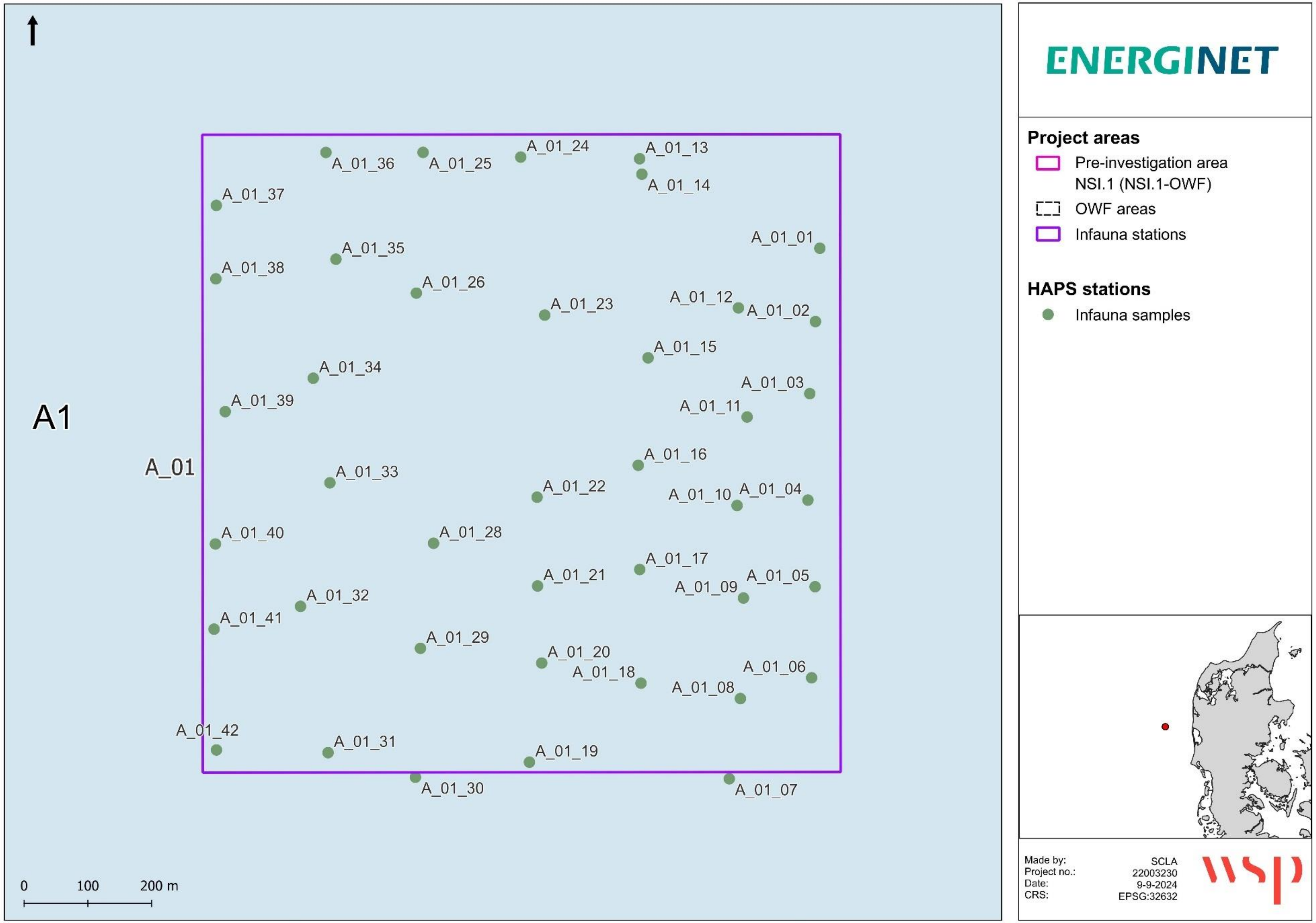


Figure 3-7. Infauna station A_01 (= area of 1x1 km) and the position of the 42 infauna HAPS samples collected within this area. See raw data in Appendix 3D and Appendix 7.

3.3 EQUIPMENT AND METHODS

Vessel, equipment and methods used for the two marine environmental surveys in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) are presented below.

3.3.1 VESSEL

The two surveys were conducted from the vessel M/S Skoven (Figure 3-8).

Skoven has excellent facilities regarding lifting equipment and deck area, as well as launch and recovery systems (LARS). The two benthic surveys were operated on a 24-hour basis, with 12-hour shifts. Skoven is equipped with an Azimuth thruster in front, keeping the vessel in position during HAPS sampling and deployment of ROV/CTDO if needed. Experience shows that the weather limitations for Skoven during survey operations is about 2.0-2.5 meters of wave height – depending on the actual task. Experience from similar seabed investigations from Skoven shows that good data quality (ROV video) is achievable up to a wave height of approximately 2.0 meters. Skoven has an adequate size for operating in the North Sea and appropriate working space on deck for handling of relevant equipment and handling of samples and has previously been used for similar baseline studies in the North Sea.

Figure 3-8. Research vessel M/S Skoven.

3.3.2 CTDO – WATER COLUMN PROFILING

A CTDO (conductivity, temperature, depth, oxygen) profiler was used for profiling of salinity, temperature, and oxygen concentration and saturation in the water column. The unit is lowered slowly from the surface and data is logged on a PC in real time. The unit can be a stand alone CTDO unit (see Figure 3-9), or as an ROV integrated CTDO. The stand-alone unit is an AQUATROLL 600 Temp/Conductivity sensor and RDO fast cap Optical Oxygen sensor. The core element in the integrated CTDO is a Campbell Scientific CR310 datalogger with online ethernet connection to the surface, which can host a wide variety of sensors. For this specific task, the following sensors are used: conductivity with a digital Ponsel C4E sensor, fast responding temperature sensor (I2C, ±0.1 °C), Bar30 pressure sensor (MS5837-30BA), Oxygen with a Ponsel OPTOD (Optical Dissolved Oxygen) sensor.

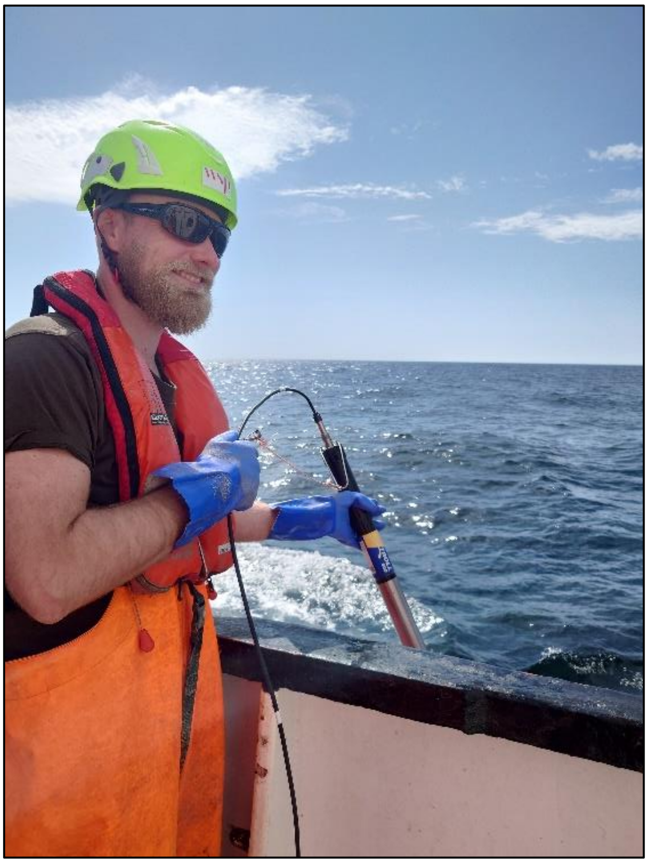


Figure 3-9. Stand alone CTDO unit being lowered from the ship.

CTDO data are presented in Appendix 4.

3.3.3 ROV – VISUAL VERIFICATION

A ROV (Remotely Operated Vehicle) was used for visual inspection of the seabed and quantification of sediment type and characteristics, benthic flora and fauna including species/taxa number and coverage (%) and the number of fish species and coverage (%) (Figure 3-10). The first activity on each station was a ROV inspection showing the seabed characteristics, together with flora and fauna live on deck. Visual inspection of the seabed with ROV was always done before HAPS sampling (for grains size, chemical analysis and infauna) to ensure sampling on loose sediment (i.e. avoiding hard/rocky bottom).

A ROV of the type "BlueROV2" (Figure 3-10) with positioning system was used, which gives information of the exact position of the ROV as well as showing the position in each frame/photography. WSP has two complete ROV systems, and thus, an identical backup was brought on the surveys in case of equipment failure. The equipment can be set up so both the helmsman and the ROV operator can see the image/video in real time. While recording the video, a team of two experienced marine biologists work together to watch the video, speak it in real time and fill out the logbook for each station. One biologist watch and speak the ROV video (voice-over) recording observed sediment types, species, area coverages, infauna activity and other relevant information. The other biologist fills out the logbook for the parameters listed below for each station, respectively. The field logbook includes position, depth, seabed sediment types/composition, determination of species (flora and fauna) and coverage of species, traces of species/groups in the seabed and biogenic structures observed on the seabed surface (e.g. sandworm tubes and piles, sea potato burrows/holes, fish foraging holes in the seabed, etc.), samples, videos and pictures taken ect. All sampling activities sampled at the same station are included in the field logbook such as CTDO and HAPS samples for grain size (See Appendix 3A and 3B for sampling at ROV stations from May and June 2023, respectively). The video speaking and a detailed field logbook are invaluable to enhance the quality, when the videos are reviewed in detail later in the office. Sufficient storage media was ensured, and back-up of all data was performed at least twice a day on two hard discs.

Figure 3-10. ROV (remotely operated vehicle) being pulled out of the water.

3.3.4 HAPS – SEDIMENT CORE SAMPLING

HAPS SAMPLING METHOD

A HAPS core sampler (Figure 3-11) was used for sampling of sediment cores, which were later analysed for sediment characteristics, chemical analyses and infauna quantification. The HAPS core sampler samples a seabed area of 0.0143 m^2 (Hansen, L. S. and Josefson, A., 2019). This instrument complies with the technical requirements for soft bottom fauna sampling in the Danish NOVANA monitoring program (Hansen, L. S. and Josefson, A., 2019).

Figure 3-11. HAPS core sampler on deck before deployment.

The first activity at each station was a ROV inspection of the seabed in the sampling area, showing the seabed characteristics, flora and fauna live on deck. If the ROV-video at a station showed that it was not possible to use the HAPS core sampler due to presence of hard sediment, a new sampling position was located within approximately 50 meters of the original position. The number of HAPS samples collected in the pre-investigation area are listed Appendix 1 and shown in Figure 3-3 for grain size samples, Figure 3-5 for chemical analysis of pollutants and Figure 3-6 for infauna.

On deck, each successful HAPS-core sediment sample was visually described together with descriptions of sediment composition, colour, smell and visible fauna. This was logged in the logbooks (see Appendix 3C-D).

CHEMICAL ANALYSIS AND GRAIN SIZE ANALYSIS

Chemical analysis of the concentration of pollutants in the sediment was performed in both pre-investigation areas, where sediment might be suspended due to digging, cable trenching, cable flushing or other sediment disturbing project activities, that may bring pollutants in suspension in the water column. Release of pollutants through resuspension of sediment from wind farm activities are potential project impacts for the environmental parameters.

Three types of HAPS samples for chemical analysis were collected in the two pre-investigation areas (see Figure 3-5):

- Full HAPS corresponding to 0-20 cm sediment depth (analysed by Eurofins (EF)), analysed for pollutants.
- Full HAPS corresponding to 0-20 cm sediment depth (analysed by Aarhus University (AU1)), analysed for pollutants and grain size.
- Surface samples from upper 0-2 cm sediment of the HAPS (analysed by Aarhus University (AU2)), analysed for pollutants and grain size.

Material from the HAPS sample was taken from the centre to avoid sediment, which had been in contact with the HAPS cylinder wall. The material was thereafter mixed/homogenized and divided into a 50 g plastic box (grain size) and a 200 g rilsan bag (for chemical analysis). The plastic box was put in the cooler and the rilsan bag was stored in the freezer for later analysis.

Analysis for gran size was furthermore conducted for three HAPS samples per infauna station. HAPS samples for grain size analyses at infauna stations (see Figure 3-3 and Figure 3-6), were stored in rilsan bags and stored in the cooler.

Two laboratories are used due to their respective expertise in getting the lowest detection limit for each selected chemical compound.

Analyses of grain size and pollutants are described in section 3.4.5 and 3.4.6, respectively. Data are presented in Appendix 5 and 6.

INFAUNA QUANTIFICATION

Sample sieving (1 mm sieve) and storage/preservation of samples were carried out in accordance with technical requirements for soft bottom fauna (Hansen, L. S. and Josefson, A., 2019). All samples were stored in 70 % ethanol in plastic buckets with a tight lid and secured in a dedicated safe area on the vessel. The buckets had labels inside and labelling on the lid. All samples were treated individually in WSP's laboratory by a certified Danish infauna expert. The samples were sieved in a 0.5 mm sieve to remove ethanol before sorting. All animals were sorted out using a low power stereo microscope and identified to the lowest taxonomical level possible. The total biomass of the individual species, including shells of bivalves, were determined as total wet weight and total dry weight after drying at 60°C for a minimum of 24 hours or until stable weight was reached. Polychaetes were subtracted from their tube before weighing, except for single species where the animal and tube are too difficult to separate. Thus, *Phoronis* sp., *Pygospio elegans* and *Galathowenia oculata* were weighed along with the individual tube after prior removal of "excess tube material" without body content. Barnacles are not infauna and were only indicated as being present, and species determined if possible, however biomass was not determined. Infauna raw data are presented in Appendix 7A.

3.4 DATA ANALYSIS

Data analyses conducted for the relevant sampling activities are described below.

3.4.1 CTDO – ANALYSIS

The CTDO-profiles at relevant stations from both May and June are presented and analysed for the presence of stratification. The water column is stratified when two separate water masses with different salinities and temperatures are present, and there is a mixing zone between the two water masses, where temperature and salinity changes rapidly (the stratified water layer). This is called a thermocline for temperature and a halocline for salinity (see Figure 5-2). The water column is not stratified when the water column is well mixed, and measurements of temperature and salinity are constant throughout the water column.

3.4.2 ROV – VIDEO ANALYSIS

All ROV videos were reviewed by an experienced geologist and biologist at WSP. The geologist adjusted the observed sediment types (on the ROV video) according to the side scan sonar data and vise versa to create the sediment type map. The biologist added species/taxa and detailed coverages (%) of the dominant species in the logbooks. Thereafter, the final nature type map was produced as the combination of the sediment type mapping and the observed benthic communities on each sediment type. Species determination of benthic flora and fauna on ROV video was done mainly according to (Køie M. & Kristiansen A., 1999, 2023).

3.4.3 SEDIMENT TYPE MAPPING (SSS)

The sediment type map shows the distribution of sediment types within the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) (see Sediment map in Figure 5-5). The sediment types were mapped by WSP based on side scan sonar data (SSS) from the geophysical mapping in the area conducted by the research vessel and company *Ocean Infinity* and the visual verifications of the sediment types on the ROV stations sampled by WSP.

First generation mapping – Side scan data interpretation

The 1st generation sediment map is based on the interpretation of side scan sonar data , in order to determine the roughness of the seabed and coverage of cobbles and boulders as defined by the Danish Authorities in statutory order no. 1680 of 17/12/2018 (Ministry of Environment of Denmark, 2018). Based on the side scan data, the different types of sediments are then subdivided into the following categories:

- **Type 1 – Sand and soft sediments:** Can be dynamic and is chiefly composed of fine-grained material from mud to firm sands. Subtypes 1a, 1b and 1c are dominated by silt, sand or clay, respectively. The sediment may contain some gravel (0.2-2 cm) and pebbles/small cobbles (2-10 cm). Furthermore, the sediment may contain a few (<1 %) large rocks (>10 cm). In this study, an intermediate sediment type "1a/1b" dominated the pre-investigation areas. This sediment type can be characterized as sand with a silty surface layer.
- **Type 2 – Sand, gravel, pebbles and small rocks with a few larger rocks (area coverage 1-10 %):** Composed chiefly of sand and/or silt, but with varying amounts of gravel and pebbles/small cobbles. The sediment may contain some (1-10 %) scattered boulders (>10 cm). There are two subtypes: Type 2a - coarse sand, gravel and pebbles i.e. small rocks < 10 cm. Type 2b – sand and few large rocks >10 cm (area coverage of 1-10%).
- **Type 3 – Sand, gravel, pebbles (<10 cm) and larger rocks (>10 cm, coverage 10-25 %):** Composed of varying amounts of sand, gravel, pebbles/small cobbles as well as larger cobbles and boulders (>10 cm), with boulders covering 10-25 % of the sea floor. Also includes pebble fields and scatterings of small cobbles.
- **Type 4 – Stone reef, sedimentary rock and till, consisting of many larger boulders (coverage >25 %):** Dominated by cobbles and boulders, from close scatterings to reefs rising from the sea floor, with or without cavity forming elements. Boulders (>10 cm) cover 25-100 % of the sea floor. Other sediments may be sand, gravel and pebbles in varying amounts.

Second generation mapping – Sediment type map

Second generation sediment type mapping is done by verifying the interpreted seabed sediment types from the first-generation mapping with the actual ROV-video recordings of the *in situ* seabed sediment type (see ROV stations in Figure 3-4). The product is a sediment type map of the two pre-investigation areas (see section 5.2.1 - Results/Sediment types).

3.4.4 NATURE TYPE MAPPING (= BENTHIC COMMUNITIES)

The nature type map is based on the second-generation sediment type map, combined with the observed benthic communities (benthic flora and fauna) from the ROV-videos at each of the sediment types. A nature type map describes the biological communities or benthic communities living in the habitat type found on each sediment type – as opposed to the term habitat types, which describes the habitat where and under which conditions the organism lives.

When assigning nature types based on sediment type maps, sometimes several sediment types are merged into one nature type, because the same benthic flora and benthic fauna communities are observed on the ROV-videos. In this study, merging of two sediment types into one nature type/benthic community was done for sediment type 2a and 2b, which were converted to nature type 2 – mixed community. Also, sediment type 3 and 4 were converted to nature type 3/4 - hard-bottom community based on similar observed benthic communities dominated by epifauna on ROV video.

3.4.5 HAPS – GRAIN SIZE ANALYSIS

Grainsize analysis and measurement of Total Organic Carbon (TOC), were conducted by Aarhus University (AU) on the chemical HAPS samples. Furthermore, Eurofins (EF) conducted grain size analysis and measurement of Total Organic Carbon (TOC) in samples from the infauna stations (three grain size samples per infauna station. Results are presented in section 5.2.2 – Physical parameters/Grain size and TOC. Raw data are presented in Appendix 5.

3.4.6 HAPS - CHEMICAL ANALYSIS

Chemical analysis of sediment samples was performed at stations in the three OWF areas and along the three export cable corridors for assessment of concentrations of relevant pollutants in the sediment. The description of chemical parameters follows legal requirements and assessment tools given as threshold values provided by the Danish Environmental Protection Agency (EPA), the European Commission, OSPAR and HELCOM (see section 5.2.3 - Chemical Parameters/Pollutants).

Chemical parameters analysed:

- Metals (10): Arsenic (As), lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), silver (Ag), vanadium (V) and zinc (Zn)
- PAH compounds (20): Naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(b+j+k)fluoranthene, benzo(e)pyrene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene, benzo(g,h,i)perylene, 1-methylnaphthalene, 2-methylnaphthalene, dimethylnaphthalene, trimethylnaphthalene
- Phenols (2): nonylphenols (sum) and 4-tert-octylphenol
- Phthalates (3): Benzyl butyl phtalate (BBP), bis(2-ethylhexyl) adipate (DEHA) and Bis(2-ethylhexyl) phthalate (DEHP)

The four methylnaphthalenes will hereafter be considered as one compound, as the threshold value is for the sum of the four individual compounds. Analysed chemical pollutants were chosen based on typically found pollutants in the North Sea, as well as recommendations from DCE (Aarhus University (AU), on which pollutants to analyse for in sediment.

Sediment samples for chemical analysis were analysed for concentrations of the relevant pollutants by the accredited companies Eurofins (EF) and Aarhus University (AU). Measured concentrations of pollutants were then evaluated by WSP based on available quality standards and threshold values specifically for sediments and prioritized according to recommendations from the Danish Centre for Environment and Energy, Aarhus University (DCE) (Strand & Larsen, 2013). The NEQS are the primary assessment tool in this study, as the NEQS are our current national standards and statutory threshold values determined in the BEK. no. 796 of 13th of June 2023 (Miljøstyrelsen, 2023a).

Threshold values are prioritized in the following order:
1) NEQS: National Environmental Quality Standards, Danish EPA (Miljøstyrelsen, 2023a) (Miljøstyrelsen, 2023b)
2) NQC: National Quality Criteria, Danish EPA (Miljøstyrelsen, 2023b)
3) EAC: The Environmental Assessment Criteria, OSPAR (OSPAR, 2009)
4) ERL: Effect Range Low, US EPA (OSPAR, 2009)

5) LAL: Lower Action Level, Klapvejledningen (Miljøstyrelsen, 2008)

Results of the chemical analyses, concentrations and threshold exceedances are presented in section 5.2.3 (Chemical Parameters/Pollutants) and compared to relevant existing data from the area (4.3.3 – Existing data/Chemical parameters/Pollutants). All data for the chemical analyses are presented in Appendix 6.

3.4.7 HAPS – INFAUNA ANALYSIS

The statistical indices and analyses presented below are used to describe the infauna communities within the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC), including their respective subareas (A1-3 and ECC1-3). Se area definitions in Figure 3-6.

For each infauna HAPS station, the following was calculated:

- Species richness (number of species)
- Species abundance and biomass per m^2
- Species diversity (Shannon Wiener diversity)*
- AMBI index*
- DKI (Danish Quality Index)*
- Bray-Curtis similarity index and MDS-plot (ANOSIM-test and SIMPER-analysis)

* The indices are not developed for comparison of different locations/areas, as e.g. wave action, sediment- and the degree of pollution can vary between locations. For example, in high dynamic areas, it is not expected that sensitive species will be present, which will be mirrored in the index value. Instead, the indices can be used to compare the infauna community and the environmental status within the same location over time.

INDICES

In this study, the Shannon-Wiener diversity index (H'), the AMBI index and the DKI index were used to describe the species diversity and sensitivity of the infauna community sampled in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) and the subareas (A1-3 and ECC1-3). The Shannon-Wiener diversity index (H') indicates the species diversity, where a high H' indicates high species diversity. The AMBI index is a "sensitivity index", i.e. it indicates the environmental condition of a location, based on the composition of the infauna community. Low AMBI values indicate good environmental conditions, with the possible presence of infauna species that are sensitive to eutrophication. High AMBI values, on the other hand, indicate that the infauna community is dominated by species that are tolerant towards eutrophication. The DKI index combines the Shannon-Weiner diversity index (H') and the AMBI index and corrects for the salinity at the sample site. This correction is grounded in the expected species diversity at different salinity levels where more diverse communities are expected at higher salinity levels and lower diversities in brackish waters.

A high abundance of sensitive species is not expected in the study area of the North Sea, as this area is highly dynamic, thus selecting for robust species.

SHANNON-WIENER INDEX – SPECIES DIVERSITY INDEX

Shannon-Wiener diversity index (*H'*) increases as both the richness (species number) and the evenness (how similar the abundances of the different species are in the community) of the infauna community increase. The fact that the index incorporates both components of biodiversity can be seen as 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. H' will be low if there are few species, where some species dominate with high abundances. On the other hand, many species with similar abundances (high evenness) will result in a high H'. Typical values are generally between 1.5 and 4 in most ecological studies and the index is rarely greater than 4.

Equation 1

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

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

Note that the index score can only be used to compare within the same area or between areas, where the physical and environmental parameters are similar.

AMBI INDEX - CONDITION OF COMMUNITY/DISTURBANCE

The AMBI index is a marine index used to evaluate the effect of eutrophication on infauna in European estuaries, coastal areas, and sea areas (Borja et. al., 2000). This index is derived from the individual numbers of species in five ecological fauna groups (GI-GV – see text below and Figure 3-12), which are classified by their sensitivity/tolerance to an environmental stress gradient, and describes the overall environmental quality of an area based on the composition of the infauna community. The AMBI index cannot be used for comparisons between different locations, but rather to assess the development of the infauna community / locality over time at the same location. Four NOVANA stations have been sampled for infauna in the area from 2015-2023, where one station is within the pre-investigation area of NSI.1 (NSI.1-OWF) (Figure 4-1). The other three NOVANA stations are located south and west off NSI.1-OWF. These stations have been sampled similarly to this study with 42 HAPS samples within an area of 1x1 km and over time (two samples every second year). The AMBI index can therefore be used to assess changes in the environmental quality of each of the NOVANA stations over time. These data will be compared to the AMBI values found for the infauna stations sampled in this study in the two pre-investigation areas.

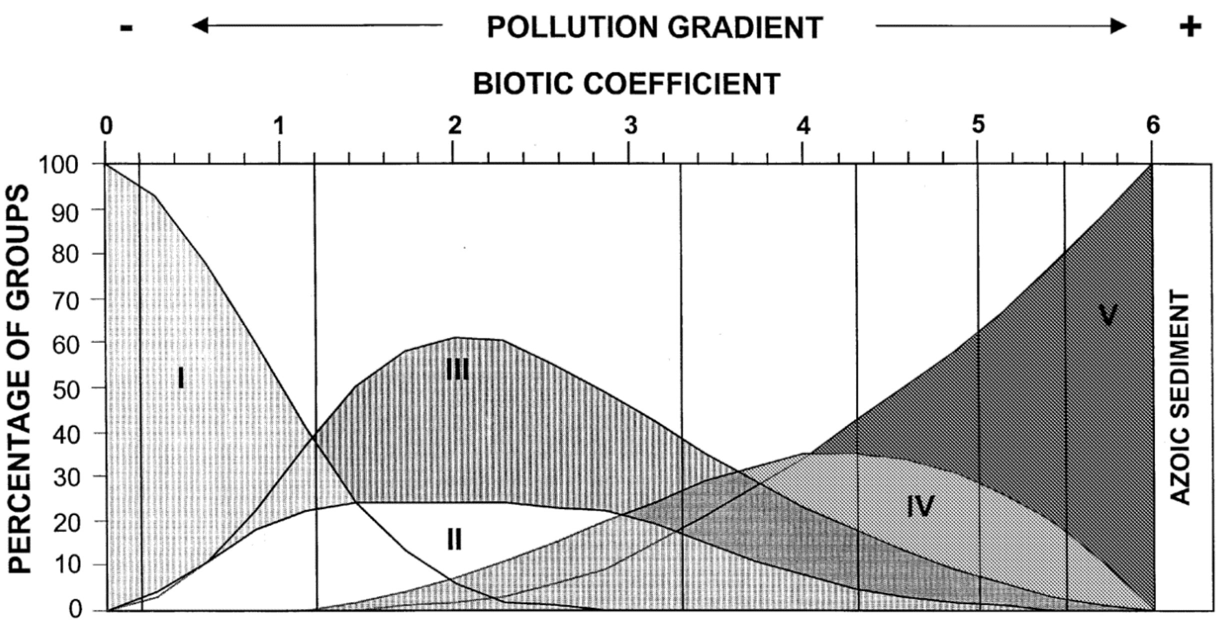


Figure 3-12. Theoretical development of the five infauna groups (Group I: species very sensitive; Group II: species indifferent; Group III: species tolerant; Group IV: second-order opportunistic species; Group V: first-order opportunistic species), according to their sensitivity to an increasing pollution (stress) gradient, and the corresponding AMBI values ("biotic coefficient") across the stress gradient. A value >6 indicate azoic (no life) sediment. Source: modified from (Borja et. al., 2000).

The five fauna groups are described as follows (Borja et. al., 2000)**:**
<u>Fauna group GI:</u> Species very sensitive to organic enrichment and present under unpolluted conditions (initial state). They include the specialist carnivores and some deposit-feeding tubicolous polychaetes.

<u>Fauna group GII:</u> Species indifferent to enrichment, always present in low densities with non-significant variations with time (from initial state to slight unbalance). These include suspension feeders, less selective carnivores, and scavengers.

<u>Fauna group GIII:</u> Species tolerant to excess organic matter enrichment. These species may occur under normal conditions, but their populations are stimulated by organic enrichment (slight unbalanced situations). They are surface deposit-feeding species, such as tubicolous spionids.

<u>Fauna group GIV:</u> Second-order opportunistic species (slightly to pronounced unbalanced situations). Mainly small sized polychaetes: subsurface deposit-feeders, such as cirratulids.

<u>Fauna group GV:</u> First-order opportunistic species (pronounced unbalanced situations). These are deposit feeders, which proliferate in reduced sediments.

The AMBI value can be calculated from the formula:

Equation 2

$$AMBI = \frac{0 * \%GI + 1{,}5 * \%GII + 3 * \%GIII + 4{,}5 * \%GIV + 6 * \%GV}{100}$$

The AMBI value describes the condition/pollution/health of the bottom fauna as well as the degree of disturbance of the location (Borja et. al., 2000). The scale ranges from Normal to Azoic (having no living beings) for the bottom fauna and from undisturbed to extremely disturbed for the locality (Table 3-3).

Table 3-3. Overview of AMBI-index values. Modified from (Borja et. al., 2000). The values can be interpreted from Figure 3-12.

AMBI	Dominating ecological group	Condition / health of the benthic community	Disturbance of the location
0,0 < AMBI ≤ 0,2	I	Normal	Undisturbed
0,2 < AMBI ≤ 1,2		Impoverished	
1,2 < AMBI ≤ 3,3	III	Unbalanced	Slightly disturbed
3,3 < AMBI ≤ 4,3		Transitional to pollution	Meanly disturbed
4,3 < AMBI ≤ 5,0	IV-V	Polluted	Meanly disturbed
5,0 < AMBI ≤ 5,5		Transitional to heavy pollution	Heavily disturbed
5,5 < AMBI ≤ 6,0	V	Heavy polluted	Heavily disturbed
Azoic	Azoic	Azoic	Extremely disturbed

DKI V3 INDEX

The Danish Quality Index (DKI) is developed to assess the condition of a water body in accordance with the EU's Water Framework Directive. DKI combines factors such as diversity (expressed as Shannon-Wiener diversity) and the sensitivity level in the infauna community (AMBI). DKI is also calculated for individual HAPS samples (DKI version 3).
The formula is given:

Equation 3

$$\text{DKI vers. 3} = \left(\frac{\left(1 - \frac{\text{AMBI} - \text{AMBI}_{\text{min}}}{7}\right) + \left(\frac{\text{H}}{\text{H}_{\text{max99}}}\right)}{2}\right) * \left(1 - \frac{1}{\text{N}}\right)$$

, where N equals the count of individuals.
Further, AMBI_{min} and H_{max99} are given by the formulas:

Equation 4

$$\text{AMBI}_{\text{min}} = 3{,}083 - 0{,}111 * \text{salinity (o/oo)}$$

Equation 5

$$\text{H}_{\text{max(H99)}} = 2{,}117 + 0{,}086 * \text{salinity(o/oo)}$$

AMBI_{min} must never be <0; if it is, set its value to 0.
$\text{H}/\text{H}_{\text{max}}$ must never be >1; if it is, H_{max} is set to 1.

For the calculation of DKI version 3, different salinities have been used based on the location of the samples.

To assess the condition of a water body (Danish “Vandområde”), the threshold values shown in Table 3-4 are used for the North Sea (“Vesterhavet, Nord”) cf. (BEK nr 792 af 13/06/2023).

Table 3-4. Threshold values for the Danish Quality Index (DKI) for assessing the environmental status for the quality element “infauna” in water body “Vesterhavet, Nord”. Source: (BEK nr 792 af 13/06/2023).

Bad	Poor	Moderate	Good	High
<0.2	0.2-0.4	0.4-0.6	0.6-0.8	>0.8

MULTIVARIATE STATISTICAL ANALYSES

Multivariate analysis is applied to explore the infauna abundance data to examine spatial trends in infauna species community composition and distribution at the stations and whether these spatial trends are determined by any abiotic and/or physical factors. Investigated factors in this study include depth, salinity, oxygen concentration, sediment type, grains size and grain size uniformity (d60/d10). Only the parameters significantly determining the infauna abundance at the infauna stations are presented in section 5.5.2 – Infauna/Multivariate analysis.

The multivariate statistical analyses applied in the current report include multidimensional scaling (MDS), Analysis of Similarity (ANOSIM) and Similarity Percentages (SIMPER). These analyses combined can provide a comprehensive understanding of marine infauna abundance data, where MDS offers a visual exploration, ANOSIM provides statistical validation of the observed patterns, and SIMPER delves into the specifics of species contributions to these patterns. Each method is described in further detail below.

Bray-Curtis similarity index and NMDS analysis (Non-metric Multidimensional Scaling)
Similarities and dissimilarity in the composition of taxons between the single samples and localities are analyzed using Non-metric multidimensional scaling (NMDS – afterwards referred to as MDS) by Bray-Curtis similarities (BC_{ij}) (Equation 6 below) calculated pairwise for all combinations of samples. For this, the software PRIMER (Primer-E, version 7, see

(Clarke & Gorley, 2006)) is used. Data input is abundance of all infauna species present in each HAPS sample at all stations, where there are 42 samples at each infauna station. Data is transformed (square root) before analysis, in order to suppress abundance of dominating taxa.

Equation 6

$$BC_{ij} = 1 - \frac{2C_{ij}}{S_i + S_j}$$

Where C_{ij} is the sum of the smallest value of the species that are in both samples / localities. S_i and S_j is the total number of species found in the sample/ locality. The calculated Bray-Curtis similarity index is shown as an MDS plot where separated groups can be identified. The MDS plot helps comparing the composition of infauna species between different samples by visualising similarities and dissimilarities between infauna samples. Samples that are close together in the MDS plot have a more similar species composition than the samples that are far away from each other in the MDS plot.

In the interpretation of data, the stress number of the 2-D MDS-plot is evaluated. Stress varies between 0 and 1, where values close to 0 indicate a more accurate representation of data. A stress number less than 0.1 indicates an excellent representation in the interpretation of data in 2-D, whereas the interpretation of data in 2-D is subject to greater uncertainty at stress values greater than 0.2. The MDS analysis will be combined with ANOSIM (see details below) to validate observed patterns, which, in case of a high stress number in the 2-D MDS plot, has the possibility of supporting what is visually observed in the MDS plot.

When conducting multivariate statistical analyses, outliers were removed by identification from the MDS plot. Outlier samples were present in the 2-D MDS plot as points far away from the other samples/points. Outliers were single samples with zero species, only one species present in low abundances (1 specimen found in the sample) or a sample with rare species present, i.e. species that were only present in a few samples in low abundance.

ANOSIM (Analysis of Similarity)

Results from an ANOSIM analysis can be used to assess whether observed patterns in an MDS plot represent an actual ecological difference in infauna community composition and distribution, or whether the observed patterns are due to random variation. The ANOSIM method uses Bray-Curtis similarity values and gives a P-value (significance level) and an R-value (the strength of the factors on the samples). The R-value is typically between 0 and 1, but can be negative, as low as -1, but often close to 0. An R-value close to 1 indicates a high degree of separation (high dissimilarity) between samples from one station vs. samples from another station, while R-values close to 0 indicate low separation (low dissimilarity) between samples of the two stations. The R-value is both affected by the variation in the distribution of taxa between samples within each station as well as the variation between samples from the other stations.

In an ANOSIM, it should initially be tested if there is a significant difference between samples sorted e.g. after depth intervals or sediment types, and thereafter the Global R-value / the strength of the analysis is assessed. Afterwards, pair-wise comparisons and the R-value for these can be assessed. It is possible that there is a significant difference, but that the R value is low (e.g. <0.2), which means that the strength of the analysis is low, and results should be interpreted with care.

In the present report, we define the following R-values' strength as: R<0.2: weak and not relevant, 0.2< R <0.4: low, 0.4< R < 0.6: moderate, R>0.6: high.

SIMPER (Similarity percentages)

SIMPER is often used in conjunction with other multivariate techniques like ANOSIM (Analysis of Similarities) and/or nMDS (Non-metric Multidimensional Scaling) to provide a more comprehensive understanding of ecological patterns. SIMPER analysis can be used for dissecting and understanding the contributions of individual species to the overall patterns observed in multivariate ecological data. A SIMPER analysis is not an actual test but more a description of which species that can explain the similarity/dissimilarity you test for in the ANOSIM analysis. More specifically, SIMPER helps identify which species contribute most to the similarity or dissimilarity between groups of samples. This can highlight key species that define the ecological differences or similarities between different locations or conditions. SIMPER analysis calculates the contribution of each species (%) to the similarity/dissimilarity between groups of samples and thus which species that contribute most to the similarity/dissimilarity observed.

4 EXISTING DATA

This baseline study uses existing data sources in and close to the pre-investigation areas and the subareas within, e.g. OWF areas (A1-3) and export cable corridors (ECC1-3).

4.1 EXISITING DATA SOURCES

Existing data used in this baseline report are based on various sources, i.e. the geophysical surveys of NSI.1, the Danish environmental monitoring program i.e. the NOVANA program (TOC, Eelgrass, macroalgae and infauna stations), the Danish Environmental Portal and from local OWFs and projects: Thor, Vesterhav Syd (MariLim, 2015a), Vesterhav Nord (MariLim, 2015b) and Horns Rev III (Orbicon, 2014), the EIA report of coastal nourishment (0-8 m depth) along the West Coast of Denmark from Nymindegab to Lodbjerg and sand extraction site 578-AA Husby Klit. Survey data are compared to existing data from the area when available and relevant.

Existing data sources and placement for the parameters described in this report are shown in relation to the two pre-investigation areas in Figure 4-1 and Table 4-1 below.

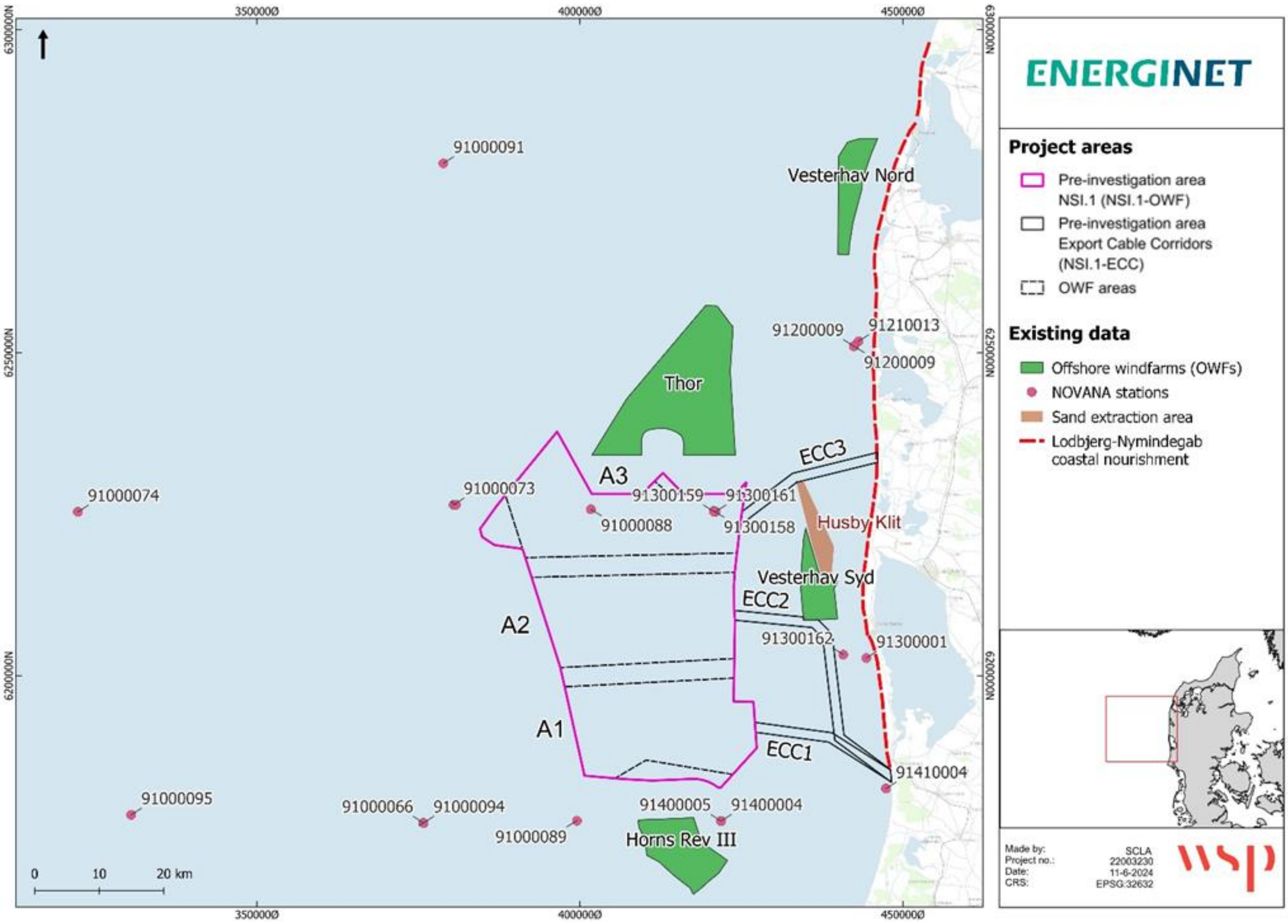


Figure 4-1. Existing data used for the two pre-investigation areas for NSI.1 OWF including three OWF areas (A1-3) and for the three export cable corridors (ECC1-3).

Table 4-1. Projects and stations used for description of existing data in the two pre-investigation areas.

Bornholm existing data	Sampling period	Selected stations	Reference
Depth			
GEUS Dataverse			**(GEUS, 2024a)**
Sediment			
GEUS Martha database			(GEUS, 2024)
Geophysical report (side scan sonar data and grain size)			
Geophysical surveys	April-September 2023		(Ocean Infinity, 2023) (Ocean Infinity, 2024)
CTDO-data			
Vesterhav Syd OWF	March 2013		(Energinet, 2015)
Thor OWF	March and May 2020		(Energinet, 2021)
TOC			
NOVANA stations	2008 - 2022	91300161 (DMU1035) 91000073 (DMU1072) 91300162 (RKB-VE44) 91410004 (RKB-VE2) 91000094 (DMU1044) 91210013 (RKB-VE-Thors-S) 91200009 (RKB-VE-Thor-N) 91000091 (DMU1025)	(Danmarks Miljøportal, 2023a)
Nutrients			
NOVANA stations	1989 - 2024	91300159 – Nordsøen (DMU1035) 91000066 – Nordsøen (DMU1044) 91000088 – Nordsøen, Husby Klit II (DMU1071) 91000089 – Nordsøen, Henne II (DMU1043) 91400004 – Nordsøen (DMU1042) 91300001 – Vesterhavet (RKB43)	(Danmarks Miljøportal, 2024a)
Pollutants			
NOVANA stations	2012 – 2022	91000074 (DMU1074) 91000073 (DMU1072) 91300161 (DMU1035) 91000095 (DMU1046) 91000094 (DMU1044) 91410004 (RKB-VE2) 91200009 (RKB-VE-Thors-N)	(Danmarks Miljøportal, 2024b)
Macroalgae and seagrasses			
Vesterhav Syd	2011-2018		(Miljøstyrelsen, 2020) (MariLim, 2015a)
Vesterhav Nord	March 2014		(MariLim, 2015b)
Thor OWF	2008-2020		(Danmarks Miljøportal, 2023b) (NIRAS, 2024) (Energinet, 2021)
Horns Rev III OWF	March 2013		(Orbicon A/S, 2014)

Bornholm existing data	Sampling period	Selected stations	Reference
Coastal nourishment Lodbjerg-Nymindegab (0-8 m depth)	October 2018		(Rambøll, 2020a)
578-AA Husby Klit New area 2016-A	15 th, 17 th, 18th of June 2021	Sand extraction areas	(WSP, 2022)
Epifauna and benthic communities			
Vesterhav Syd	12th and 13th of March 2014		(Vattenfall, 2020b) (MariLim, 2015a)
Vesterhav Nord	10th and 13th of March 2014		(Vattenfall, 2020a) (MariLim, 2015b)
Thor OWF	28th of March 2020 7th-9th and 18th – 19th of May 2020		(Energinet, 2021)
Horns Rev III	March 2013		(Orbicon, 2014)
Infauna			
NOVANA Stations	2015 - 2023	91300158 (DMU1035) 91400005 (DMU1042) 91000081 (DMU1044) 91000086 (DMU1072)	(Danmarks Miljøportal, 2024c)
Vesterhav Syd	12th and 13th of March 2014		(Vattenfall, 2020b) (MariLim, 2015a)
Thor OWF	28th of March 2020 7th-9th and 18th – 19th of May 2020		(NIRAS, 2024) (Energinet, 2021)

4.2 ABIOTIC DATA

Physical parameters such as depth, salinity and oxygen concentration are determining factors for the living conditions and habitat types available for benthic fauna and flora and are presented below. Salinity, temperature and oxygen profiles are measured in the water column by use of a CTDO.

4.2.1 DEPTH

Depths were measured in the pre-investigations areas of this study during the geophysical surveys from April to September 2023 (Ocean Infinity, 2024) and are presented in the results section 5.1.1 – Depth.

4.2.2 SALINITY, TEMPERATURE AND OXYGEN (CTDO)

CTDO measurement provides profiles of salinity, temperature and oxygen concentration in the water column.

Salinity and temperature generally vary little in the North Sea due to very dynamic wave and current conditions. Modelled surface salinities (psu) and satellite measurements of surface temperature in May 2024 for the Danish waters are shown in Figure 4-2 and Figure 4-3 below, The North Sea is characterized by being the most saline of the Danish waters (Figure

4-2) with salinity ranging from 28 – 35 psu (Ærtebjerg et al., 2003) and temperature ranges of approximately 4-11 °C (averaged annual temperatures from 1960-2020) (Hansen J.W. & Høgslund S. (red.), 2024) (Figure 4-3).

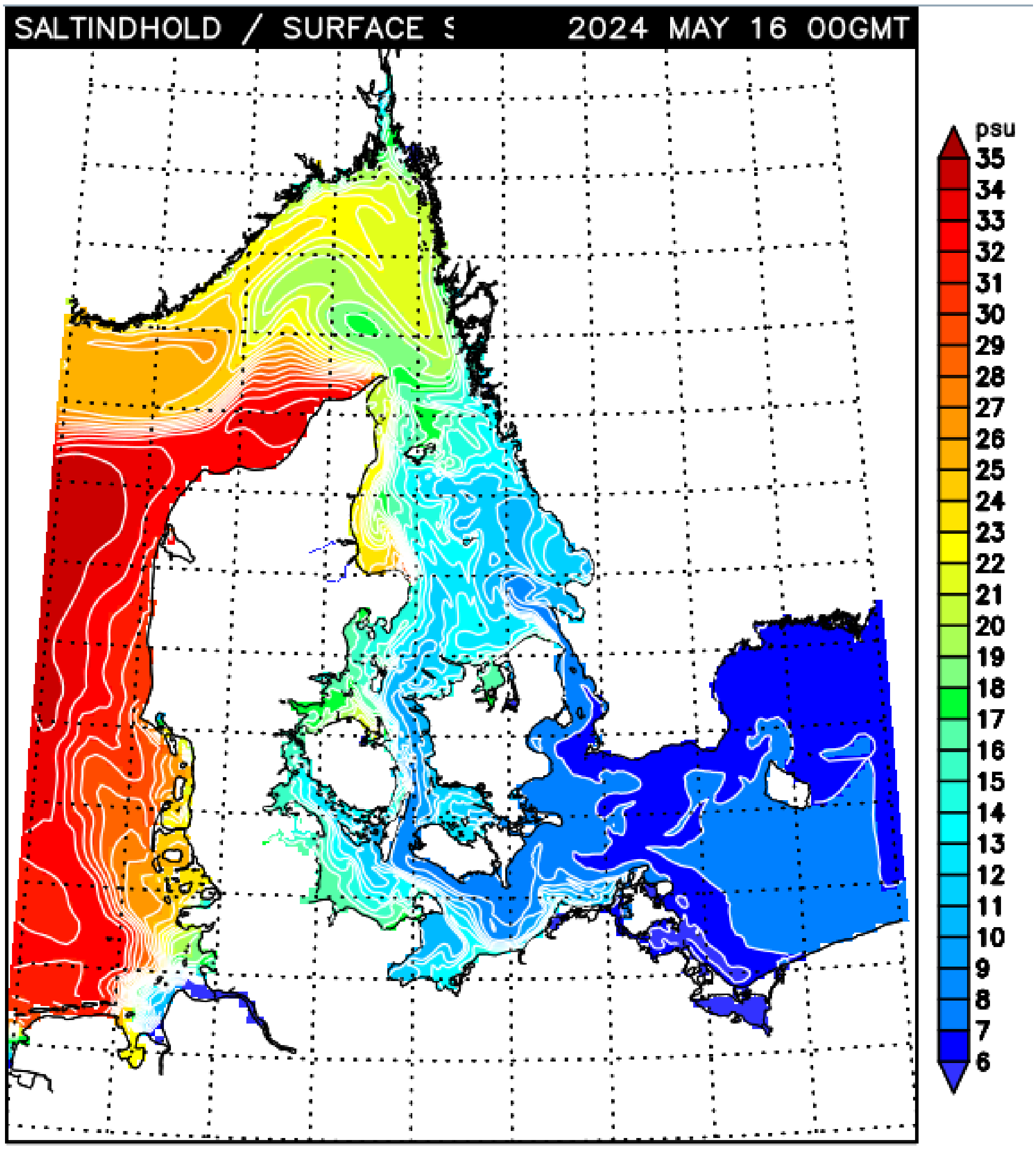


Figure 4-2. Modelled surface salinity in the Danish waters for the 16th of May 2024. Source: (DMI, 2024a).

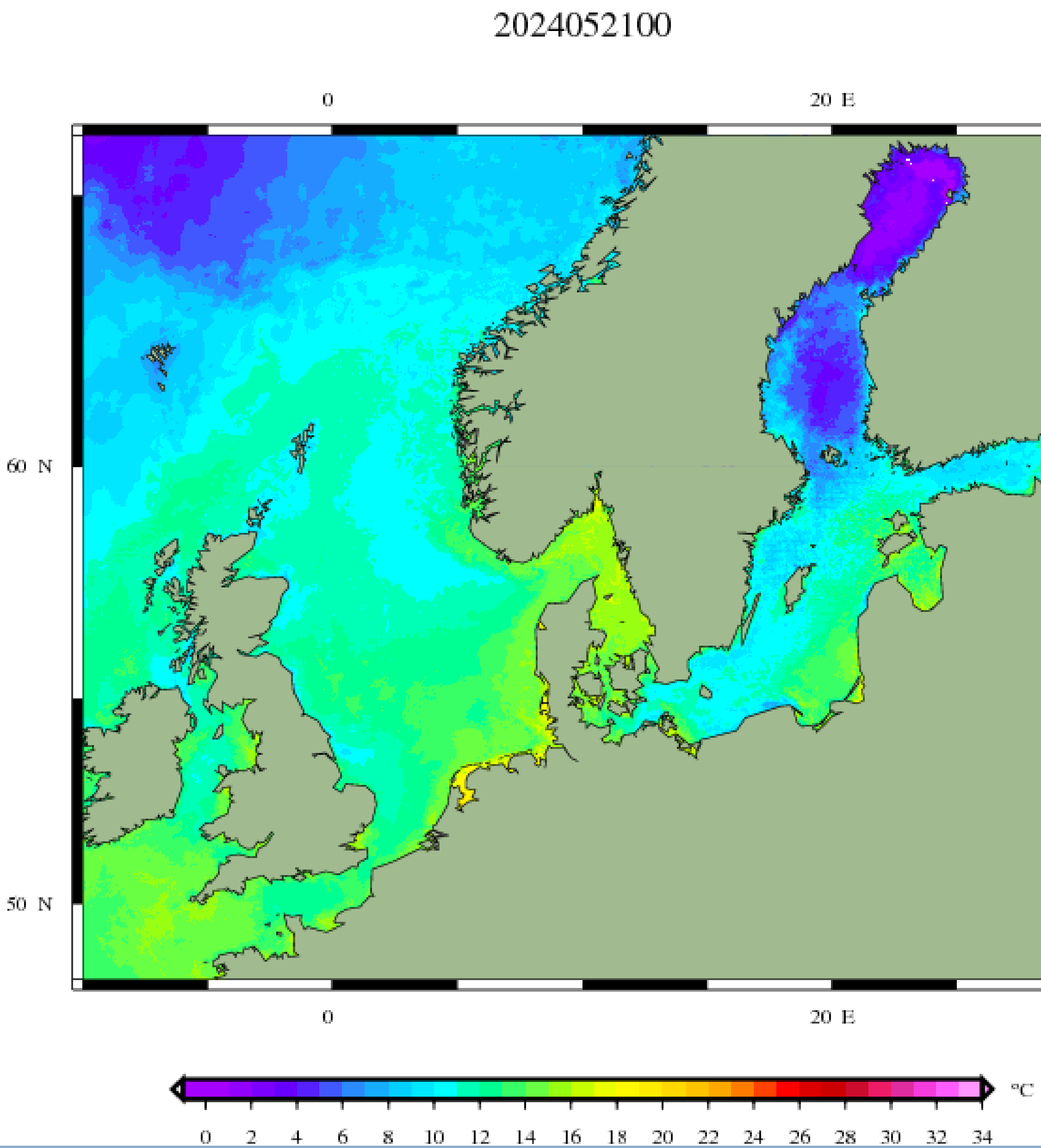


Figure 4-3. Surface water temperature in Danish waters on the 21st of May 2024 measured by satellite. Source: (DMI, 2024b).

CTDO measurements from baseline studies for Thor OWF, Vesterhav Syd OWF, Horns Rev III OWF and the present study (all sampled in spring (March to May)) (see Table 4-1), showed no stratification and fully oxygenized water columns. The details for each existing baseline study are presented below.

Moderate oxygen deficiency is defined as oxygen concentrations between 2-4 mg O_2/l and severe oxygen deficiency as <2 mg O_2/l. Oxygen deficiency is a very rare event in the North Sea west of the Danish coast due to the very dynamic conditions, and the Danish monitoring program NOVANA, therefore, does not monitor oxygen deficiency in the Danish North Sea (Hansen J.W. & Høgslund S. (red.), 2024).

Moderate oxygen deficiency (2-4 mgO_2/l) generally results in a reduced number of benthic fauna species and abundance. Oxygen concentrations below 2 mgO_2/l are critical for benthic organisms and will typically result in death of most organisms depending on species resilience (Rambøll, 2019; Hansen & Høgslund, 2021).

VESTERHAV SYD

Hydrographical conditions during the field campaign (12th to 13th March 2013) were measured at four random stations distributed across the study area (Figure 4-4). No considerable gradient between surface and bottom layer for temperature, salinity or oxygen concentration was present. Temperatures were in a range of 5.4 to 6.5 °C and this is a normal value for March. Salinity ranged between 29.4 and 33.6 psu, which is close to the prevalent salinity of approximately 31-33 psu in this region of the North Sea. Oxygen concentration varied between 12.7 and 13.8 ml/l and the water was saturated with oxygen throughout the water column. Stratification of the water column was not observed at any of the stations and the water column was thoroughly mixed.

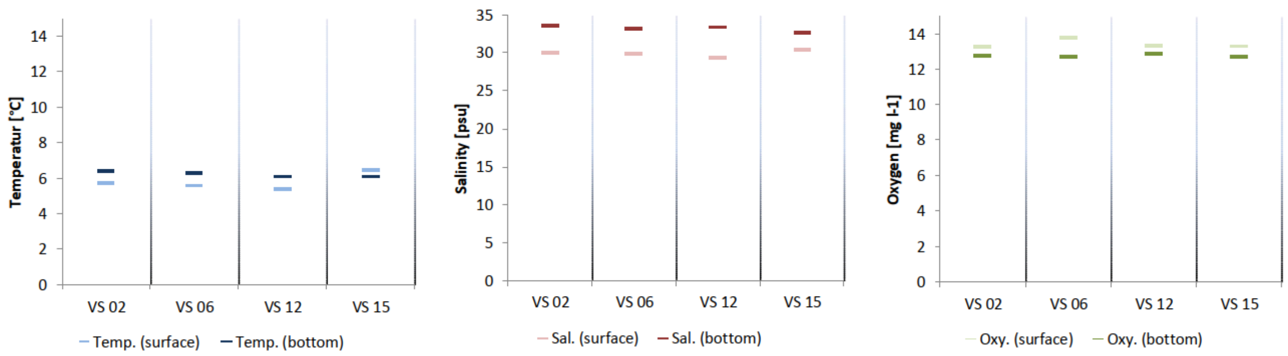


Figure 4-4. Measurements of surface (lighter colored bar) and bottom temperature (°C) (darker colored bar), salinity (psu) and oxygen (mg l^{-1}) from CTDO-profiling in the pre-investigation area for Vesterhav Syd OWF. Source: (Energinet, 2015).

THOR OWF

Salinity-, temperature- and oxygen concentrations and saturation (%) were measured in March and May 2020 at approximately 1 m above the seabed at 190 stations – 150 stations in the gross area for Thor OWF, 20 stations in the northern cable corridor (R2) and 20 stations in the southern cable corridor (R3) (Energinet, 2021). The range of data is presented in Table 4-2 below. No stratification and a fully oxygenized water column were observed at all stations in the Thor OWF area and in the export cable corridors (Figure 4-5).

Table 4-2. Range of oxygen (saturation % and mg/l), salinity (psu), temperature (°C) and depth approximately 1 meter above the seabed. GA = Thor OWF pre-investigation area. CC = cable corridor. Source: (Energinet, 2021).

	Oxygen (%)	Oxygen (mg/L)	Salinity (PSU)	Temperature (°C)	Depth (m)
GA	88.7-104.6	10.4-12.3	34-35	7.9-9.1	21.8-35.6
CC_R2	94.4-99.5	10.7-11.5	34.1-34.5	9.4-10	8.4-28
CC_R3	92.1-102.8	10.5-11.9	34.2-35	9.3-9.9	14.3-29.6

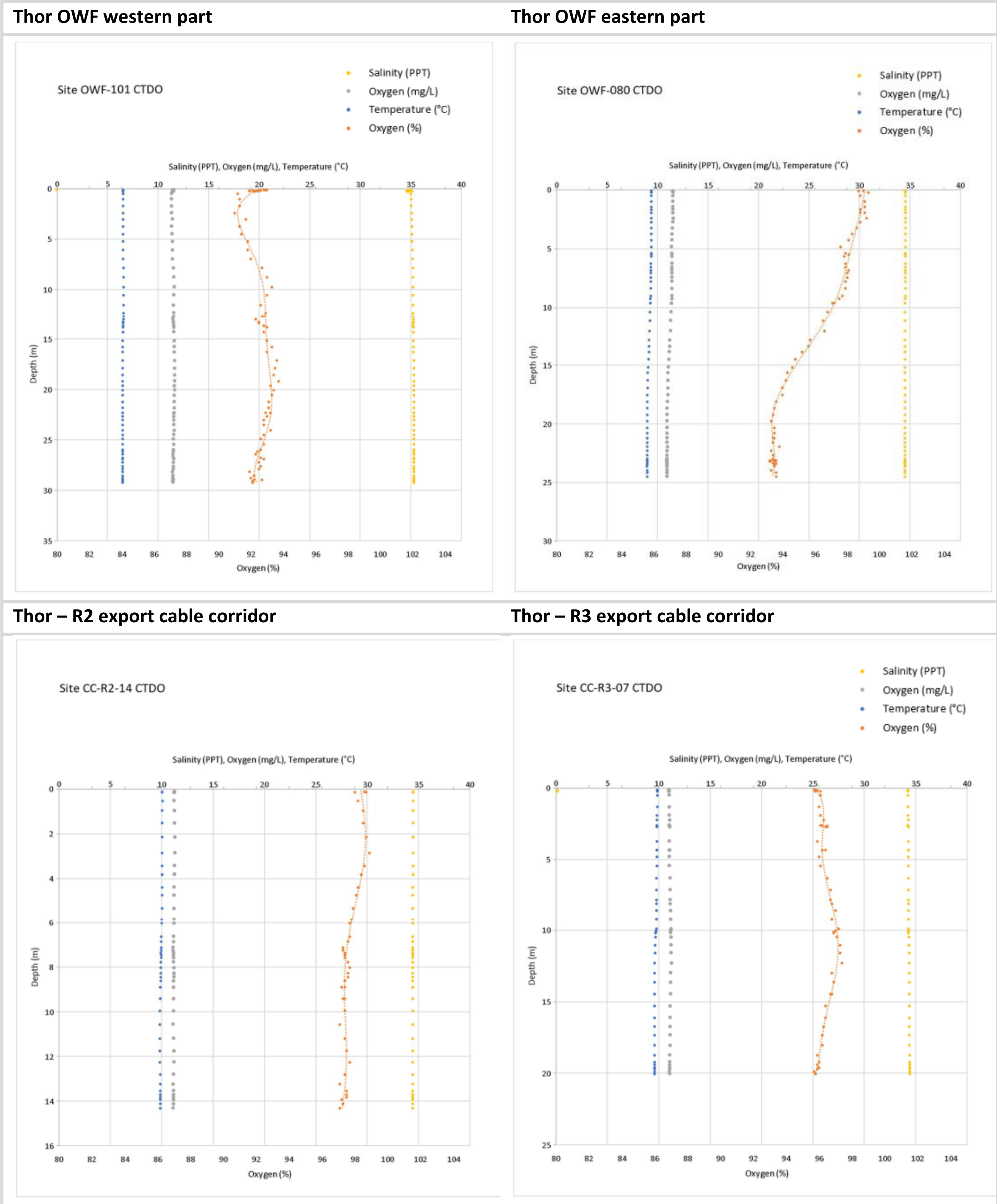


Figure 4-5. CTDO-profiles from the Thor OWF pre-investigation area (upper figures) and the export cable corridors (lower figures). Source: (Energinet, 2021).

4.3 SEABED SEDIMENT CHARACTERISTICS

The seabed sediment types in an area determines the living conditions and habitats available for benthic fauna and flora in that area. Benthic flora lives attached to hard substrate/sediment types such as larger stones (>10 cm), epifauna lives on hard substrate or on the surface of the seabed, whereas infauna lives buried in the seabed in soft/loose sediments such as silt, sand and gravel.

The physical and chemical sediment parameters are used as supporting parameters, where relevant, in the statistical analysis of infauna composition and distribution in the two pre-investigation areas (NSI.1-OWF and NSI-1-ECC).

4.3.1 SEDIMENT TYPES

Existing data for the overall distribution of seabed sediments in the two pre-investigation areas is presented below in Figure 4-6. The map is based on data from the national geophysical database provided by GEUS (Marta database, (GEUS, 2024)). The conversion between GEUS sediment types and the sediment types used in this baseline study are given in Table 4-3 below.

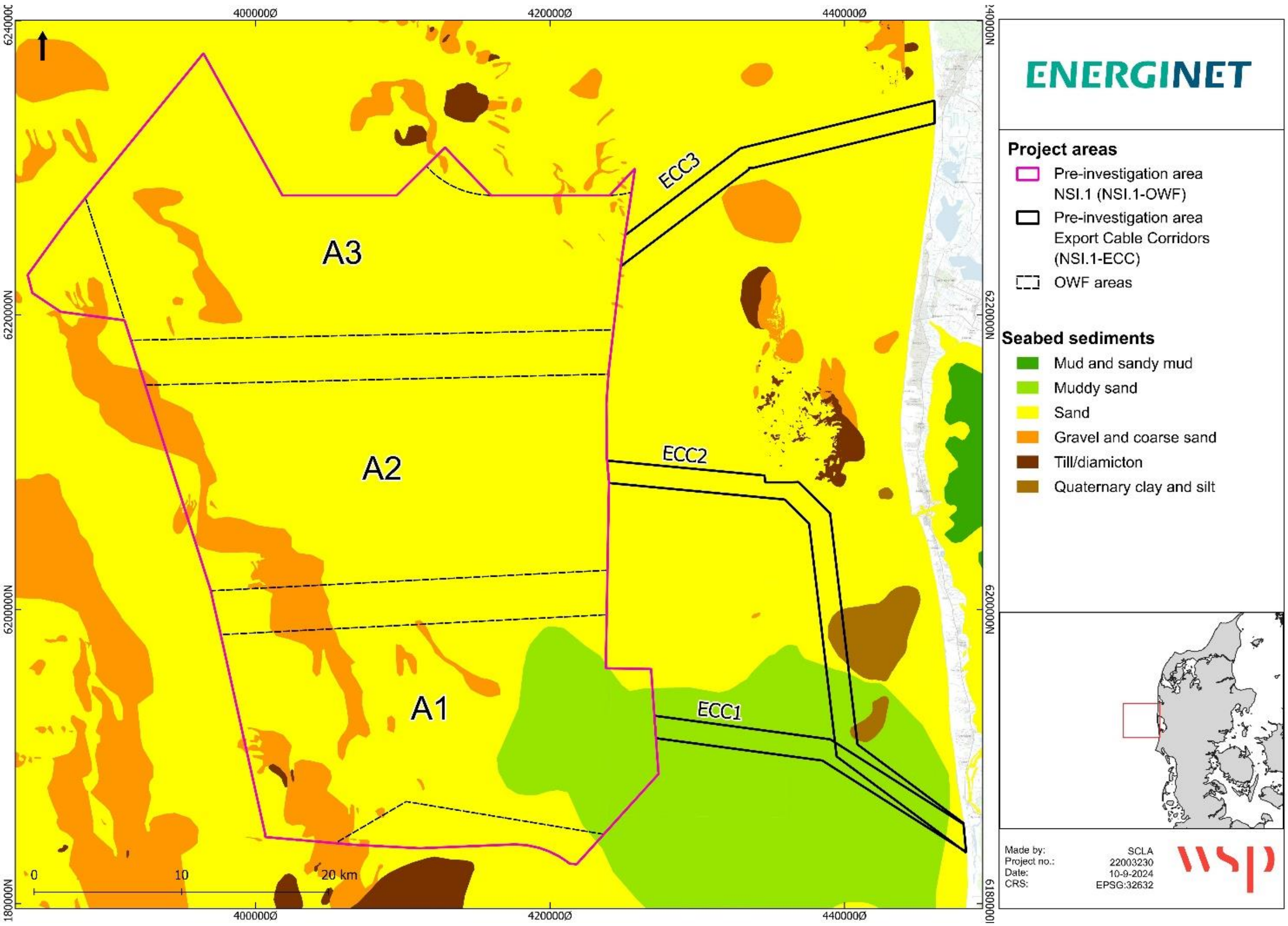


Figure 4-6. GEUS map of seabed sediment types in the two pre-investigation areas for North Sea I.1 including the OWF areas (A1-3) and the pre-investigation area for the three export cable corridors (ECC1-3) based on GEUS´ sediment map. Sources (GEUS, 2024).

The GEUS sediment type map in Figure 4-6 shows, that the two pre-investigation areas are dominated by “Sand” with small local areas of “Gravel and coarse sand”, “Quarternary clay and silt” and in the southeastern corner “Muddy sand”.

The GEUS map of sediment types in the pre-investigation areas is relatively broad-scale and does not fully illustrate the high natural variation in these areas. This is seen when comparing this map to the more fine-scaled sediment type map made by WSP for the two pre-investigation areas (see the results in section 5.2.1 – Sediment types).

Table 4-3. Conversion between GEUS sediment types and sediment types used in this report. It is not always possibly to convert directly, as e.g. till/diamiction coverseveral of the sediment types used in this report.

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 seabed is highly variable and dynamic along the West Coast of Jutland with a general dominance of the sediment type “Sand”. Thus, the smaller patches in the GEUS sediment map of “Gravel and coarse sand”, “Quarternary clay and silt” and “Muddy sand” as seen in Figure 4-6, may vary in size and placement depending on sampling month and year.

OWF AREAS

Existing data shows that the pre-investigation area for NSI.1-OWF is relatively homogenously with dominance of the sediment type “Sand” and smaller local patches of “Gravel and coarse sand”. However, the southeastern part is composed of a larger patch with “Muddy sand”.

Consequently, the three OWF areas A1-A3 are relatively uniform except for at large patch of “Muddy sand”, which is found in area A1.

EXPORT CABLE CORRIDORS

The pre-investigation area for each of the three export cable corridors (NSI.1-ECC) shows individual variations.

The northernmost 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 finally in the most southeastern part of “Muddy sand”. In the southern cable corridor (ECC1), only “Muddy sand” is mapped.

4.3.2 PHYSICAL PARAMETERS

Grain size is a measure for particle size (in mm to cm) and thus a measure for the sediment type. Grain size and organic content is determining for the habitat available to the benthic flora and fauna and for oxygen conditions.

GRAIN SIZE

Sediment was sampled and analysed for grain size in the pre-investigation area for NSI.1 by “Ocean Infinity” during the geophysical survey and is reported in the “Geotechnical report” (Ocean Infinity, 2023). The results of grain size distribution in the pre-investigation area for NSI.1 are presented in Figure 4-7 showing dominance of “Sand” and small local patches of “Gravel”. Sand is defined as particle sizes between 0.06-2 mm and “Gravel” is defined as particle sizes from 2-60 mm in the Geotechnical report.

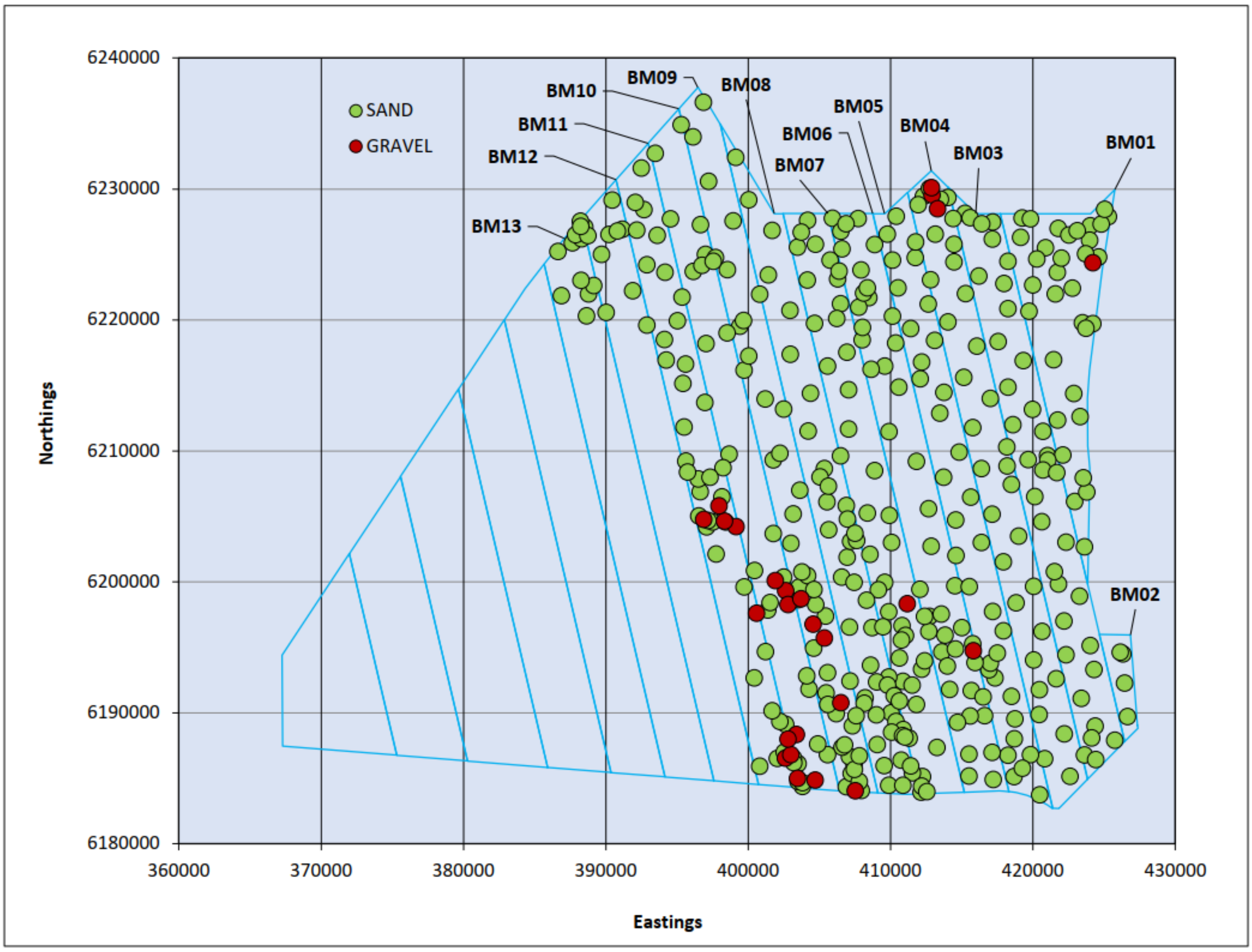


Figure 4-7. Summary of grab sample locations and material types. Source: (Ocean Infinity, 2023).

The grain size distribution presented in Figure 4-7 does not show the same distribution of ”Gravel” as seen in GEUS' sediment type map in Figure 4-6. This is likely due to the fact, that the seabed is very dynamic in this area, and because of different approaches in regard to producing a sediment type map. GEUS' sediment type map shows the surface sediment, determined from side scan sonar data and large-scale interpolation between areas with available data, while grain size is based on sieving analyses of grab samples taken in 0-20 cm depth of the seabed.

TOTAL ORGANIC CARBON CONTENT (TOC)

The geotechnical report does not contain data on Total Organic Carbon (TOC) from the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC).

NOVANA STATIONS

TOC measurements done at MFS sediment stations under the Danish monitoring programme NOVANA, are presented in Table 4-4 and the positions of the stations are shown in Figure 4-1. The NOVANA data from the stations in the area from the period of 2015-2022 (Table 4-4), show that TOC concentrations in the sediment, both close to the coast and at depth, are very low i.e. below or close to the detection limit for TOC (<0.077-<0.2 % TS). Note that the detection limit varies between years as it was generally below <0.2 % TS but in some years lower, presumably because of differing measuring methods. Measured TOC concentrations that were above the detection limit were in the range of 0.077-0.24 % TS. This illustrates that TOC concentrations in the sediment are very low in the area, so low that it is difficult to measure. Furthermore, TOC is observed to be highly variable both between stations and years within one order of magnitude (10 times) but always near or below detection limit.

Table 4-4. TOC (% TS) concentration measurements in the North Sea in and around the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC). Data are from the Danish monitoring program NOVANA. "<" indicates that the TOC concentration is below the detection limit. The detection limit is generally 0.2 % TS except in 2016 where it was 0.05 % TS. Concentrations in the data below detection limit are indicated by <0.2 in the table. Note that some years detection limit is lower presumably due to differing measuring method. Station placement is presented in Figure 4-1. Data source: (Miljøportalen, 2024a).

Locality ID	Sampling period	TOC (% TS)
91300161 (DMU1035)	2015	<0.2
91000073 (DMU1072)	2015 2016	<0.2 0.09
91300162 (RKB-VE44)	2019	0.24
91410004 (RKB-VE2)	2014 2022	<0.2 0.26
91000094 (DMU1044)	2016	0.077
91210013 (RKB-VE-Thors-S)	2008	<0.2
91200009 (RKB-VE-Thor-N	2008 2012 2018	<0.2 <0.2 <0.2
91000091 (DMU1025)	2016 2022	0.091 <0.2

THOR OWF

TOC was also measured for Thor OWF pre-investigation area and was within the range of <0.1-5.3 % TS with an average of 1.03 % TS. The TOC concentration was generally low with average values of 0.1-0.2 % TS. Only in the more homogeneous southwestern part of the pre-investigation area was TOC measurements >0.5 % TS.

OTHER OWFS

TOC was not measured in connection with the baseline study for Vesterhav Syd OWF (NIRAS, 2024) or Horns Rev III OWF (Orbicon A/S, 2014).

4.3.3 CHEMICAL PARAMETERS

Sediment that is suspended in the water column due to digging or flushing activities during construction of wind farms may cause release of nutrients, heavy metals and organic pollutants. Release of nutrients can increase phytoplankton concentration and epiphyte coverage and reduce light availability and growth of macroalgae on the seabed. High concentrations of pollutants in the seabed may be determining for the abundance and distribution of infauna in the seabed. The chemical sediment parameters are therefore used as supporting parameters in the statistical analysis of infauna composition and distribution in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC).

NUTRIENTS

Nutrients including total nitrogen (N) and phosphorous (P) are essential elements for various life processes and are utilized by marine micro- and macroalgae, thus playing a crucial part of primary production (Siriwardana, Samarasekara, Damsara, & Vithanage, 2024). N and P enter water bodies through natural processes such as erosion, but in particular through anthropogenic sources such as run-off from fertilization and industrial releases (Lenhart, Mills, Baretta-Bekker, & Wakelin,

2010) and are often limited in marine waters. While nutrients are essential to various fluxes and processes, some of these are captured in the sediments. As an indirect effect of sediment spill by e.g. dredging or digging activities, nutrients buried in the sediment can potentially be released into the water column, thus increasing the nutrient concentration in the water.

Existing data for nutrients are described based on six stations from the study area sampled by the Danish monitoring program (NOVANA) (Danmarks Miljøportal, 2024a). Station location is presented in Figure 4-1 and data for total nitrogen (TN) and total phosphorous (TP) concentrations measured at the stations are presented in Table 4-5. TN and TP concentrations are generally low. One of the six stations is located close to the coast, where the most northern cable corridor (ECC3) is planned, while the remaining four stations are located offshore. There are more NOVANA stations located within the pre-investigation area for the export cable corridors, but these are not included since they have not been sampled in the past 10 years.

Total nitrogen (TN) concentrations ranged between 50-2307.6 µg/l at the six NOVANA stations and total phosphorous (TP) concentrations ranged between 3-340 µg/l (Danmarks Miljøportal, 2024a). The highest concentrations of TN and TP was measured at the station closest to the coast (91300001 – Vesterhavet) (Danmarks Miljøportal, 2024a), which is to be expected, as nutrient concentrations are generally higher near the coast due to e.g. run-off from land (Lenhart, Mills, Baretta-Bekker, & Wakelin, 2010). In conclusion, nutrient concentrations measured at the NOVANA stations in and around the two pre-investigation areas of this study (NSI.1-OWF and NSI.1-ECC) varied between stations and years, generally very low and within background concentrations for the North Sea region (Seiter et al. , 2004)

Table 4-5. Total nitrogen (TN) and phosphorus (TP) (µg/l) measured in the sediment in and around the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC). Source: (Danmarks Miljøportal, 2024a).

NOVANA station ID	Sampling period	TN (µg/l)	TP (µg/l)
91300159 - Nordsøen	2014 - 2024	50 - 471	5.45 - 50
91000066 - Nordsøen	2014 - 2024	50 - 339	3.25 - 50
91000088 – Nordsøen, Husby Klit II	2018 - 2019	97 - 310	4.4 - 31.3
91000089 – Nordsøen, Henne II	2018 - 2019	151 - 359	7.8 - 22.4
91400004 - Nordsøen	2014 - 2024	50 - 509	7 - 50
91300001 - Vesterhavet	1989 - 2024	138.6 – 2307.6	3 - 340

There are no threshold values for total nitrogen (TN) or phosphorous (TP), but comparing with measurements in the open inner Danish waters, the concentrations in Table 4-5 are generally low and comparable to what is normally measured in the North Sea (Hansen J.W. & Høgslund S. (red.), 2024).

POLLUTANTS

Locations of the NOVANA stations (= the Danish monitoring program) identified as relevant to this study in regard to pollutants, are presented in Figure 4-1 and in Figure 4-8. In total, seven NOVANA stations are included. Only one station (9130161) is located in the pre-investigation area of NSI.1, all other stations are located in the area around the two pre-investigation areas.

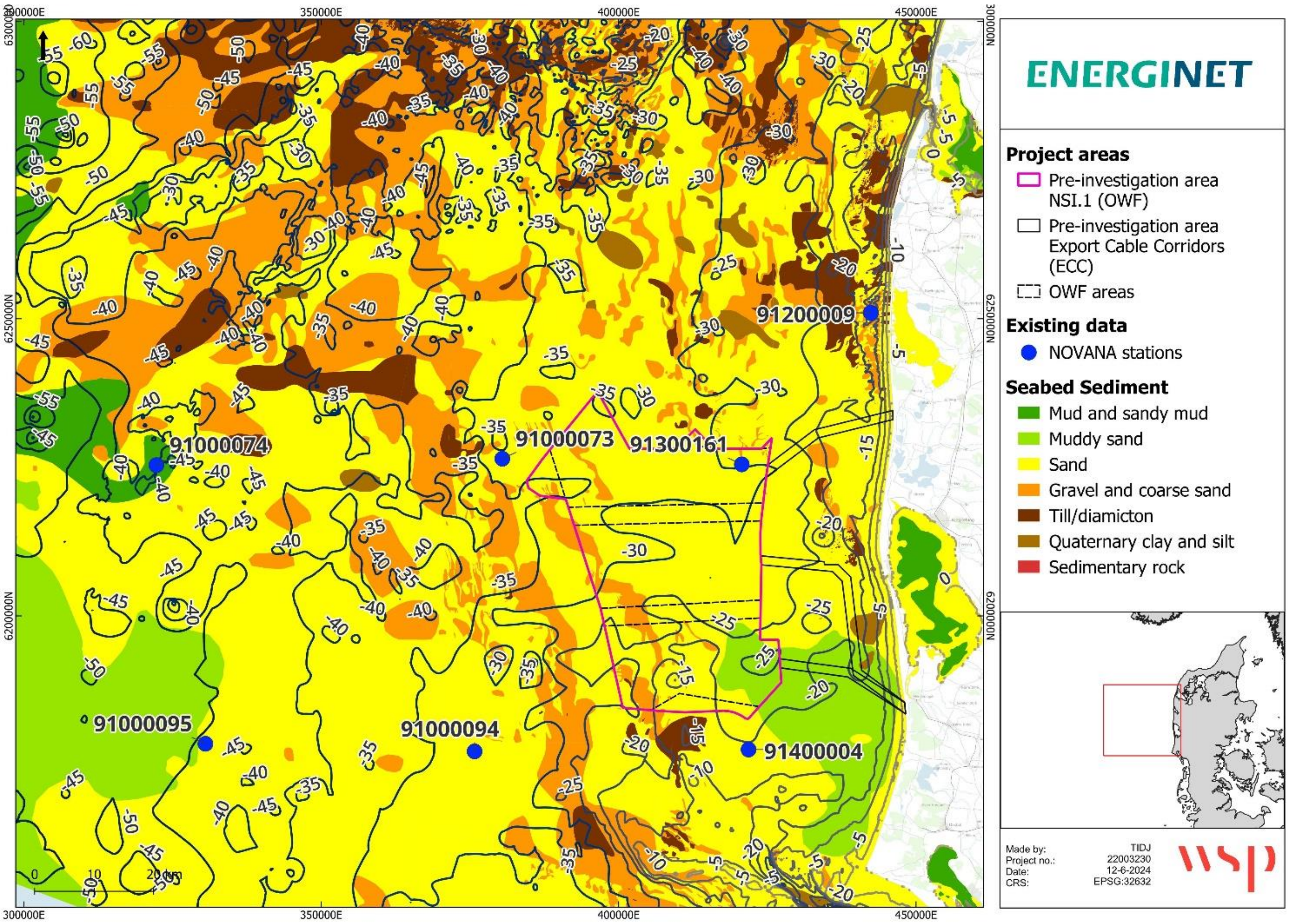


Figure 4-8. NOVANA stations for pollutants in sediment with GEUS sediment types and depth ranges as background. Sources: (GEUS, 2024; GEUS, 2024a).

Measured sediment concentration of each individual pollutant is assessed by comparing the measured concentrations at the NOVANA stations with sediment threshold values. This is done by following a prioritized order of different threshold values, as described in section 3.4.6 HAPS - Chemical analysis. For each pollutant, the measured concentrations are therefore only compared to the threshold value of highest priority. The assessment and description of the presence of pollutants are separated into statutory threshold values (NEQS) and non-statutory thresholds (NQS). Pollutants measured at the NOVANA stations, which exceed the threshold values, are presented in Table 4-6 (Danmarks Miljøportal, 2024b).

For a number of the pollutants, the threshold values are calculated by the content of organic matter (TOC in %) in the sediment of each sample (Miljøstyrelsen, 2023a) (Miljøstyrelsen, 2023b). This applies to the NEQS of the heavy metal silver (Ag), the PAH-compounds anthracene, naphthalene and the methylnaphthalenes (sum), and the phenols, nonylphenols (sum) and 4-tert-octylphenol. The same applies to the NQC for the four PAH-compounds benz(a)anthracene, chrysene, phenanthrene and pyrene. As a result of the very low TOC values (Total Organic Carbon) in this part of the North Sea (see section 4.3.2 – Physical parameters/TOC), the NEQS for the pollutants where TOC are used to determine the NEQS, are very low, and in some cases the NEQS is lower than the detection limit of the laboratory analysis.

In general, pollutants adsorb to the organic content of sediments, because many pollutants easily bind to the carbon chains in organic matter, such as algae (Larsen & Strand, 2018), and only a minor part will dissolve in the porewater. Furthermore, fine-grained sediment will adsorb greater quantities of pollutants than coarse-grained sediment, such as sand and gravel, because of the large surface to volume ratio.

Comparing all NOVANA stations, five metals (arsenic, chromium, nickel, vanadium, and zinc), are found in concentrations exceeding both statutory (NEQS) and non-statutory (NQC) sediment threshold values (see Table 4-6). Six PAH-compounds (anthracene, benz(a)anthracene, chrysene, napthalene, phenanthrene and methylnaphthalenes (sum)) are found in concentrations exceeding both statutory and non-statutory sediment threshold values. At the NOVANA station 9130161 located in OWF area A3, only arsenic exceeded the threshold value, and anthracene was below the detection limit.

Arsenic was the only pollutant to exceed threshold values at all NOVANA stations, and at 3 of the 7 NOVANA stations the concentration of anthracene was below the detection limit. Highest concentrations were observed at NOVANA station 91000074, located approximately 63 km vest of the pre-investigation area of NSI.1 (NSI.1-OWF), in the sediment type "mud and sandy mud". This sediment type theoretically has a higher adsorption potential for the pollutants, compared to the rest of the NOVANA stations, where the sediment is either "sand" or "gravel/coarse sand" according to GEUS sediment map (see Figure 4-8). However, the station where most pollutants exceeded the threshold values was station 91000095, located approximately 70 km vest of the pre-investigation area, where the sediment type is "sand". Both station 91000074 and 91000095 are located in areas with depths below 40 meters. Station 91200009, which is located close to shore at around 8 meters of depth, had approximately the same concentrations as the rest of the NOVANA stations. Thus, there was no correlation between pollutant concentrations and sediment type or depth for the NOVANA stations. This may be caused by the very dynamic seabed in the area continuously mixing the sediment and distributing pollutants randomly in the area and/or a sediment map, that is not detailed enough and varies from year to year.

Table 4-6. Pollutants exceeding prioritized threshold values in the sediment at the local NOVANA monitoring stations. For station locations see Figure 4-1. NEQS (national environmental quality standards, (Danish: Miljøkvalitetskrav) and NQC (national quality criteria, kvalitetskriterier) are calculated based on the organic content (TOC) for relevant pollutants. Exceedances of the NEQS (statutory) are represented by red numbers, and exceedances of the NQC (non-statutory) are represented by black numbers. f_{oc} is the fraction of TOC in the sediment. <LOD = below limit of detection, but detection limit is higher than the threshold value. NA = compound is not measured. Empty cells = no exceedances. Source: (Danmarks Miljøportal, 2024a).

		Metals (mg/kg DW)					PAH (µg/kg DW)						Organo-tin (µg/kg DW)
Threshold values /Stations	TOC (%)	Arsenic	Chromium	Nickel	Vanadium	Zinc	Anthracene	Benz(a)anthracene	Chrysene	Naphthalene	Phenanthrene	Methylnaphthalenes (sum)	Tributyltin (TBT)
NEQS					**23.6**		**96 x f_{oc}**			**2760 x f_{oc}**		**478 x f_{oc}**	
NQC		0.4	9.2	6.8		150		600 x f_{oc}	462 x f_{oc}		7800 x f_{oc}		1.3
NOVANA station (year)													
91000074 (2022)	0.26	17			**25**		**3**	0.6				**5.8**	
91000073 (2016)	0.09	3.4			NA		**0.9**	3.1	1.2			**2.4**	
91300161 (2015)	0.2	2.1			NA		**<LOD**						
91000095 (2016)	0.085	4	14	7.6	NA	220	**2.5**	6.6	4.3	**3.3**	9.3	**7**	
91000094 (2016)	0.077	2.6			NA	210	**0.7**	1.9	1		2.3		
91410004 (2022)	0.2	5	14.7		**11.8**		**<LOD**		1.1		2		
91200009 (2012)	0.2	4.8	27.1	8.2	NA		**<LOD**						<LOD

4.4 BENTHIC FLORA

Benthic flora reported here includes seagrasses and macroalgae, which are the common benthic flora found in Danish waters.

4.4.1 SEAGRASSES

Seagrasses generally do not occur along the exposed part of the West coast of Jutland, due to high sediment dynamic, sediment transport and wave exposure. The exposed and dynamic seabed makes it very difficult for seagrasses to achieve stable attachment and to establish stable colonies. The Danish environmental monitoring program (NOVANA), therefore, does not monitor the exposed part of the West coast of Jutland for seagrasses – only the protected fjords and the inner part of the Wadden Sea are monitored (Hansen & Høgslund (red.), 2024).

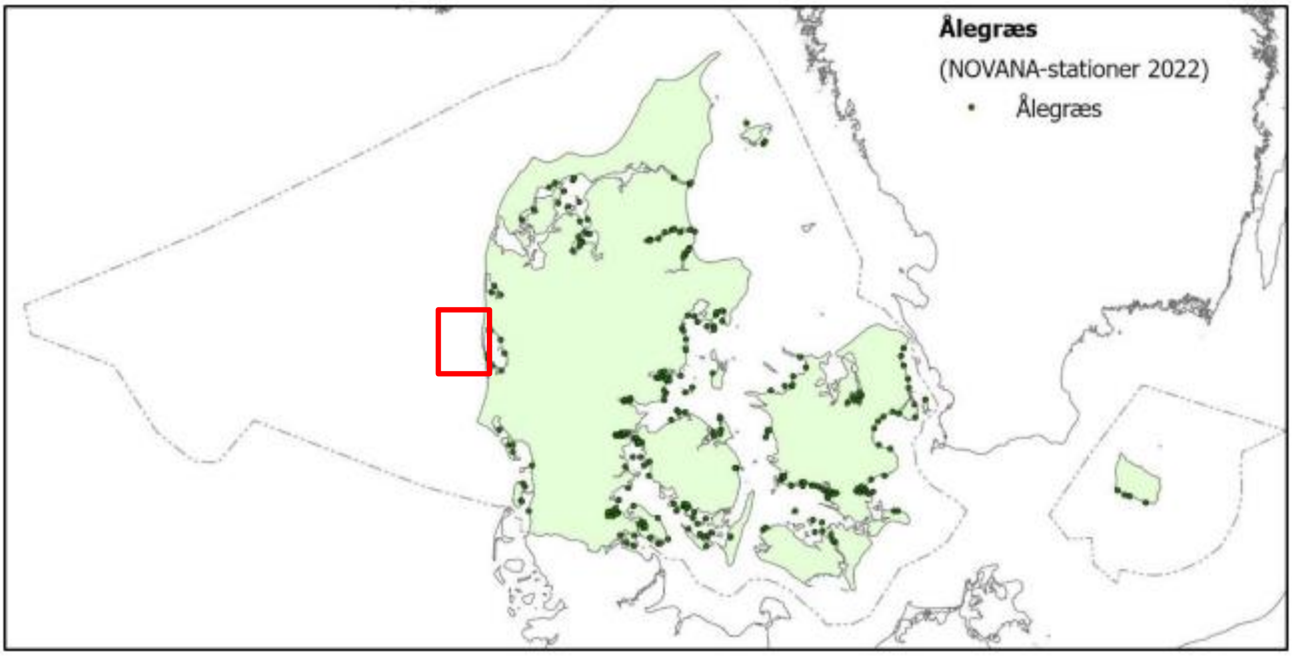


Figure 4-9. Danish monitoring stations for seagrasses monitored in 2022 with the two pre-investigation areas (NSI.1 OWF and NSI.1-ECC) indicated by a red square. Seagrasses are monitored once a year during the period from June to September. The Danish Exclusive Economic Zone (EEZ) is indicated by the grey, broken line. Source: (Hansen & Høgslund (red.), 2024).

Furthermore, no seagrasses were observed in connection with the EIA baseline studies for Thor (NIRAS, 2024), Vesterhav Syd (MariLim, 2015a), Vesterhav Nord (MariLim, 2015b), Horns Rev III - (Orbicon A/S, 2014). Also, no seagrasses were observed in the EIA report of coastal nourishment (0-8 m depth) along the West Coast of Denmark from Nymindegab to Lodbjerg (Rambøll, 2020a) or within raw extraction site 578-AA Husby Klit in June 2021 (WSP, 2022).

4.4.2 MACROALGAE

Macroalgae live attached to hard substrate i.e. rocky sediment and larger stones generally ≥ 10 cm within the photic zone. The photic zone is generally defined as depths, where more than 1 % of surface irradiance is present and it varies according to wave induced resuspension of the seabed, silt and marine snow in the water column.

Similar to seagrasses (Hansen J.W. & Høgslund S. (red.), 2024), macroalgae are only monitored in the fjords by The Danish environmental monitoring program (NOVANA), and not in the open part of the North Sea. The cumulated coverage of macroalgae in Danish coastal waters in the period of the NOVANA-monitoring (1990-2020) has shown a significant upward trend, which is most likely a result of overall improved water quality (Hansen & Høgslund, 2021). However, the NOVANA monitoring in 2021 concludes that the degree of coverage of macroalgae (seaweed) has stagnated in all water types and at stoney reefs (Hansen & Høgslund, 2023).

Macroalgae was not observed in the pre-investigation areas of the nearby OWFs projects: Vesterhav Syd (MariLim, 2015a), Vesterhav Nord (MariLim, 2015b) and Horns Rev III (Orbicon, 2014). Also, no macroalgae were observed in the EIA report of coastal nourishment (0-8 m depth) along the West Coast of Denmark from Nymindegab to Lodbjerg (Rambøll, 2020a) or most recently in June 2021 within the sand extraction site 578-AA Husby Klit (WSP, 2022).

In the baseline study of Thor OWF (Energinet, 2021) macroalgae were not observed in the cable corridors, however, two species of red crust algae were observed in the OWF area. One specimen of *Hildenbrandia rubra* (red crust) was observed at ROV station OWF_046 at 29.8 meters depth, which is right at the expected depth limit for this algae type in the Danish part of the North Sea (Køie M. & Kristiansen A., 1999, 2023). Two small spots (approx. 5 cm in diameter) of *Phymatolithon laevigatum* was observed at station OWF_013 at approx. 27.8 m depth (see Figure 4-10), which is below this species reported depth limit in the Danish waters of approximately 20 m depth (Køie M. & Kristiansen A., 1999, 2023). The technical report for the Thor OWF concludes that the lack of benthic flora communities is expected due to the very exposed and dynamic nature of the West coast of Jutland and light limitation at greater depth in the pre-investigation area for Thor OWF (Energinet, 2021).

Figure 4-10. Two specimens (red arrows) of the red crust alga *Phymatolithon laevigatum* in the Thor OWF area. ROV-station OWF_013. Source: (Energinet, 2021).

4.5 BENTHIC FAUNA

Benthic fauna refers to invertebrates associated with the seabed surface (epifauna) or living buried in the seabed (infauna). Both epi- and infauna are presented in the following compilation of existing data from the North Sea and the West coast of Jutland. This review is done to provide comparable data for epifauna and infauna distribution, species numbers, abundance, biomass and ecological indexes (for infauna) and to illustrate that the species found in this study are common species for the North Sea and for the local area off the West coast of Jutland.

In general, the benthic fauna in the North Sea is very variable and heterogeneous, both spatially and between and within years (Reiss et al, 2010; Reiss & Kröncke, 2006). It can therefore be difficult to directly compare areas such as the pre-investigation areas for NSI.1_OWF and cable corridors (NSI.1-ECC) with adjacent, deeper areas or sandbanks, which are situated elsewhere in the North Sea (Vanosmael et al., 1982; Salzwedel et al., 1985; Degraer et al., 1999). Generally, local fauna communities display high variability in spatial and temporal distribution patterns (Rambøll, 2020a; Neumann et al., 2009).

Infauna and epifauna species diversity are highest in the northern parts of the North Sea, and generally quite low along the West coast of Jutland where the two pre-investigation areas in this baseline study are located (see Figure 4-11). The abundances of infauna and epifauna are generally higher in the southern parts of the North Sea (see Figure 4-12).

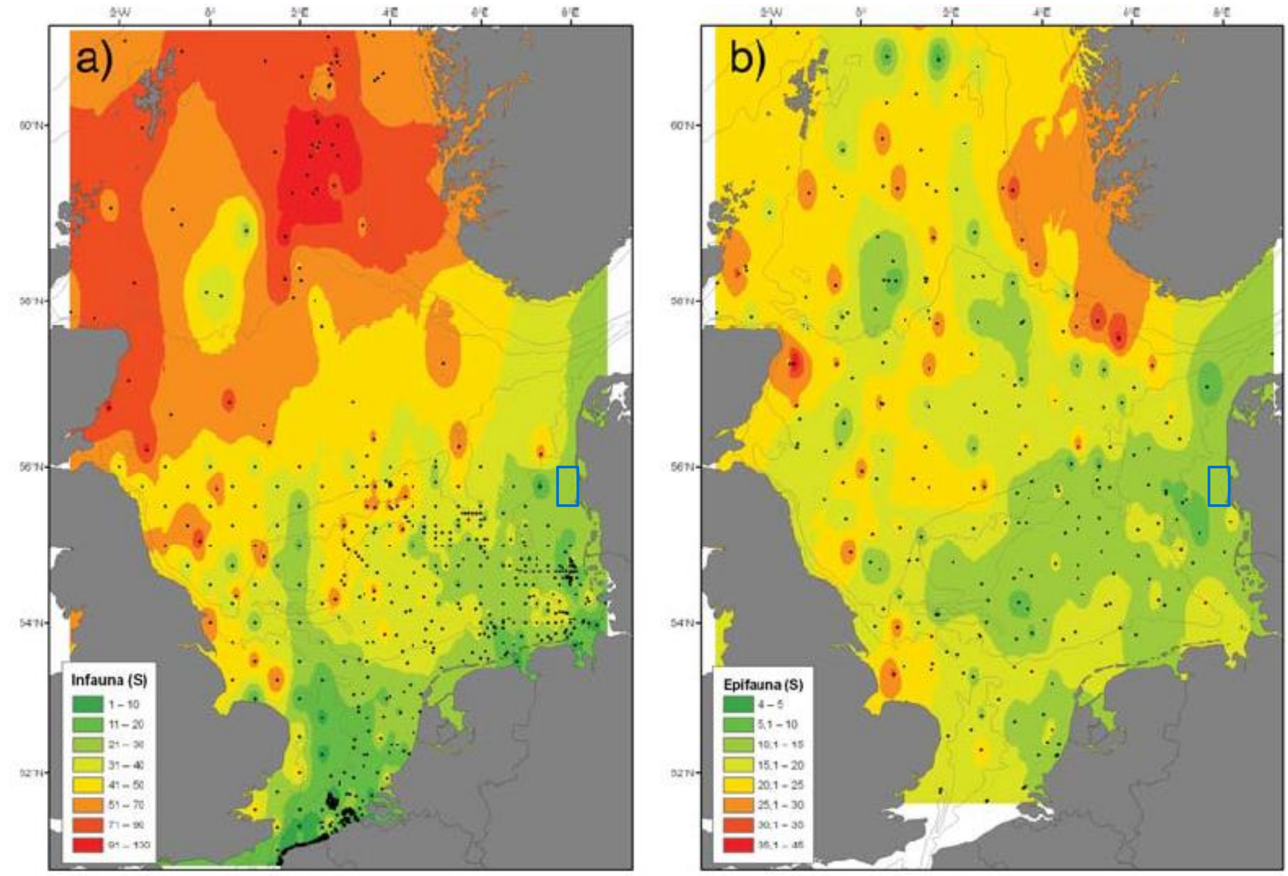


Figure 4-11. Number of species in the North Sea of a) Infauna species and b) Epifauna. The approximate location of the two pre-investigation areas for the NSI.1 OWF and cable corridors are indicated by a blue square. Source: Modified from Reiss et al. 2010 in (Orbicon, 2014).

The study by (Reiss et al, 2010) shows that the number of infauna species is approximately 21-30, and the number of epifauna species approximately 10-15 in the pre-investigation areas for this study. The abundances of infauna and epifauna is approximately 1,000-1,500 individuals/m^2 and 100-500 individuals/m^2, respectively.

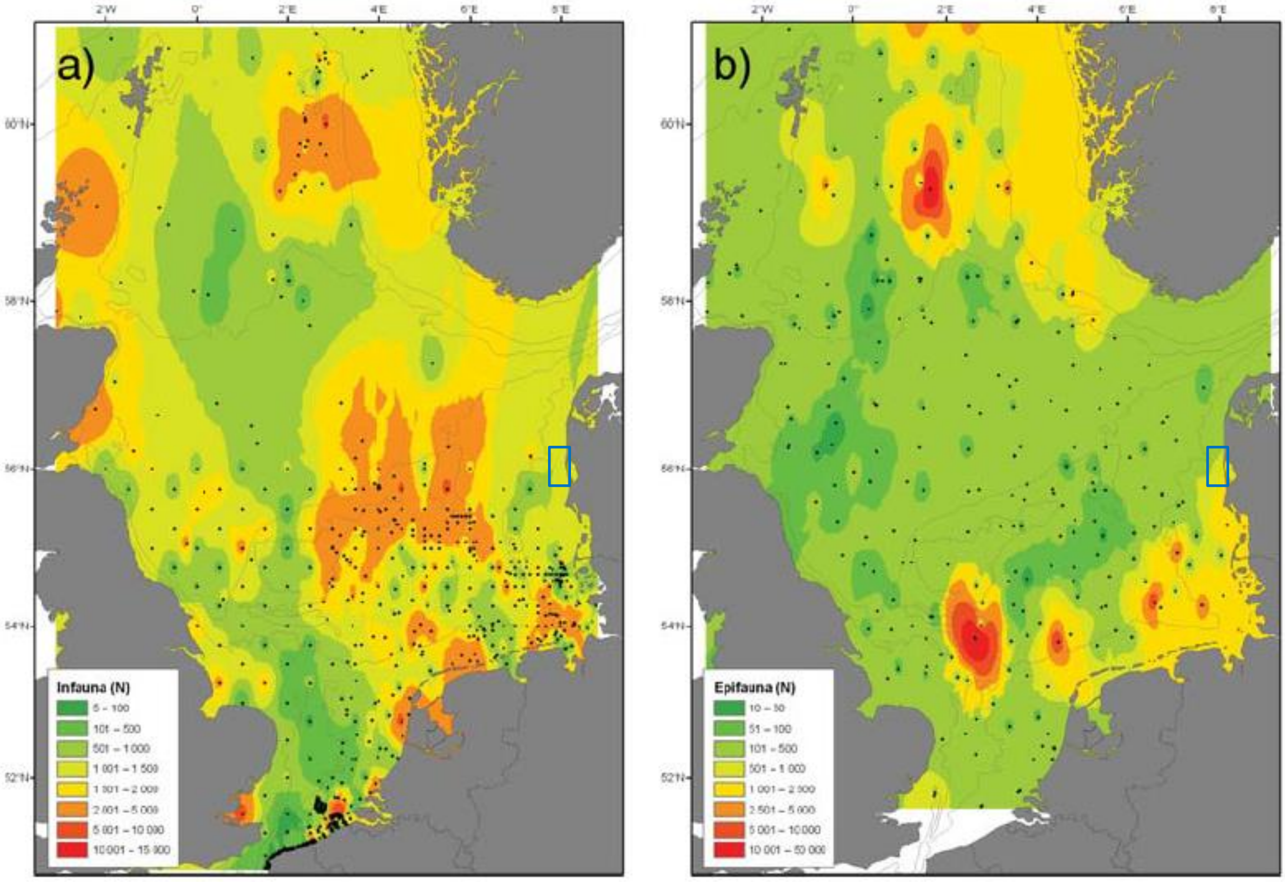


Figure 4-12. Abundance of infauna and epifauna in the North Sea. A: Infauna species (ind./m^2) and b) Epifauna species (ind./500 m^2). Black dots indicate samples taken. The approximate location of the two pre-investigation areas (NSI.1-OWF and NSI-1-ECC) are indicated by a blue square. Source: Modified from Reiss et al. 2010 in (Orbicon, 2014).

The benthic fauna along the West Coast of Jutland is transported with the currents and distributed along the entire West coast (Göke et al , 2019), and therefore has a good recovery and reestablishment potential in affected areas.

This is supported by a recent study from 2018 of the infauna community along the West coast of Jutland from Lodbjerg to Nymindegab (0-8 meters depth), which showed that it is generally the same infauna community that exists along the shallow part of west coast of Jutland (Nymindegab-Lodbjerg) due to the larvae being transported and distributed along the coast by the coastal currents (Rambøll, 2020a). The study also shows that this community is highly variable in regard to distribution, species numbers, abundance and biomasses due to the highly dynamic environment (Rambøll, 2020a; Neumann et al., 2009).

4.5.1 EPIFAUNA

Data for epifauna communities observed in the nearby Thor OWF, Vesterhav Nord and Syd OWFs are included to provide comparable data with this study, and to explore whether the data obtained in this study is common for the area or not.

THOR OWF

In total, 34 taxa of benthic fauna were observed in the pre-investigation area, 33 in the Thor OWF area, - 24 taxa in the northern cable corridor (R2) and 19 taxa in the southern cable corridor (R2) (Energinet, 2021).

Three epifauna communities were identified by combining the sediment type map with the observation of epifauna on the sediment type (ROV video at ROV stations), as done in this study (see Figure 4-13):

1) Sandy-bottom communities dominated by infauna end very few epifauna species, such as starfish (*Astropecten irregularis*), crabs (*Corystes cassivelaunus* and *Liocarcinus depurator*), sea potatos (*Echinocardium* spp.) and local patches of sand mason worm (*Lanice conchilega*) tubes (Sediment type 1b).
2) Hard-bottom communities dominated by tube worms (*Pomatoceros triqueter*), hydroids, leafy bryozoans (*Flustra foliacea*), dead man´s fingers (*Alcyonium digitatum*) and several species of sea anemones (Sediment type 3 and 4)
3) Mixed communities with both sand- and hard-bottom communities (Sediment type 2a and 2b), which may have any combination of species from the two former communities.

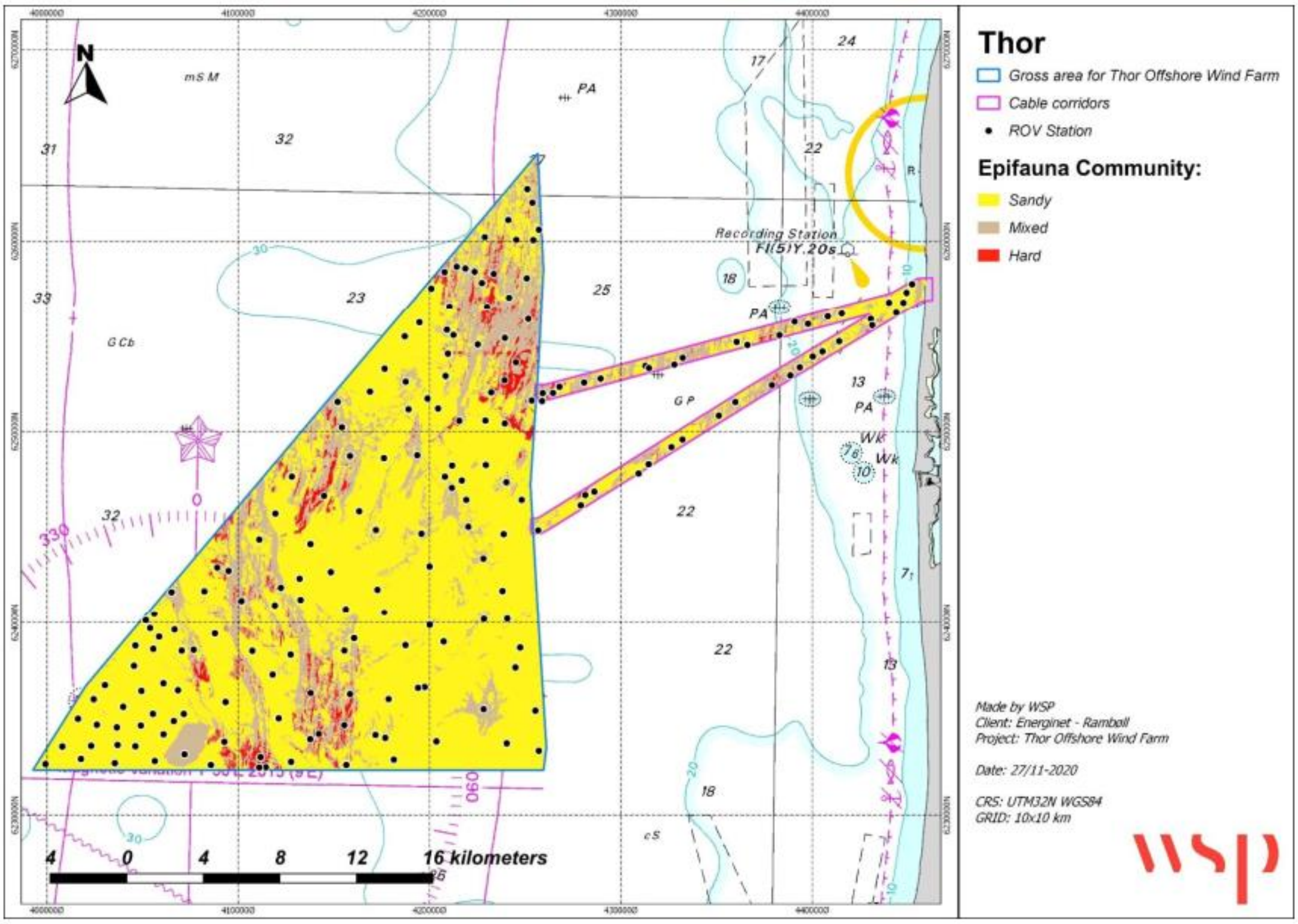


Figure 4-13. Map of epifauna communities in the pre-investigation area (gross area) for Thor offshore wind farm (OWF) and cable corridors. Source: (Energinet, 2021).

The sandy-bottom community dominated the investigated area with 75% of the OWF area and >50% of the cable corridors. Hard-bottom communities rarely had area coverages of more than 2-4%. Examples of the dominating epifauna species in hard-bottom communities are shown in the left column of Figure 4-14 below and in the sand-bottom communities in the right column of Figure 4-14. A full list of species and taxa observed in the Thor OWF area and cable corridors with Latin, English and Danish names are presented in Table 4-7 below.

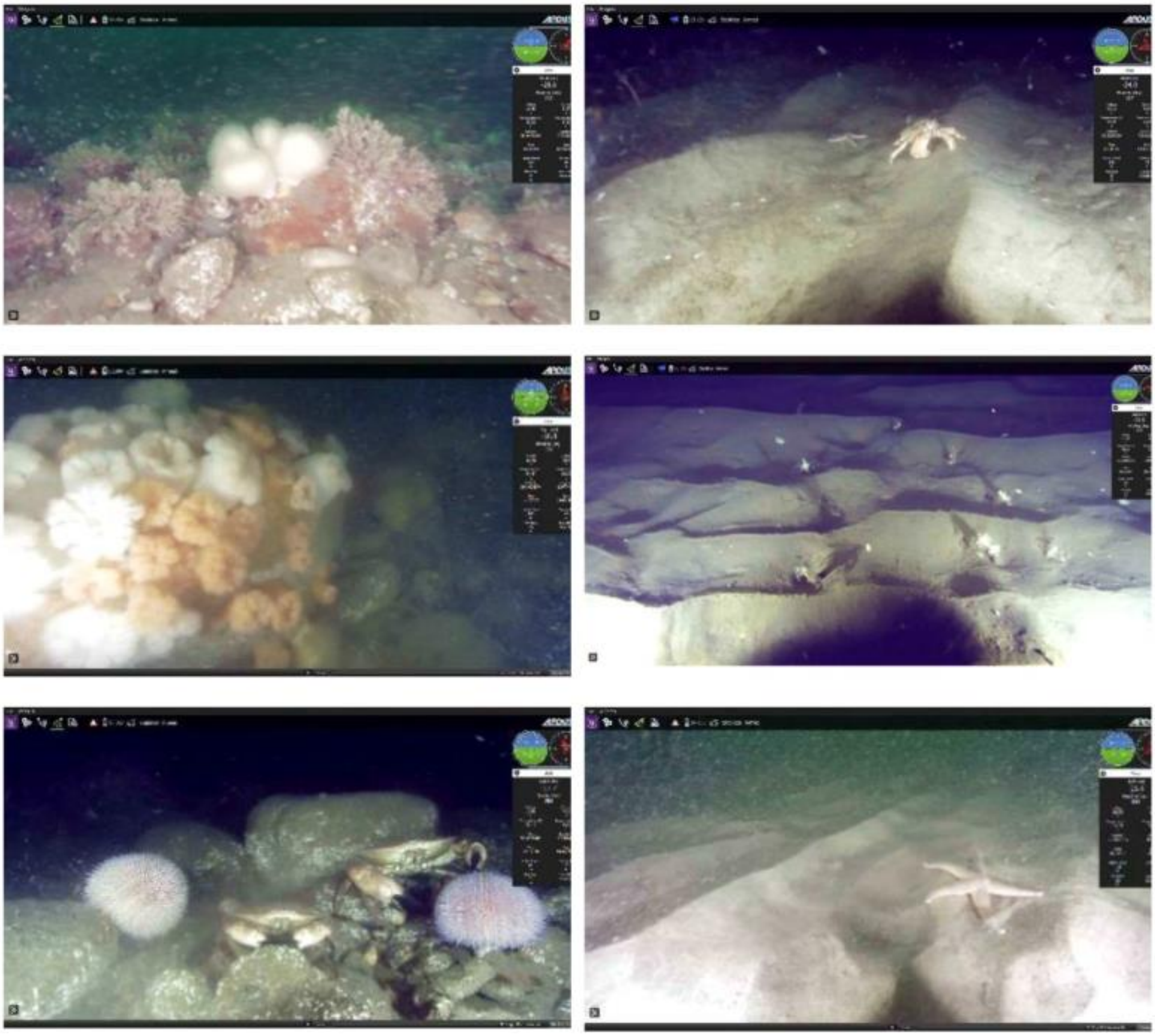


Figure 4-14. Examples of observed epifauna communities illustrating some of the most common species. Left column shows epifauna on hard bottom. Upper figure: keel worm (*Pomatoceros triqueter*), leafy bryozoan (*Flustra foliacea*) and dead man´s fingers (*Alcyonium digitatum*). Middle figure: Sea anemones (Anthozoans). Lower figure: brown crab (*Cancer pagurus*) and sea urchin (*Echinus esculentus*). Right column shows epifauna on sandy bottom (sediment type 1b). Upper figure: hermit crab (*Pangurus bernhardus*) and unspec. starfish. Middle figure: *Lanice conchilega* tubes. Lower figure: common starfish (*Asterias rubens*) and common shrimp (*Crangon crangon*). Source: (NIRAS, 2024).

Table 4-7. Epifauna taxa or species found in the investigated area divided into the pre-investigation/gross area for Thor OWF (GA) and the two cable corridors: R2 – northern corridor and R3 – southern corridor. * Only one specimen found. 1 empty shell. – no common English name found. Source: (Energinet, 2021).

Latin name or taxa name	Danish name/ English name	Phylum/class	Sediment type	Investigated area		
				GA	R2	R3
Sandy-bottom community:						
Asterias rubens	Almindelig søstjerne/ common starfish	Echinodermata	1b, 2a, 2b,3,4	x	x	x
Astropecten irregularis	Kamstjerne/sand seastar	Echinodermata	1b, 2b	x	x	x
Ophiura sp.	Slangestjerne/brittle star	Echinodermata	1b	x		
Echinocardium spp.	Sømus/Sømusskal/sømushul/Sea potato	Echinodermata	1b,2a[1],3[1]	x	x	x
Echinocardium flavesens	Guldmus/-	Echinodermata	1b	x		
Corystes cassivelaunus	Maskekrabbe/masked crab	Crustacea	1b	x	x	x
Liocarcinus depurator	Svømmekrabbe /harbour crab	Crustacea	1b	x	x	x
Hyas araneus	Sandkrabbe/great spider crab	Crustacea	1b,4	x		x
Pangurus bernhardus	Eremitkrebs/hermit crab	Crustacea	1b,2a, 2b	x	x	x
Crangon crangon	Hestereje/ common shrimp	Crustacea	1b		R2_014 *	
Buccinum undatum	Konksnegle-hus/common whelk	Gastropoda	1b	x		
Aporrhais pespelecani	Pelikanfodsnegl /pelikan´s foot	Gastropoda	1b	x		
Bivalve shells	Muslingeskaller	Bivalvia	1b	x	x	x
Ensis spp.	Knivmusling/razor clams	Bivalvia	1b, 3	x		x
Arctica islandica	Molbøstersskal/ black clam shell		1b	x		
Cerastoderma spp.	Hjertemusling spp./common edible cockle		1b	x		
Lanice conchilega	*Lanice* /Sand mason worm	Annelida	1b,2a,2b	x	x	x
Ophiodromus sp.	***Ophiodromus sp./***	Annelida	1b	x	R2_010 *	
Hard-bottom community:						
Tube worms spp.	Kalkrørsorm spp.	Annelida	2a,2b,3,4	x	x	x
Pomatoceros triqueter	Trekantorm/keel worm	Annelida	2a,2b,3,4	x	x	x
Spirorbis tridentatus	Kølet posthornsorm/-	Annelida	2a,2b,3,4	x	x	x
Hydrozoans	Hydroider spp./hudroids	Cnidaria/ hydrozoa	2a,2b,3,4	x	x	x
Sertularia cupressina	Cyprespolyp/white weed	Cnidaria/ hydrozoa	2b,3	x	x	

Latin name or taxa name	Danish name/ English name	Phylum/class	Sediment type	Investigated area		
				GA	R2	R3
Flustra foliacea	Bredt bladmosdyr, Leafy bryozoan	Bryozoa	3,4	x	x	x
Alcyonium digitatum	Dødningehåndkoral, dead man´s fingers	Anthozoa	2a,2b,3,4	x	x	x
Metridium senile	Sønellike/frilled anemone	Anthozoa	2a,2b,3,4	x	x	x
Stomphia coccinea	Karminrød søanemone/spotted swimming anemone	Anthozoa	2b,4	x	x	
Unspec. sea anemone	Søanemone spp./-	Anthozoa	2a,2b,3,4	x	x	x
Cancer pagurus	Taskekrabbe/brown crab	Crustacea	(1b), 2a, 2b,3,4	x	x	
Echinus esculentus	Stort søpindsvin/com-mon sea urchin	Echinodermata	3,4	x	x	
Echinoidea	Uspec. Søpindsvin/sea urchin	Echinodermata	3,4	x	x	
Marthasterias glacialis	Pigget søstjerne/spiny starfish	Echinodermata	4	x		
Tunicates	Søpungkoloni sp./sea squit	Chordata	3	x		
Porifera	Havsvampe/marine fugi	Porifera	2b,3,4	x	x	x
Total number of fauna species/taxa				**33**	**24**	**19**

VESTERHAV NORD AND SYD OWFS

Drop-camera investigations in the nearby Vesterhav Nord (Vattenfall, 2020a) and Vesterhav Syd (Vattenfall, 2020b) OWFs and cable corridors were conducted in 2015.

Video from the baseline studies in Vesterhav Nord and Vesterhav Syd OWF and cable corridors showed similar epifauna communities (Figure 4-15). Epifauna living on the seabed surface consisted of few species and individuals, dominated by common starfish (*Asterias rubens*). The sandy bottom was dominated by common starfish (*Asterias rubens*), hermit crab (*Pangurus bernhardus*) and a few unspecified species of crab. The larger rocks were either covered with leafy bryozoans (*Flustra foliacea*), species of sea anemone or without fauna. At many stations no surface-living life was observed, presumably due to sand scrubbing of the rocks along the very dynamic West coast of Denmark. For both Vesterhav Nord and Syd OWFs, the observed number of epifauna was low (<7 species/taxa) and mainly common starfish (*Asterias rubens*) in Vesterhav Nord OWF and common starfish (*Asterias rubens*) and brittle stars (Ophiuraidea) in Vesterhav Syd OWF.

The observed species were common for the North Sea and along the West coast of Denmark. No red-list species or protected species or habitat types were observed. Likewise, there was no evidence of any biogenic reef structures such as blue mussels (*Mytilus edulis*), oysters (*Ostrea edulis* and *Crassostrea gigas*) or *Sabellaria* reef structures.

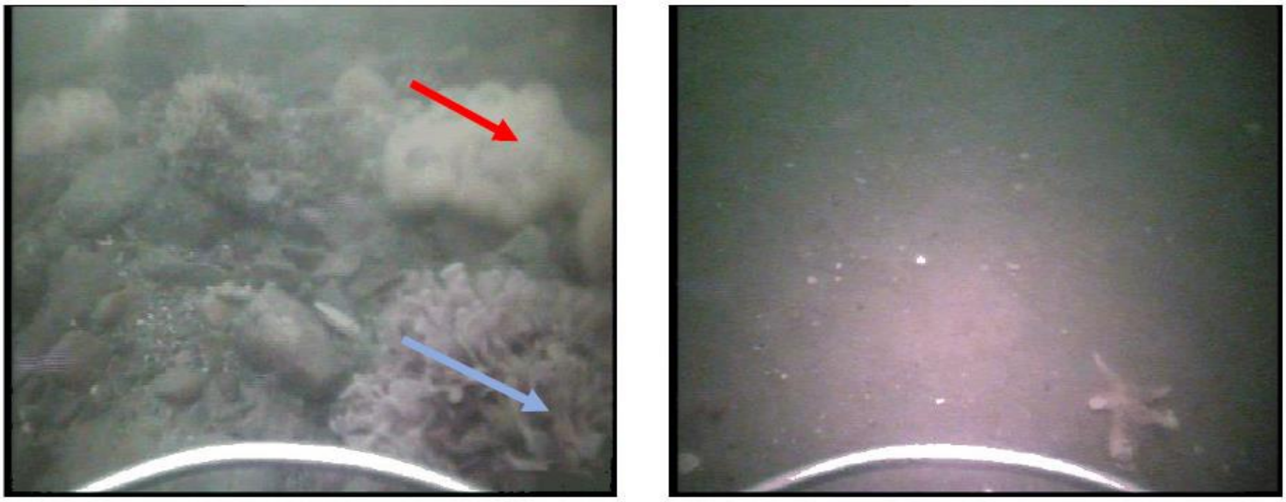


Figure 4-15. Leafy bryozoans (*Flustra foliacea*, blue arrow) and anthozoans (red arrow), as characteristic epifauna species in rocky hard bottom areas (left) and starfish in sandy and silty bottom areas (sand and silt) (right) (Vattenfall, 2020b).

4.5.2 INFAUNA

Data for infauna communities observed at local Danish monitoring stations for infauna (NOVANA stations) and comparable investigation areas to this study are included for comparison. NOVANA data provides time series for infauna in the area. Also, other comparable baseline studies from this area of the North Sea make it possible to say whether the data from this study is representative for the region. Existing data are used for comparison with infauna data collected in this study and is presented in section 5.5.2 – Results/Infauna.

Infauna can be divided into a number of communities on the basis of the species composition, which depends on the surrounding environment (e.g. sediment type, sediment dynamics, water depth, salinity and oxygen conditions at the bottom).

Representative results from the baseline studies in the area at similar depths and sediment types are listed below, including Thor OWF and Vesterhav Syd OWF.

NOVANA DATA

There are four NOVANA stations in the area (Figure 4-1), where one is located within the pre-investigation area of NSI.1-OWF (DMU1035). Two of the four stations are sampled during spring every year. Data has been collected at these four stations since 2015 and there are four data points per station from 2015-2023.

As visible in the data from the four NOVANA stations, there is a large variation in species number, abundance, and biomass between years and between stations (Table 4-8), indicating a highly dynamic area. Similarly, the Shannon-Wiener, AMBI and DKI indices differed between years and between stations. For comparison with findings in this study, species dominance (abundance and biomass) is further described below, but only for the recent data (from 2022 and 2023).

Table 4-8. Data on infauna species number, abundance, and biomass at each of the four NOVANA stations sampled four times during 2015-2023. Furthermore, indices (Shannon-Weiner index (H'), AMBI and DKI-values) are presented for each station. The station DMU1035/91300158 are situated within NSI.1-OWF – in the northeastern part of OWF area A3 (see Figure 4-1).

Station	Year	Number of species (per sample)	Number of species (total per station)	Abundance (ind./m^2)	Biomass (g WW/m^2)	H'	AMBI	DKI
DMU1035 / 91300158	2015	6.9	49	766	201	1.76	1.23	0.52
	2017	7.8	63	976	642	1.79	1.60	0.52
	2019	8.4	74	1337	215	1.80	1.56	0.53
	2022	12.3	71	3696	270	1.85	1.84	0.54
DMU1042 / 91400005	2015	6.9	56	1112	156	1.54	1.17	0.49
	2017	6.5	42	1334	209	1.38	1.27	0.47
	2019	7.8	60	1577	72	1.43	0.93	0.54
	2022	6.5	50	871	196	1.50	1.29	0.47
DMU1044 / 91000081	2016	11.8	72	6447	553	1.21	1.39	0.51
	2018	11.8	53	2384	229	1.95	1.35	0.58
	2021	11.4	62	7827	382	1.23	1.40	0.51
	2023	7.9	42	8252	611	0.76	1.32	0.47
DMU1072 / 91000086	2016	11.5	68	9227	464	0.86	1.45	0.47
	2018	9.4	56	3725	210	1.30	1.40	0.51
	2021	12.7	70	15936	413	0.80	1.35	0.48
	2023	11.8	71	7566	467	1.12	1.27	0.51

The dominating species regarding abundances was, for three of the four stations, horseshoe worm (*Phoronis* spp.), where horseshoe worm contributed 27 %, 83 % and 71 % at the stations DMU1035, DMU1044 and DMU1072, respectively. At DMU1035, the second most abundant species was the bristle worm species *Owenia fusiformis,* contributing 21 %, followed by the bristle worm *Spiophanes bombyx* (13 %) and *Nemertea* (13 %). At DMU1042, horseshoe worm contributed only 2 % of the total abundance of infauna. Here, the dominating species was the bristle worm species sand mason worm (*Lanice conchilega*) contributing 15 %, followed by the bristle worm *Spiophanes bombyx* (10 %) and the bristle worm species (*Magelona mirabilis*), contributing 9 %.

The dominating species regarding biomass (wet weight (g WW)) at all four stations was the sea potato heart urchin (*Echinocardium cordatum*), contributing 39 %, 36 %, 56 % and 56 % at station DMU1035, DMU1042, DMU1044 and DMU1072, respectively. The second most abundant species regarding biomass was horseshoe worm (*Phoronis spp.*), contributing 24 %, 29 % and 24 % at the stations where horseshoe worm also dominated the abundance: DMU1035, DMU1044 and DMU1072, respectively. The second most dominating species at station DMU1035 was the bristle worm species *Owenia fusiformis,* which contributed 19 % of the total infauna biomass. At station DMU1042, sand mason worm (*Lanice conchilega*) dominated in regard to abundance, and was the second most dominating species regarding biomass, contributing 26 % of the total infauna biomass. The second highest biomass at station DMU1042 was constituted by the bivalve mollusc species thick surf clam (*Spisula solida*) with 17%.

THOR OWF

SPECIES NUMBERS, ABUNDANCE AND BIOMASS

The number of species, abundance and biomass observed in the gross area for Thor OWF (GA) and the two cable corridors (CC) are presented in Table 4-9. Species number is given as a total for all samples in the different areas (GA, CC, R2 and R3), whereas abundance and biomass are shown per m^2 (Energinet, 2021).

Table 4-9. Number of species, individuals, and biomass expressed as wet weight and dry weight in the gross area for Thor OWF and cable corridors (CC): R2 - northern cable corridor and R3 - southern cable corridor.

	Gross area	R2	R3	CC (R2 + R3)
No. of species	81	43	46	63
No. of individuals per m^2	2342	1352	2369	1877
Wet weight per m^2 (g)	170	93	210	153
Dry weight per m^2 (g)	90	42	106	75

The number of species per sample varied between 0-14 in the gross area for Thor OWF (average 5.7 species per sample), 4-11 in the northern corridor (R2) (average 6.3 species per sample) and 1-17 in the southern corridor (R3) (average 6.6 species per sample). Species numbers varied between samples within the gross area for Thor OWF and the two cable corridors. The only clear pattern was a more species rich area in the southwestern part of gross area for Thor OWF, where the sediment had a higher silt and clay content (Energinet, 2021).

The gross area for Thor OWF was dominated by the horseshoe worm *Phoronis* sp. (73 %), the two bristle worms *Spiophanes bombyx* (5 %), *Magelona mirabilis* (4 %) and the sea urchin (*Echinocyamus pusillus*, 2 %) (Numbers are given as the % contributed by this species out of the total number of individuals in the area).

The southern cable corridor (R3) was also dominated by horseshoe worm (*Phoronis* sp., 58 %), the two bristle worms *Magelona mirabilis* (18 %), *Spiophanes bombyx* (3 %), and the mussel bean-like Tellina (*Fabulina fabula*, 2 %).

The northern cable corridor (R2) was, however, dominated by several bristle worms including *Magelona mirabilis* (32 %), *Protodorvillea kefersteini* (20 %), *Spiophanes bombyx* (12 %), ribbon worms Nemertini (4 %), pea urchin (*Echinocyamus pusillus*, 2 %), the marine amphipod *Urothoe poseidonis* (2 %), and the mussel bean-like Tellina *(Fabulina fabula*, 2%).

INFAUNA DIVERSITY AND ECOLOGICAL INDICES

The results for different infauna indices that are used to describe the infauna communities in Danish waters are shown in Table 4-10.

Table 4-10. Overview of the results of the Shannon-Wiener diversity index (H'), Pielou´s Evenness index (J'), AMBI and DKI index in the gross area for Thor OWF (Gross area) and cable corridors (CC): R2 – northern cable corridor and R3 – southern cable corridor.

	GA	R2	R3	CC (R2 + R3)
Shannon-Wiener diversity(H')	1.00	1.40	1.13	1.26
Pielou´s Evenness index (J')	0.69	0.78	0.71	0.74
AMBI	1.57	1.62	1.14	1.33
DKI	0.78	0.81	0.83	0.82

The indices illustrate an infauna community with lower-than-normal species diversity: The gross area and the northern cable corridor (R2) was dominated by robust generalists and classified by the AMBI index as an unbalanced infauna community. The southern cable corridor (R3) had a few more specialist carnivores and some deposit feeding polychaetes resulting in the area being categorized as "undisturbed". The Danish quality index (DKI), which is a supporting parameter for the evaluation of the ecological status in the Water Framework Directive, scores the gross area for Thor OWF as having "good ecological status" and the two cable corridors as having "high ecological status". The indices are, thus, indicative of a dynamic environment determining the composition and condition of the infauna community in both the gross area for Thor OWF and the two cable corridors.

VESTERHAV SYD

OWF area: In Vesterhav Syd OWF, a total of 77 infauna species were found, distributed over different taxonomic groups. Species of bristle worms dominated and was by far the most dominant taxa group with 35 taxa in total, followed by other taxa groups with 17 taxa (including e.g. echinoderms, sea anemones, and Nematoda), and species of molluscs with 16 taxa. Crustaceans were represented by 9 different taxa. The bristle worm *Notomastus latericus,* which is a typical species found at sandy bottoms, showed a slight dominance in relation to abundance distribution, as it had the highest mean relative abundance (13 %), followed by two other small species of bristle worms *Pisione remota* (11 %), *Protodorvillea kefersteini* (9 %), and the bivalve *Nucula nitidosa* (9 %). Shannon and Evenness values were high for all stations with sandy bottoms and lower for stations with coarse sediment or mixed substrate, thus showing higher species richness in sandy areas and more distinctly dominant species in areas with coarser sediments. Shannon Wiener index values for the OWF ranged between 1.89 and 3.93 and Pielou-Evenness values ranged between 0.52 and 0.89. The Shannon-Wiener diversity index indicates the diversity of species in a community, where the lower the value, the lower the diversity. In this case, the Shannon-Wiener diversity index is medium. Pielou-Evenness ranges from 0 to 1, where 0 indicates no evenness and 1 indicates complete evenness in relation to abundance of individuals of each species in an area.

Cable corridors: In the area of the cable corridors (and landfalls) of Vesterhav Syd a total of 40 infauna taxa were found. Bristle worms were the dominant taxa group with a total of 21 species, followed by crustaceans with 9 species, while Molluscs and the remaining taxa amounted to 5 species. The bristle worm species (*Pisione remota, Magelona johnstoni, Protodovillea kefersteinii and Polygordius appendiculatus*) dominated the abundance distribution of infauna species, most of them commonly fond in coarse sediments. *Magelona johnstoni* dominated the areas with sand at the northern cable corridor and the shallower part of the southern cable corridor, while the other three species of bristle worms only occurred at the deeper part of the southern cable corridor which comprised coarse sediment or mixed substrate. The lowest number of infauna species were found at the shallowest station, which also showed the lowest absolute abundance of all stations. Shannon Wiener index values for the cable corridors (and landfall) ranged between 2.44 and 3.16 and Pielou-Evenness values between ranged 0.6 and 0.92, which shows lower values than in the OWF area indicating lower species richness.

The lower overall species richness in the cable corridors area can be explained by the fact that large parts of the cable corridors comprise shallow areas above 20 m depth contour, comparable with the northern-eastern region of the OWF subarea. This type of habitat is recognized to comprise a restricted species richness as few taxa are adapted to high exposure and wave action. Generally, the infauna species abundance was evenly distributed, thus, evenness was high, which indicated a balanced faunal community without presence of strongly dominant species. Correspondingly, other stations showed dominance of one or two species and an accordingly uneven distribution of abundances. An example is station 20 (deep station at the southern corridor) within the coarse sediment area, that had the highest overall abundance of infauna but the lowest evenness due to the dominance of the small bristle worms.

4.6 BENTHIC COMMUNITIES

Benthic communities/nature types mapped in the baseline studies for the surrounding OWFs are presented below. Sampling period for the different baseline studies are listed in Table 4-1.

The maps are created from three different data types; 1) the sediment type map overlayed with 2) the observed benthic flora and fauna on ROV video for the different sediment types, and with 3) the observed dominating infauna species from HAPS sampling where relevant for Thor OWF. For Vesterhav Syd OWF, drop down camera was used and data on surface communities observed by ROV was very limited. Benthic communities for Vesterhav Syd OWF were therefore based on 1) sediment types and 3) infauna data. The habitat/nature type map for Horns Rev III OWF area is based on 1) the sediment type map and 2) the observed benthic flora and fauna on ROV video while infauna data from HAPS sampling was not included. The placement of the OWFs in relation to NSI.1 OWF area is presented in Figure 4-1. The map of benthic communities from Thor OWF is most comparable to the map of benthic communities in this baseline study.

THOR OWF

Benthic habitats in the pre-investigation area/gross area for Thor OWF and the two alternative cable corridors were mainly characterized by infauna communities. In sandy-bottom areas, different infauna species dominated, whereas in mixed bottom areas and hard bottom areas where stones were available, epifauna such as tube worms (*Pomatoceros triqueter* and *Spirorbis tridentatus*), hydroids, leafy bryozoans (*Flustra foliacea*), dead man´s fingers (*Alcyonium digitatum*) and anthozoans dominated (See full species list in Table 4-7). Epifauna coverage in hard bottom areas decreases with dynamic and water depth of the seabed. The registered benthic fauna species were robust due to their adaptation to the dynamic conditions along the exposed West coast of Jutland with strong wave action during stormy weather events and periodic occurrence of large amounts of resuspended material in the water column, which result in frequent scrubbing of the stones and covering of fauna with sand (Rambøll, 2020a; Vattenfall, 2020a; Vattenfall, 2020b).

The largest part of the gross area for Thor OWF is characterized by sandy bottom with horseshoe worm (*Phoronis* sp.). Abundance and biomass varied strongly with the deepest, southwestern part having the highest numbers of species, abundance and biomass. The same species dominated but more species were found as well at higher abundance and biomass in general in this area. In general, Phoronids sp. dominated the abundance and Echinodermata dominated the biomass in the gross area for Thor OWF. The shallower parts of the cable corridors (7.5-17.5 m) were dominated by sandy bottom with *Magelona mirabilis* and bean-like Tellina (*Fabulina fabula* = synonym *Tellina fabula*), followed by *Spiohanes bombyx* and *Protodorvillea kefersteini* (12.5-27.5 m), and also had a high percentage of mixed sediment with sparse epifauna. Abundance was dominated by bristle worms in the northern cable corridor (R2) and *Phoronis* sp. in southern corridor (R3). Biomass was dominated by bivalves in R2 and Echinodermata in R3.

Stone reef habitats were located in small patches and constituted 2-4 % of the gross area for Thor OWF and each cable corridor.

The different communities observed are presented in Figure 5-35.

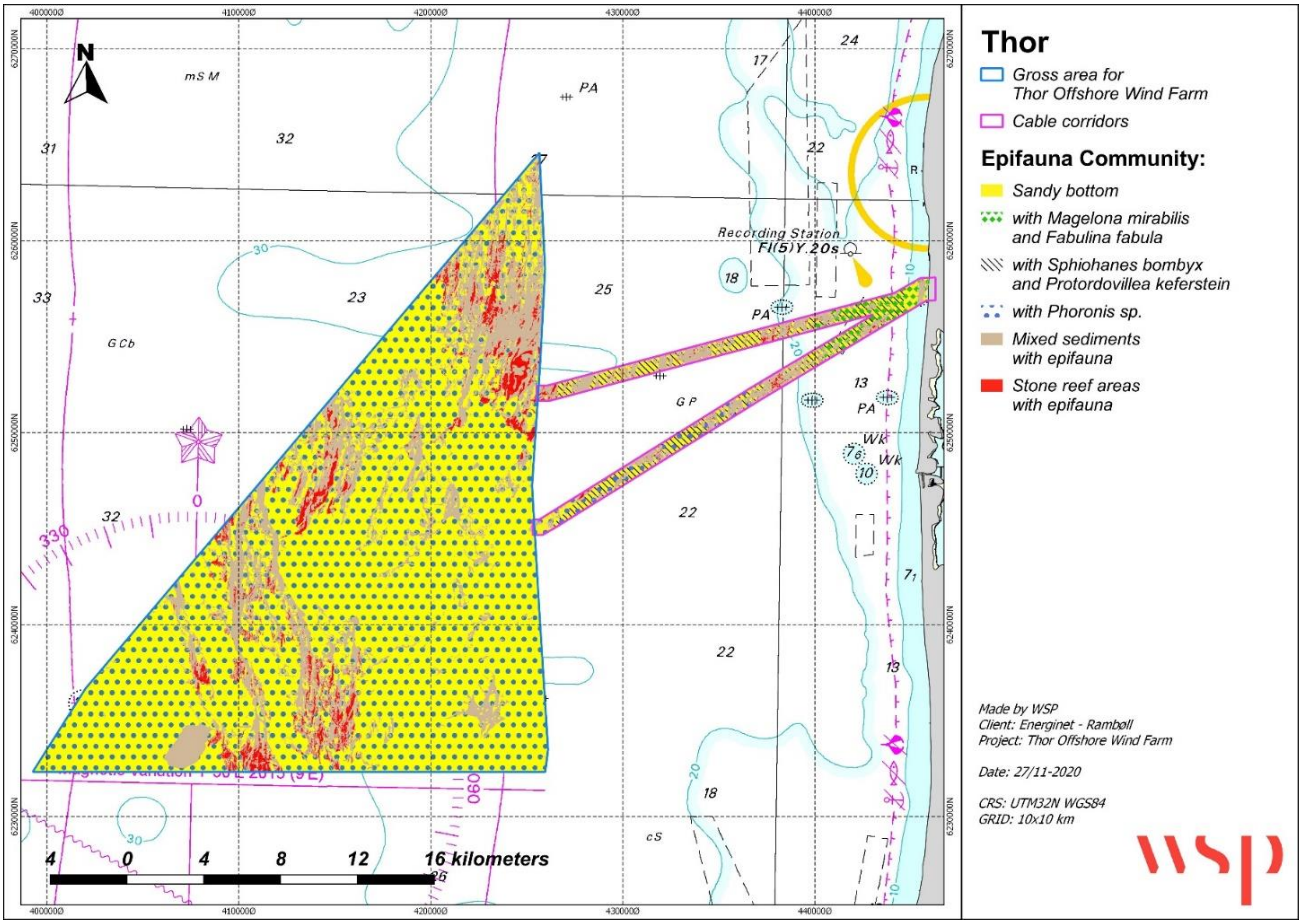


Figure 4-16. Thor OWF - Map of benthic habitats in the pre-investigation area (gross area) for Thor OWF and the cable corridors. Note overlap between sandy-bottom communities in the cable corridors. Source: (Energinet, 2021).

VESTERHAV SYD OWF

OWF area: Benthic habitats/nature types at Vesterhav Syd OWF (Figure 4-17) were mainly characterised by infauna communities. Only in areas where stones were available to a certain degree (mixed substrate), epibenthos like anthozoans and bryozoans occurred. No macroalgae were observed. The largest part of Vesterhav Syd OWF (below 22 m water depth) was characterised by "Sand with *Nucula nitidosa*". Abundance and biomass varied strongly between stations, but the bivalve *Nucula nitidosa* was dominant in terms of biomass and represented at least 25–50 % of the fauna biomass in this habitat. In the north-eastern part of the OWF area, the biotope "Sand with *Tellina fabula*" (bean-like tellin) dominated. This area represents the shallower sandy bottoms of the area (around 16 to 19 m deep). At some small, restricted locations in the middle of the investigation area "Silty sediment with *Nucula nitidosa*" dominated.

Coarse sediment was characterised by a variety of different bristle worm species (e.g. *Aonides paucibranchiata*, *Pisione remota*), but none of them were dominant in terms of biomass. Mixed substrate with epifauna was located at some areas at the southern and eastern part of Vesterhav Syd OWF. Characteristic epifauna species included a variety of anthozoans and bryozoans (mainly *Flustra* sp.), with none of them representing a dominant component.

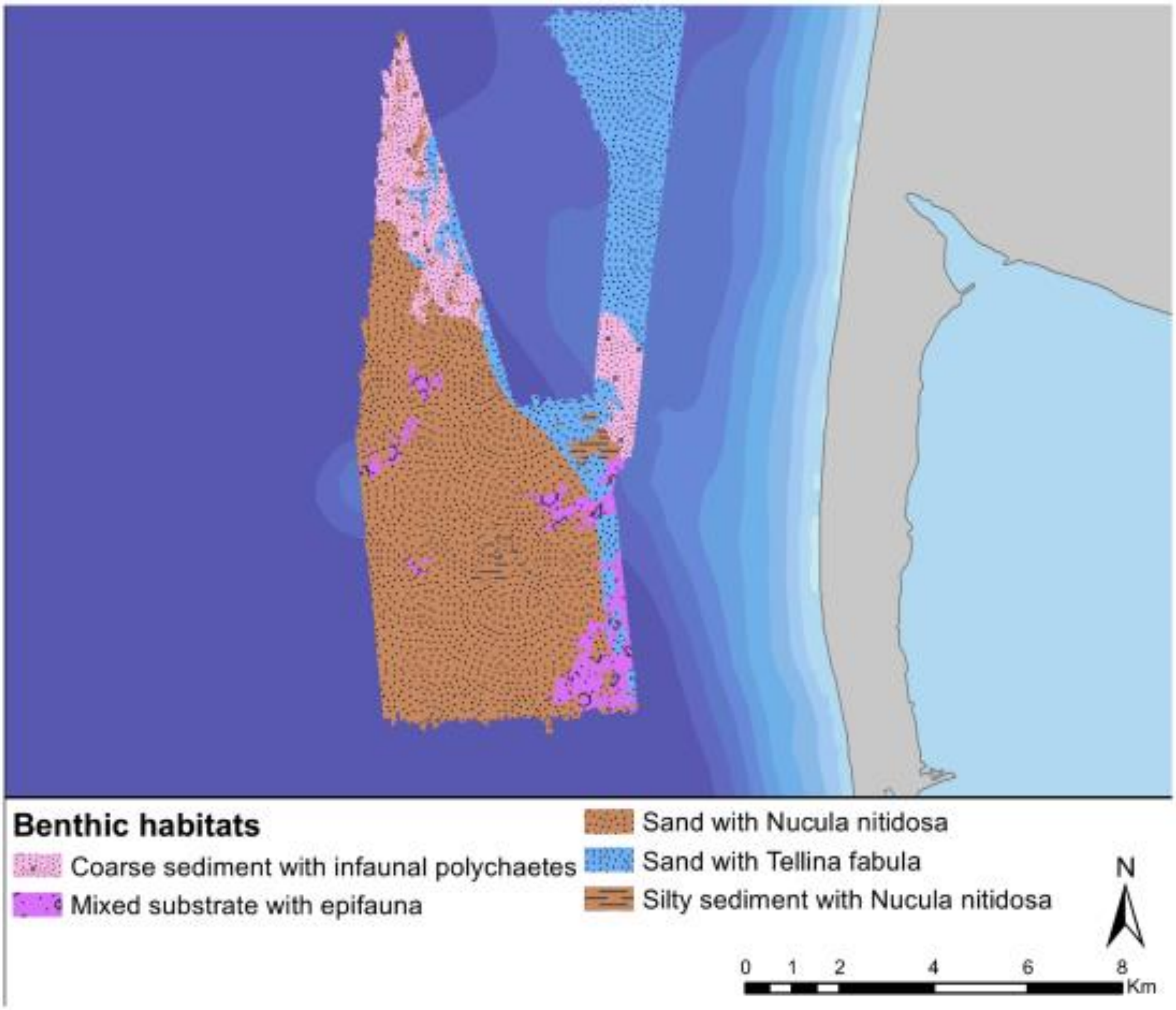


Figure 4-17. Vesterhav Syd OWF – Benthic habitats. Source: (MariLim, 2015a).

Cable corridors: Benthic habitats at the cable corridors and landfalls are illustrated in Figure 4-18. The surf zone as well as most of the cable corridor areas, were without any hard substrates or epibenthic biological structures, and characterised by the species poor "Sand with *Tellina fabula*" biotope. Only at the southern cable corridor at some smaller locations, "Mixed substrate with epifauna" and "Coarse sediment with *Spisula elliptica*" (elliptic trough shell) occurred.

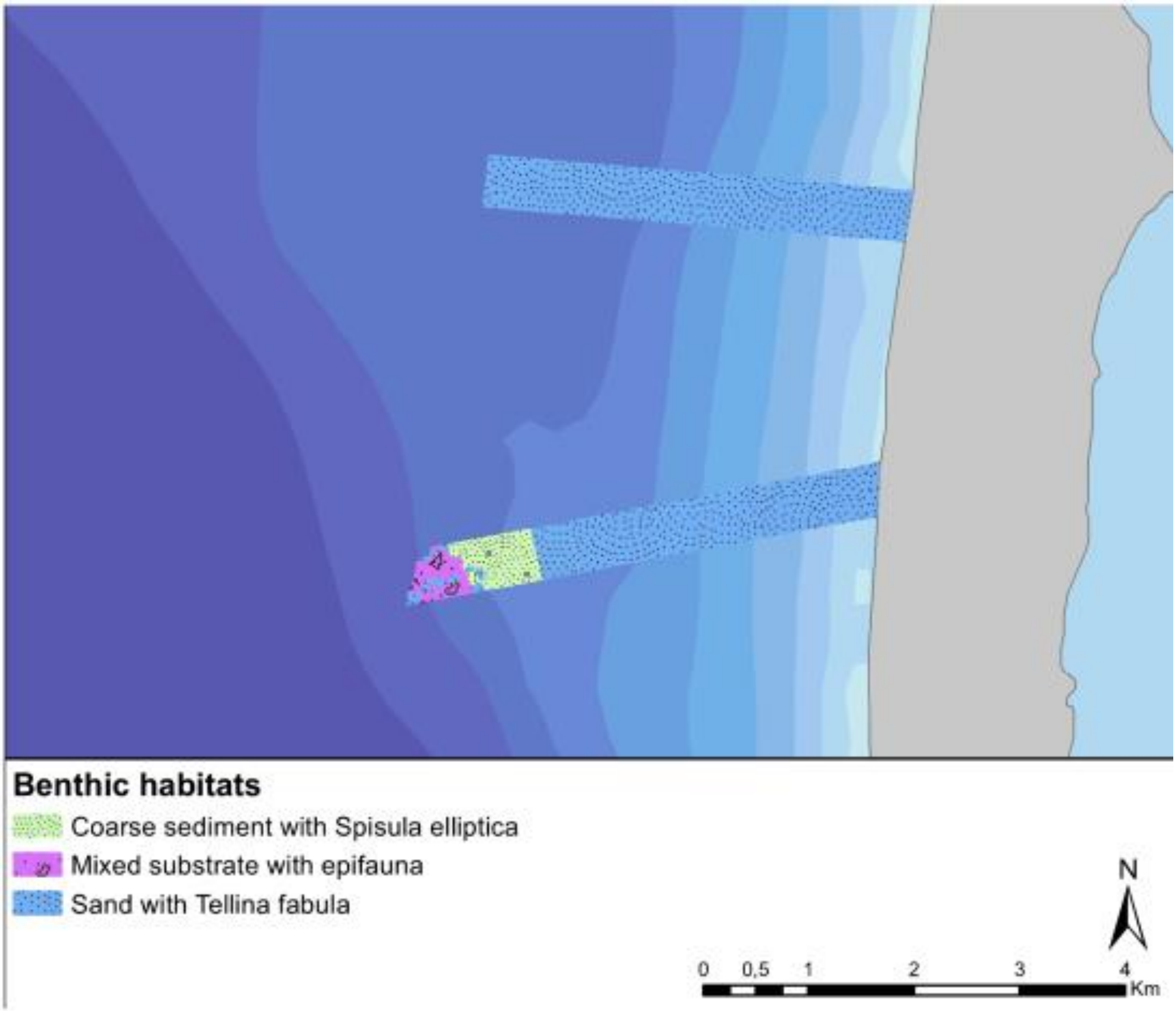


Figure 4-18. Vesterhav Syd cable corridors – Benthic habitats. Source: (MariLim, 2015a).

HORNS REV III OWF

As can be seen in Figure 4-19, the habitats in the baseline study for Horns rev III were predominantly habitat type 1 (sandy), with small areas along the northern and western borders, which contained habitat type 2 (slightly coarser). The expected dominating species in the study area were infauna taxa connected to these habitats, as well as generalist epifaunal species.

The only occurrence of habitat type 4 is an "artificial reef" in the south-western corner of the study area, which is formed by a sunken barge with a cargo of stones.

An over-view of general benthic habitat types observed in the baseline study of Horns Rev III is given in Table 4-11.

Table 4-11. Horns Rev III OWF - Habitat types, dominating species and corresponding sediment descriptions. Source: (Orbicon, 2014).

Habitat type	Habitat description
1	The most common habitat type in the Horns Rev 3 project area is a habitat dominated by fine to coarse sand (substrate subtype 1B). Even in the photic zone, very few macro algae are present. If present, algae will mostly be annual species such as *Polysiphonia* sp. and *Ceramium* sp. The habitat is generally well suited for infauna, such as burrowing bivalves and polychaetes, but also contains generalist species such as *Pagurus bernhardus*, *Carcinus maenas* and *Asterias rubens*.
2	Contains species similar to habitat type 1, but also some species associated with coarser substrates. If within the photic zone, some macro algae, such as the annual species *Polysiphonia* sp. and *Ceramium* sp. as well as scattered brown algae may be present. Common invertebrate species found in the Horns Rev 3 project area could be: *Pagurus bernhardus*, *Carcinus maenas* and *Asterias rubens*, *Urticina felina, Ophelia borealis* and members of the genus *Spio*.
3	Not found in the Horns Rev 3 project area during present study. Contains species similar to above habitat types, but more species associated with hard substrates may be present. Within the photic zone, perennial macro algae species such as delesseriacids and kelps may be abundant. Invertebrate hard substrate species could be Porifera sp., *Balanus sp., Urticina felina*, *Metridium senile*, *Promatoceros triqueter* and *Cancer pagurus.*
4	Generally high diversity. Contains species similar to other habitat types, but may also have many species associated with hard substrates. If within the photic zone the hard substrates can be dominated by layered growths of perennial macro algae species such as delesseriacids and kelps, with an undergrowth of many red algae species. If below the photic zone, the hard substrate may be dominated by suspension feeders such as *Alcyonium digitatum*, *Urticina felina* and *Metridium senile.* Other invertebrate species could be *Promatoceros triqueter*, *Cancer pagurus*, Porifera sp., *Balanus sp.* and *Homarus gammarus*.

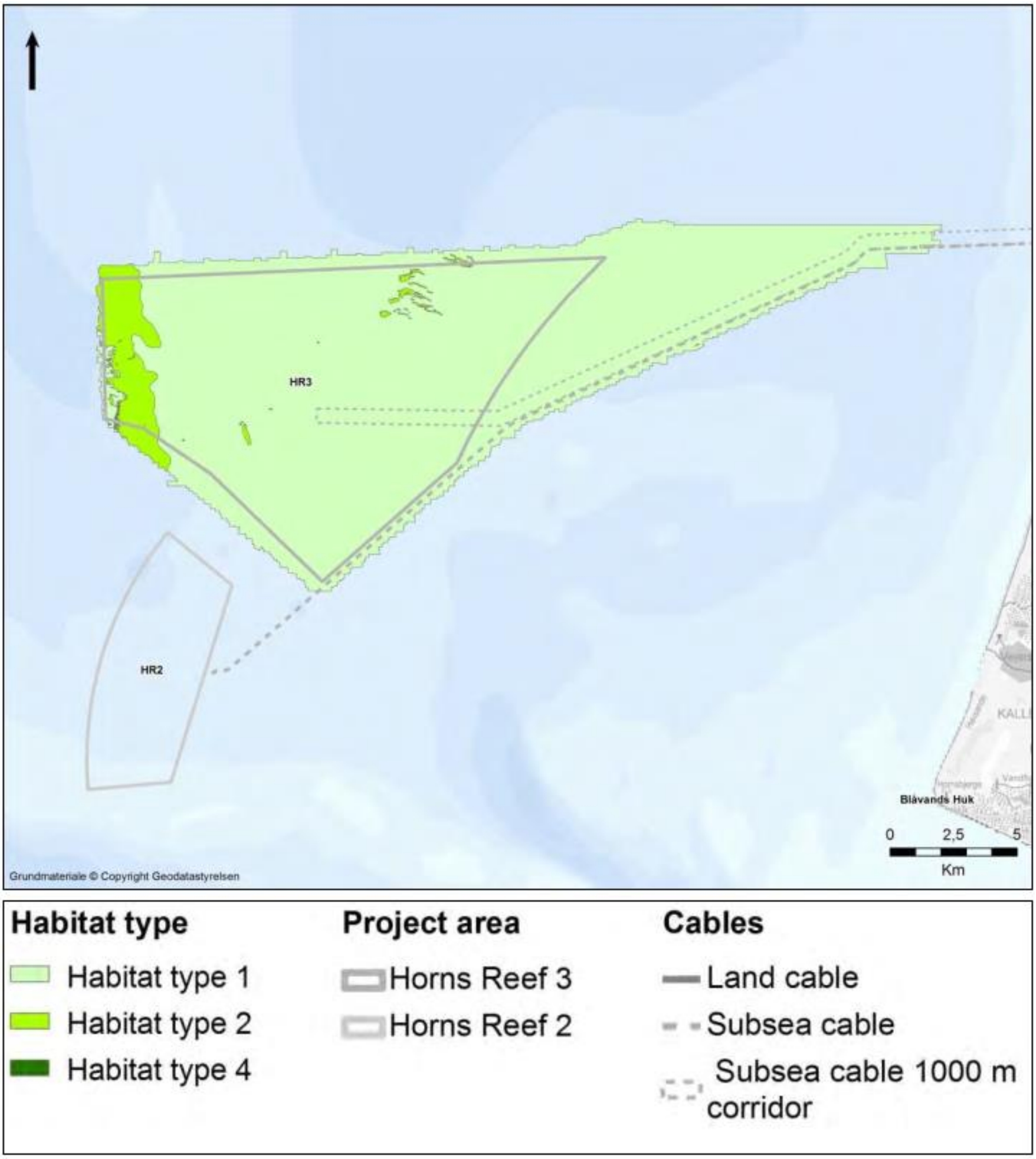


Figure 4-19. Horns Rev III OWF - Habitat type mapping of the Horns Rev 3 pre-investigation area. Source: (Orbicon, 2014).

5 RESULTS – SURVEY DATA

This technical report (baseline study/report) for benthic ecology, maps the distribution and composition of sediment, benthic flora and fauna in the pre-investigation area for NSI.1 (NSI.1-OWF) and the pre-investigation area for the export cable corridors (NSI.1-ECC) (se area definitions in Figure 2-1). In this chapter, survey data representing the results of the two marine environmental surveys (MES) and analyses of the data are presented for abiotic data, seabed sediments, benthic communities, benthic flora and benthic fauna.

5.1 ABIOTIC DATA

Physical parameters such as depth, salinity and oxygen concentration are determining factors for the living conditions and habitat types available for benthic fauna and flora and are presented below. Salinity, temperature and oxygen profiles are measured in the water column by use of a CTDO.

5.1.1 DEPTH

Depth is an important factor for both benthic flora and fauna. Depth determines the light available for benthic flora. Benthic flora needs light for growth and therefore lives within the photic zone where light is sufficient for plant growth (see section 4.4 - Benthic flora).

Depth data for the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) were collected during the geophysical surveys conducted in relation to the project. Depth in the two pre-investigation areas is presented in Table 5-1 and Figure 5-1 and ranges from 16 to 33 meters depth in the pre-investigation area for NSI.1-OWF and from 0 to 27 meters in the pre-investigation area for the three export cable corridors (NSI.1-ECC). The shallowest parts are found in the cable corridors and in the southern part of NSI.1-OWF. The deepest parts are found in the northern and northwestern part of the NSI.1-OWF.

Table 5-1. Depth ranges in meters in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) and subareas within, based on data from the geophysical surveys. The pre-investigation area for NSI.1-OWF includes three smaller OWF areas A1-3. The pre-investigation area for the export cable corridors (NSI.1-ECC) includes three corridors (ECC1-3). Depth data source is (Ocean Infinity, 2023).

Depth ranges	Lowest (m)	Highest (m)
Pre-investigation area for NSI.1 OWF area (NSI.1-OWF)	16	33
Pre-investigation area for export cable corridors (NSI.1-ECC)	0	27
OWF Areas:		
A1	17	27
A2	21	32
A3	24	33
Export cable corridors:		
ECC1	0	24
ECC2	0	27
ECC3	0	27

Comparing depth ranges within the OWF areas A1-3, the depth is generally highest in the northernmost OWF area A3 and lowest in the southernmost OWF area A1. Two cable corridors (ECC2 and ECC3) had similar depth ranges from 0 to 27 meters, whereas the southern cable corridor (ECC1) had slightly lower depth ranging from 0-24 meters.

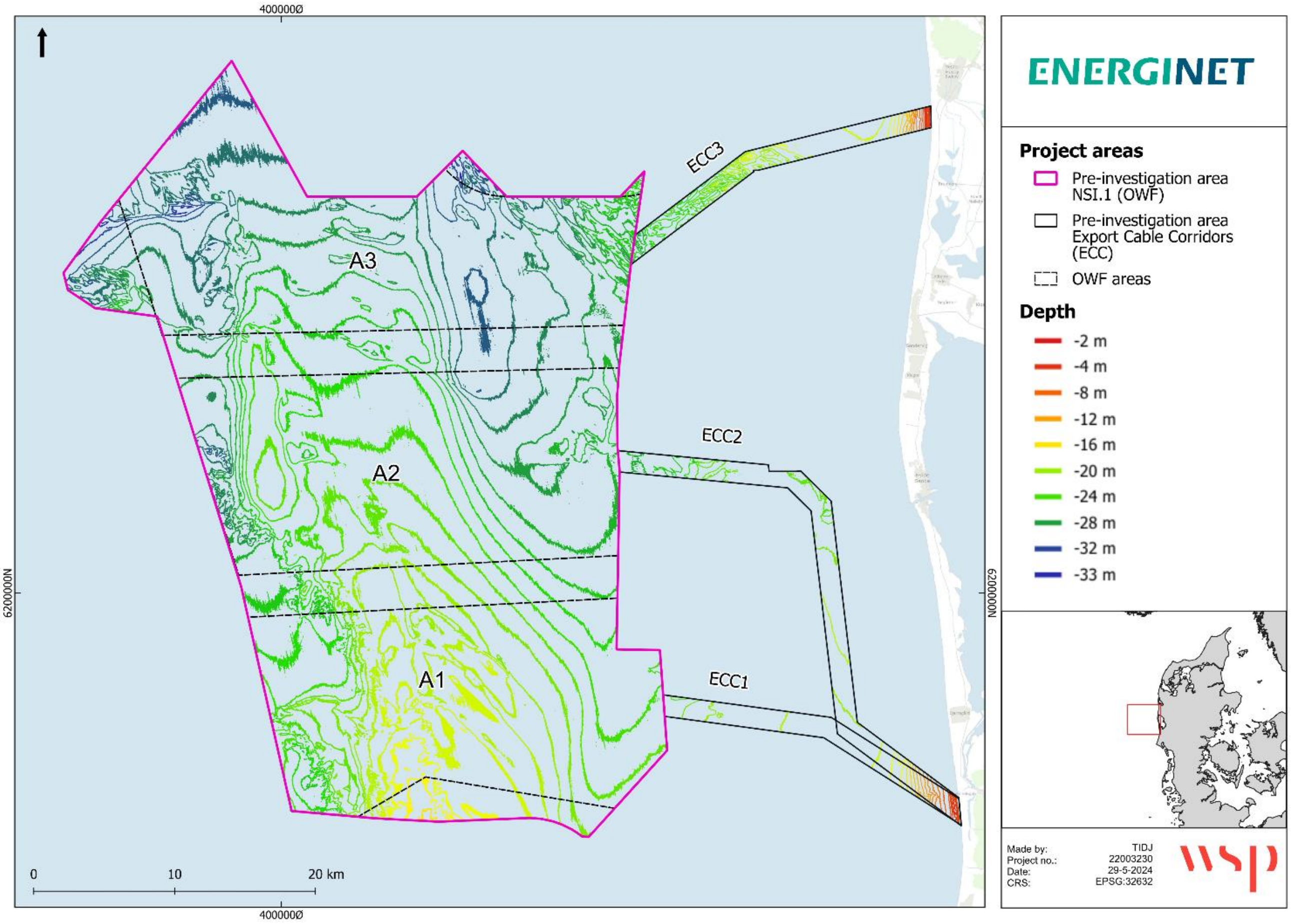


Figure 5-1. Depth map for the two pre-investigation areas and subareas. Source: (Ocean Infinity, 2023).

5.1.2 SALINITY, TEMPERATURE AND OXYGEN (CTDO)

Salinity, temperature and oxygen at the seabed contributes to the physical conditions of the benthic habitats in which the benthic flora and fauna lives. CTDO profiles of salinity, temperature and oxygen were used for statistical analysis of the controlling abiotic parameters for infauna composition in the two pre-investigation areas (only May CTDO data sampled at the 11 infauna stations). The statistical analysis of the controlling parameters for infauna is presented in section 5.5.2 – Infauna/Multivariate statistical analysis.

CTDO profiles of salinity, temperature, and oxygen concentrations in mg/l and % saturation down through the water column were sampled in the two pre-investigation areas in May and June 2023, 11 in May and 30 CTDO stations in June 2023. The number of stations within the pre-investigation areas and subareas are given in Table 5-2 below for both May and June. Station location can be seen in Figure 3-2. Raw data from all CTDO stations is given in Appendix 4A and selected profiles from May and June are shown in Appendix 4C.

Table 5-2 shows the ranges of salinity, temperature and oxygen extracted approximately 1 meter above the seabed (= the deepest measurement) within the two pre-investigation areas and the different subareas (A1-3 and ECC1-3). Comparing the ranges for May and June, the measurements are quite stabile with little variation, however the data shows a slight but general increase over time in all parameters i.e. salinity, temperature and oxygen (both sat% and concentration). That is to be expected for salinity and temperature, but not for oxygen as the water column is more stratified in June, which should decrease the oxygen concentration and saturation % at the seabed below the stratified layer (thermocline and/or halocline). However, in June a subsurface bloom of oxygen producing phytoplankton in the stratified layer may contribute to higher-than-expected oxygen concentrations in the water column. The differences are relatively small and do not impact the benthic flora and fauna communities.

Comparing May and June CTDO-profiles shows a generally well mixed water column and a few stations with weak stratification (at infauna station ECC_07, 08, 10, 11) in May and a more stratified water column in June (Figure 5-3) except for the shallowest stations (Figure 5-4) close to the coast, where wave mixing of the water column is more prevalent. This is illustrated in Figure 5-2 where two stations sampled in May (OWF_02_02) and June (OWF_41) close to each other in OWF Area A3 are compared (see location of stations in Figure 3-2). The CTDO profiles show a well mixed water column in May at OWF_02_02 with constant temperature and salinity trough the water column. The CTDO profiles in June show that the water column is generally stratified with two separate water masses with different salinities and temperature and a mixing zone in between the two water masses, where temperature and salinity changes rapidly - called a thermocline for temperature and halocline for salinity (see Figure 5-2). The thermocline is observed between 9-15 meters of depth and the halocline is observed between 9-14 meters of depth at CTDO station OWF_41 (Figure 5-2).

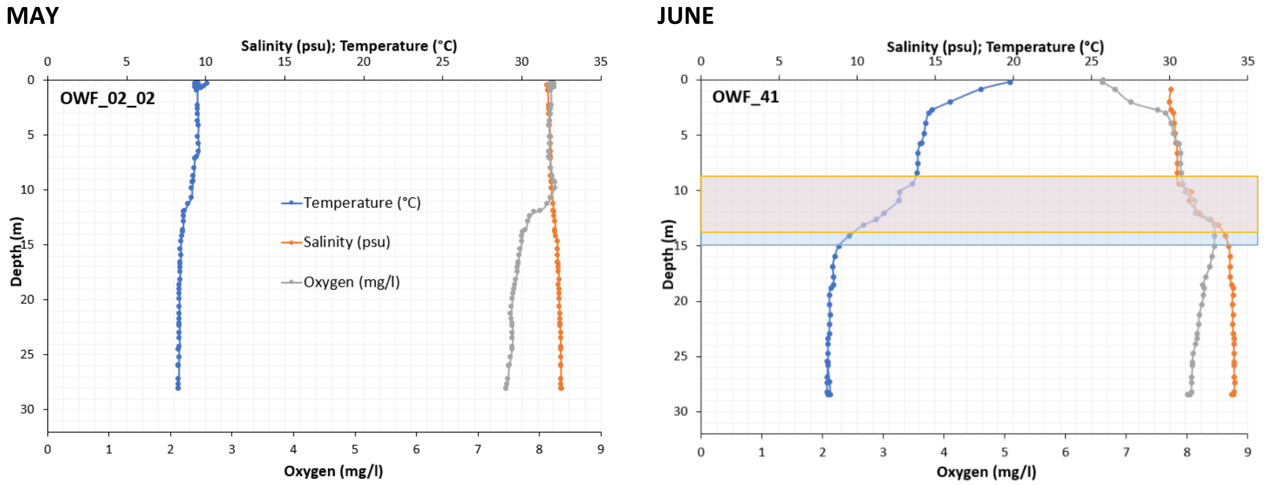


Figure 5-2. Comparison of CTDO profiles sampled (Left figure) in May and (Right figure) in June 2023. The stations are placed relatively close to each other in in OWF area A3 (see Figure 3-2). The thermocline is given with blue box and the halocline with an orange box in the right figure.

Oxygen conditions were good at all stations in both May and June (i.e. >4 mg O_2/l). Moderate oxygen deficiency (2-4 mg O_2/l) and severe oxygen deficiency (<2 mg O_2/l) were not observed at the seabed at any of the sampled stations in May or June as all measurements showed values above 6.6 mg O_2/l (Table 5-2). In Figure 5-2 oxygen concentration increases in the halocline at OWF_41, most likely due to a subsurface bloom of phytoplankton producing oxygen in the halocline (9-14 meters of depth). Subsurface blooms of phytoplankton are common in the Danish waters during summer, as the phytoplankton bloom descends in the water column as the surface layers are depleted of nutrients.

Table 5-2. Range of CTDO measurements of salinity (psu), temperature (°C) and oxygen (saturation % and concentration mg/l) at approximately 1 meter (= deepest measurement) above the seabed in May and June 2023. The CTDO is not lowered fully to the seabed as the CTDO can sustain damage. May numbers are given in black. June numbers are given in red. Depth is given as the depth of the deepest CTDO measurement. Data for bottom measurements at all stations are given in Appendix 4B. Source: (Energinet, 2021).

Areas May/June	Amount of stations (May/June)	Salinity (psu)	Temperature (°C)	Oxygen (% saturation)	Oxygen concentration (mg/l)	Depth (CTDO) (meters)
Pre-investigation area NSI.1-OWF	6/ 18	32.11 - 32.81 / 32.68 - 34.22	7.96 - 8.96 / 7.84 - 12.74	73.11 - 85.85 / 78.12 - 93.94	6.62 - 7.62 / 7.07 - 8.32	19.23 - 30.5/ 17.42 - 30.9
Pre-investigation area NSI.1-ECC	5/ 12	31.55 - 32.36 / 32.73 - 33.96	8.17 - 9.01 / 8.75 - 15.15	78.41 - 88.32 / 81.59 - 95.12	7.03 - 7.83 / 7.22 - 8.17	18.59 - 23.04 / 10.86 - 26.97
OWF areas:						
A1	2/ 5	32.11 - 32.81 / 32.68 - 33.61	8.04 - 8.96 / 10.67 - 12.74	73.11 - 85.85 / 89.29 - 93.94	6.62 - 7.62 / 7.64 - 7.79	19.23 - 24.44 / 17.42 - 24.94
A2	2/ 5	32.20 - 32.81 / 33.36 - 33.87	7.96 - 8.59 / 8.52 - 10.45	76.20 - 82.05 / 82.58 - 91.20	6.92 - 7.34 / 7.40 - 7.84	23.86 - 30.5 / 22.42 - 28.7
A3	2/ 6	32.51 – 32.63 / 33.56 - 34.22	8.17 – 8.29 / 7.84 - 8.96	80.41 - 82.81 / 78.12 - 90.04	7.27 – 7.46 / 7.07 - 8.05	27.05 - 28.08 / 28.5 - 30.9
Export cable corridors:						
ECC1	2/ 3	31.55 - 31.75 / 32.73 - 33.56	8.51 – 8.66 / 12.27 - 15.15	78.41 – 80.50 / 87.24 - 93.23	7.03 – 7.20 / 7.22 - 7.39	19.42 - 20.64 / 19.68 -21.5
ECC2	2/ 6	31.55 - 31.76 / 33.09 - 33.58	8.17 – 8.66 / 8.75 – 15.15	80.50 - 81.68 / 81.59 - 90.24	7.20 - 7.38 / 7.28 - 7.47	19.42 - 23.04 / 10.86 - 26.97
ECC3	2/ 4	32.09 - 32.36 / 33.27 - 33.96	8.52 - 9.01 / 9.79 - 12.55	85.29 - 88.32 / 92.25 - 95.12	7.65 - 7.83 / 7.60 - 8.17	18.59 - 21.96 / 17.0 - 25.56

When comparing the two pre-investigation areas, salinity was generally the same for May or June stations, with a slight increase in temperature and oxygen saturation and concentration in the pre-investigation area for the export cable corridors, likely due to generally lower depth and therefore better heating, and also mixing and oxygenation (see Table 5-2, Figure 5-3 and Figure 5-4).

Comparing with existing data from the baseline studies of Vesterhav Syd OWF and Thor OWF, Thor OWF was sampled in March and May 2020 and Vesterhav Syd OWF was sampled in March 2013 (se section 4.2.2 – Salinity, temperature and oxygen). Direct comparison is thus not possible as sampling was conducted in different months and seasons. However, both studies were sampled in the spring where the water column is well mixed. These results are similar to the results from May in this study, showing a well mixed water column with little stratification and good oxygen conditions at the seabed (>>4 mg O_2/l).

OWF AREAS (A1-3)

In general, similar conditions were observed in the three OWF areas A1-3 (Table 5-2). Slight differences are observed only in June related to the depth differences between the three OWF areas, i.e. the deepest areas have highest salinity and lowest temperature, strongest stratification and therefore lowest oxygen concentrations at the seabed. This pattern was observed in the OWF areas with increasing salinity and decreasing temperature and oxygenation from OWF area A1 (shallowest) to A3 (deepest) and A2 being intermediate (Figure 5-3). However, the differences are small and have no impact on the benthic communities.

Examples of CTDO profiles from the OWF areas A1-3 are given below in Figure 5-3.

EXPORT CABLE CORRIDORS (ECC1-3)

Depth was also determining for the slight differences in salinity, temperature and oxygen concentrations observed in the three export cable corridors. The southern cable corridor (ECC1) was the shallowest and the northern cable corridor (ECC3) was the deepest with ECC2 showing intermediate depth. As explained above, increasing salinity and decreasing temperature and oxygenation were observed as the depth increased from ECC1 to ECC3 (Figure 5-4). This pattern is clearest in June and more random in May. However, the differences are small and have no impact on the benthic communities.

Examples of CTDO profiles from the three export cable corridors (ECC1-3) are given in Figure 5-4. In this figure, the stratification of the deeper stations and the well mixed shallower stations (ECC_53 and ECC_76) are illustrated.

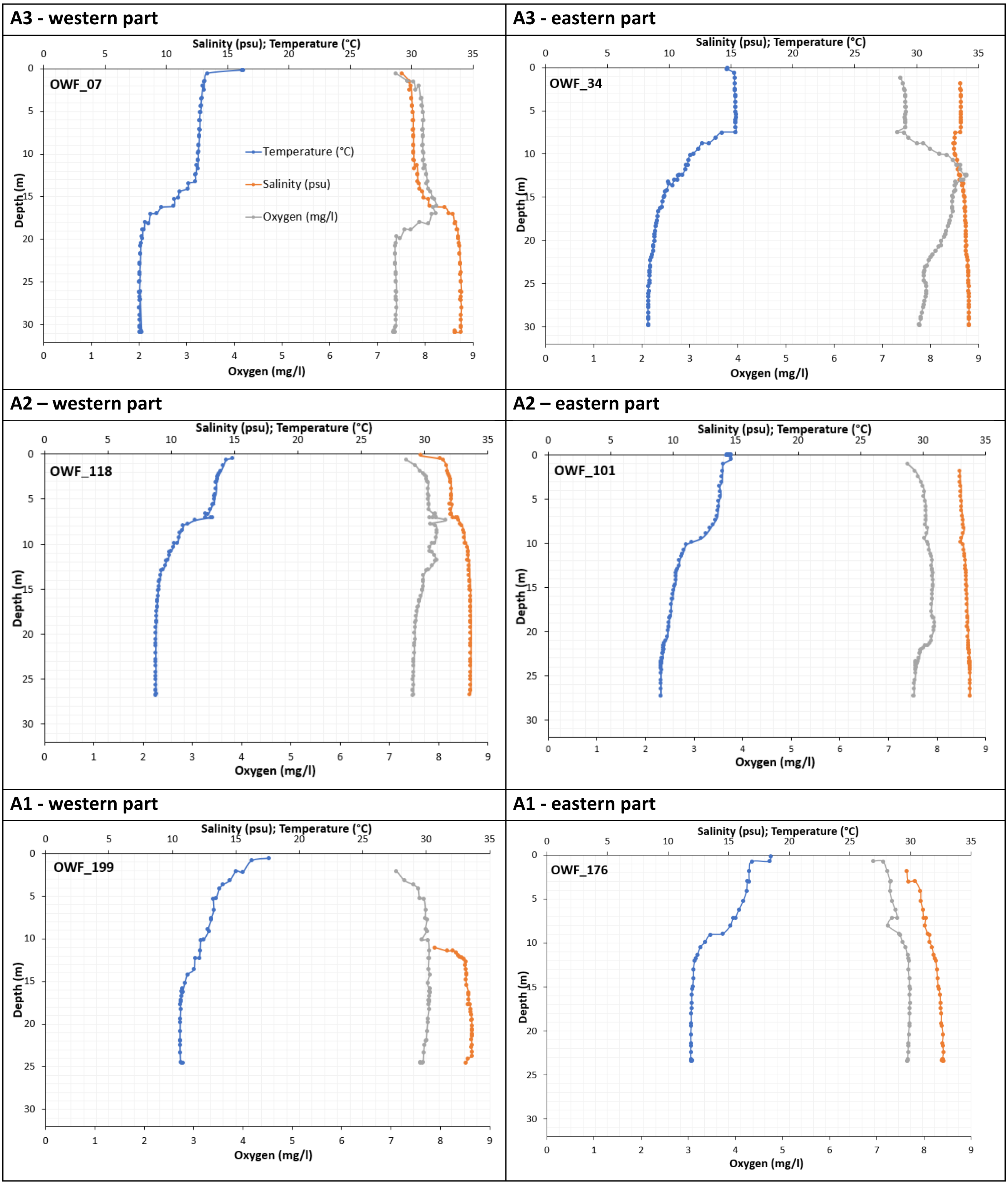


Figure 5-3. Selected CTDO profiles from OWF stations in June 2023 in each of the three OWF areas (A1-A3) with the left figure being farthest from land (western part) and the right figure closest to land (eastern part). See station location in Figure 3-2. The large shifts in temperature, salinity and oxygen in the upper 1 meter (surface layer) at some stations are likely due to a measuring error when lowering the CTDO instrument into the surface of the water until depth and equilibrium is reached below the upper 1 meters of depth.

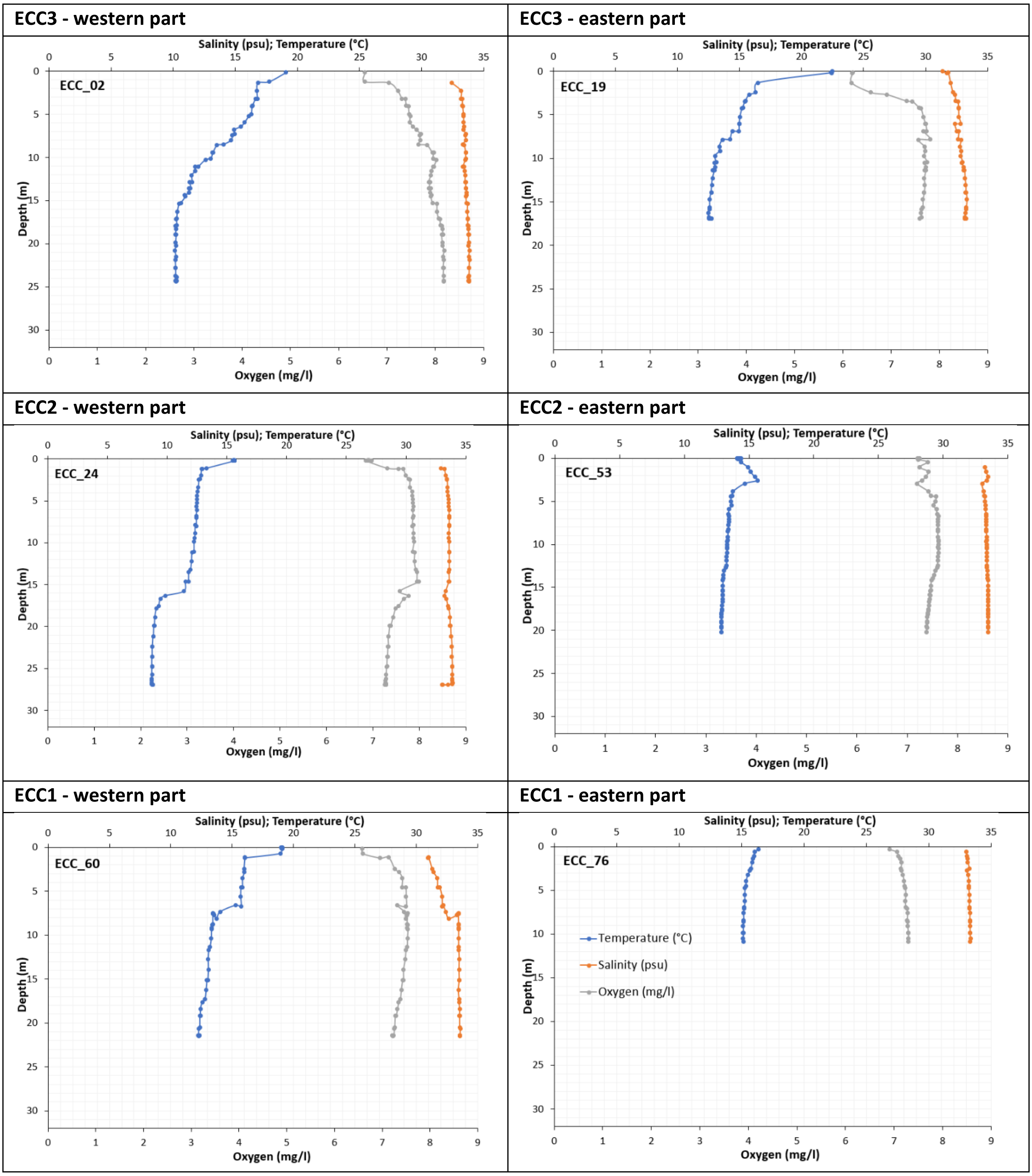


Figure 5-4. Selected CTDO profiles from the three export cable corridors (ECC1-3) in June 2023 with the left figure being farthest from land (western part) and the right figure closest to land (eastern part). See station location in Figure 3-2. Note stratification in deep wester stations and a more well mixed water column at shallow eastern stations in each cable corridor especially station ECC-76 which is the shallowest of approximately 11 meters of depth. The large shifts in temperature, salinity and oxygen in the upper 1 meter (surface layer) at some stations are likely due to a measuring error when lowering the CTDO instrument into the surface of the water until depth and equilibrium is reached below the upper 1 meters of depth.

5.2 SEABED SEDIMENT CHARACTERISTICS

In the following, the seabed sediment types are described for the two pre-investigation areas of NSI.1 OWF area (NSI.1-OWF) and the pre-investigation area for the three cable corridors (NSI.1-ECC).

5.2.1 SEDIMENT TYPES

The sediment types were mapped in the two pre-investigation areas by side scan sonar in combination with ROV video verification of the seabed sediment types (see section 3.4.3 – Sediment type mapping). Sediment types mapped in this baseline study are presented in Figure 5-5 below. The map of the sediment types combined with the visual observations (ROV video stations) of the benthic flora and fauna present in the different sediment types are used to describe the different benthic flora and fauna communities (section 5.3 – Benthic communities) in the investigated area and to create a map of benthic communities (see Figure 5-7).

In total, seven sediment types were observed in the two pre-investigation areas. The sediment types were mapped in the two pre-investigation areas and the area distribution of these is presented in Figure 5-5 and the area coverage in percent is listed in Table 5-3:

- **Sediment type 1a/1b - silty sand** is a mix of sediment type 1a and 1b and consists of sand with a surface silt layer
- **Sediment type 1b - sand** is sandbed with ripples as indication of dynamic
- **Sediment type 1c – clay** is clay outcrops exposed on the seabed
- **Sediment type 2a - coarse sand, gravel and pebbles** is sandy seabed with a high concentration of small stones (<10 cm)
- **Sediment type 2b – seabed with single large stones** consists of sand, gravel and pebbles with few large stones (>10 cm, 1-10 % large stones)
- **Sediment type 3 - Moderate stone coverage** i.e. sandbed and pebbles with large rocks (coverage of large stones 10-25 %)
- **Sediment type 4 - stone reef** (coverage of large stones >25 %)

Still photos grabbed from ROV video showing examples of the sediment types are shown in Figure 5-6.

The pre-investigation area for the NSI.1 (NSI.1-OWF) was dominated by sediment type 1a/1b – silty sand and sediment type 1b - sand with an area coverage of 65 % and 34 %, respectively. All other sediment types constituted less than 1 % of the area coverage. The pre-investigation area for the export cable corridors (NSI.1-ECC) was also dominated by silty sand (83 %) and sand (16 %).

Table 5-3. Percent area coverage of the sediment types in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC), including the subareas OWF areas A1-3 and three export cable corridors (ECC1-3). *Note that the area coverages are given for the full ECC1 and ECC2 cable corridor e.g. including the overlap between the two areas.

Sediment type/ Areas	1a/1b	1b	1c	2a	2b	3	4
Pre-investigation area for NSI.1 (PNSI.1-OWF)	901.9 km^2 65 %	472.1 km^2 34 %	0.005 km^2 0.0003	9.7 km^2 0.7 %	3.1 km^2 0.2 %	0.3 km^2 0.03 %	0.006 km^2 0.0005 %
A1	178.9 km^2 49 %	183.5 km^2 50 %	0 km^2 0 %	3.01 km^2 0.8 %	0.6 km^2 0.2 %	0.03 km^2 0.007 %	0.0004 km^2 0.0001 %
A2	260.6 km^2 65 %	133.4 km^2 33 %	0 km^2 0 %	4.6 km^2 1.2 %	1.9 km^2 0.5 %	0.3 km^2 0.06 %	0.004 km^2 0.0009 %

Sediment type/ Areas	1a/1b	1b	1c	2a	2b	3	4
A3	342.1 km² 86 %	58 km² 15 %	0.003 km² 0.0007 %	0.1 km² 0.04 %	0 km² 0 %	0.0004km² 0.0001 %	0.0004km² 0.0001 %
Pre-investigation area for export cable corridors (ECC1-3) (NSI.1-ECC)	98.02 km² 83 %	19.07 km² 16 %	0.01 km² 0.008 %	0.2 km² 0.21 %	0.6 km² 0.5 %	0.1 km² 0.1 %	0.1 km² 0.1 %
ECC1	32.6 km² 96 %	1.3 km² 4 %	0 km² 0 %	0.09 km² 0.3 %	0.02 km² 0.05 %	0.0005 km² 0.001	0 km² 0 %
ECC2	55.5 km² 92 %	4.2 km² 7 %	0.008 km² 0.01 %	0.2 km² 0.3 %	0.3 km² 0.5	0.08 km² 0.1 %	0.05 km² 0.1 %
ECC3	20.4 km² 58 %	14.5 km² 41 %	0.001 km² 0.003 %	0.0001 km² 0.0004 %	0.3 km² 0.8 %	0.06 km² 0.2 %	0.06 km² 0.2 %

For the sediment type 1a/1b – "silty sand", the results show that the silt layer is generally quite thin and only present in the surface layer of the seabed (upper few cm), whereas the seabed below is sediment type 1b – sand (see Figure 5-6). It should be noted, that the silt coverage in the pre-investigation areas is highly variable both temporally and spatially, as illustrated by the large differences in area coverage, when comparing the coverage of "silty sand" in this baseline study (see Figure 5-5) with the coverage of "Muddy sand" in the GEUS sediment type map from the same area (Figure 4-6). "Silty sand" (this study) and "muddy sand" (GEUS map) are not exactly the same, as "silty sand" most likely contains less organic matter (silt%) than "muddy sand", but it is the best approximation between the existing data from GEUS and this baseline study.

Sediment type 1c – "clay outcrops" was observed on side scan sonar but not on ROV video, due to the very low area coverage of this sediment type. The sediment type was observed in OWF area A3 and cable corridor ECC2 and ECC3 constituting less than 0.01 % of the areas (Table 5-3).

Sediment types with large stones (2b, 3 and 4) were very scarce in the two pre-investigation areas, constituting maximally 0.8 % or much less of the area (see Table 5-3). The sediment type map in Figure 5-5 shows that the stony sediment types were only present in the southwestern part of the pre-investigation area of NSI.1-OWF and were present as small patches in all three cable corridors.

Sediment type 4 – stone reef occurred only as small patches with higher stone coverage (>25 %) within sediment type 3 – moderate stone coverage (large stones 10-25 %). Sediment type 3 was also often observed as seabed covered with small stones/pebbles and fewer large stones (see Figure 5-6).

OWF AREAS (A1-3)

Comparing the area coverage of the sediment types in the three OWF areas A1-3, OWF area A2 and A3 were dominated by sediment type 1a/1b "silty sand" with a coverage of 65 % and 86 %, respectively, whereas OWF area A1 had 49 % and 50 % of "silty sand" and "sand", respectively. Sediment type 1b – sand, covered 33 % and 15 % in A2 and A3, respectively. All other mapped sediment types constituted 1.2 % or less of the three OWF areas (A1-3).

Sediment types with large stones (2b, 3 and 4) were very scarce in both A1 and A2 (≤0.5 %) and very rare in A3 (≤0.0001 %) (see Table 5-3). The sediment type map in Figure 5-5 shows that the stony sediment types with small stones (pebbles) (<10 cm; sediment type 2a) or large stones (>10 cm; sediment type 2b, 3 and 4) were present mainly in the southwestern part of both OWF area A1 and A2.

EXPORT CABLE CORRIDORS (ECC1-3)

All three cable corridors (ECC1-3) were dominated by sediment type 1a/1b – silty sand with area coverage ranging from 58-96 % (Table 5-3). Sediment type – sand covered from 4-41 % and all other sediment types covered less than 0.8 %.

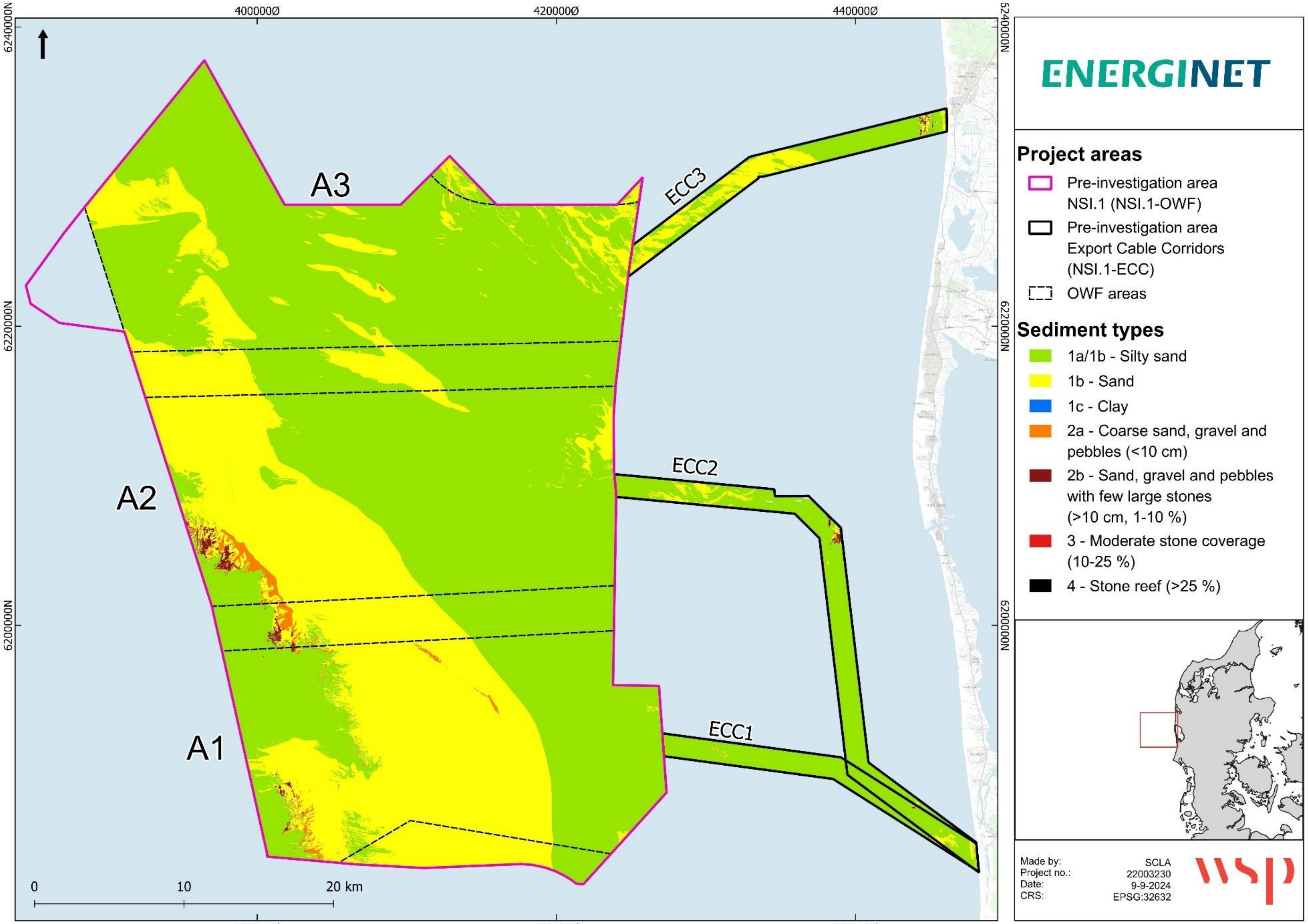
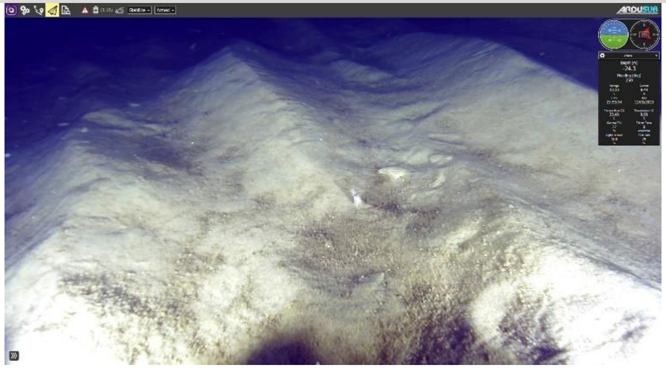


Figure 5-5. Sediment type map for the surface seabed in the two pre-investigation areas: NSI.1-OWF and NSI.1-ECC.

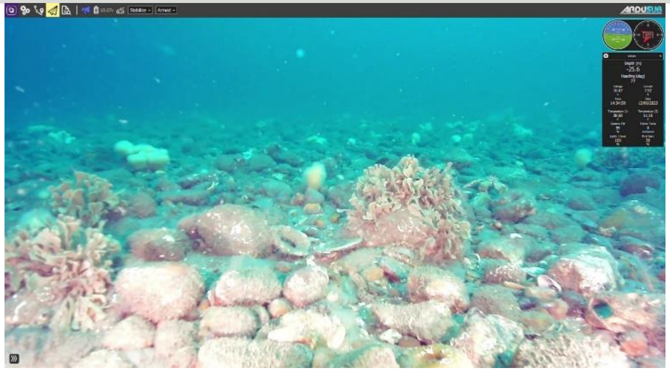
Sediment type 1a/1b – silty sand: ROV_OWF_001_0004



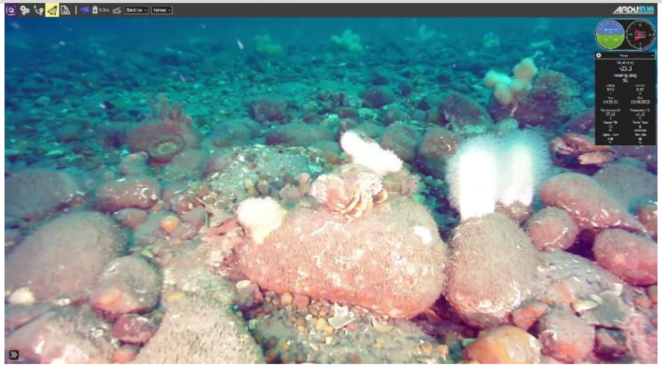
Sediment type 1b - sand: ROV_OWF_001_0004

Sediment type 2a – coarse sand, gravel and pebbles: ROV_OWF_159_0006

Sediment type 2b – sand with single large stones: ROV_OWF_199_00008, Large stones (>10 cm) 1-10 %



Sediment type 3 – moderate stone coverage: ROV_OWF_197_0001 Large stones (>10 cm) 10-25 %



Sediment type 4 – stone reef: ROV_OWF_001_0004 Large stones (>10 cm) >25 %

Figure 5-6. Examples of sediment types observed on ROV video in the pre-investigation area of NSI.1-OWF. ROV station number and still photo number is given in the figure. The secondary sediment type 1c – "clay" was only observed on side scan sonar and not on ROV video and is therefore not shown here.

5.2.2 PHYSICAL PARAMETERS

The grain size of the sediment and total organic content (TOC) can be some of the determining parameters for the habitat available to the benthic flora and fauna and for oxygen conditions. The data for the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) are presented below. Oxygen deficiency arises when bacteria degrade organic matter in the seabed using oxygen in the process and thereby decreasing the available oxygen for benthic flora and fauna. Due to the dynamic, mixed seabed and water column in this area of the North Sea, oxygen deficiency is very unlikely to occur and has not been observed in this study or earlier studies from the area (se section 5.1.2 - Salinity, temperature and oxygen (CTDO)).

GRAIN SIZE

In total, 47 HAPS stations for grain size were sampled; 23 in the pre-investigation area of NSI.1-OWF and 24 in pre-investigation area of the export cable corridors (NSI.1-ECC) (Figure 3-3). The grain size analysis is conducted on a mixed HAPS sample of approximately 0-20 cm of the sediment. Raw data for grain size analyses are presented in Appendix 5.

Generally, the sediment type "sand" is defined as >50 % sand in a sample and the sediment type "gravel" is defined as >50 % gravel and larger grain sizes in a sample. The uniformity coefficient (Cu) = d60/d10 shows the uniformity of the grain sizes in a sample, where Cu>6 indicates low uniformity and large range of gran sizes and Cu<4 indicates a uniform sediment with a narrow range of particle sizes.

All samples analysed in this study have been defined as "sand", as they all have a percentage of sand constituting more than 50 % of the sample (Table 5-4). Gravel was present in 77 % of the samples (36/47*100 %) but constituted a low percentage of the grain sizes in the HAPS samples (0.05-12.9 %). The silt% range is very similar comparing the pre-investigation area of NSI.1-OWF and the pre-investigation area for the cable corridors (NSI.1-ECC) with 0.5-32.1 % and 1.4-33.4 %, respectively. Comparison of the uniformity coefficient (Cu) = d60/d10 between the two pre-investigation areas, shows that particle sizes are generally very uniform with Cu<4. Only one sample in ECC3 at a depth of 22.6 m, has a Cu = 4.88 (ECC_GSA_A10-02), which still indicate relatively uniform particle sizes. There was generally little difference between the two pre-investigation areas.

The sediment type map in Figure 5-5) indicates, that a large part of the seabed consists of "silty sand" (sediment type 1a/1b), which consists of sand with a thin silt layer covering the surface of the sand and mixed down into the upper few cm of the sediment. The dominance of "sand" (sediment type 1b) in the grain size analyses is explained by these samples being analysed as a mix of the upper 0-20 cm of the sediment, which is thus mainly sand, since the silt in this study is present mainly in the upper centimeters of the sediment. It is therefore not possible, in this baseline study, to directly compare the sediment type map with the grain size analyses. The silt covering large parts of the sandy seabed in the two pre-investigation areas likely originates from outflow from local fjords, the Wadden Sea and German river outlets. This input likely varies greatly with weather, currents and between years.

OWF AREAS (A1-3)

When comparing the three OWF areas A1-3, the main difference is a higher silt% in the A2 OWF area. This is due to a single station with higher silt% (OWF_GSA_A04-03, 32.1% silt), whereas the other stations within the A2 OWF area have the same range of silt% (1-12.4% silt) as seen for A1 and A3. The silt% range is therefore generally very similar in between the three OWF areas (A1-3), as seen for all other parameters. (see Table 5-4).

EXPORT CABLE CORRIDORS (ECC1-3)

In regard to grain size, the export cable corridors, ECC1 and ECC2 are very similar, whereas ECC3 has lower silt%, higher sand%, higher gravel%, resulting in the largest overall variance in grain sizes (Cu=d60/d10) - up to 4.88 (see Table 5-4). This difference is likely due to a larger range in sampling depth (12.1-25.6 m) within ECC3, whereas the sampling depth range was slightly lower for ECC1-2 (19.7 to 23.5 m). However, the uniformity coefficient (<6) shows that the sediment is uniform with low particle size range in all three cable corridors.

Table 5-4. Grain size ranges (minimum-maximum), uniformity coefficient (d60/d10) and depth for the grain size HAPS samples sampled in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) including subareas (OWF areas A1-3 and cable corridors ECC1-3). The uniformity coefficient (Cu) = d60/d10 shows the uniformity of the grain sizes in a sample, where Cu>6 indicates low uniformity and a large range of gran sizes and Cu<4 indicates a uniform sediment with a narrow range of particle sizes.

Grain sizes/ Areas	silt% <0.063 mm	sand% 0.063-2 mm	gravel% 2-16 mm	D60/d10	Depth m
Pre-investigation area NSI.1 (NSI.1-OWF)	0.5-32.1	67.7-99.4	0-0.4	1.55-2.55	19.4-31.5
Pre-investigation area ECC1-3 (NSI.1-ECC)	1.4-33.4	66.5-98.5	0-12.9	1.8-4.88	12.1-25.6
OWF Areas:					
A1	0.5-13.1	91.8-99.4	0-0.39	1.78-2.56	19.4-28.8
A2	1-32.1	67.7-98.9	0-0.2	1.55-1.95	24.0-30.9
A3	0.9-10.0	89.9-98.7	0-0.4	1.64-2.56	21.1-28.5
Export cable corridors:					
ECC1	3.2-33.4	66.5-96.8	0-3.0	2.07	19.7-21.2
ECC2	8.8-33.4	66.5-90.6	0-1.1	2.88	19.7-23.5
ECC3	1.4-16.9	83.1-98.5	0-12.9	1.8-4.88	12.1-25.6

TOTAL ORGANIC CARBON CONTENT (TOC)

Total organic carbon (TOC) was measured in the HAPS samples and analysed for pollutants by Aarhus university (AU). The results are presented in Table 5-5. TOC concentrations were very low and ranged from 0.03 to 0.32 % TS for all samples from both pre-investigation areas. As the detection limit of the analysis was 0.1, measurements below that value are noted as <0.1 in the table. There was no difference between the range of TOC concentrations found in surface samples (0-2 cm of HAPS core sampled, <0.1-0.31 % TS) and in deeper samplings (0-20 cm of HAPS core sampled, <0.1-0.32 % TS). The TOC concentrations for the pre-investigation area of NSI.1 (OWF areas A1-3) ranged from 0.1 to 0.24 % TS and for the pre-investigation area for the export cable corridors from <0.1 to 0.32 % TS. Overall, the two pre-investigation areas had very low and similar TOC concentrations, both between and within each of the pre-investigation areas. Similarly, TOC was very low and with insignificant differences, when comparing the three OWF areas (A1-3) and the three export cable corridors ECC1-3.

Existing data from the Danish monitoring program NOVANA in the area, show similar low TOC concentrations of 0.077-0.24 % TS (see Table 4-4 in section 4.3.2 – Existing data/Physical parameters/TOC).

The similarity in TOC between stations in this study and existing data supports the fact, that this area is very homogenous, due to the highly dynamic seabed and a water column, which is continuously mixed.

Table 5-5. Total organic carbon (TOC) (% TS) ranges in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) and their subareas (OWF area A1-2 and ECC1-3). TOC concentrations from HAPS samples were analysed by Aarhus University (AU). Detection limit of the analysis = 0.1.

Grain sizes/ Areas	TOC (% TS)
Pre-investigation area for NSI.1 (NSI.1-OWF)	0.10 - 0.24
Pre-investigation area for export cable corridors ECC1-3 (NSI.1-ECC)	<0.1 - 0.32
OWF Areas:	
A1	0.12 - 0.14
A2	0.10 - 0.12
A3	0.17 - 0.24
Export cable corridors:	
ECC1	0.23
ECC2	0.28 - 0.32
ECC3	<0.1 - 0.07

5.2.3 CHEMICAL PARAMETERS

Sediment that is suspended in the water column due to digging or flushing activities during construction of the cable corridor may cause release of nutrients, heavy metals and organic pollutants. Release of nutrients can increase phytoplankton concentration and epiphyte coverage and reduce light availability and growth for macroalgae on the seabed. Also, high concentrations of pollutants in the seabed may be determining for the abundance and distribution of infauna in the seabed.

Pollutants were measured in sediment samples collected by HAPS core sampler. (see stations in Figure 3-5). Nutrients were not sampled and analyzed in this study but are presented under existing data based on data from the nearest NOVANA stations (section 4.3.3 - Existing data/Chemical parameters/Nutrients). The national surveillance program for the aquatic environment and nature (NOVANA) monitors nutrients (Nitrogen and Phosphorous) yearly at several stations in and around the pre-investigation area for North Sea I (DCE, 2024).

NUTRIENTS

Nutrients were not sampled in the two pre-investigation areas in this baseline study. See instead existing data for nutrient concentrations measured in the pre-investigation areas by the Danish NOVANA program, which is presented in section 4.3.3 – Existing data/Chemical parameters/Nutrients.

POLLUTANTS

In the following the chemical conditions of the sediment within the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) and subareas (OWF area A1-3 and ECC1-3) are described. Concentrations of the individually measured pollutants are assessed by comparing the results from the chemical analyses with sediment threshold values following the priority as described in section 3.4.6. The assessment and description of the presence of pollutants are separated into statutory threshold values (NEQS) and non-statutory threshold values (NQC). The non-statutory thresholds are used as guiding values. For the threshold values, which are calculated based on TOC content, either the sample specific TOC or the average TOC of 0.17 % were used. Additionally, a standard value of 5 % TOC was used, as given in the statutory order, to illustrate the lower number of exceedances at higher TOC levels. The complete analytical reports from the laboratories can be seen in Appendix 6.

The sampling stations were divided into two groups: AU-stations (Aarhus University, DCE) and EF-stations (EuroFins). The AU-station samples were analyzed for phenols (2 different pollutants) and phthalates (3 different pollutants). The samples from the EF-stations were analyzed for metals (10 different pollutants) and PAH's (20 different pollutants, however 17 with methylnaphthalenes summed). In total, the concentration of 35 pollutants were measured. They represent a wide range of pollutants and typical expected pollutants prevalent within Danish, marine sediments. As the four methylnaphthalenes are summed and considered as one compound, a total of 32 compounds were compared to threshold values.

For a number of the pollutants, the threshold values are calculated by the content of organic matter (TOC in percentage) in the sediment for each sample (Miljøstyrelsen, 2023a) (Miljøstyrelsen, 2023b). This applies to the NEQS for silver (Ag), the PAH compounds anthracene, naphthalene and methylnaphthalenes (summed) and the phenols, nonylphenols (summed) and 4-tert-ocylphenol; as well as the NQC for the four PAH-compounds benz(a)anthracene, chrysene, phenanthrene and pyrene. The calculated threshold values are presented in Table 5-6 (only AU data with one TOC measurement per station) and Table 5-7 (EF stations without specific TOC measurements).

The content of TOC was measured at 14 (AU stations) out of 29 stations. The TOC content was very low at the 14 AU stations (between 0.03 to 0.32 %), as expected for the North Sea. An average TOC content from the 14 stations (0.17 %), was used on the remaining 15 stations, where TOC had not been measured (= EF stations).

Table 5-6. Calculated thresholds for relevant pollutants based on measured TOC values at each of the AU stations. Note that only phenols and phthalates are analysed on AU stations and threshold values based on measured TOC are therefore only calculated for these pollutants.

Threshold values/ Station ID	TOC	Nonylphenols (sum)	4-tert-octylphenol
	%	µg/kg TS	
NEQS		2500 x f_{oc}	3930 x f_{oc}
OWF_MFS_ AU2_01	0.1	2.5	3.93
ECR_MFS_ AU2_01	0.07	1.75	2.751
ECR_MFS_ AU2_02	0.31	7.75	12.183
ECR_MFS_ AU2_03	0.23	5.75	9.039
OWF_MFS_ AU1_01	0.17	4.25	6.681
OWF_MFS_ AU1_02	0.24	6	9.432
OWF_MFS_ AU1_04	0.14	3.5	5.502
OWF_MFS_ AU1_05	0.12	3	4.716
ECR_MFS_ AU1_01	0.03	0.75	1.179
ECR_MFS_ AU1_02	0.06	1.5	2.358
ECR_MFS_ AU1_03	0.12	3	4.716
ECR_MFS_ AU1_04	0.28	7	7.86
ECR_MFS_ AU1_05	0.32	8	12.576
ECR_MFS_ AU1_06	0.2	5	7.86

Table 5-7. Calculated thresholds based on an average TOC value of 0.17 % and a standard value of 5 %. TOC of 0.17 % is used in this section, and a TOC value of 5 % is used in the last subsection in this section titled "Exceedances using a TOC value of 5 %".

Threshold values/ Station ID	TOC	Silver	Acenaphthene	Anthracene	Benz(a)anthracene	Chrysene	Phenanthrene	Pyrene	Methylnaphthalenes (sum)	Naphthalene	Nonylphenols (sum)	4-tert-octylphenol
	%	mg/kg TS	µg/kg TS	µg/kg TS	µg/kg TS	µg/kg TS	µg/kg TS	µg/kg TS	µg/kg TS	µg/kg TS	µg/kg TS	µg/kg TS
NEQS		260 x f_{oc}		96 x f_{oc}					478 x f_{oc}	2760 x f_{oc}	2500 x f_{oc}	3930 x f_{oc}
NQC			960 x f_{oc}		600 x f_{oc}	462 x f_{oc}	7800 x f_{oc}	8400 x f_{oc}				
TOC 0.17 %	0.17	0.44	1.6	0.16	1.02	0.8	13.3	14.3	0.8	4.7	4.3	6.7
TOC 5 %	5	13	48	4.8	30	23.1	390	420	23.9	138	125	196.5

Of the 32 measured pollutants, a statutory NEQS exist for nine of the pollutants or sum of pollutants; the four metals - lead (Pb), cadmium (Cd), silver (Ag) and vanadium (V); the three PAH-compounds - anthracene, naphthalene and the sum of methylnaphthalenes (1-methylnaphthalene, 2-methylnapthalene, dimethylnaphthalene and trimethylnaphthalene) and the phenols - 4-tert-octylphenol and the sum of nonylphenols (sum of 4-tert-nonylphenol, 4-n-nonylphenol and linear nonylphenols) (Miljøstyrelsen, 2023a)

For the remaining 23 measured pollutants with no statutory NEQS, a NQC exists for 16 of the pollutants: the three metals arsenic (As), chromium (Cr) and nickel (Ni), the ten PAH-compounds acenaphthene, benz(a)anthracene, benzo(g,h,i)perylene, benzo(b+j+k)fluoranthene, benzo(a)pyrene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene and pyrene and the three phthalates Benzyl butyl phtalate (BBP), bis(2-ethylhexyl) adipate (DEHA) and Bis(2-ethylhexyl) phthalate (DEHP) (Miljøstyrelsen, 2023b). ERL-values were used for the three metals cobber (Cu), mercury (Hg) and zinc (Zn) as well as the three PAH-compounds acenaphthylene, dibenz(a,h)anthracene and fluorene (OSPAR, 2009). For the last PAH (benzo(e)pyrene), no threshold is found. Concentration of pollutants exceeding the threshold values are described in the following.

When comparing the results of this study to the existing NOVANA data, concentrations of the metals chromium (Cr), nickel (Ni), vanadium (V) and zinc (Zn) were not exceeded in this study but were exceeded in the NOVANA data. Concentrations of nonylphenols and 4-tert-octylphenol were higher in this study, compared to the existing NOVANA data. The remaining pollutant-concentration levels were the same in this study and the NOVANA data (see NOVANA data in section 4.3.3 – Chemical parameters/Pollutants).

When comparing the concentration of pollutants at the different sample stations with station depth, no correlation was found.

No correlation between pollutant concentration and sediment type was observed in the three OWF areas (A1-3), as concentrations at all sampling stations were similar regardless of sediment type. However, OWF_MFS_EF_03 in OWF area A2, which was the only station in the OWF areas where the sediment type was "silty sand", did show higher concentrations of anthracene, benz(a)anthracene, naphthalene and methylnaphthalenes (sum).

A relationship between pollutant concentration and sediment type (determined for the specific HAPS sample) was clearer, when comparing the samples within the three export cable corridors (ECC1-3), as concentrations of PAH's and phenols were higher in both ECC2 and ECC3, where the overall sediment type in the HAPS samples was "silt"; compared to ECC1 where the overall sediment type was "sand" (see Tabel 5-8). When comparing the OWF - and ECC areas, the same pattern was observed. Pollutant concentrations were higher in ECC2-3 compared to OWF area 1-3, corresponding to the dominance of “silt” in the ECC areas and the presence of “sand” in the OWF areas.

In three sediment samples (OWF_AU2_01, ECC_AU2_02 and ECC_AU2_03) only the sample surface layer was analysed (sample depth of 0-2 cm in HAPS sediment core) compared to the rest of the samples where 0-20 cm depth of the HAPS sediment core sample was analysed (see stations in Figure 3-5 and data in Table 5-8). When comparing the analyses of the surface sediment (0-2 cm) to the deeper sediment samples (0-20 cm), no difference was observed between pollution concentration and sampling depth, which is likely due to the continuous mixing of the seabed in this part of the North Sea.

Overall, there was no correlation between pollutant concentrations and station depth, or analysis depth in the sediment core, but there was observed a relationship between sediment type (silty sand compared to sand) and pollutant concentration, for some of the pollutants.

Table 5-8. Pollutant threshold values and exceedances calculated based on measured TOC: Pollutants exceeding prioritized threshold values in the sediment in the three OWF areas (A1-3) and in the three export cable corridors (EEC1-3), showing concentrations and threshold values as well as depth and sediment type for the HAPS sample. NEQS (national environmental quality standards, statutory, miljøkvalitetskrav) and NQC (non-statutory, national quality criteria, kvalitetskriterier) are calculated based on the organic content (TOC) for all compounds except for arsenic. Threshold values are calculated from specific TOC measurements at each AU station (see Table 5-6) and on an average of 0.17 % for EF station (see Table 5-7). Exceedances of the NEQS are represented by **red numbers**, and exceedances of the NQC are represented by **black numbers**. f_{oc} is the fraction of TOC in the sediment. <DL = below detection limit, but detection limit is higher than the threshold value. "NA" = compound is not measured. Empty cells = no exceedances. Sediment type describes the dominant sediment found in the HAPS sample on deck. For station locations see Figure 3-5.

Threshold values /Stations	Heavy metals (mg/kg DW)	PAH (µg/kg DW)					Phenols (µg/kg DW)		Sediment type	Depth (m)
	Arsenic	Anthracene	Benz(a)anthracene	Chrysene	Naphthalene	Methylnaphthalenes (sum)	Nonylphenols (sum)	4-tert-octylphenol		
NEQS		96 x f_{oc}			2760 x f_{oc}	478 x f_{oc}	2500 x f_{oc}	3930 x f_{oc}		
NQC	0.4		600 x f_{oc}	462 x f_{oc}						
Pre investigation area: NSI.1 OWF area (NSI.1-OWF)										
A1										
OWF_ AU1_01	NA	NA	NA	NA	NA	NA	32	8	Sand	25.4
OWF_ AU1_02	NA	NA	NA	NA	NA	NA	8	22	Sand	25.4
OWF_EF_01	1.9	<DL	<DL	1.4		8.66	NA	NA	Sand	26.0
A2										
OWF_EF_02	1.7	<DL	<DL	<DL		<DL	NA	NA	Sand	20.5
OWF_ AU2_01	NA	NA	NA	NA	NA	NA		10	Sand	21.0
OWF_EF_03	2.4	0.6	2.5	4.4	4.8	29.9	NA	NA	Sand/silt	24.7
A3										
OWF_ AU1_04	NA	NA	NA	NA	NA	NA	18	12	Sand	25.8
OWF_EF_04	3	<DL	<DL	<DL		<DL	NA	NA	Sand	18.2
OWF_ AU1_05	NA	NA	NA	NA	NA	NA	11	12	Sand	20.7
OWF_EF_05	2.6	<DL	<DL	<DL		<DL	NA	NA	Sand	21.6
Pre-investigation area: Export Cable Corridors (NSI.1-ECC)										
Export Cable Corridor 3 (ECC3)										
ECC_EF_01	3.4	<DL	<DL	<DL		<DL	NA	NA	Sand	23.0
ECC_ AU1_01	NA	NA	NA	NA	NA	NA	3	13	Sand	22.6
ECC_EF_02	8.1	<DL	<DL	<DL		<DL	NA	NA	Sand	16.6

Threshold values /Stations	Heavy metals (mg/kg DW)	PAH (µg/kg DW)					Phenols (µg/kg DW)		Sediment type	Depth (m)
	Arsenic	Anthracene	Benz(a)anthracene	Chrysene	Naphthalene	Methylnaphthalenes (sum)	Nonylphenols (sum)	4-tert-octylphenol		
ECC_ AU2_01	NA	NA	NA	NA	NA	NA			Sand	16.2
ECC_EF_03	3.1	**<DL**	<DL	<DL		**<DL**	NA	NA	Sand/silt	16.3
ECC_ AU1_02	NA	NA	NA	NA	NA	NA	**5**	**9**	Sand	9.1
Export Cable Corridor 2 (ECC2)										
ECC_ AU1_03	NA	NA	NA	NA	NA	NA	**11**	**23**	Sand	23.6
ECC_EF_04	2.6	**<DL**	<DL	1.3		**<DL**	NA	NA	Sand	20.2
ECC_ AU2_02	NA	NA	NA	NA	NA	NA			Sand	20.0
ECC_EF_05	8.3	**1.1**	3.7	6.5	**6.2**	**33.3**	NA	NA	Sand/silt/mud	21.8
ECC_ AU1_04	NA	NA	NA	NA	NA	NA		**21**	Silt	18.6
ECC_EF_06	3.2	**<DL**	1.8	3.4		**17.5**	NA	NA	Silt	18.1
ECC_ AU1_05	NA	NA	NA	NA	NA	NA	**10**	**20**	Silt	17.6
ECC_EF_09	4.3	**0.8**	4.4	6.4		**23.6**	NA	NA	Silt	17.3
ECC_ AU2_03	NA	NA	NA	NA	NA	NA			Silt	17.0
ECC_EF_10	3.2	**0.8**	6.3	7.8		**23.2**	NA	NA	Silt	15.2
Export Cable Corridor 1 (ECC1)										
ECC_EF_07	1.9	**<DL**	<DL	1.9		**12.2**	NA	NA	Silt	19.7
ECC_ AU1_06	NA	NA	NA	NA	NA	NA			Sand	18.1
ECC_EF_08	3.3	**<DL**	<DL	2.5		**13.7**	NA	NA	Silt	17.3
ECC_EF_09	4.3	**0.8**	4.4	6.4		**23.6**	NA	NA	Silt	17.3
ECC_ AU2_03	NA	NA	NA	NA	NA	NA			Silt	17.0
ECC_EF_10	3.2	**0.8**	6.3	7.8		**23.2**	NA	NA	Silt	15.2

OWF AREAS (A1-3)

Within the three OWF areas (A1, A2 and A3), a total of ten stations were sampled and used for chemical analysis of pollutants. The HAPS core samples were taken at station depths between 18 to 26 meters and in sediment that consisted mainly of sand. Exceedances of NEQS (statutory) and NQC values (non-statutory) are listed in Table 5-8 and in Table 5-9, and locations of stations are shown in Figure 3-5.

Table 5-9. Pollutants exceeding the threshold values in the three OFW areas A1-3.

NSI.1 OWF areas	Arsenic	Anthracene	Chrysene	Naphthalene	Benz(a)-anthracene	Methyl-naphthalenes (sum)	Nonylphenols (sum)	4-tert-octylphenol
A1	X	X	X		X	X	X	X
A2	X	X	X	X	X	X		X
A3	X	X	X		X	X	X	X

No clear pattern in the spatial distribution of the exceedances and concentrations of the pollutants was observed between the three OWF areas A1-3. However, for all three OWF areas, the same pollutants exceeded the threshold values, except for naphthalene, which only exceeded the threshold values in OWF area A2, and nonylphenols, which exceeded the threshold values in A1 and A3 (see Table 5-9). In the following, the exceedances of NEQS and NQCs are discussed separately.

Pollutants exceeding statutory National Environmental Quality Standards (NEQS)

NEQS used for assessing the pollutant concentrations are specified in the Danish consolidation act BEK. no. 796 of 13/06/2023 (Miljøstyrelsen, 2023a). For further details on threshold values see section 3.4.6 – HAPS chemical analyses.

No exceedances were observed within the three OWF areas (A1-3) for the four metals lead (Pb), cadmium (Cd), silver (Ag) and vanadium (V).

In total, five pollutants exceeded their respective NEQS across seven out of ten stations (i.e. 70 % of the stations) (three PAH-compounds, anthracene, naphthalene, and methylnaphthalenes (sum), and the phenols 4-tert-octylphenol and nonylphenols (sum). The stations with exceedances include: OWF_AU1_01, OWF_AU1_02, OWF_EF_01, OWF_AU2_01, OWF_EF_03, OWF_AU1_04 and OWF_AU1_05 Table 5-8).

For some of the pollutants, the NEQS value were below the detection limit used in the laboratory analysis. Therefore, it is not possible to assess if the concentration for these pollutants exceeded their respective NEQS. As a precautionary measure, concentrations of these pollutants are handled as exceedances at the following stations, i.e. they are listed in Table 5-8 for the PAH-compound anthracene at OWF_EF_01, OWF_EF_02, OWF_EF_04 and OWF_EF_05, and the PAH-compound methylnaphthalene (sum) at OWF_EF_02, OWF_EF_04 and OWF_EF_05.

Concentrations exceeding non-statutory threshold values (NQC)

For pollutants with no statutory NEQS for sediment, other threshold values were used as guiding values in prioritized order (see section 3.4.6 – HAPS chemical analyses), to assess the chemical condition of the sediment within the OWF areas.

In total, three pollutants exceeded their respective NQC across five out of ten stations (i.e. 50 % of the stations). The heavy metal arsenic (As) exceeded the NQC value at all five stations, while the PAH-compound chrysene exceeded the threshold at two stations and the PAH-compound benz(a)anthracene exceeded the threshold at one station. The stations with exceedances include: OWF_EF_01, OWF_EF_02, OWF_EF_03, OWF_AU1_04 and OWF_AU1_05 (Table 5-8).

No exceedances of NQC were observed within the three OWF areas (A1-3) for the two metals chromium (Cr) and nickel (Ni), the eight PAH-compounds acenaphthene, benzo(g,h,i)perylene, benzo(b+j+k)fluoranthene, benzo(a)pyrene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene and pyrene and the three phthalates BBP, DEHA and DEHP (Miljøstyrelsen, 2023b). No exceedances of any relevant ERL-value were observed.

For the PAH-compound chrysene, the NQC value was below the detection limit used in the laboratory analysis. This means that it is not possible to assess whether the concentration of chrysene exceeds the NQC. As a precautionary measure, concentrations of chrysene are handled as exceedances at the following stations: OWF_EF_02, OWF_EF_04 and OWF_EF_05, i.e. they are listed in Table 5-8.

EXPORT CABLE CORRIDORS (ECC1-3)

Within the three export cable corridors (ECC1-3), results for a total of 20 HAPS stations were sampled and used for chemical analysis. The samples consist mainly of a sandy substrate and were taken at station depths between 9 to 23 meters below sea level (Table 5-8). Exceedances of NEQS and NQC values are listed in Table 5-8 and Table 5-10 and location of stations are shown in Figure 3-5.

Table 5-10. Pollutants exceeding the threshold values in the three export cable corridors (ECC1-3).

NSI.1 cable corridors	Arsenic	Anthracene	Chrysene	Naphthalene	Benz(a)-anthracene	Methyl-napththalenes (sum)	Nonylphenols (sum)	4-tert-octylphenol
ECC1	X	X	X		X	X		
ECC2	X	X	X	X	X	X	X	X
ECC3	X	X	X		X	X	X	X

No clear pattern in the spatial distribution of the exceedances and concentrations of the pollutants were observed between the three export cable corridors ECC1-3. However, for all three cable corridors the same pollutants generally exceeded the threshold values. Exceptions were naphthalene, which only exceeded the threshold values in ECC2 and the phenols, which did not exceed threshold values in ECC1 (see Table 5-10). In the following the exceedances of NEQS and NQCs are discussed separately.

Pollutants exceeding statutory National Environmental Quality Standards (NEQS)

NEQS used for assessing the pollutant concentrations are specified in the Danish consolidation act BEK. no. 796 of 13/06/2023 (Miljøstyrelsen, 2023a). For further details on threshold values see section 3.4.6 – HAPS chemical analyses.

No exceedances were observed within the three export cable corridors (ECC1-3) for the four metals lead (Pb), cadmium (Cd), silver (Ag) and vanadium (V).

ECC1

For ECC1, six samples were collected at station depths between 15 and 20 meters. Anthracene and methylnaphthalenes (sum) were the only pollutants found in concentrations exceeding NEQS in four of the six stations. For anthracene the NEQS value was below the detection limit at two of the stations. As a precautionary measure, concentrations of anthracene are handled as an exceedance at the following stations: ECC_MFS_EF_07 and ECC_MFS_EF_08, i.e. they are listed in Table 5-8.

ECC 2

For ECC2, 10 samples were collected at station depths between 17 to 23 meters. Anthracene, naphthalene, methylnaphthalenes (sum), nonylphenols (sum) and 4-tert-octylphenol were found in concentrations exceeding NEQS. For anthracene and methylnaphthalenes (sum), the NEQS values were below the detection limits at some of the stations. As a precautionary measure, concentrations of these pollutants are handled as an exceedance at the following stations: ECC_MFS_EF_04 (anthracene and methylnaphthalenes (sum)) and ECC_MFS_EF_06 (anthracene), i.e. they are listed in Table 5-8.

ECC 3

For ECC3, seven sediment samples were collected at station depths between 9 to 23 meters. Nonylphenols and 4-tert-octylphenol were found in concentrations exceeding NEQS at the two stations ECC_AU1_01 (at 22.6 meters depth) and ECC_AU1_02 (at 9.1 meters depth). For the PAH-compounds anthracene and methylnaphthalene (summed), the NEQS value were below the detection limits at three stations. As a precautionary measure, concentrations of these pollutants are handled as exceedances at the following stations: ECC_MFS_EF_01, ECC_MFS_EF_02 and ECC_MFS_EF_03, i.e. they are listed in Table 5-8.

Concentrations exceeding non-statutory threshold values (NQC)

For pollutants with non-statutory NQC threshold values, other threshold values are used as guiding values in prioritized order (see section 3.4.6 – HAPS chemical analyses) to assess the chemical conditions of the sediment within the project area.

No exceedances of NQC were observed within the ECC's for the two metals chromium (Cr) and nickel (Ni), the eight PAH-compounds acenaphthene, benzo(g,h,i)perylene, benzo(b+j+k)fluoranthene, benzo(a)pyrene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene and pyrene and the three phthalates BBP, DEHA and DEHP (Miljøstyrelsen, 2023b). No exceedances of any relevant ERL-value were observed.

ECC1

For ECC1, six samples were collected at depths between 15 and 17 meters below sea level. Arsenic (As) and chrysene were observed in concentrations exceeding NQC at the following four stations: ECC_EF_07, ECC_EF_08, ECC_EF_09 and ECC_EF_10. Benz(a)anthracene was observed in concentrations exceeding NQC at the latter two stations.

ECC2

For ECC2, 10 samples were collected at station depths between 7 and 23 meters. Arsenic (As) and chrysene were observed in concentrations exceeding NQC at the following stations: ECC_EF_04, ECC_EF_05, ECC_EF_06, ECC_EF_09 and ECC_EF_10. Benz(a)anthracene was observed in concentrations exceeding NQC at the latter four stations, only exempting ECC_EF_04.

ECC 3

For ECC3, seven samples were collected at station depths between 17 to 23 meters. Arsenic (As) was the only observed pollutant with concentrations exceeding NQC in ECC3. The exceedances were observed at the following stations: ECC_EF_01, ECC_EF_02 and ECC_EF_03. For the PAH-compounds chrysene and benz(a)anthracene, the concentrations were below the detection limit used in the laboratory analysis at the same three stations. As the NQC value is below the detection limit, it is not possible to assess whether the concentration for chrysene and benz(a)anthracene exceeds the NQC. As a precautionary measure, concentrations under the detection limit of chrysene are handled as exceedances at these stations, i.e. they are listed in Table 5-8.

EXCEEDANCES USING A TOC OF 5 %

In this section threshold values and exceedances are calculated from a 5 % TOC content (see Table 5-11 below) instead of the measured TOC as used above in Table 5-8 according to act BEK. no. 796 of 13/06/2023 (Miljøstyrelsen, 2023a). This is done experimentally, as a very low TOC content results in very low calculated threshold values for the pollutants. The result is that in clean sand with very little TOC, as is the case in the pre-investigation areas, calculated threshold values are very low – often below background concentrations - which makes it very difficult not to exceed threshold values. The problem is that even though you are working with some of the cleanest sediment in the Danish waters, the calculation method creates threshold exceedances although actual pollutant concentrations are low.

The Danish Environmental Agency is aware of this problem and is in process of finding out how to handle this bias by e.g. setting a minimum TOC content in sediments with low TOC to a set percent of e.g. to 2 or 5 %. A TOC of 5 % was chosen in this section, since the Danish consolidation act BEK. no. 796 of 13/06/2023 (Miljøstyrelsen, 2023a) states that, a TOC of 5 % can be used when TOC has not been measured in the sediment samples for chemical analysis of pollutants. In this study, TOC was not measured at 15 stations out of 29 stations (=EF stations).

Threshold values and pollutant exceedances are calculated for a set value of 5 % TOC in Table 5-11 below. Using a TOC content of 5 % unsurprisingly results in a significant reduction in the number of pollutants exceeding the threshold values compared to using the low measured TOC content at the AU stations (average of 0.17 %) as used in Table 5-8 above. The threshold for arsenic is not calculated based on TOC, therefore the exceedances for arsenic are unaffected by the change in TOC content. For the remaining pollutants, only three exceeded threshold values at 5 % TOC, compared to the seven pollutants when using the low average TOC of 0.17 % (Table 5-8) within the three OWF areas (A1-3). Within the ECC areas, only methylnaphthalenes (sum) exceeded the threshold at one station within ECC2, when applying a TOC of 5 %.

Table 5-11. Pollutant threshold values and exceedances calculated based on 5 % TOC: Pollutants exceeding prioritized threshold values in the sediment in the offshore wind farm areas (A1, A2 and A3) and in the three export cable corridors (EEC1, EEC2 and EEC3), showing concentrations and threshold values as well as depth and sediment type for the HAPS sample. NEQS (national environmental quality standards, statutory, miljøkvalitetskrav) and NQC (non-statutory, national quality criteria, kvalitetskriterier) are calculated based on the organic content (TOC), for all compounds except for arsenic, using an average TOC of 5 %. Exceedances of the NEQS are represented by **red numbers**, and exceedances of the NQC are represented by **black numbers**. f_{oc} is the fraction of TOC in the sediment. <DL = below detection limit, but detection limit is higher than the threshold value. "NA" = compound is not measured. Empty cells = no exceedances. Sediment type describes the dominant sediment observed in the HAPS sample on deck. For station locations see Figure 3-5.

Threshold values /Stations	Heavy metals (mg/kg DW)	PAH (µg/kg DW)					Phenols (µg/kg DW)		Sediment type	Depth (m)
	Arsenic	Anthracene	Benz(a)anthracene	Chrysene	Naphthalene	Methylnaphthalenes (sum)	Nonylphenols (sum)	4-tert-octylphenol		
NEQS		**96 x f_{oc}**			**2760 x f_{oc}**	**478 x f_{oc}**	**2500 x f_{oc}**	**3930 x f_{oc}**		
NQC	0.4		600 x f_{oc}	462 x f_{oc}						
Pre-investigation area: NSI.1 OWF area (NSI.1-OWF)										
A1										
OWF_ AU1_01	NA	NA	NA	NA	NA	NA	**32**	**8**	Sand	25.4
OWF_ AU1_02	NA	NA	NA	NA	NA	NA	**8**	**22**	Sand	25.4
OWF_EF_01	1.9						NA	NA	Sand	26.0
A2										
OWF_EF_02	1.7						NA	NA	Sand	20.5
OWF_ AU2_01	NA	NA	NA	NA	NA	NA		**10**	Sand	21,0
OWF_EF_03	2.4					**29.9**	NA	NA	Sand/silt	24.7
A3										
OWF_ AU1_04	NA	NA	NA	NA	NA	NA	**18**	**12**	Sand	25.8
OWF_EF_04	3						NA	NA	Sand	18.2
OWF_AU1_05	NA	NA	NA	NA	NA	NA	**11**	**12**	Sand	20.7
OWF_ EF_05	2.6						NA	NA	Sand	21.6
Pre-investigation area: Export Cable Corridors (NSI.1-ECC)										
Export Cable Corridor 3 (ECC3)										
ECC_EF_01	3.4						NA	NA	Sand	23.0
ECC_ AU1_01	NA	NA	NA	NA	NA	NA			Sand	22.6
ECC_EF_02	8.1						NA	NA	Sand	16.6
ECC_ AU2_01	NA	NA	NA	NA	NA	NA			Sand	16.2
ECC_EF_03	3.1						NA	NA	Sand/silt	16.3

Threshold values /Stations	Heavy metals (mg/kg DW)	PAH (µg/kg DW)					Phenols (µg/kg DW)		Sediment type	Depth (m)
	Arsenic	Anthracene	Benz(a)anthracene	Chrysene	Naphthalene	Methylnaphthalenes (sum)	Nonylphenols (sum)	4-tert-octylphenol		
ECC_ AU1_02	NA	NA	NA	NA	NA	NA			Sand	9.1
Export Cable Corridor 2 (ECC2)										
ECC_ AU1_03	NA	NA	NA	NA	NA	NA			Sand	23.6
ECC_EF_04	2.6						NA	NA	Sand	20.2
ECC_ AU2_02	NA	NA	NA	NA	NA	NA			Sand/silt/mud	20.0
ECC_EF_05	8.3					**33.3**	NA	NA	Silt	21.8
ECC_ AU1_04	NA	NA	NA	NA	NA	NA			Silt	18.6
ECC_EF_06	3.2						NA	NA	Silt	18.1
ECC_ AU1_05	NA	NA	NA	NA	NA	NA			Silt	17.6
ECC_EF_09	4.3						NA	NA	Silt	17.3
ECC_ AU2_03	NA	NA	NA	NA	NA	NA			Silt	17.0
ECC_EF_10	3.2						NA	NA	Silt	15.2
Export Cable Corridor 1 (ECC1)										
ECC_EF_07	1.9						NA	NA	Silt	19.7
ECC_ AU1_06	NA	NA	NA	NA	NA	NA			Sand	18.1
ECC_EF_08	3.3						NA	NA	Silt	17.3
ECC_EF_09	4.3						NA	NA	Silt	17.3
ECC_ AU2_03	NA	NA	NA	NA	NA	NA			Silt	17.0
ECC_EF_10	3.2						NA	NA	Silt	15.2

5.3 BENTHIC COMMUNITIES (NATURE TYPES)

Benthic communities are defined as different benthic flora and fauna communities determined by sediment type, depth, salinity and oxygen levels. This section gives a description of the dominating species/groups in the observed benthic communities of the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC). For greater details on species and specific taxa groups, see sections on benthic flora (section 5.4) and benthic fauna (section 5.5).

Benthic communities are also called nature types in this report and are determined from unique combinations of sediment type (see section 5.2.1 – Sediment types) as well as unique benthic flora (see section 5.4 – Benthic flora) and fauna taxa/species (see section 5.5 – Benthic fauna) associated with these. Benthic flora and fauna species living on or in the different sediment types are mapped by use of ROV video. The ROV stations are shown in Figure 5-8. The benthic communities/nature types, are mainly determined from the epibenthic communities living on the sediment (epifauna). However, visible infauna and signs of infauna activity such as phoronids, mussel shells, sea potato burrows/holes, bivalve holes, bristle worm piles and tubes, are also included in the list of taxa. Infauna is described in more detail in section 5.5.2 – Infauna.

Four different benthic communities/nature types were found in the two pre-investigation areas:

- **Soft-bottom community** (Nature type 1a/1b corresponding to sediment type 1a/1b and 1c), primarily dominated by Phoronids (*Phoronis* sp.) and echinoderms such as sea potato (*Echinocardium* spp.) and brittle stars (*Ophiura* spp.). Also, the bristle worm *Lanice conchilega* was observed with varying coverage throughout this nature type.
- **Sand-bottom community** (Nature type 1b corresponding to sediment type 1b) dominated by Phoronids (*Phoronis* sp.) bristle worms and bivalves with generally less area coverage and species numbers than seen for the "Soft-bottom community".
- **Mixed community** (Nature type 2 corresponding to sediment type 2a and 2b) with benthic fauna constituting a mix between sand-bottom and hard-bottom communities.
- **Hard-bottom community** (Nature type 3/4 corresponding to both sediment type 3 and 4) and dominated by epifauna species associated with large stones (>10 cm) such as various species of sea anemone, leafy bryozoans (*Flustra foliacea*), dead man´s fingers (*Alcyonium digitatum*), hydroids, calcareous tube worms (*Pomatoceros triqueter*), white weed (*Satularia cuppresina*), seasponges and tunicates sp. (Sediment type 3 and 4).

The benthic communities observed in this baseline study are presented as a community map in Figure 5-7. See Table 5-14 for full species lists and the sediment types they were observed on. Percent area coverages (overall coverage for benthic fauna) for the different benthic communities are shown in Table 5-12 below. The benthic communities are described in greater detail in the sections below.

The soft-bottom community and sand-bottom community dominated the pre-investigation areas. All other benthic communities (nature types) including the mixed community (Nature type 2) and the hard-bottom community (Nature type 3/4), were scarce with a low area coverage percentage in the pre-investigation of NSI.1-OWF and NSI.1-ECC (0.9 % and 0.03 %, respectively) (see Table 5-12). The benthic community map in Figure 5-7 shows that mixed and hard-bottom communities are present in the stonier southwestern part of the pre-investigation area of NSI.1-OWF and were present as small patches in all three cable corridors.

Table 5-12. Area coverage of the benthic communities (nature types) given in percent and in km² in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) and subareas (OWF area A1-3 and ECC1-3). Substrate type 1c is included in nature type 1a/1b.

Benthic communities (Nature type)/ Areas	Soft-bottom (1a/1b)	Sand (1b)	Mixed (2a + 2b)	Hard-bottom (3 + 4)
Pre-investigation area for NSI.1 (NSI.1-OWF)	901.9 km^2 65 %	472.1 km^2 34 %	12.9 km^2 0.9 %	0.4 km^2 0.03 %
A1	178.9 km^2 49 %	183.5 km^2 50 %	3.6 km^2 1.0 %	0.03 km^2 0.007 %
A2	260.6 km^2 65 %	133.4 km^2 33 %	6.5 km^2 1.6 %	0.2 km^2 0.06 %
A3	342.1 km^2 86 %	58 km^2 15 %	0.1 km^2 0.04 %	0.0008 km^2 0.0002 %
Pre-investigation area for export cable corridors (NSI.1-ECC)	98.02 km^2 83 %	19.1 km^2 16 %	0.8 km^2 0.7 %	0.3 km^2 0.2 %
ECC1	32.6 km^2 96 %	1.3 km^2 4.0 %	0.1 km^2 0.4 %	0.0005 km^2 0.001 %
ECC2	55.5 km^2 92 %	4.2 km^2 7 %	0.5 km^2 0.8 %	0.1 km^2 0.2 %
ECC3	20.4 km^2 58 %	14.5 km^2 41 %	0.3 km^2 0.8 %	0.1 km^2 0.3 %

Total area coverage of benthic fauna in the nature types are shown in Figure 5-8. Total area coverage of benthic fauna generally shows no clear relation between nature type/sediment type and depth. The lowest area overage of benthic fauna (<1 % see small white circles) is observed on sediment type 2a – coarse sand, gravel and pebbles in the southwestern part of the pre-investigation area for NSI.1. In general, the same range of fauna coverage % were observed in the pre-investigation area of NSI.1-OWF and the pre-investigation area of the three export cable corridors (NSI.1-ECC). The similarities of fauna area coverage in the pre-investigation areas are due to the dominance of horseshoe worm, which is generally present in high abundance on both sediment type 1a/1b – silty sediment and sediment 1b - sand, which dominate the two pre-investigation areas. For more detail, see section 5.5.1 – Epifauna/Total area coverage %.

Comparing with earlier mapping of sediment types (GEUS map in Figure 4-6) and benthic communities for Thor OWF, Vesterhav Syd OWF and Horns Rev III OWF (see section 4.6 – Benthic communities), similar sediment types, benthic communities and area coverages were observed. However, it seems that the soft-bottom community on "silty sand" is more prevalent in this study than observed in existing studies from the area.

Thus, observed benthic flora and fauna species and communities are all common for the North Sea and have been observed with similar dominating species, benthic communities and area coverage as reported for the local OWFs (Thor, Vesterhav Syd, Vesterehav Nord, Horns Rev III), which have been mapped in a comparable way. Furthermore, none of the observed species of benthic flora and fauna in the pre-investigation areas are considered threatened (Critically Endangered, Endangered or Vulnerable) according to the HELCOM red list (HELCOM, 2024a). The masked crab (*Corystes cassivelaunus*) is, however, listed as Near Threatened (NT) (HELCOM, 2023b). The masked crab was commonly observed in both pre-investigation areas (NSI.1-OWF and NSI.1-ECC). Additionally, there was not found evidence or indicators of biogenic reef structures from blue mussel (Mytilus edulis), European oyster (*Ostrea edulis*) or Sabellaria reef compositions.

OWF AREAS (A1-3)

Comparing the area coverage of the benthic communities in the three OWF areas A1-3, OWF area A2 and A3 were dominated by the soft-bottom community (Nature type 1a/1b) with 65 % and 86 %, respectively (Table 5-12), whereas the sand-bottom community covered 33 % and 15 %, respectively. In comparison, OWF area A1 had 49 % and 50 % of the soft-bottom and sand-bottom communities, respectively. The mixed community (Nature type 2) had similar percentage area coverage in OWF area A1 and A2 and very low coverage in A3 (0.04 %). Hard-bottom community dominated by epifauna living on the large stones was very scarce in all three OWF areas A1- A3, with area coverages of 0.0002-0.06 % (see Table 5-3). The benthic community map in Figure 5-7 shows that the hard-bottom community living on stony sediment types with large stones (>10 cm; sediment type 2b, 3 and 4) were present mainly in the southwestern part of OWF areas A1 and A2 and constituted very small areas, barely visible on the map.

The total area coverage of benthic fauna observed at the ROV stations showed the highest coverages in OWF area A2 and A3 and the lowest in the shallower OWF area A1 (see Figure 5-8).

EXPORT CABLE CORRIDORS (ECC1-3)

All three cable corridors (ECC1-3) were dominated by Nature type 1a/1b – soft bottom community with area coverage ranging from 58-96 % (Table 5-3). Nature type – sand bottom community covered from 4-41 % and all other nature types covered less than 0.8 %.

Total area coverage of benthic fauna was high and similar in ECC2 and ECC3 and slightly lower in ECC 1. The same pattern as seen for the three OWF areas (see Figure 5-8).

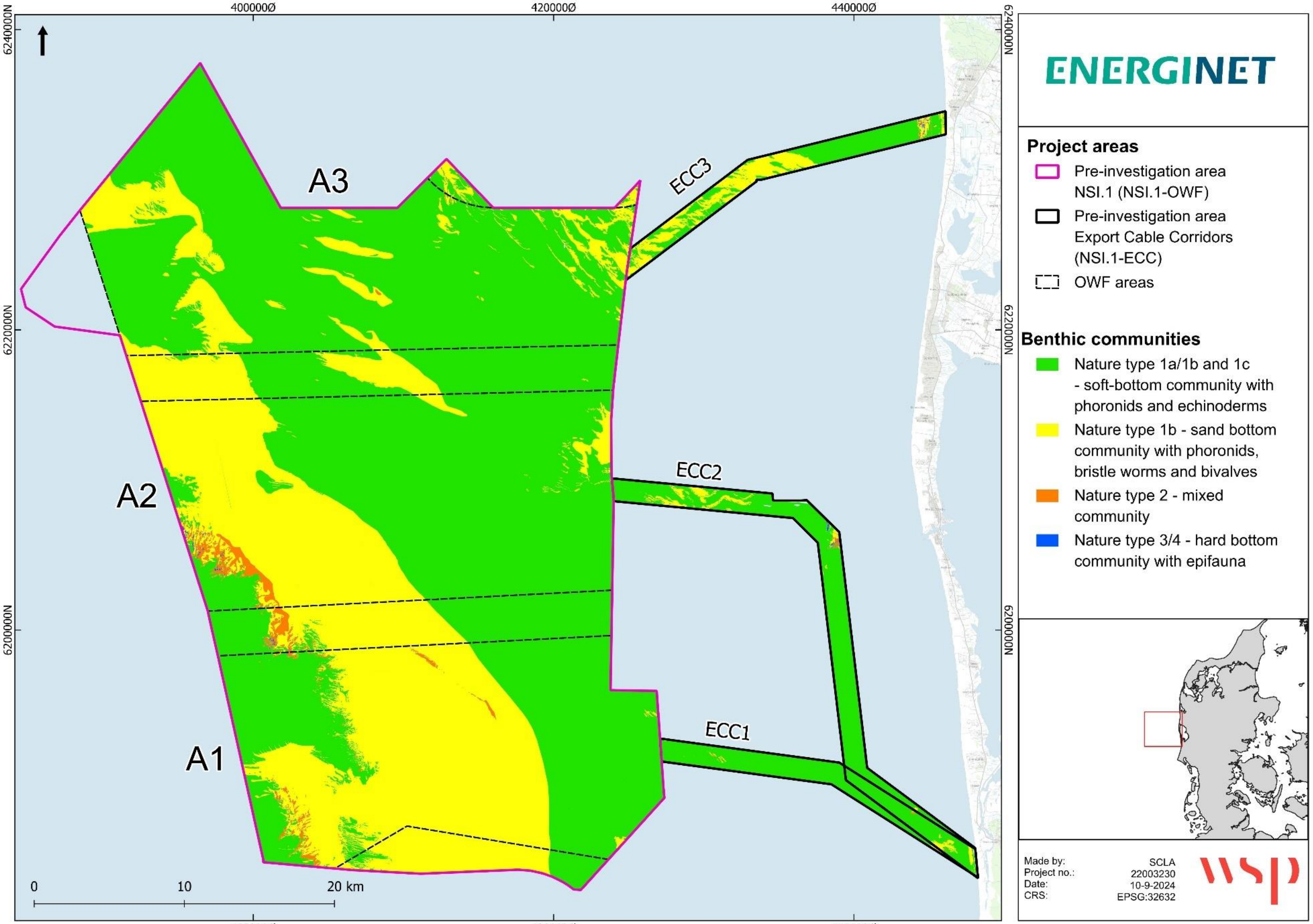


Figure 5-7. Map of benthic communities (Nature types) in the pre-investigation areas for North Sea I.1 (NSI.1-OWF) including the OWF areas (A1-3) and the pre-investigation area for the three export cable corridors (NSI.1-ECC) including ECC1-3.

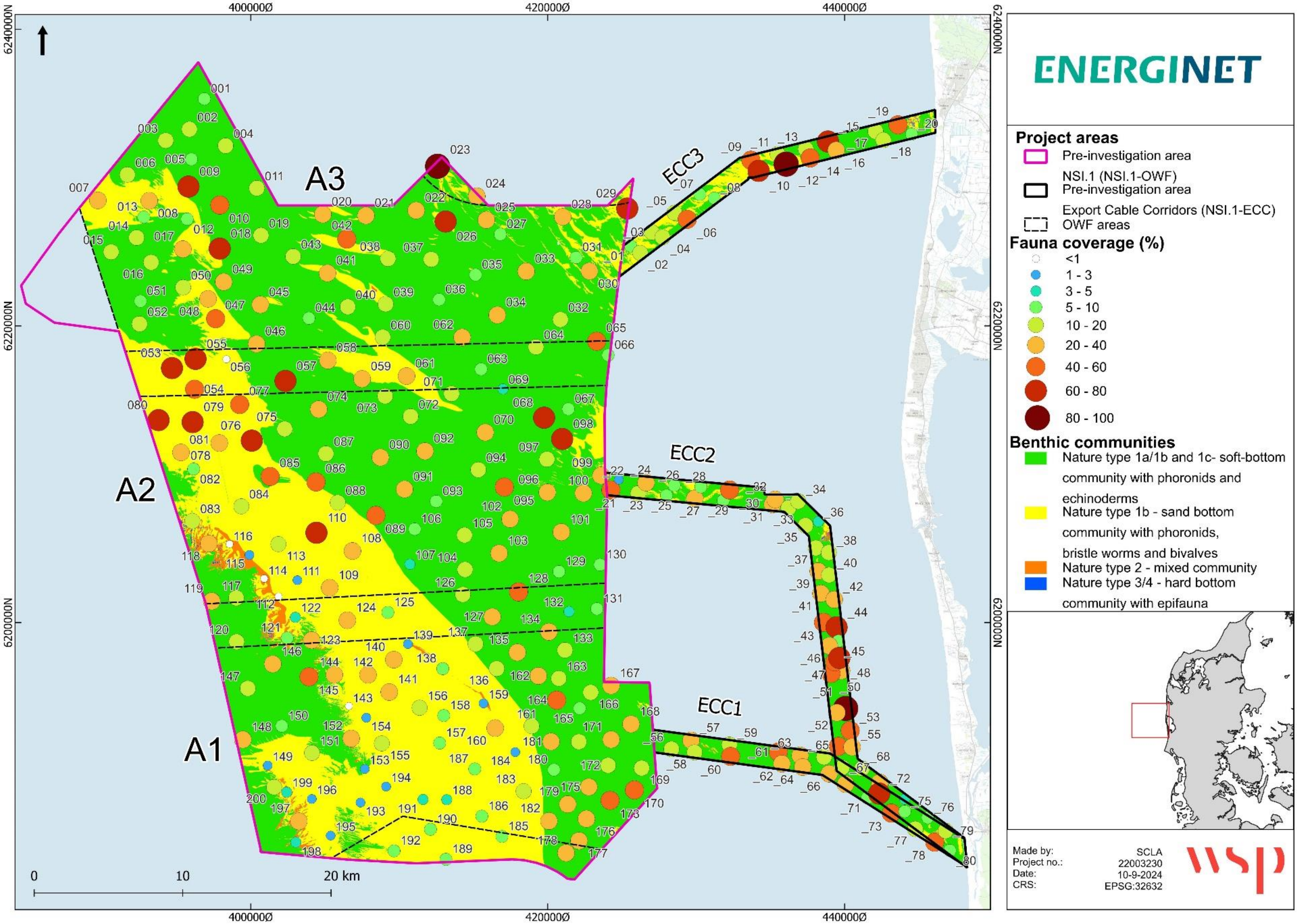


Figure 5-8. Map of benthic communities (Nature types) and total area coverage % of the benthic fauna observed on the ROV stations. The map presents the pre-investigation areas for North Sea I.1 (NSI.1-OWF) including the OWF areas (A1-3) and the pre-investigation area for the three export cable corridors (NSI.1-ECC) including ECC1-3. Note that area coverages in the logbooks (see Appendix 3A and 3B) are given as a range and this figure shows the maximum coverage in that range.

5.3.1 NATURE TYPE 1A/1B – SOFT-BOTTOM COMMUNITY

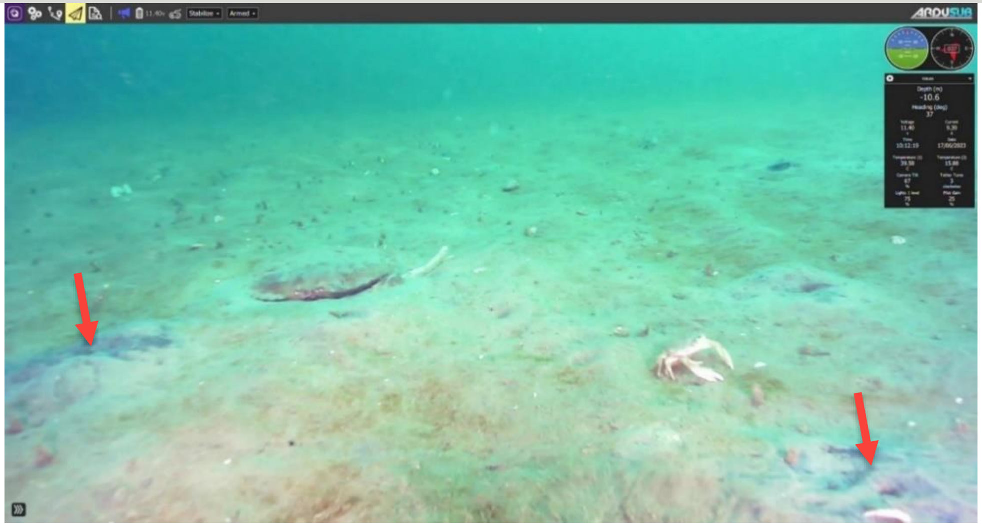
The soft-bottom community (nature type 1a/1b) dominated the pre-investigation area for NSI.1 (NSI.1-OWF) and the pre-investigation area for the export cable corridors (NSI.1-ECC) and was observed on sediment type 1a/1b – “silty sand” characterised by being a sandbed with silt on the surface and mixed down into the upper centimeters of the sediment (Table 5-12 and Figure 5-7). Geologically, the seabed in the pre-investigation areas is generally “sand”, However, the thin surface silt layer is enough to induce a change in the biological community, compared to sand with no silt (or very little) showing a soft-bottom community that is dominated by infauna species feeding on or in the silt such as horseshoe worm (*Phoronis* sp.) (suspension feeder), echinoderms such as sea potato (*Echinocardium spp*.) (feeding on organic matter deposited on the seabed surface), brittle stars (*Ophiura spp*.) (feeds on small animals in the silt) and marine bristle worms, including *Lanice conchilega* (suspension feeder) (Køie M. & Kristiansen A., 1999, 2023) (Figure 5-9 and Figure 5-10).

The dominating species and especially horseshoe worm had high area coverages (*Phoronis* sp., NSI.1-OWF: 1-80 % and NSI.1-ECC: 1-90 % area coverage), as did the tube-living bristle worm *Lanice conchilega* (NSI.1-OWF: <1-20 % and NSI.1-ECC: <1-4 %), sea potato (*Echinocardium* spp., NSI.1-OWF: <1-10 % and NSI.1-ECC: <1-7 %) and brittle star (*Ophiura* sp., NSI.1-OWF: <1-15 % and NSI.1-ECC:<1-6 %).

Epifauna in the soft-bottom community was scarce and consisted mainly of few starfish (*Asterias rubens* and *Astropecten irregularis*), masked crab and swimming crab (*Corystes cassivelaunus* and *Polybius depurator*), Firework anemone (*Pachycerianthus multiplicatus*) and North Sea tube-dwelling sea anemone (*Synarachnactis llodyii*) along with hermit crab (*Pagurus bernhardus*) (Figure 5-10). For all species observed, see species list in Table 5-14, i.e. species observed on sediment type 1a/1b.

Figure 5-9. Dominating species of the soft-bottom community (nature type 1a/1b) observed on ROV video in the pre-investigation areas for the NSI.1-OWF. The still photo grabbed from the video shows small Phoronid tubes (red arrow), a sea potato and sea potato burrows/holes (yellow arrows), Lanice tubes (blue arrows) and a star fish. ROV station OWF_ROV_019_00002.

Soft-bottom community. ROV station: OWF_ROV_06_01_0006



Soft-bottom community. ROV station: ECC_ROV_78_00012

Soft-bottom community. ROV station: OWF_ROV_101_00006

Soft-bottom community. ROV station: ECC_ROV_07_00005

Figure 5-10. Examples of the soft-bottom community (nature type 1a/1b). Left: NSI.1-OWF, OWF stations and Right: NSI.1-ECC, ECC stations. Upper left: sand covered with thin silt layer with starfish firework anemone (*Pachycerianthus multiplicatus*) and small Phoronid tubes (*Phoronis* sp., red arrow). Lower left: silt with brittle stars (*Ophiura* sp.). Upper right: sand with thin silt coverage. Note grey sand color in the holes (red arrow) indicating thin silt layer. Also, Brown crab (*Cancer pagurus*), Swimming crab (*Polybius depurator*) and small *Lanice conchilega* tubes in the background. Lower right: silt covered sand with shell fragments, brittle stars (*Ophiura* sp.) and sand sea star (*Astropecten irregularis*).

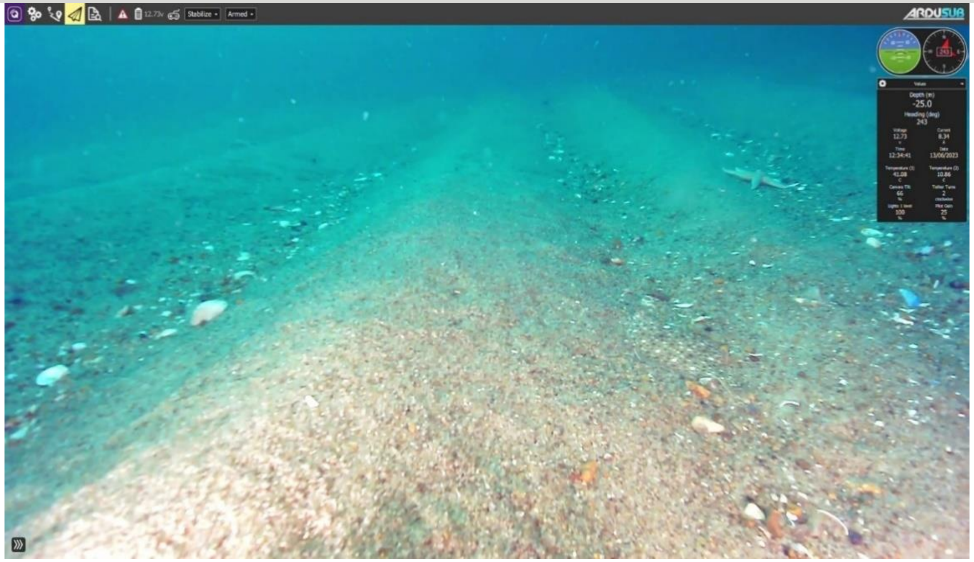
5.3.2 NATURE TYPE 1B – SAND-BOTTOM COMMUNITY

The sand-bottom community (nature type 1b) corresponds to sediment type 1b and was the second most dominant sediment type in the pre-investigation area for NSI.1 (NSI.1-OWF) and in the pre-investigation area for the export cable corridors (NSI.1-ECC) and was observed on sediment type 1b – sand (Table 5-12 and Figure 5-7). Except for Phoronid area coverage, area coverages and number of benthic fauna species were lower on the sandbed than on the "silty sand" (nature type 1a/1b).

The sand-bottom community was dominated by infauna (organisms living buried in the seabed) such as horseshoe worm (*Phoronis* sp.) (area coverage NSI.1-OWF: 1-99% and NSI.1-ECC: 1-40%) phoronid tubes, Lanice tubes (*Lanice conchilega*) (area coverage NSI.1-OWF: <1-4% and NSI.1-ECC: <1-4%), sea potato (*Echinocardium* sp.) (area coverage, NSI.1-OWF: <1-10% and NSI.1-ECC: <1-10%), bivalve shells, tubes and holes in the seabed (Figure 5-11 and Figure 5-16).

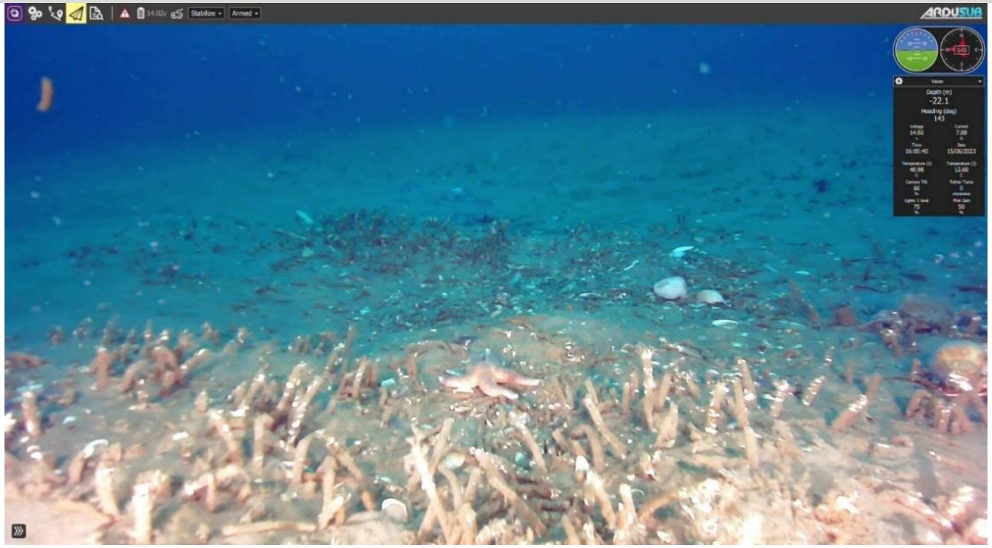
Epifauna observed in the soft-bottom community was scarce and consisted mainly of few starfish incl. *Asterias rubens* (area coverage, NSI.1-OWF: <1-2% and NSI.1-ECC: <1-4%) and *Astropecten irregularis* (area coverage, NSI.1-OWF: <1% and NSI.1-ECC: <1%), two species of crab (*Corystes cassivelaunus* and *Polybius depurator*) and hermit crab (*Pagurus bernhardus*) (Figure 5-10). For all species observed, see species list in Table 5-14, i.e. species observed on sediment type 1b.

Figure 5-11. Dominating species of the sand-bottom community (nature type 1b) observed on ROV video in the two pre-investigation areas. The still photo grabbed from the video shows hermit crab (*Pagurus bernhardus*) and star fish (*Asterias rubens*) feeding on a dead fish. Also, common welk snail shells (*Bucchinum undatum*) and additionally small Phoronid tubes (red arrow). ROV station: OWF_ROV_155_00007.



Sand-bottom community. ROV station: OWF_ROV_149_00007

Sand-bottom community. ROV station: ECC_ROV_10_01_000003



Sand-bottom community. ROV station: OWF_ROV_182_00006

Sand-bottom community. ROV station: ECC_ROV_10_02_00002

Figure 5-12. Examples of sand-bottom community (nature type 1b) and dominating species. Left: NSI.1-OWF, OWF stations and Right: NSI.1-ECC, ECC stations. Upper left: coarse sand with starfish. Lower left: finer sand with *Lanice conchilega* tubes. Upper right: sand with small ripples with small horseshoe worm tubes (*Phoronis* sp., red arrow), sea potato shells and a starfish. Lower right: sand with white bivalve shell fragments.

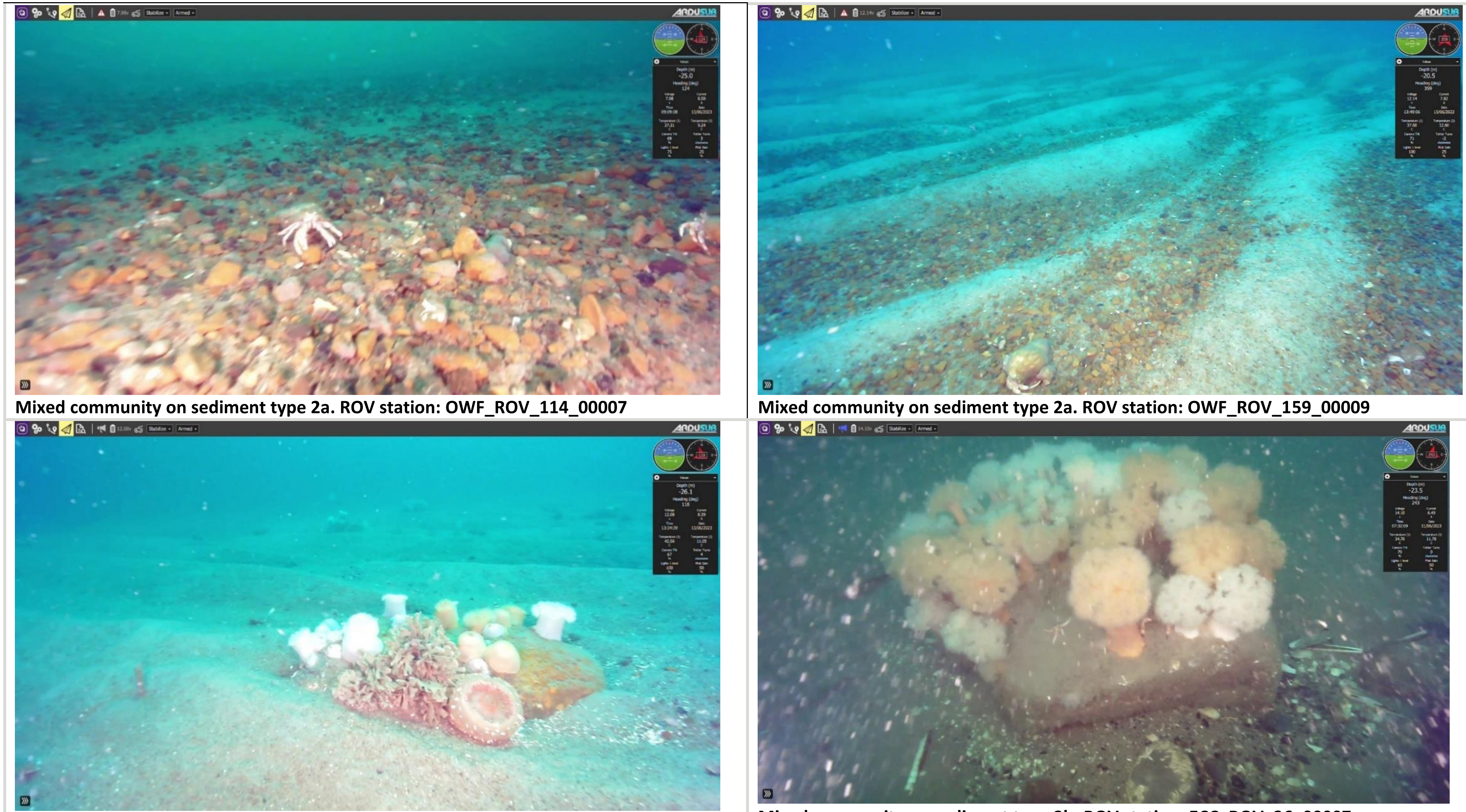
5.3.3 NATURE TYPE 2 – MIXED COMMUNITY

The mixed bottom community was observed on sediment type 2a – “coarse sand, gravel and pebbles” and 2b – “sand with few stones” (1-10 % area coverage of large stones). The mixed community had very low area coverage percent in both the pre-investigation area for NSI.1 (NSI.1-OWF: 0.9 %) and the pre-investigation area for the export cable corridors (NSI.1-ECC: 0.7 %) (Table 5-12 and Figure 5-7). Sediment type 2a – coarse sand, gravel and pebbles had the lowest number of epifauna species of all sediment types.

The mixed-bottom community contained a mix of sand-bottom species and hard-bottom species as previously described. The area coverage of epifauna varied and was generally low, likely due to the dynamic conditions and sand scrubbing of the stones (<1-25% in NSI.1-OWF and 5% in NSI.1-ECC).

Epifauna observed in the mixed community was scarce and consisted mainly of few starfish (*Asterias rubens*) (area coverage, NSI.1-OWF: <1-1%) and *Astropecten irregularis* (area coverage, NSI.1-OWF: <1% %), species of sea anemone (area coverage, NSI.1-OWF: 8%), hydrozoan sp. (area coverage, NSI.1-OWF: 1-3%) and bryozoa sp. (area coverage, NSI.1-OWF: 5%), Dead Man’s Fingers (*Alcyonium digitatum*) and hermit crabs (Figure 5-10). For all species observed, see species list in Table 5-14, i.e. species observed on sediment type 2a and 2b.

Figure 5-13. Mixed community (Nature type 2a and 2b) on sediment type 2a with coarse sand, pebbles and sand ripples. ROV stations: OWF_ROV_143_00002.



Mixed community on sediment type 2a. ROV station: OWF_ROV_114_00007

Mixed community on sediment type 2a. ROV station: OWF_ROV_159_00009

Mixed community on sediment type 2b. ROV station: OWF_ROV_200_00004

Mixed community on sediment type 2b. ROV station: ECC_ROV_36_00007

Figure 5-14. Examples of mixed community (nature type 2) and dominating species. Stations from NSI.1-OWF and only lower right: NSI.1-ECC, ECC stations as only one ECC station with nature type 2. Upper left: coarse sand with minor stones and gravel along with a hermit crab (*Pagurus bernhardus*). Lower left: finer sand and rocks with attached species of sea anemone incl. Plumose sea anemone (*Metridium senile),* dahlia sea anemone (*Urticina felina*) and Hornwrack (*Flustra foliacea*) and dead man's fingers (*Alcyonium digitatum*). Upper right: sand ripples with gravel in between the throughs and a hermit crab. Lower right: sand with single stone with sea anemones.

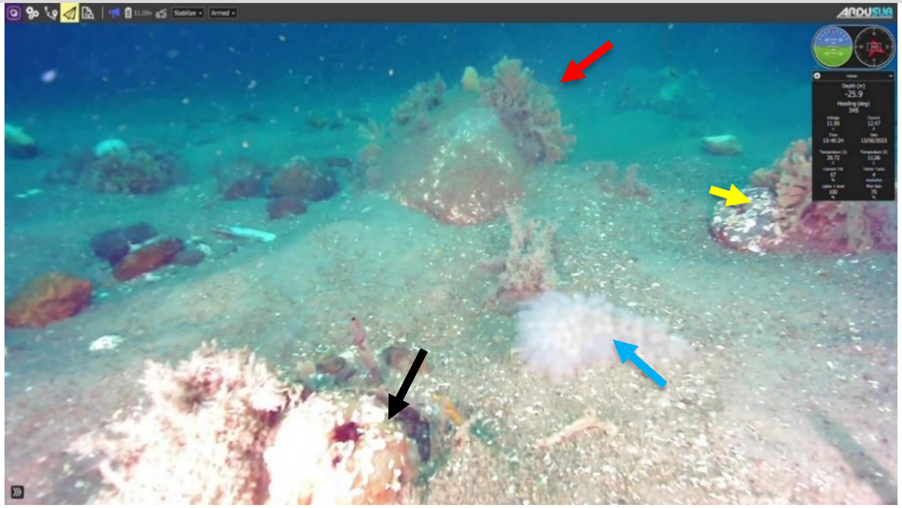
5.3.4 NATURE TYPE 3/4 – HARD-BOTTOM COMMUNITY

The hard bottom community was observed on sediment type 3 – "moderate stone coverage" (10-25% large stones >10 cm) and sediment type 4 – stone reef >25% large stones. These sediment types are collectively termed stone reefs (when observed together) and had the highest number of epifauna species. The hard-bottom community was the rarest community type with very low area coverage in both the pre-investigation area for NSI.1 (NSI.1-OWF: 0.03 %) and the pre-investigation area for the export cable corridors (NSI.1-ECC: 0.2 %) (Table 5-12 and Figure 5-7).

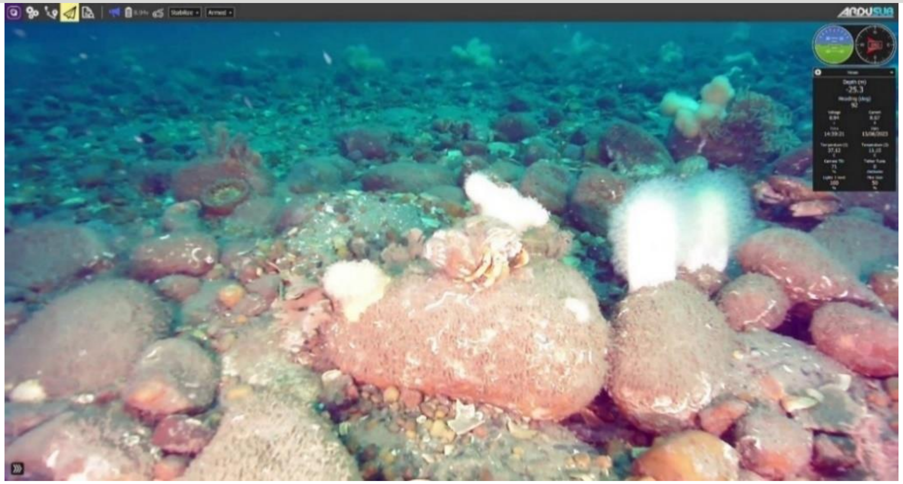
The hard-bottom community contained hard-bottom species and few sand-bottom species. The area coverage of epifauna varied from low to medium, likely due to the dynamic conditions and sand scrubbing of stones (NSI.1-OWF: <5-30% and NSI.1-ECC: no stations with nature type 3/4).

The hard-bottom community was dominated by epifauna attached to the larger stones (>10 cm). The hard bottom community was observed mainly on sediment type 3 and on small patches within sediment type 3 with higher stone coverage (>25 %) corresponding to sediment type 4. The epifauna community was dominated by sea anemones incl. Plumose anemone (*Metridium senile),* Dahlia sea anemone (*Urticina felina*) and spotted sea anemone (*Stomphia coccinea*), lime tube worms (*Spirobranchus triqueter* and *Spirorbis tridentatus*), hydroids, leafy bryozoans/hornwrack (*Flustra foliacea*), Dead Man´s Fingers (*Alcyonium digitatum*), hermit crab (*Pagurus bernhardus*) and tunicates. All species observed are displayed in the species list in Table 5-14, i.e. species observed on sediment type 3 and 4.

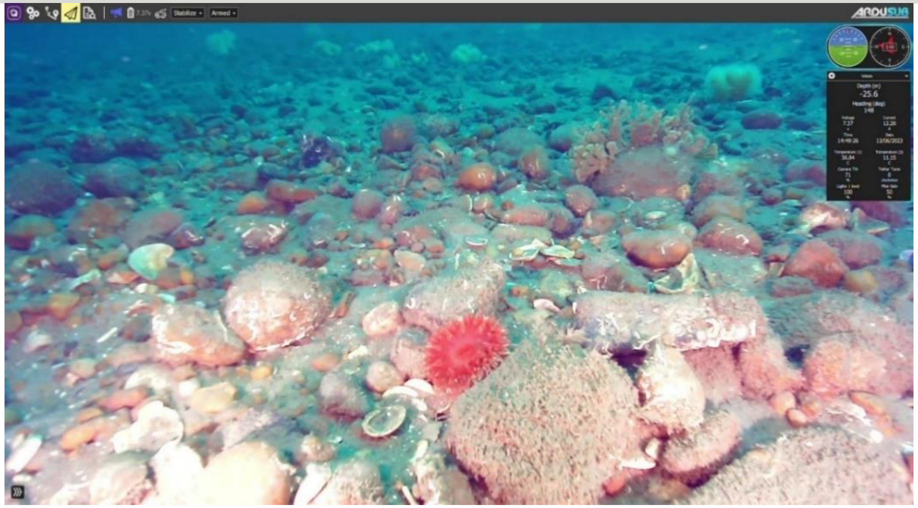
This benthic community type was not observed on ROV video in the three export cable corridors.



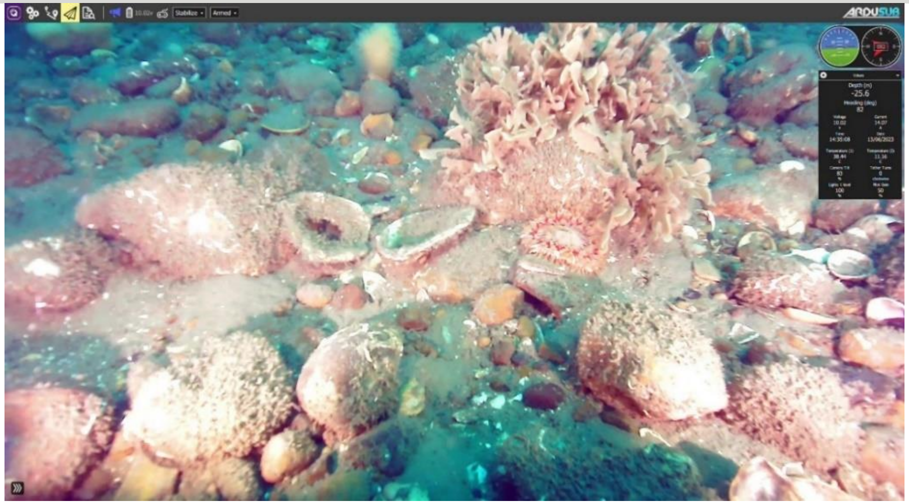
Hard-bottom community on sediment type 3. ROV station: OWF_ROV_200_00023



Hard-bottom community on sediment type 3 and local 4. ROV station: OWF_ROV_197_00006



Hard-bottom community on sediment type 3. ROV station: OWF_ROV_197_00024



Hard-bottom community on sediment type 3 and local 4. ROV station: OWF_ROV_197_00003

Figure 5-15. Examples of hard-bottom community (nature type 3 and 4) and dominating species in NSI.1-OWF - no stations in NSI.1-ECC. Left and right: sediment type 3 and 3 with local patch of sediment type 4. Upper left: coarse sand with large stones with hornwrack (*Flustra foliacea*) (red arrow), polychaete tubes (black arrow), octopus eggs (blue arrow) and white keel worm on stones (*Spirobranchus triqueter*), yellow arrow). Lower left: pebbles, cobbles and large stones (>10cm) of varying size with spotted sea anemone (*Stomphia coccinea*) and bryozoa. Upper right: pebbles, cobbles and larger stones with Dead Man's Fingers (*Alcyonium digitatum*), keel worm (*Spirobranchus triqueter*) and hermit crab. Lower right: Rocky substrate with sea anemone (*Stomphia coccinea*), bryozoa (*Flustra foliacea*) and Dead Man's Fingers (*Alcyonium digitatum).*

5.4 BENTHIC FLORA

Benthic flora reported here includes seagrasses and macroalgae, which are the common benthic flora found in Danish marine, waters. Seagrasses generally do not occur along the exposed part of the West coast of Jutland, due to high sediment dynamic, sediment transport and wave exposure (see section 4.4.1). Macroalgae live attached to hard substrate i.e. rocky sediment and larger stones, generally, larger than 10 cm within the photic zone (see section 4.4.2). Benthic flora observed on ROV video recorded at the ROV stations in this study include only macroalgae and are described below in section 5.4.2.

5.4.1 SEAGRASSES

As expected, no seagrasses were observed during the two surveys in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) as it is a highly wave exposed area. See section 4.4.1 – Seagrasses, for further information.

5.4.2 MACROALGAE

As macroalgae needs hard substrate for attachment, usually defined as stones larger than 10 cm, macroalgae are only expected to be found on sediment types with larger stones including sediment type 2b, 3 and 4 (see Sediment type map in Figure 5-5).

Macroalgae needs light in order to thrive, while red algae crusts have been found down to 29.8 meters of depth in the pre-investigation area of Thor OWF, north of the two pre-investigation areas of this study (see section 4.4.2 for further details). Macroalgae observed in this study are presented in Table 5-13 below.

Table 5-13. Observed macroalgae species and %-coverage at ROV stations within the two pre-investigation areas. Subarea is given. A1 = OWF area A1 and SC is sailing corridor between A1 and A2 see Figure 2-1.

ROV-Station	Subarea	Species	%-coverage	Depth (m)	Primary sediment type
OWF_ROV_123	SC1	Hildenbrandia sp.	<1%	23.0	2b/1b - sand and few stones
OWF_ROV_188	A1	*Chorda filum (loose algae)*	<1%	18.8	1b - sand
OWF_ROV_195	A1	Brown crust and *Hildenbrandia* sp.	<1%	23.0 m	1b - sand
OWF_ROV_197	A1	Brown crust and *Hildenbrandia* sp.	1-2%	25.8	3 - stone coverage
OWF_ROV_200	A1	Brown crust and *Hildenbrandia* sp.	<1%	26.2	2b/3 sand and stones

In this study, macroalgae were found only at four ROV stations in the pre-investigation area for NSI.1 (NSI.1-OWF) and not in the export cable corridors. Observed macroalgae included only small, single specimens of red algae crusts (*Hildenbrandia* sp.) and brown crusts found at depths down to between 22.7 and 25.8 meters with very low area coverage (<1-2 %). The observed crust algae were found in the southern OWF area A1 and in the corridor between A1 and A2 (SC1), corresponding to the presence of sediment types with large stones (>10 cm) suitable for macroalgae attachment (Sediment type 2b, 3 and 4) (see sediment type map in Figure 5-5 and ROV station map in Figure 3-4).

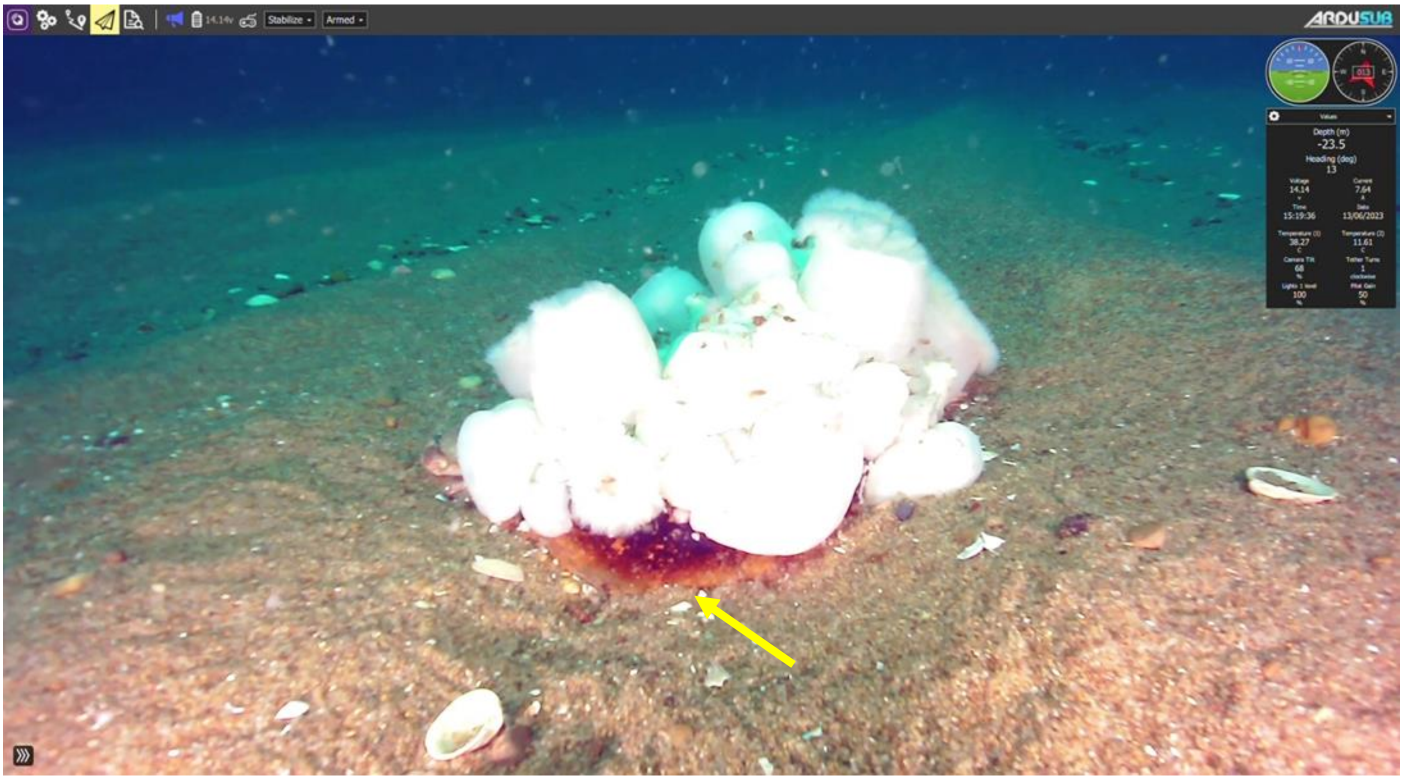


Figure 5-16. Single large stone on sandy bottom with coverage of sea anemones and below these a small patch with red crust alga (*Hildenbrandia* sp) (yellow arrow). ROV station: OWF_ROV_195.

One larger brown alga was observed (*Chorda filum*) but this specimen was not attached to the seabed and was likely transported to greater depth, far from its natural habitat in shallow water (1-5 m depth) (Køie M. & Kristiansen A., 1999, 2023).

The lack of macroalgae is likely due to large depth and resulting light limitation in the pre-investigation area for NSI.1-OWF and in the deeper parts of the export cable corridors (NSI.1-ECC). The seabed is very dynamic with few larger stones for attachment, which results in frequent scrubbing of the stones and covering of flora and fauna with sand (Rambøll, 2020a; Vattenfall, 2020a; Vattenfall, 2020b). Also, larger stones may be covered by silt, which hinders attachment and growth of crust algae, which are able to grow at greater depth.

5.5 BENTHIC FAUNA

In the following. baseline data for epifauna and infauna sampled in the two pre-investigation areas for the NSI.1 (NSI.1-OWF) and the export cable corridors (NSI.1-ECC) including subareas (OWF areas A1-3 and ECC1-3) are presented. Epifauna is benthic fauna that lives on the surface of the seabed – e.g. on the surface of sand, gravel, rocks etc., while infauna is benthic fauna that lives buried in the seabed.

5.5.1 EPIFAUNA

In this section species observed on ROV video are presented. This includes epifauna and visible infauna such as mussel shells, bivalve wholes and siphons, bristle worm piles and tubes, as well as sea potato holes/burrows. Epifauna coverage % therefore includes all observed benthic fauna on the seabed.

Benthic fauna was mapped in the two pre-investigation areas by use of ROV video of the seabed at each ROV station (see Figure 3-4). The epifauna community is described both in general and separately for the two pre-investigation areas and the subareas. Note that species numbers are limited to the number of species it is possible to identify to species level on video, compared to e.g. a diver inspection or microscope species determination.

SPECIES NUMBERS

In total, 56 taxa of benthic fauna were observed on ROV video of the seabed in the two pre-investigation areas in this baseline study (Table 5-14). In the pre-investigation area for NSI.1 OWF (NSI.1-OWF), a total of 49 species were observed and slightly fewer in the pre-investigation area for the export cable corridors (NSI.1-ECC), i.e. 37 taxa. All species and taxa observed in the two pre-investigation areas and subareas are listed in Table 5-14 below. The sediment type is determining for the species composition, and the species composition in the sediment types is not different between the two pre-investigation areas.

OWF AREAS (A1-3)

Species number was 42, 29 and 28 for OWF area A1, A2 and A3, respectively. As the number of taxa is generally determined by the number of different sediment types, the highest number of taxa was observed in the A1 OWF area (42 taxa), which is the only OWF area where sediment types with large stones (>10 cm) were observed at the ROV stations. However, stone areas are also found in the A2 OWF area on the sediment type map but were not covered with ROV stations (see Figure 5-5). Therefore, the species numbers are likely the same for A1 and A2, while likely lower for A3, as there are not observed any stone sediment types (sediment type 2b, 3 and 4) in the A3 OWF area.

EXPORT CABLE CORRIDORS (ECC1-3)

The taxa number is relatively similar in the three export cable corridors (28, 31 and 24 taxa). The slightly higher number of taxa in ECC2 is likely due to the presence of more stony areas in ECC2 (see sediment type map in Figure 5-5).

Table 5-14. Epifauna and visible infauna species observed at ROV stations in the two pre-investigation areas presented here for the subareas (OWF areas A1-3 and ECC1-3). Note that species numbers here are limited by how many of the observed species it is possible to identify to species level on video, compared to e.g. diver inspection or microscope species determination. Sp. = unknown species. Spp. = several unknown species. D = Dominating. Data from Appendix 3A and 3B. Note, that there is an overlap of three stations in ECC1 and ECC2.

Phylum/class	Genus/species	English name (Danish name)	Sediment type	A1	A2	A3	ECC1	ECC2	ECC3
Number of stations				74[1]	61	58[2]	28[3]	52[4]	26
ROV stations				OWF_ROV_133-177, 179-184,186-188, 191, 193-200 (June) and OWF_ROV_05_01-03, 06_01-03 (May)	OWF_ROV_067 – 119, 129 and 130 (June) and OWF_ROV_03_01-03, 04_01-03 (May)	OWF_ROV_001 – 022, 25-52, 60, 62 (June) and OWF_ROV_01_01-03, 02_01-03 (May)	ECR_ROV_56 -66, 67-80 (June) and ECR_ROV_07_01-03, 08_01-03 (May)	ECR_ROV_21 – 55, 67-68, 70–80 (June) and ECR_ROV_09_01-03, 08_01--03 (May)	ECR_ROV_01 -20 (June) and ECR_ROV_10_01-03, 11_01-03 (May)
Coverage (%)				<1-50%	<1-80%	1-99%	1-70%	1-90%	<1-90%
Phoronida	*Phoronids sp.*	Phoronids/horseshoe worm (phoronider)	1a/1b, 1b	D	D	D	D	D	D
Gastropoda	*Gastropod sp.*	Gastropod sp.	1a/1b, 1b			X	X	X	X
Gastropoda	*Hydrobia sp.*	Mudsnail (Dyndsnegl)	1a/1b, 1b			X			
Gastropoda	*Bucchinum undatum*	Common whelk (Almindelig konksnegl) incl. eggs	1a/1b, 1a/2	X	X	X	X	X	
Gastropoda	*Gastropoda sp.*	Unindentified orange snail	1a/1b			X	X	X	X
Gastropoda	*Aporrhais pespelecani*	Pelican's Foot (Pelikanfod)	1a/1b						X
Bivalvia	*Spp.*	Bivalvia spp.	1a/1b, 1b	X			X		
Bivalvia	*Cerastoderma sp.*	Cockle (Hjertemusling)	1b	X	X	X	X	X	X
Bivalvia	*Acenthocardia echinata*	Prickly cockle (Pigget hjertemusling)	1a/1b						X

Phylum/class	Genus/species	English name (Danish name)	Sediment type	A1	A2	A3	ECC1	ECC2	ECC3
Bivalvia	*Mactra stultorum*	Rayed trough mussel (Smuk trugmusling)	1a/1b, 1b	X	X	X	X	X	X
Bivalvia	*Arctica islandica*	Ocean quahog (Molboøsters)	1a/1b, 1b	X	X	X	X	X	
Bivalvia	*Mya arenaria*	Sand gaper (Sandmusling)	1a/1b	X					
Bivalvia	*Myidae sp.*		1a/1b, 1b	X	X		X		X
Bivalvia	*Ostrea edulis*	European oyster (Europæisk østers)	1b	X					
Bivalvia	*Phaxas pellucidus*	Razor clam (Lille knivmusling)	1a/1b, 1b	X	X	X	X	X	
Crustacea	*Balanus spp.*	Barnacles (Rurer)	1b	X	X	X		X	
Crustacea	*Corystes cassivelaunus*	Masked crab (Maskekrabbe)	1a/1b, 1b	X	X	X	X	X	X
Crustacea	*Polybius depurator*	Sandy swimming crab (Almindelig svømmekrabbe)	1a/1b, 1b	X	X	X	X	X	X
Crustacea	*Cancer pagurus*	Brown crab/Edible crab (Taskekrabbe)	1a/1b, 1b	X	X	X	X	X	X
Crustacea	*Pagurus bernhardus*	Hermit crab (Eremitkrebs)	1a/1b, 1b		X		X	X	X
Crustacea	*Crangon sp.*	Shrimp sp. (Reje)	1b				X	X	
Crustacea	*Hyas Araneus*	Great spider crab (Sandkrabbe)	1a/1b, 1b	X					
Asteroidea	*Spp.*	Starfish (Søstjerne)	1a/1b, 1b	X	X	X	X	X	
Asteroidea	*Asterias rubens*	Common starfish (Alm. Søstjerne)	1a/1b, 1b	X	X	X	X	X	X
Asteroidea	*Astropecten irregularis*	Sand Sea Star (Kamstjerne)	1a/1b, 1b	X	X	X	X	X	X
Echinoidea	*Ophiura spp.*	Brittle star spp. (Slangestjerne)	1a/1b (1b)	X	X	X	X	X	X
Echinoidea	*Echinocardium sp.*	Sea potato (Sømus)	1a/1b, 1b	D	D	D	D	D	D
Echinoidea	*Holothurian sp.*	Sea cucumber (Søpølse)	1a/1b, 2b		X	X			
Echnioidea	*Echinus sp.*	Sea urchin (Søpindsvin)	1a/1b						X
Polychaeta	*Spp.*	Bristle worms (havbørsteorme)	1a/1b, 1b	D	D	X	X	D	X

Phylum/class	Genus/species	English name (Danish name)	Sediment type	A1	A2	A3	ECC1	ECC2	ECC3
Polychaeta	*Lanice conchilega*	Sand mason worm (Lanice)	1a/1b, 1b	D	D	X	X	D	X
Polychaeta	*Arenicola marina*	Lugworm (sandorm)	1a/1b				X	X	
Polychaeta	*Lagis koreni*	Trumpet worm (Lige kambørsteorm)	1a/1b, 1b	(X)	X	X	X	X	X
Polychaeta	*Owenia fusiformis*	Tubeworm (Owenia)	1b,			X			
Polychaeta	*Pygospio elegans*	Pygospio worm (Pygospio orm)	1b	(X)				X	
Polychaeta	*Spp.*	Calcareuos tube worms (kalkrørsorm)	1b, 2, 2b, 3	X	X	X		X	X
Polychaeta	*Spirobranchus triqueter*	Keel worm (trekantorm)	3 (4)	X					
Polychaeta	*Pectinariidae sp.*	Pectinariidae sp.	1a/1b, 1b	X	X				
Bryozoa	*Spp.*	Bryozoans (Mosdyr)**	1a/1b, 2a		X			X	X
Bryozoa	*Flustridae sp.*	Bryozoan sp.	1a/1b, 1b	X	X				
Bryozoa	*Flustra foliacea*	Hornwrack (bredbladet mosdyr)	2b, 3	X					
Bryozoa	*Electra pilosa*	Thorny sea-mat (Pigget hindemosdyr)	1a/1b	X					
Bryozoa	*Securiflustra securifrons*	Narrow-leaved hornwrack (N/A)	1a/1b	X					
Anthozoa	*Sea anemone sp.*	Sea anemone sp.	1a/1b, 2b/3	X	X	X	X		
Anthozoa	*Synarachnactis sp.*	Cylinder anemone (cylinderrose)	1a/1b, 1b						X
Anthozoa	*Metridium senile*	Plumose anemone (Sønellike)	1a/2, 1b, 2b, 3	X				X	
Anthozoa	*Alcyonium digitatum*	Dead Man's Fingers (Dødningehånd)	1a/2, 3	X	X			X	
Anthozoa	*Synarachnactis lloydii*	Tube-dwelling sea anemone (Tynd cylinderrose)	1a/1b	X	X	X	X	X	
Anthozoa	*Stomphia coccinea*	Spotted swimming anemone (Karminrød søanemone)	2b	X					

Phylum/class	Genus/species	English name (Danish name)	Sediment type	A1	A2	A3	ECC1	ECC2	ECC3
Anthozoa	*Pachycerianthus multiplicapus*	Firework anemone (Tyk cylinderrose)	1a/1b			X	X	X	
Anthozoa	*Urticina felina*	Dahlia sea anemone (Stor søanemone)	2b,3	X					
Hydrozoa	*Spp.*	Hydroids (Hydroider)	1a/1b, 1b	X	X	X	X	X	X
Hydrozoa	*Sertularia cuppressina*	White weed (Cyprespolyp)	1a/1b, 3	X					
Hydrozoa	*Sertularia argentea*	Air fern	1a/1b	X					
Ascidiacea	*Spp.*	Tunicates (sækdyr)	3	X					
Porifera	*Spp.*	Sea sponges (havsvampe)	2b/3	X					
Total numbers	**All species = 56**		**Subareas**	**42**	**29**	**28**	**28**	**31**	**24**
		Pre-investigation areas		**NSI.1-OWF = 49**			**NSI.1-ECC = 37**		

TOTAL AREA COVERAGE (%)

Total area coverage percent of all observed benthic fauna (epifauna + visible infauna) and the dominating species were estimated from the video recording of the seabed at ROV stations (Figure 5-17). Total area coverage is generally determined by the coverage of the most abundant species. In this study, the dominant species is horseshoe worm (*Phoronis* sp.), although not at all stations. The area coverage of horseshoe worm is described in the section for the dominating species below (see Figure 5-19).

Total area coverage in this study shows no clear relation to benthic community/nature type, sediment type or depth. The clearest pattern is that the lowest area coverage of benthic fauna (<1 % see small white circles) is observed on sediment type 2a – "coarse sand, gravel and pebbles" in the southwestern part of the pre-investigation area for NSI.1 (NSI.1-OWF). In general, the same range of fauna coverage % were observed in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC). The main reason for similarities of area coverage of fauna in the pre-investigation areas is the dominance of horseshoe worm, which is present with a generally high percent area coverage on both sediment type 1a/1b – "silty sediment" and sediment 1b – "sand", which dominate the two pre-investigation areas. Furthermore, both pre-investigation areas are very dynamic with high mixing and transport of the seabed and organisms, which consists of the same benthic communities and species composition, which again are adapted to these very dynamic conditions. The fauna coverage and species composition are, therefore, expected to be relatively similar between the pre-investigation areas and subareas with the same ranges of area coverages (see Figure 5-17).

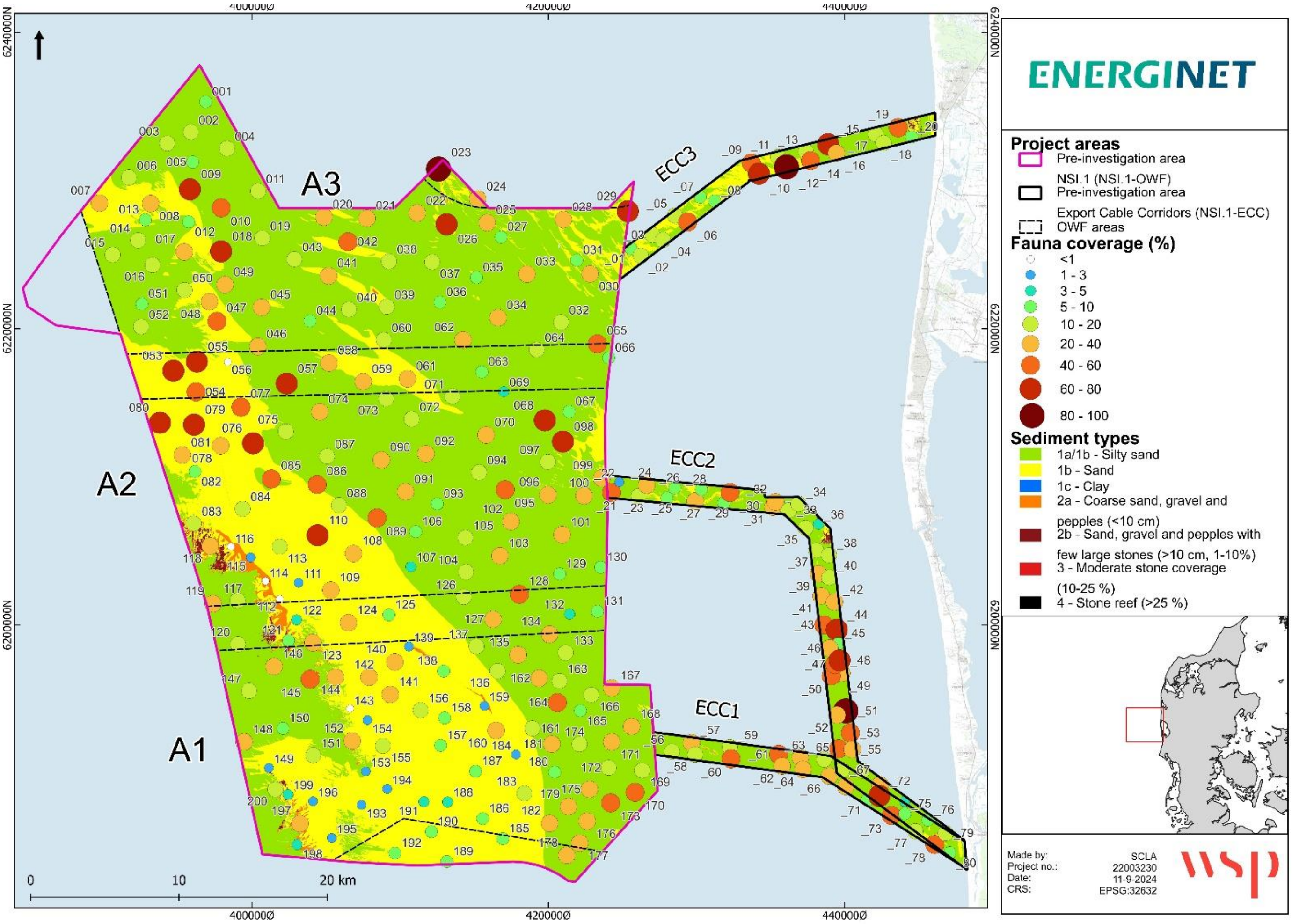


Figure 5-17. Map of area coverage (%) of total benthic fauna observed on ROV video in the two pre-investigation areas for NSI.1-OWF and export cable corridors (NSI.1-ECC) made from June 2023 data. Note that area coverage is given as a range in % at each ROV station in the logbook (see Appendix 3B). As 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.

OWF AREAS (A1-3)

When comparing the total fauna coverage in the three OWF areas (A1-A3), area coverage is generally lowest in the A1 OWF area. Highest and similar area coverages are found in OWF area A2 and A3. The reason for the total area coverage being lover in OWF area A1, is likely the larger area of sediment type 1b - sand compared to more sediment type 1a/1b – silty sand in A2 and A3. The surface silt layer in sediment type 1a/1b provides food and habitat for the highest number of species, and this sediment type generally supports the highest area coverages of fauna. Sediment type 1b – "sand" has lower species numbers compared to sediment type 1a/1b, but can also have high area coverages, since Phoronids dominate bot sediment type 1b and 1a/1b. Also, the A1 OWF area has lower depth than the two other OWF areas and is, thus, more dynamic with a coarser seabed.

EXPORT CABLE CORRIDORS (ECC1-3)

The total fauna coverage in the three export cable corridors is generally within the same coverage ranges, with ECC1 being slightly lower. ECC1 is the shallowest cable corridor and is therefore more exposed to the dynamic conditions.

DOMINATING SPECIES

The dominating species at the ROV stations were horseshoe worm (*Phoronis* sp., 0-90 % area coverage), the tube living bristle worm *Lanice conchilega* (0-25 %), sea potato (*Echinocardium* spp., 0-40 %) and brittle star (*Ophiura* sp., 0-30 %). The dominating species are represented in Figure 5-18 and area coverage of the dominating species are presented in Figure 5-19. The dominating species in the subareas (OWF area A1-3 and ECC1-3) are indicated with a "D" in Table 5-14 above.

Figure 5-18. Dominating species on "silty sand" (sediment type 1a1b) and "sand" (sediment type 1b) observed on ROV video in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC). The still photo grabbed from the video shows small Phoronid tubes (red arrow), a live sea potato and sea potato burrows/holes (yellow arrows), Lanice tubes (blue arrows) and a star fish. ROV station OWF_ROV_019_00002.

The dominating species are unsurprisingly connected to the dominating sediment types, i.e. "silty sand" (sediment type 1a/1b) and "sand" (sediment type 1b) and are generally species that feeds on or of the silt (Køie M. & Kristiansen A., 1999, 2023) that is present in varying amounts in these sediment types but highest in sediment type 1a/1b – silty sand.

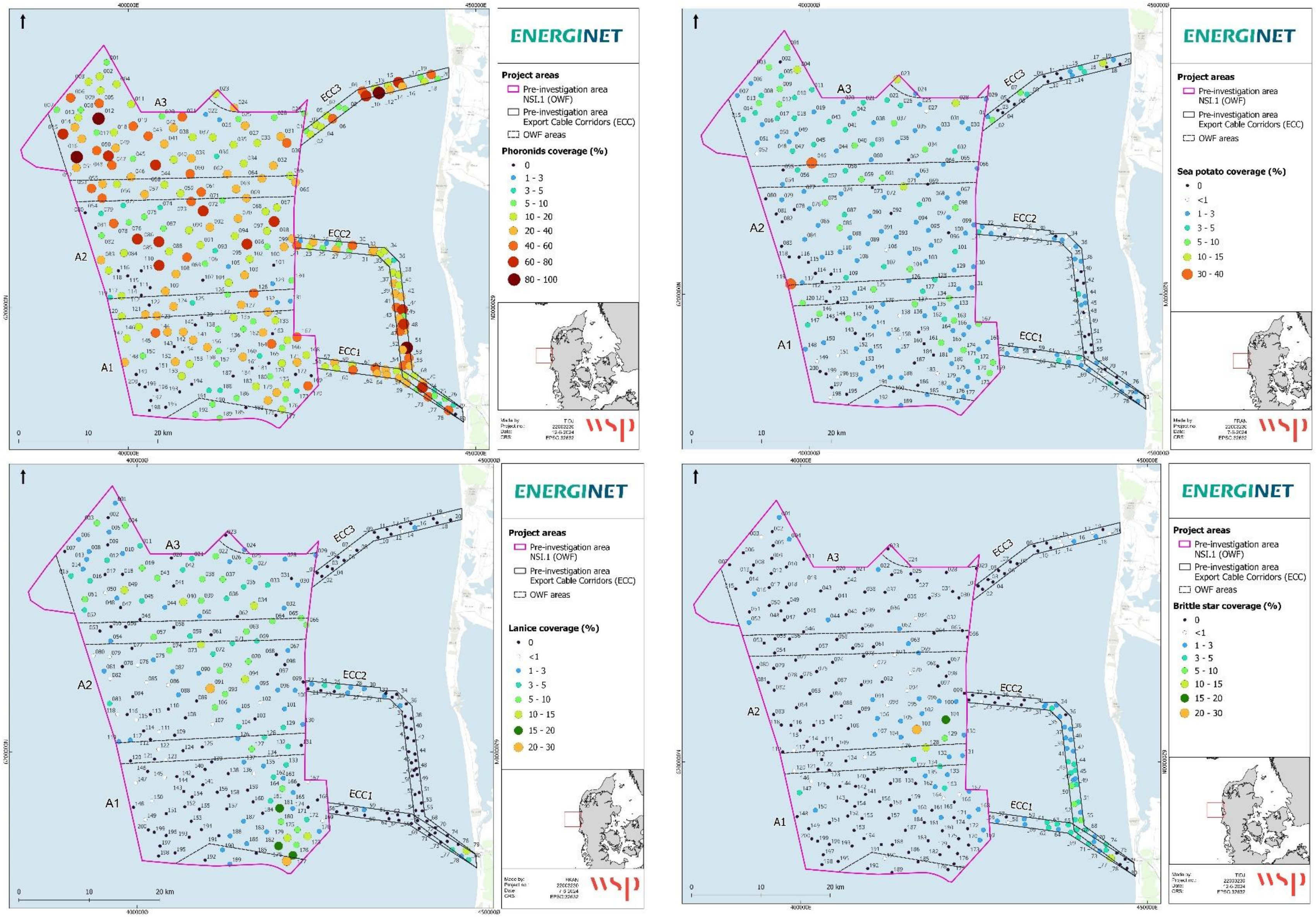


Figure 5-19. Area coverage (%) for the dominating species (Phoronids, sea potato, brittle stars and the bristle worm *Lanice conchilega*) in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC). June 2023 data is used. Note that area coverage is given as a range in % at each ROV station in the logbook (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.

OWF AREAS (A1-3)

When comparing the OWF areas A1-3, phoronids and sea potato have highest coverages in A2 and A3. *Lanice conchilega* was most widely distributed in A2 and A3 but had maximum coverages in the southeastern part of A1, corresponding to where sediment type 1a/b – silty sand was observed. Finally, brittle stars had the highest coverage in A2.

EXPORT CABLE CORRIDORS (ECC1-3)

Comparing the export cable corridors (ECC1-3), phoronids have similar ranges in the three cable corridors but maximum coverages in ECC2 and ECC3. Sea potato also have similar coverages with slightly higher coverages in ECC3. *Lanice conchilega* was most widely distributed in the deeper pre-investigation area for NSI.1 OWF (NSI.1-OWF) and sparser in the more dynamic cable corridors. This was also observed on ROV video with Lanice tubes being smaller in the cable corridors compared to the deeper and less dynamic OWF areas. Finally, brittle stars had the highest coverage in ECC1 and ECC2 and were rarer in ECC3, corresponding to higher area coverage of sediment type 1a/1b – silty sand in ECC1 and ECC2 compared to ECC3.

5.5.2 INFAUNA

Below, data on infauna species numbers, abundances and biomass are presented for each of the two pre-investigation areas: the offshore wind farm North Sea I.1 (NSI.1-OWF) including the three subareas OWF area A1-3 and the three export cable corridors (NSI.1-ECC) (ECC1-3). See Figure 3-6 for overview of the two pre-investigation areas and location of the infauna sampling stations. Each infauna station consists of an area of 1x1 km within which 42 individual infauna HAPS samples have been collected (samples 1-42 – see Figure 3-7 for an example of sampling for station A_01).

Furthermore, infauna species diversity and environmental condition of the location and infauna communities are presented in the subsection “Statistical analysis/Indices” below in this section. In addition, statistical analyses exploring similarities and dissimilarities of infauna communities’ abundances and species composition are conducted (subsection “Statistical analysis/Multivariate statistical analysis” below).

Data from the two pre-investigation areas will be compared to existing data from other projects in the area (see existing data in section 4.5.2 - Infauna), together with data from the Danish national marine monitoring program (NOVANA) (see Figure 4-1). Existing data from the area is presented in section 4.5.2 - Infauna.

Results are presented for each station as well as for each of the two pre-investigation areas. Abundance (ind./m^2) and biomass (both in wet weight (g WW/m^2) and dry weight (g DW/m^2)) are presented as overall averages of the 42 samples from each station in the two pre-investigation areas. Biomass in wet weight (WW) is included for comparison with existing data from the Danish marine monitoring program (NOVANA), where biomass is only presented in WW. However, in the below section regarding biomass of species in the two pre-investigation areas, data is presented in dry weight (DW), because biomass presented in DW is a more accurate measure of the actual biomass of the organism, while WW can easily be affected by few drops of remaining water/preservatives “sticking” to the organism.

An overview of the results on infauna species numbers, abundances and biomasses at each infauna station is summed up in Table 5-15 and in the text below. Data for each pre-investigation area is described in detail in the respective sections below.

Table 5-15. Average number of species, abundance (individuals/m²) and biomass (g DW/m² and g WW/m²) at each infauna station in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) and subareas (OWF areas A1-3 and ECC1-3). Biomass is given as dry weight (g DW/m²) and wet weight (g WW/m²). Values presented as average ± standard error (SE). Also, depth, total number of species per infauna station and sediment type are presented. Sediment type was determined from 3 ROV video stations per infauna station, for A_04 only two ROV stations were successful. * For Station A_10, samples were collected on a mixed sediment type, mainly consisting of sediment type "sand", but also to some extent "silty sand" was present at the station.

Area	Station	Depth (m)	Total number of species	Number of species (per HAPS sample)	Abundance (ind./m²)	Biomass (g DW/m²)	Biomass (g WW/m²)	Sediment type
NSI.1-OWF	**A_01-06**	Range: 19-30	109	7.4	2473	113	229	-
NSI.1-ECC	**A_07-11**	Range: 19-23	93	7.1	2003	163	339	-
A3	**A_01**	27	37	4.8	746	18	30	3: sand
	A_02	28	46	11.0	6009	204	389	3: silty sand
A2	**A_03**	24	28	2.3	162	23	55	3: sand
	A_04	30	56	12.8	4787	159	358	2: silty sand
A1	**A_05**	19	29	2.9	255	99	182	3: sand
	A_06	24	42	10.7	2877	173	357	3: silty sand
ECC1	**A_07**	21	51	8.7	2671	207	449	3: silty sand
	A_08	20	48	6.6	2316	109	218	3: silty sand
ECC2	**A_09**	23	50	8.6	3267	226	446	3: silty sand
ECC3	**A_10**	22	45	3.7	420	41	89	2: sand 1: silty sand*
	A_11	19	36	7.9	1342	229	491	3: silty sand

SPECIES NUMBERS

In the **pre-investigation area for NSI.1-OWF**, 6 infauna stations (A_01-06) and a total of 252 samples were collected (42 HAPS samples per infauna station). In four samples (sample 09, 21 and 28 at A_03, and sample 32 at A_05), no specimens of infauna were found. A total of 109 species were identified in the NSI.1-OWF (Table 5-15 and Table 5-16), and the total number of species found at each infauna station (i.e. including all 42 samples per each station) in NSI.1-OWF ranged from 28-56 species (Table 5-15).

In the **pre-investigation area for the export cable corridors** (NSI.1-ECC), 5 infauna stations (A_07-11) and a total of 210 samples were collected for (42 samples per infauna station). Here, one sample at station A_10 (sample 41) had no species present. A total of 93 species were found in the NSI.1-ECC (Table 5-15 and Table 5-16), and the total number of species found at each infauna station (i.e. including all 42 samples per each station) ranged from 36-51 species (Table 5-15).

In total, 13 taxonomical classes were found in NSI.1-OWF and 12 in NSI.1-ECC, as Oligochaeta (worms) was not found in NSI.1-ECC). In both pre-investigation areas, Polychaeta (bristle worms) was the most represented class with 45 and 39 species in NSI.1-OWF and NSI.1-ECC, respectively (Table 5-16). Malacostraca (crustaceans) had the second highest species numbers in both areas, with 26 and 20 species in NSI.1-OWF and NSI.1-ECC, respectively, followed by Bivalvia (molluscs) with 19 and 17 species in NSI.1-OWF and NSI.1-ECC, respectively. Like in the two pre-investigation areas, Polychaeta was the most represented class in all 6 subareas (A1-3 and ECC1-3), and Bivalvia and Malacostraca were represented with similar species numbers in the 6 subareas. Fewer species (50 species) were found in ECC2 – however, this area only included one infauna station (A_09), whereas the other 5 subareas each consisted of 2 infauna stations. Highest species numbers were found in subareas A2 and A3 (71 and 70 species, respectively). The full list of species found in the two pre-investigation areas can be found in Appendix 7B.

Table 5-16. The number of species found per infauna class in the two pre-investigation areas, NSI.1-OWF (A1-3) and NSI.1-ECC (ECC1-3). Note that Anthozoa taxonomically is the sub-phylum, Oligochaeta is the sub-class and Phoronida is the Phylum. The remaining are classes.

Class / Subarea	A1	A2	A3	ECC1	ECC2	ECC3	NSI.1-OWF	NSI.1-ECC
Anthozoa	1	1	1	1	1	0	1	1
Asteroidea	1	0	1	1	0	0	1	1
Bivalvia	12	12	11	14	8	10	19	17
Echinoidea	1	2	2	1	1	1	2	1
Gastropoda	3	3	3	2	3	2	6	4
Hexacorallia	2	2	1	2	2	0	2	2
Leptocardii	0	1	1	0	0	1	1	1
Malacostraca	10	12	15	9	7	11	26	20
Nemertea	1	1	1	1	1	1	1	1
Oligochaeta	0	0	1	0	0	0	1	0
Ophiuroidea	1	3	1	4	1	1	3	5
Phoronida	1	1	1	1	1	1	1	1
Polychaeta	22	33	31	25	25	29	45	39
Total number of species	**55**	**71**	**70**	**61**	**50**	**57**	**109**	**93**

The number of species per sample varied between 0-18 in NSI.1-OWF (average of 7.4 species per sample) and ranged from 0-15 in NSI.1-ECC (average of 7.1 species per sample). These are very comparable with species numbers per sample reported in the technical report from Thor OWF (Energinet, 2021), which is just north of NSI.1-OWF (see Figure 4-1), and also similar to species numbers per sample found at the four NOVANA stations in the area (Table 4-8). The species numbers were lower than the general species numbers estimated for the North Sea (see Figure 4-11a, see section 4.5 - Benthic fauna).

Figure 5-20 shows the number of species per sample at infauna station A_01 and as an average of the 42 samples at each of the 11 infauna stations located in the two pre-investigation areas NSI.1-OWF and NSI.1-ECC. Species numbers varied between samples within both pre-investigation areas (data not shown but for one of the 11 infauna stations (A_01)). The three infauna stations in the eastern part of NSI.1-OWF had the highest number of species compared to other infauna stations in both pre-investigation areas (see Figure 5-20). At the eastern stations in NSI.1-OWF, the number of species was 10-13 species per sample (42 samples), whereas only 1-5 species was found per sample in the western part of NSI.1-OWF. This pattern of species distribution between the eastern and western part was found in all 3 OWF areas (A1-3), as each area consist of a western and eastern infauna station. Stations in the middle (ECC2) and southern (ECC1) export cable corridors had higher species numbers per sample than stations in the northern export cable corridor (ECC3) (Table 5-15).

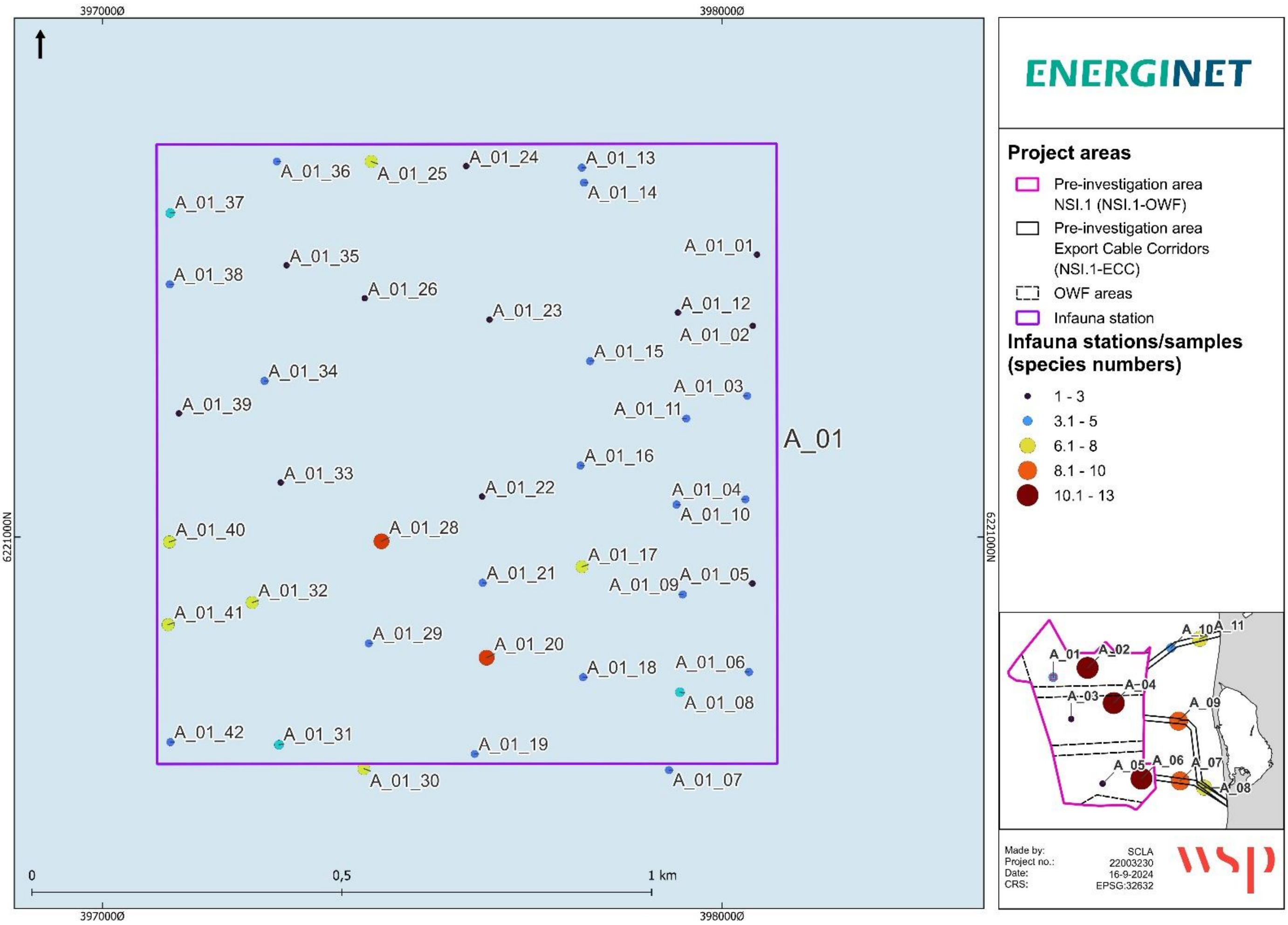


Figure 5-20. Number of infauna species per sample (HAPS sample 1-42) at infauna station A_01 (average of 42 samples) in NSI.1-OWF. The map on the right displays the average number of species found in the 42 samples pr infauna station (A_01 to A_11) in the two pre-investigation areas NSI.1-OWF and NSI.1-ECC and subareas (OWF1-3 and ECC1-3).

The difference between the western and eastern stations in NSI.1-OWF was likely be caused by more sandy sediment (sediment type 1b - sand) in the western part and more silty sediment (sediment type – silty sand)/more food in the eastern part (see multivariate analysis below) (Figure 5-21). Similarly, the two cable corridors with highest species numbers had more sediment type 1a/1b - silty sand, whereas the lowest species numbers were found in ECC3 with a higher area coverage of sediment type 1b – sand, as seen in Figure 5-21 below.

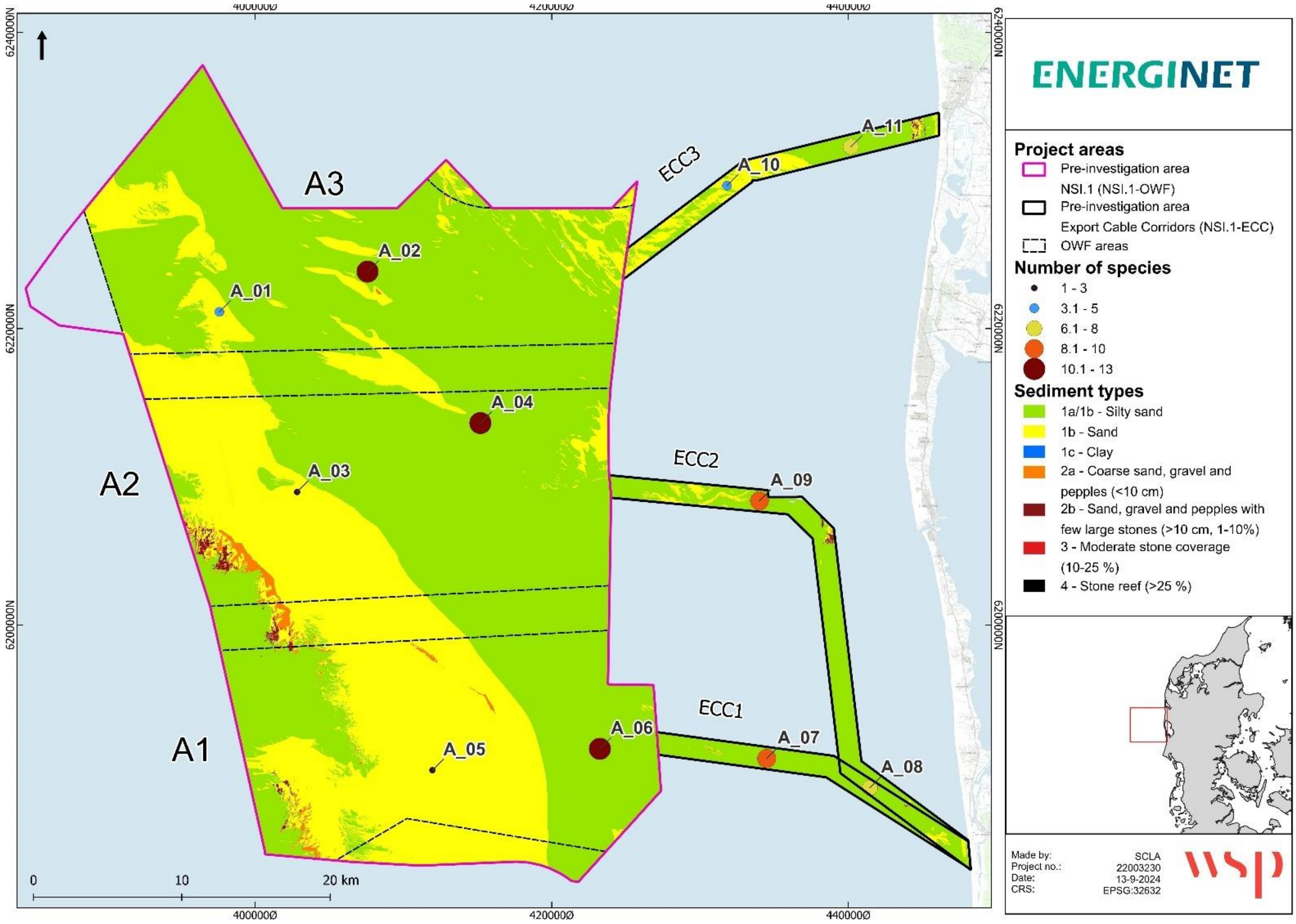


Figure 5-21. Average number of infauna species per sample (same data as shown in the right map in Figure 5-20) at infauna stations A 01-11 with the sediment type map as background layer.

Supporting this, Figure 5-22 shows two examples of infauna (and epifauna) communities present on the two different sediment types 1a/1b - silty sand (picture to the left) and sediment type 1b - sand (picture to the right). It is evident that there is much more life present on the silty sand sediment, at least on the surface. These pictures support the findings that species numbers per sample, abundances and biomass are higher in samples located on silty sediment.

Silty sand - Infauna station A_07, ECC1

Sand - Infauna station A_10, ECC3

Figure 5-22. Infauna visible on the seabed on silty sand (sediment type 1a/1b) compared to sand (sediment type 1b). Left: Silty sand - Infauna station A_07; ECC_ROV_07_02_00005. Right: Sand - Infauna station A_10; ECC_ROV_10_01_00001.

ABUNDANCE

There was high variation in the abundance of infauna (ind./m^2) between samples at each of the 11 infauna stations (data only shown for infauna station A_01 in Figure 5-23).

Abundances of infauna found in the two pre-investigation areas were within the range of abundances reported in other studies in the area, e.g. Thor OWF (Energinet, 2021) (see Table 4-9) and NOVANA stations (see Table 4-8), together with abundance estimates for the North Sea (see Figure 4-12a, in section 4.5 - Benthic fauna).

Abundance data is presented in more detail for the two pre-investigation areas and subareas (OWF area A1-3 and ECC1-3) below.

OWF AREAS (A1-3)

The abundances found at infauna stations in the pre-investigation area NSI.1-OWF ranged from 162-6009 ind./m^2 with an overall average of 2473 ind./m^2 ± 176 SE per station (Table 5-15). There was a clear difference in abundance of infauna between easterly and westerly located infauna stations in NSI.1-OWF, where the three eastern stations (A_02, 04, 06) had the highest abundances of infauna compared to the three western stations (A_01, 03, 05) (Table 5-15). The abundance from infauna stations also varied from north to south, generally decreasing from the northern OWF area A3 to the Southern OWF area A1.

The difference observed between eastern and western locations could be due to differences in the sediment type, where the sediment in the western part of NSI.1-OWF consists of "sand" while the eastern part consists of "silty sand" (see Figure 5-21 above).

EXPORT CABLE CORRIDORS (ECC1-3)

Infauna abundances at infauna stations in NSI.1-ECC ranged from 420-3267 ind./m^2 with an overall average of 2003 ind./m^2 ± 103 SE per station (Table 5-15). The highest abundance was found in the middle export cable corridor (ECC2) - at station A_09, the lowest abundance was found in the northern export cable corridor (ECC3).

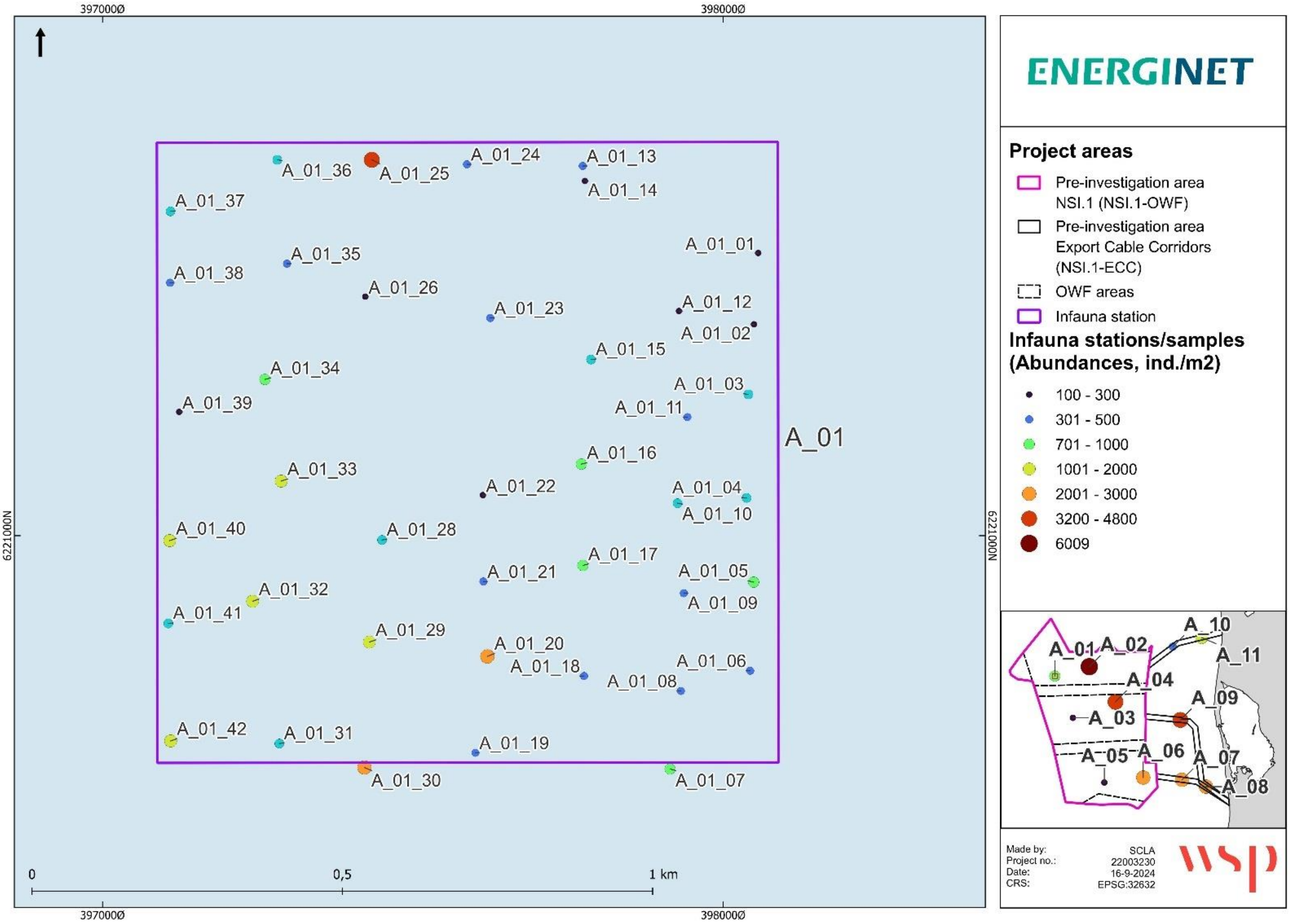


Figure 5-23. Infauna abundance (ind./m²) per sample (HAPS sample 1-42) at infauna station A_01 in NSI.1-OWF. The map on the right displays the average abundance of infauna in the 42 samples pr infauna station (A_01 to A_11) in the two pre-investigation areas NSI.1-OWF and NSI.1-ECC and subareas (OWF area A1-3 and ECC1-3).

BIOMASS

In this section, biomass of infauna species will be presented in dry weight (DW) only. Figure 5-24 displays the biomass (g DW/m²) per infauna station and additionally, biomass per sample for infauna station A_01 is presented. Total biomass at each station, in both DW and wet weight (WW), are presented in Table 5-15 above.

Biomass of infauna in the two pre-investigation areas were within the range of previously reported biomass from the area, e.g. Thor OWF (Energinet, 2021) (see Table 4-9) and NOVANA stations (Table 4-8).

OWF AREAS (A1-3)

In the pre-investigation area NSI.1-OWF, average infauna biomass at the six infauna stations ranged from 18-204 g DW/m² (overall average of 113 g DW/m²) and 30-389 g WW/m² (overall average of 229 g WW/m²), respectively. As for the abundance and number of species, there was a higher infauna biomass at the eastern stations in NSI.1-OWF, compared to the western stations in the area (Table 5-15, Figure 5-24). It is evident that there are large variations in biomass between the 42 samples at station A_01, which was the case for the other 10 infauna stations as well, which reveals a large, natural variation in biomass between infauna samples.

Biomasses in the three OWF areas (A1-3) were relatively similar. The variance within the 42 samples per infauna station was larger than between the infauna stations, which again indicates natural, large variances in infauna biomass in the area.

EXPORT CABLE CORRIDORS (ECC1-3)

In the pre-investigation area NSI.1-ECC, the average infauna biomass at the five stations ranged from 41-229 g DW/m^2 (overall average of 163 g DW/m^2) and 89-491 g WW/m^2 (overall average of 339 g WW/m^2) (Table 5-15, Figure 5-24). High infauna biomasses, comparable to the eastern stations in NSI.1-OWF, were also found at three of the stations (A_07, A_09 and A_11) in all three Export Cable Corridors (ECC1-3) (biomass of 200-230 g DW/m^2) (Table 5-15, Figure 5-24). The overall average biomass in NSI.1-ECC was higher than in NSI.1-OWF (Table 5-15).

Biomasses in the three export cable corridors (ECC1-3) were relatively similar. As for NSI.1-OWF, the variance within the 42 samples per infauna station was larger than between the infauna stations, indicating large variations in infauna biomass in the area.

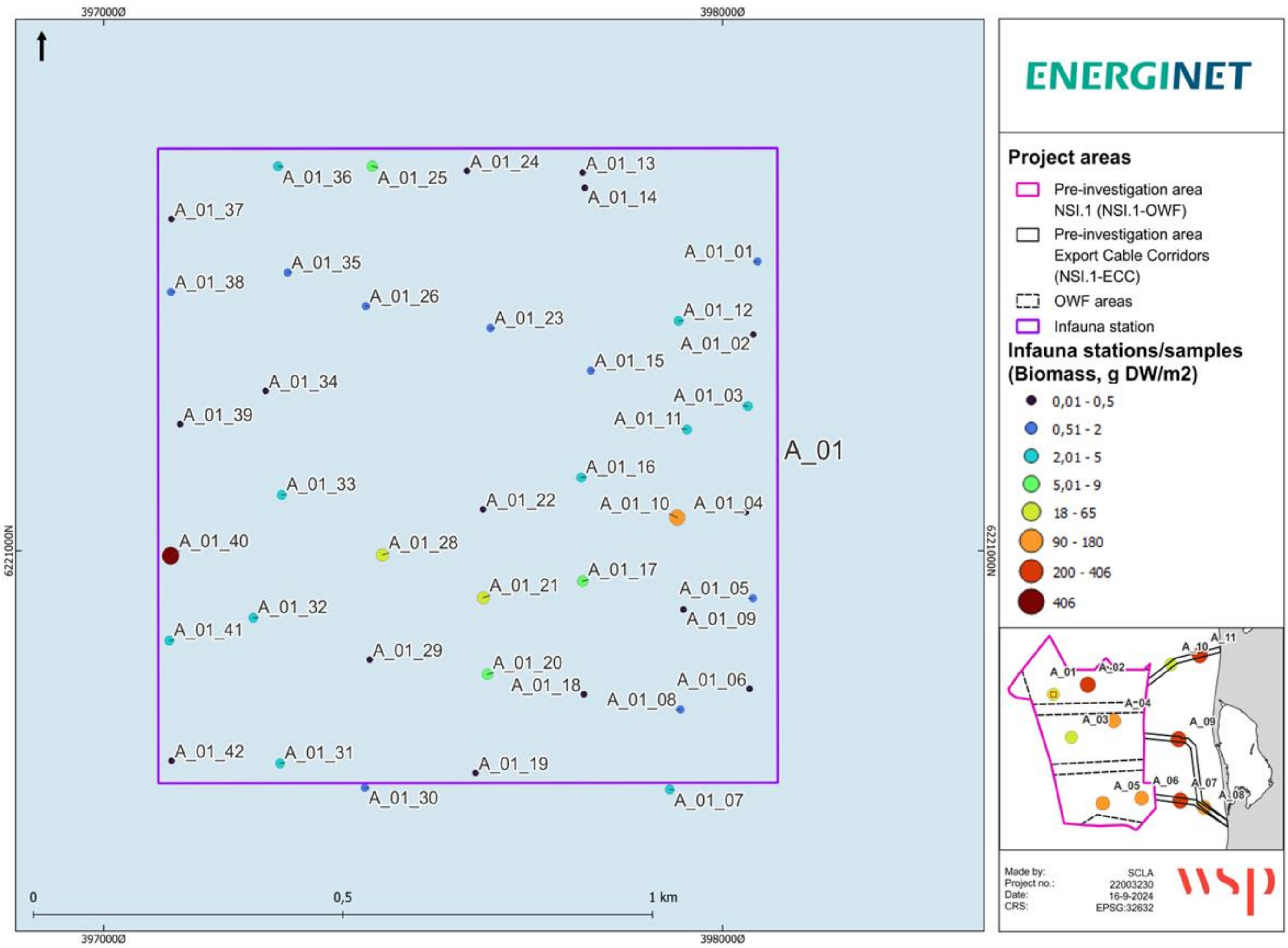
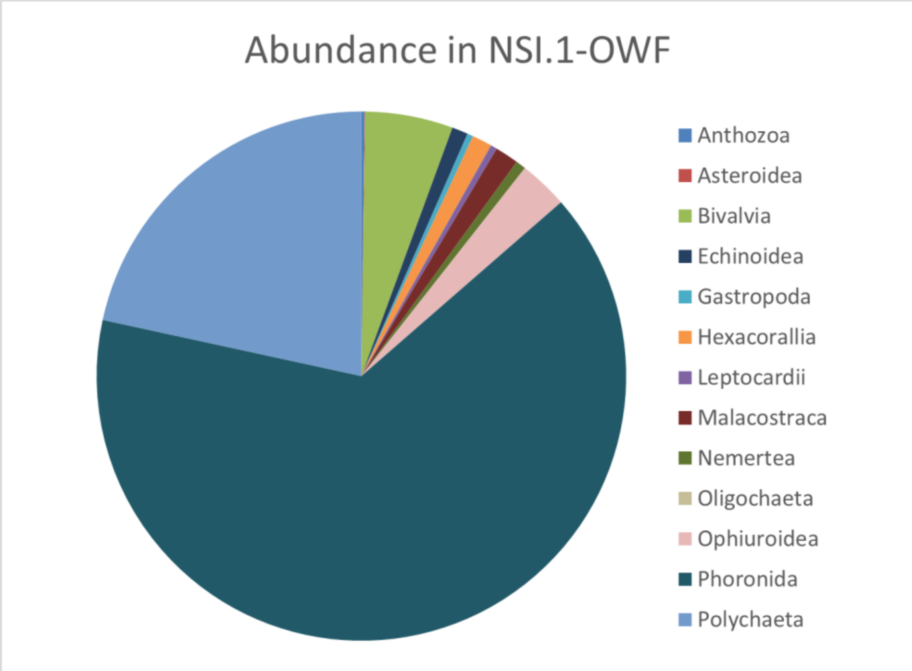


Figure 5-24. Infauna biomass (g DW/m^2) per sample (HAPS sample 1-42) at infauna station A_01 in NSI.1-OWF. The map on the right displays the average abundance of infauna in the 42 samples pr infauna station (A_01 to A_11) in the two pre-investigation areas NSI.1-OWF and NSI.1-ECC and subareas (OWF area A1-3 and ECC1-3).

CLASS DISTRIBUTION

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 the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) (Figure 5-25). 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.



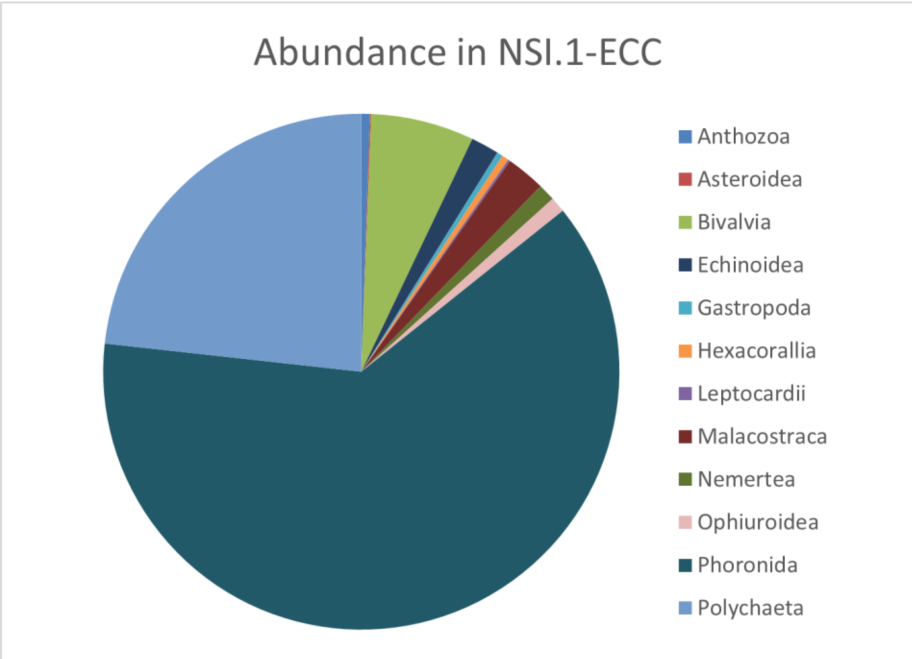
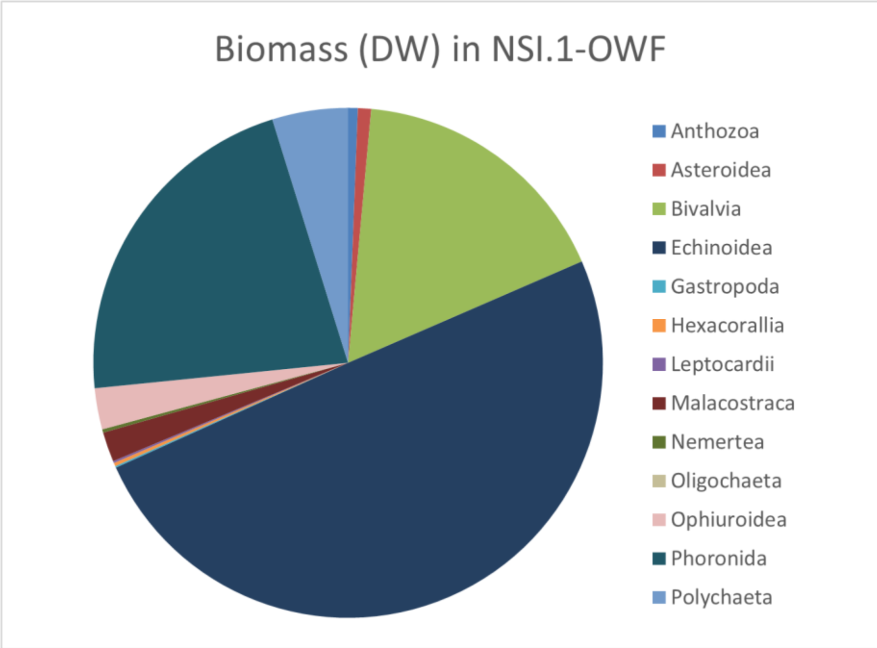


Figure 5-25. Infauna abundance distribution (%) of infauna classes in NSI.1-OWF and NSI.1-ECC. See Table 5-15 for average infauna abundance (ind./m^2) in the two pre-investigation areas. Note that Anthozoa taxonomically is the sub-phylum, Oligochaeta is the sub-class and Phoronida is the Phylum. The remaining are classes.

Like for 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 5-26). 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 with 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 %).



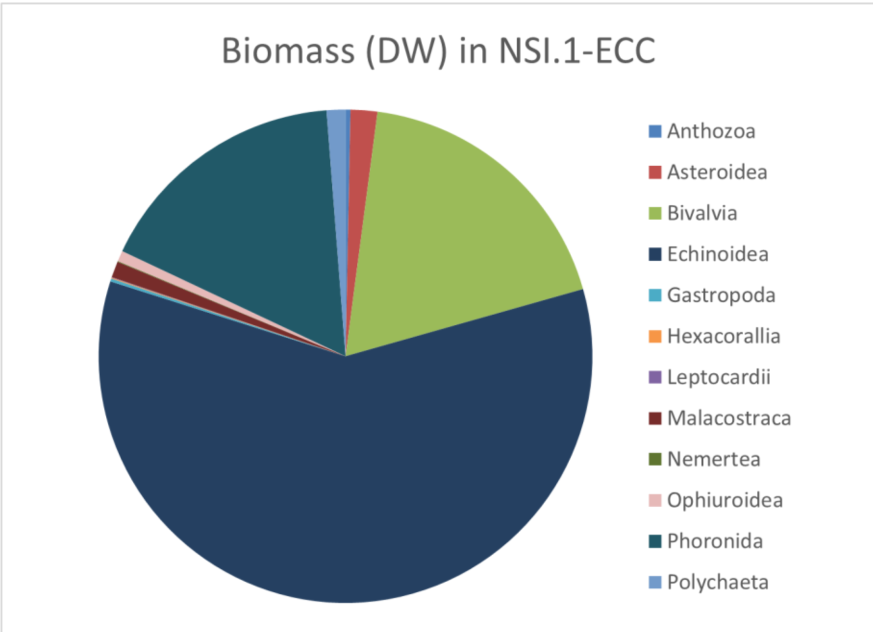


Figure 5-26. Infauna biomass distribution (%) of infauna classes in NSI.1-OWF and NSI.1-ECC. See Table 5-15 for average infauna biomasses (g DW/m^2) in the two pre-investigation areas. Note that Anthozoa taxonomically is the sub-phylum, Oligochaeta is the sub-class and Phoronida is the Phylum. The remaining are classes.

Infauna class distribution in the two pre-investigation areas was similar to the class distribution reported for Thor OWF (Energinet, 2021).

Based on Table 5-16, it is evident that the class distribution between the subareas OWF areas A1-3 and ECC1-3 are similar, and these are therefore not discussed further here.

DOMINATING SPECIES

In both pre-investigation areas, the horseshoe worm (*Phoronis* sp.) dominated the abundance (>60 % out of the total number of individuals in the two areas) of the infauna communities, whereas sea potato/heart urchin *(Echinocardium cordatum)* dominated the biomass (>50%).

In NSI.1-OWF, horseshoe worm (*Phoronis* sp.) contributed 65 % of the total number of individuals in the area. Two bristle worm species *(Magelona mirabilis* and *Owenia fusiformis)* contributed 5 % and 4 %, respectively, and brittle star *(Acrocnida brachiata)* 3 %. The sea urchin species, sea potato *(Echinocardium cordatum),* dominated the biomass with 50 %, and horseshoe worm *(Phoronis* sp.*)* contributed 22 % to the biomass, followed by the bivalve mollusc species common otter shell *(Lutraria lutraria)* with 6 %, and the bivalve clam species venus clam *(Chamelea gallina)* with 4 %.

As mentioned above, there was a difference in abundance and biomass between the eastern and western infauna stations within NSI.1-OWF. Additionally, a difference in species composition and dominance was observed. At the eastern located stations (A_02, 04, 06), horseshoe worm *(Phoronis* sp.*)* dominated the abundance of infauna, whereas horseshoe worm was not present in the three western located stations (A_01, 03, 05), except for one individual of horseshoe worm found in one sample at A_01 (data not shown). Different species dominated at the three western located stations in NSI.1-OWF, such as the bristle worm species *Protodorvillea kefersteini, Nephtys cirrosa* and *Magelona mirabilis,* the bivalve species Rayed trough shell *(Mactra stultorum)* and the sea urchin species sea potato *(Echinocardium cordatum)*.

In the total NSI.1-ECC area, horseshoe worm contributed 62 %, followed by the same two bristle worm species as in NSI.1-OWF *(Magelona mirabilis* and *Owenia fusiformis),* contributing 7 % and 6 %, respectively. The fourth most abundant species was the bivalve mollusc bean-like tellin *(Fabulina fabula)* with 3 %. Sea potato *(Echinocardium cordatum)* dominated the biomass with 59 %, and horseshoe worm *(Phoronis* sp.*)* contributed 17 % to the biomass in the area, followed by the bivalve mollusc species common otter shell *(Lutraria lutraria)* with 6 %, and the bivalve clam species venus clam *(Chamelea gallina)* with 4 %.

At most infauna stations within NSI.1-ECC, horseshoe worm, *Phoronis* sp., was the most abundant species. However, in the northern export cable corridor (ECC3), horseshoe worm was also present, but abundance was dominated by the bristle worm species *Magelona mirabilis* (a shovelhead worm) and *Owenia fusiformis* (a tubeworm), together with the bivalve bean-like tellin *(Fabulina fabula)*.

Stations in both pre-investigation areas were, in terms of biomass, clearly dominated by the sea urchin species sea potato/heart urchin *(Echinocardium cordatum)*, although the bivalve *Ensis siliqua* and *Echinocardium cordatum* had similar biomass at station A_06 in NSI.1-OWF. Horseshoe worm also had high biomass at some stations within the two pre-investigation areas.

Dominance of the horseshoe worm (*Phoronis* sp.) was also reported for Thor OWF, where the largest part of the gross area is characterized by sandy bottom with horseshoe worm (*Phoronis* sp.) (Energinet, 2021). The two bristle worms, *Spiophanes bombyx* and *Magelona mirabilis,* were also abundant in the area of Thor OWF, similar to what was found in the two pre-investigation areas of the present study. The most recent NOVANA data (collected in 2022/2023) also showed dominance in abundance of horseshoe worm at three out of the four NOVANA stations (see section 4.5.2). Additionally, sea potato *(Echinocardium cordatum)* dominated the biomass at all four NOVANA stations in 2022 and 2023, similar to what was found in the two pre-investigation areas NSI.1-OWF and NSI.1-ECC in this study.

In Table 5-17, some of the dominating species mentioned above, are described in further detail. The dominating species are all common in the North Sea and generally very robust and adapted to very dynamic areas.

Table 5-17. Description of the most abundant infauna species in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC).

Species description
Phoronis (horseshoe worm) filters and absorbs food through a so-called lophophore, which is an extension of the coelum in the form of a tentacle crown. They live in the seabed in coastal areas down to 400 m depth and is widespread almost all over the world. (Rupert, Fox, & Barnes, 2004; Emig, 1982). It has not been possible to identify specimens to species level within the genus ***Phoronis.***
The bristle worm species ***Magelona mirabilis*** (a shovelhead worm) feeds on detritus, microalgae and smaller animals found on the surface of the sediment. *M. mirabilis* is thought to be a food source for juvenile flatfish and typically lives buried in fine sand. Typically, it is found from 0-32 m depth. It is widely distributed in the North Sea and is adapted to unstable areas with strong currents, wave activity, and mobile sediment. *M. mirabilis* can be found in high abundance where the environment allows it (Rayment & Burdett, Magelona mirabilis - A shovelhead worm., 2023).
Owenia fusiformis is a species of tubeworms, which is thin, cylindrical, and segmented, and up to 10 cm long. *O. fusiformis* lives in a tough flexible tube composed of sand grains or shell fragments glued together, buried in sand or muddy sand. They are widely distributed in coastal regions and can occur from the intertidal zone (i.e. 0 m depth) and down to 4,500 m depth. *O. fusiformis* is both a suspension- and deposit feeder (Neal & Avant, 2008).
The **sea potato/heart urchin (*Echinocardium cordatum*)** is a sea urchin species with a length of up to 6-9 cm. *E. cordatum* is a sub-surface deposit feeder, which can be found at depths from 0-200 m in sandy sediments, where they live in a permanent burrow buried at about 8-15 cm depth. They are widespread almost all over the world, except in polar seas (Hill, 2008).
The **sand burrowing brittle star (*Acrocnida brachiata*)** is usually found buried in fine sand in the littoral and sub-littoral zone, down to a depth of 40 m. Its body (circular disc) can become up to 12 mm in diameter, and its long, thin and flexible arms can reach a length of up to 18 cm (Barnes, 2008).
The bivalve mollusc **bean-like tellin (*Fabulina fabula*)** is widespread in the North Sea, i.e. in the Skagerrak and along the west coast of Jutland. *F. fabula* is both capable of filtering the water for microalgae and detritus, as well as feeding on sediment. It lives buried in fine silted or coarse sand, and filters through its siphon at the surface. It is typically found at depths of 0-55 m and is adapted to unstable areas with strong currents, wave activity and mobile **sedimen**t (Rayment, 2008)**.**
The bristle worm species ***Protodorvillea kefersteini*** occurs along open coasts in depths of 10-30 m, in coarse gravelly or shelly sand, sometimes with a slight mud content. *P. kefersteini* is tolerant of organic enrichment and can show increased abundance under slightly organic enrichment conditions (Tillin & Watson, 2023).

STATISTICAL ANALYSIS

The statistical analyses presented below are used to describe the infauna communities within the two pre-investigation areas NSI.1-OWF and NSI.1-ECC and subareas (OWF areas A1-3 and ECC1-3).

INDICES

The results from the indices (Shannon-Wiener index (H’), AMBI index and the Danish Quality Index (DKI)) presented in Table 5-18 are treated in the respective sections below.

Table 5-18. Overview of indices from the two pre-investigation areas NSI.1-OWF and NSI.1-ECC and subareas (OWF areas A1-3 and ECC1-3) with Shannon-Wiener index (H'), AMBI, Salinity and DKI-values. Salinities are included in the calculation of AMBImin and Hmax (Equation 4 and Equation 5), which both are included for the calculation of DKI (see Equation 3 in section 3.4.7 - HAPS – Infauna analysis - DKI v3 index).

Area	Station	H'	AMBI	Salinity	DKI
Total NSI.1-OWF	**A_01-06**	1.13	1.35	32.43	0.43
Total-NSI.1-ECC	**A_07-11**	1.19	1.20	31.90	0.49
A3	**A_01**	1.25	1.07	32.63	0.47
	A_02	1.16	1.33	32.51	0.51
A2	**A_03**	0.64	1.86	32.20	0.21
	A_04	1.32	1.37	32.81	0.53
A1	**A_05**	0.86	1.20	32.11	0.31
	A_06	1.52	1.30	32.34	0.54
ECC1	**A_07**	1.13	1.39	31.75	0.50
	A_08	0.89	1.28	31.55	0.48
ECC2	**A_09**	1.15	1.35	31.76	0.50
ECC3	**A_10**	1.01	1.16	32.36	0.37
	A_11	1.76	0.84	32.09	0.58

SHANNON-WIENER INDEX (H')

Species diversity, calculated as Shannon-Wiener index (H'), ranged from 0.64 to 1.52 in NSI.1-OWF, with an overall average of 1.13 ± 0.19 SE (Table 5-18). In the NSI.1-ECC area, H' ranged from 0.89 to 1.76 with an overall average of 1.19 ± 0.17 SE (Table 5-18). Values from both areas are within the range calculated for the four NOVANA stations from 2015-2023 (H': 0.76 to 1.95, see Table 4-8), and also similar to values reported for Thor OWF (see Table 4-10). Compared to the average H' reported for the inner Danish water in 2022 (H' of 2.77 (Hansen & Høgslund (red.), 2024)), H' in the pre-investigation areas and the North Sea in general, are low, suggesting an infauna community with fewer species (lower biodiversity), where some species dominate with high abundances (low evenness).

AMBI INDEX

The AMBI index at stations in NSI.1-OWF ranged from 1.07 to 1.86, with an overall average of 1.35 for NSI.1-OWF (Table 5-18), which classifies the overall area, based on the observed species, as slightly disturbed and the infauna community as unbalanced (Borja et. al., 2000) (Table 3-3). At two infauna stations (A_01 and A_05), the AMBI values were 1.07 and 1.20, respectively, indicating an undisturbed area/location and an impoverished infauna community (Borja et. al., 2000) (Table 3-3).

In the NSI.1-ECC area, the AMBI index ranged from 0.84 to 1.39 at the five stations, with an overall average of 1.20. This classifies the overall area as undisturbed and an impoverished infauna community (Borja et. al., 2000) (Table 3-3).

AMBI values at stations in NSI.1-OWF and NSI.1-ECC are comparable and within the range of AMBI values found at the four NOVANA stations, where AMBI ranged from 0.93 to 1.84 from 2015-2023 (Table 4-8). AMBI values reported for Thor OWF, just north of NSI.1-OWF, were additionally similar to AMBI values found in NSI.1-OWF (Table 4-10, Table 5-18).

DKI INDEX

The DKI index ranged from 0.21-0.54 in NSI.1-OWF, with an average of 0.43 ± 0.04 SE (Table 5-18), indicating “moderate ecological status” of the marine area/water body (if applying threshold values of DKI for “Vandområde ID 133: Vesterhavet, Nord” (water body North Sea), where DKI values between 0.4-0.6 indicate “moderate ecological status” - (Miljøstyrelsen, 2023a). Two stations in NSI.1-OWF had DKI values of 0.21 and 0.31, which indicate a “poor ecological status” of the marine area (DKI from 0.2-0.4, (Miljøstyrelsen, 2023a).

DKI values in NSI.1-ECC ranged from 0.37 to 0.58, with an average of 0.49 ± 0.03 SE (Table 5-18), indicating, as for the NSI.1-OWF area, a “moderate ecological status” of the marine area/water body (“Vandområde ID 133: Vesterhavet, Nord” (water body North Sea), (Miljøstyrelsen, 2023a). Station A10 in NSI.1-ECC had a DKI value <0.4, indicating a “poor ecological status” of the marine area (DKI from 0.2-0.4, (Miljøstyrelsen, 2023a). The other four stations had DKI values >0.4, i.e. a “moderate ecological status”.

The range of DKI values in both NSI.1-OWF and NSI.1-ECC are comparable to DKI values calculated for the four NOVANA stations from 2015-2023, where DKI ranged from 0.47 to 0.58 (Table 4-8). DKI values reported for Thor OWF (ranging from 0.78 to 0.83, Table 4-10) were higher than the DKI values in the two pre-investigation areas. The average DKI value (v.3) for the inner Danish waters is 0.69 (Hansen & Høgslund (red.), 2024), i.e. higher than the DKI found in both pre-investigation areas and at the four NOAVANA stations close to the pre-investigation areas, indicating a natural lower DKI index in this area of the North sea.

MULTIVARIATE STATISTICAL ANALYSIS

Multivariate analyses can be used to explore relationships between infauna communities and environmental variables (such as depth and sediment type) and help understanding the factors driving infauna community structure. Here, multivariate analyses were conducted to 1) investigate the variance in data and 2) to find the determining factors for infauna species abundance and -composition at the 11 infauna stations in the two pre-investigation areas and subareas (OWF area A1-3 and ECC1-3). The input data is the abundance of each species observed in the sample, and hereby the species composition (i.e. which species that are present and in which numbers they occur). Environmental parameters investigated include temperature, salinity, oxygen, depth, sediment fraction D60/D10 and sediment type (determined from ROV data, i.e. 1b - sand or 1a/1b – silty sand) measured at each of the 11 infauna stations.

VARIANCE IN DATA

The variance in species abundance between the 42 HAPS samples sampled at each of the 11 infauna stations (A01-11) is presented in an MDS plot in Figure 5-27. The MDS plot in Figure 5-27 shows that infauna species abundance in the 42 samples per infauna station is highly variable, both within one infauna station where the 42 samples are collected within an area of 1x1 km, and when comparing the samples between the 11 infauna stations. Some stations overlap, illustrated in the MDS plot by overlap of samples/points from several stations, indicating that the infauna communities are somewhat similar at these stations/samples. A 2-D stress of 0.13 (“moderate stress”) indicates a relatively strong representation of data as the stress is less than 0.2. A stress above 0.2 indicates that the interpretation of data in 2-D is subject to greater uncertainty.

The MDS plot shows a clear difference in variance in the infauna community composition in the 42 HAPS samples collected per station. 4 stations have high variance, i.e. a large spread in their samples (OWF1=A_01, OWF3=A_03, OWF5=A_05 and ECC10=A_10), and 7 stations are more similar (overlapping and closer samples i.e. more similar) with lower variance between samples (OWF2=A_02, OWF4=A_04, OWF6=A_06, ECC7=A_07, ECC8=A_08, ECC9=A_09 and ECC11=A_11). The data reveals that samples within the most varying infauna stations have low species number and abundances of each species compared to the least varying infauna stations (see Table 5-15). The reason for the variance is due to high variance between the 42 samples of each infauna station regarding which species are sampled, i.e. one species is found in a few of the 42 samples, whereas in the samples of the more similar infauna stations, the same species are found in most of the 42 samples. Sampling of species is thus more homogenous in the most similar infauna stations and highly random and heterogenous in the samples of the infauna stations with high variance between the 42 samples.

The ANOSIM analysis show that there is a significant difference in the species abundance and composition of infauna communities between samples taken at the different infauna stations (P=0.001), with a moderate strength of the analysis (a Global R of 0.574). This means that there is a difference of infauna communities between stations.

ANOSIM also allows for pairwise comparisons between stations. Looking at the R value of the pairwise comparisons of the infauna species abundance and composition at the infauna stations, three (OWF3, OWF5 and OWF10) and two stations (OWF2 and OWF4) were relatively similar (R< 0.2, which indicates minimal separation of infauna communities between samples, i.e. suggesting the infauna communities in these samples are quite similar), which can be seen in the MDS plot as stations with overlapping samples/points.

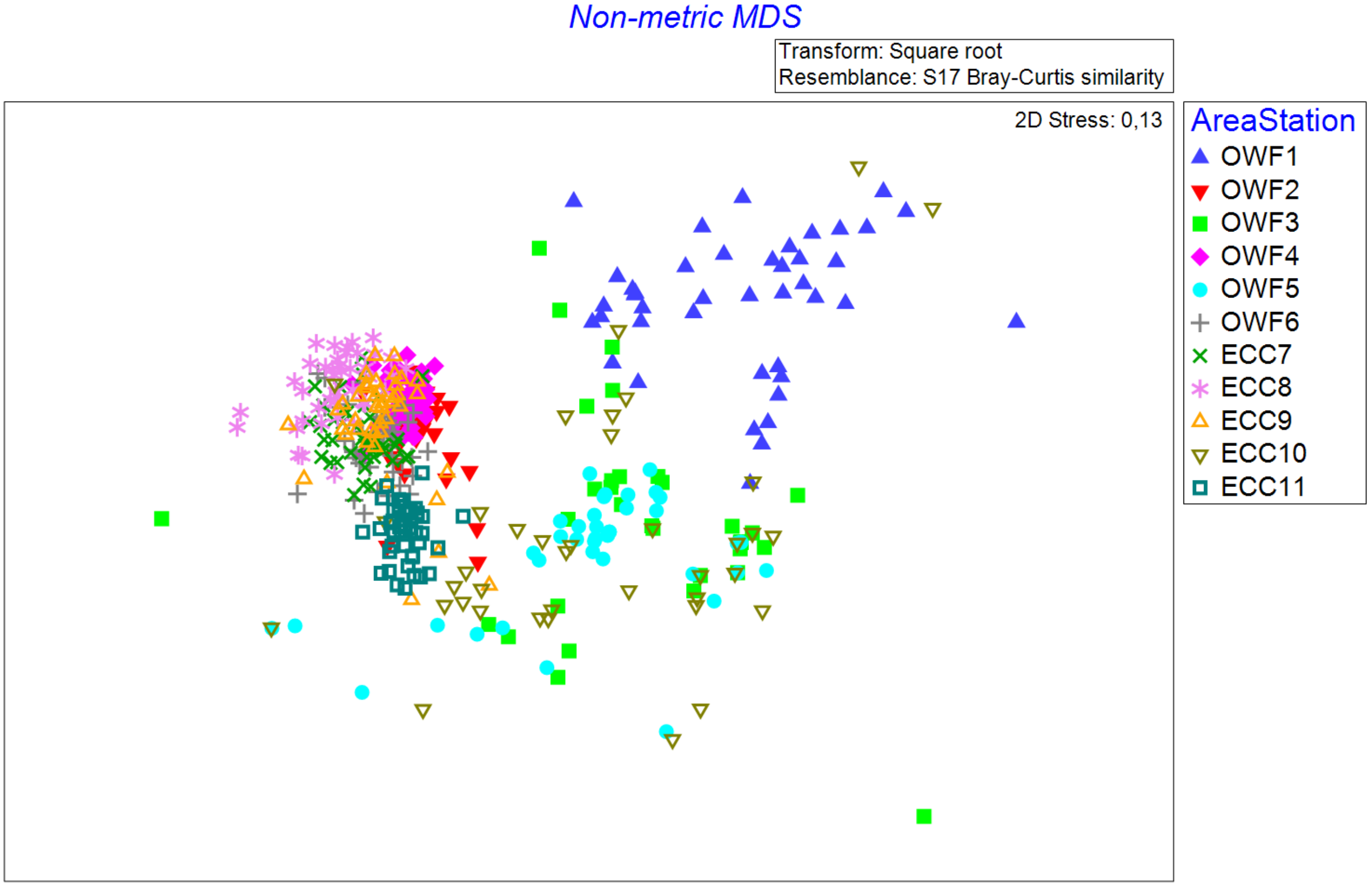


Figure 5-27. The MDS plot illustrates variance between infauna community structure (species abundance) at stations in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC) and subareas (OWF area A1-3 and ECC1-3). OWF1 is infauna station A_01 and OWF indicates that the station is placed in one of the three OWF areas. Similarly, ECC7 is infauna station A_07 and ECC indicates that the station is placed in one of the cable corridors. A total of 12 outliers were removed from the analysis due to empty samples (i.e. no specimens present in the sample) and/or low abundances and/or rare species. See also section 3.4.7 - HAPS – Infauna analysis for methods.

To compare the variance observed in this baseline study with existing data from the area, the variance at infauna station A_02 (this study) was compared with data from NOVANA station DMU1035. NOVANA station DMU1035 is located close to infauna station A_02, inside OWF area A3, within the same depth range and on the same substrate type. The MDS plot in Figure 5-28 illustrate the variance between the 42 samples collected at infauna station A_02 in this study in 2023, and the 42 samples collected at NOVANA station DMU1035 in 2015, 2017, 2019 and 2022. A stress of 0.25 indicates that the interpretation of data in 2-D is subject to greater uncertainty. However, the ANOSIM analysis supports the visual presentation of data in the MDS plot and show that there is a significant difference between the infauna communities between station A_02 (this study) and the NOVANA station between years (P=0.001, Global R=0.59 – i.e. moderate strength of analysis).

The MDS plot shows that infauna species abundance varied between years at the NOVANA station, and that the variance found at infauna station A_02 in this study is within the variance observed at the NOVANA station in different years. Furthermore, it shows that the infauna communities changes with time (clear separation of communities between years – although there is an overlap between the infauna communities in 2017 and 2019). Additionally, ANOSIM indicates low separation between these two years (R=0.125)), i.e. quite similar infauna communities at the NOVANA station in 2017 and 2019.

In conclusion, the infauna data collected in this study and at NOVANA station DMU1035 shows high variance both within the 42 samples of one infauna station, between the 11 infauna stations in this study and between years based on the NOVANA data. This highlights the natural high spatial and temporal variance in the infauna communities in this area and in the dynamic North Sea in general.

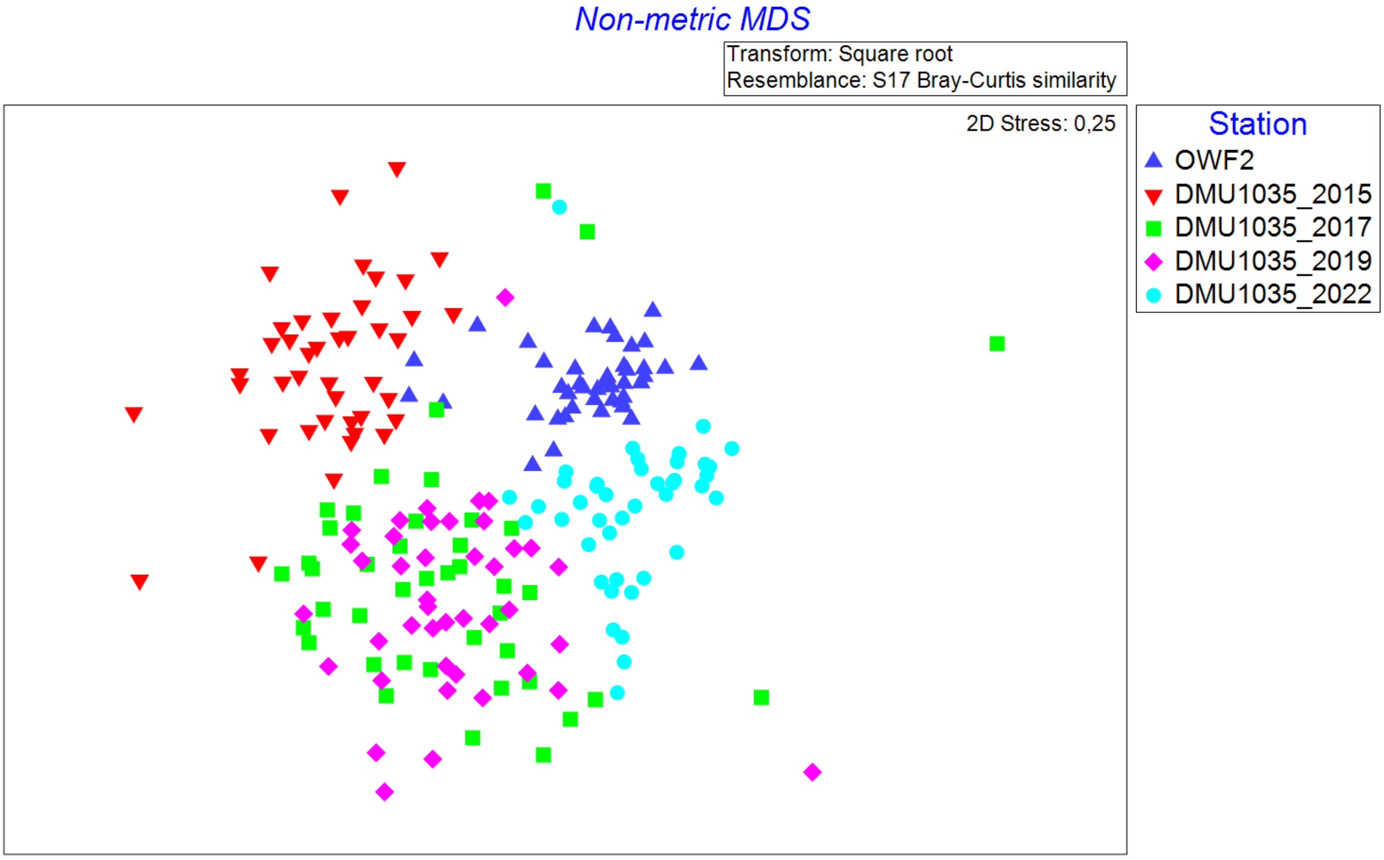


Figure 5-28. MDS plot of variance within one infauna station (OWF2=A_02) and between years at NOVANA station DMU1035. The MDS plot illustrate similarities and dissimilarities in infauna species abundance and composition between station A_02 within OWF area A3 (blue triangle) and the nearest NOVANA station DMU1035 (also named st. 91300158 in Figure 4-1) between years (2015, 2017, 2019 and 2022). 42 HAPS samples are plotted per infauna station and per year. No outliers were removed from the data.

DETERMINING FACTORS FOR INFAUNA SPECIES ABUNDANCE

Multivariate statistical analyses were conducted to investigate the determining factors for infauna species abundance and composition at the 11 infauna stations in the two pre-investigation areas and subareas (OWF area A1-3 and ECC1-3). The parameters investigated statistically included temperature, salinity, oxygen, depth, sediment fraction D60/D10 and sediment type (determined from ROV data, i.e. 1b - sand or 1a/1b – silty sand).

Similar measurements were observed at all infauna stations for temperature, salinity, oxygen, depth (19-30 m) and D60/D10 due to the well mixed water column and very dynamic seabed in the area in May 2023. These parameters could therefore not explain the variances in species abundance and composition within and between the infauna stations and were therefore not determining parameters for the infauna community in this study.

Multivariate statistical analysis in this study found one determining parameter for infauna species abundance at the infauna stations - the parameter being sediment type. The sediment type was determined from the three ROV video stations recorded per infauna station (three ROV video stations within an 1x1 km area) and are shown in Table 5-15. Sediment type recorded for the infauna stations included 3 types: sediment type 1b – sand found at 3 stations (OWF1=A_01, OWF3=A_03 and OWF5=A_05), sediment type 1a/1b – silty sand at 7 stations (OWF2=A_02, OWF4=A_04, OWF6=A_06, ECC7=A_07, ECC8=A_08, ECC9=A_09 and ECC11=A_11) and finally one station with a mixed sediment type including both sand (mainly) and silty sand (ECC10=A_10).

The difference in variance observed between the 11 infauna stations in Figure 5-27 is explained by the sediment type at the infauna station in the MDS plot in Figure 5-29 and in Table 5-19 below. The MDS plot of species abundance and composition divided into sediment type shows that infauna stations with highest variance (samples more spread out in the MDS plot) was placed on sand (1b). The mixed station with both sand and silty sand also showed high variance, whereas stations placed on silty sand (1a/1b) were more similar with greater overlap of samples. The placement of the station in the OWF or ECC subareas had no impact on the variance in infauna species abundance and -composition, showing that the infauna community was determined by sediment type and that the placement within pre-investigation areas was not important.

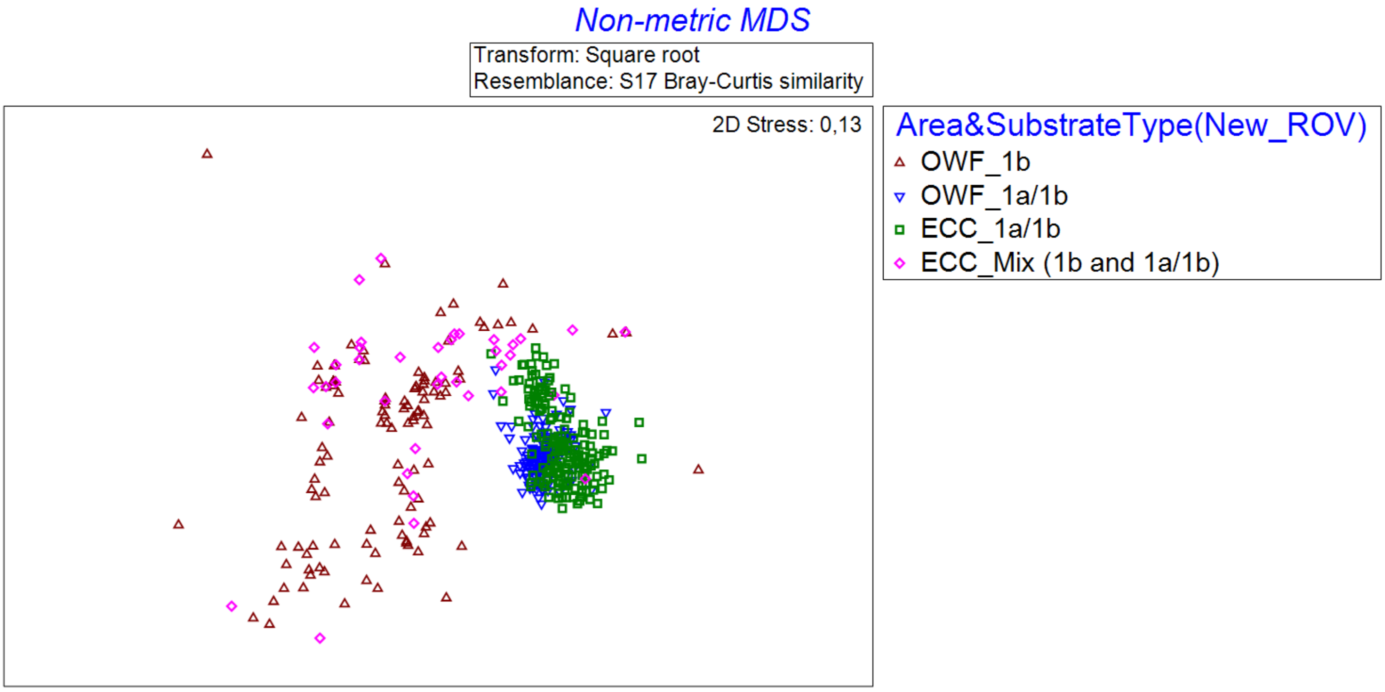


Figure 5-29. MDS plot of variance of species abundance according to sediment type. Multivariate analysis of similarities and dissimilarities regarding infauna species composition and abundance as determined by sediment type in the two pre-investigation areas NSI.1-OWF and NSI.1-ECC and subareas (OWF area A1-3 and ECC1-3). Sediment types are divided into sediment type 1b – sand, sediment type 1a/1b – silty sand and a mix of sand and silty sand (see Table 5-15). A total of 12 outliers were removed from the analysis due to empty samples (i.e. no specimens present in the sample) and/or low abundances and/or rare species. See also section 3.4.7 - HAPS – Infauna analysis for methods. A 2-D stress of 0.13 ("moderate stress") indicates a relatively strong representation of data in the MDS plot.

The ANOSIM analysis show that there is a statistically significant difference in the composition and abundance of infauna communities between samples taken at different sediment types (1b – sand, 1a/1b – silty sand and mix) (P=0.001) and with a moderate strength of the analysis (Global R=0.518). Looking at the pairwise comparisons between sediment types/subareas, i.e. including same sediment type in the two pre-investigation areas, it is evident that infauna species abundance and composition are significantly different between all combinations of sediment types/areas (P<0.05). However, the R value for the comparison between "OWF_1b" (i.e. sandy sediment in area NSI.1-OWF) and "ECC_Mix (1b and 1a/1b)" (i.e. mixed sediment types in area NSI.1-ECC) was very low (0.019). The low R-value of 0.019 between "sand" and "mix" suggests, that while there is a statistically significant difference, the actual ecological separation of infauna communities between these two sediment types is minimal. In other words, the infauna communities in "sand" and "mix" are quite similar, despite being statistically different. This is supported by the sediment types being somewhat similar (sand) as the "mixed" station mostly consists of sand (2 ROV stations with sand and one with silty sand). Samples taken at "OWF_1a/1b" and "ECC_1a/1b" also had a low R value (0.143), similarly indicating a minimal ecological separation between infauna communities with similar sediment types independent of subarea, i.e. the subareas (OWF and ECC) have largely overlapping infauna communities or share many of the same species. For the remaining comparisons between sediment types/subareas, R was >0.67, indicating a strong ecological separation/difference between the infauna communities present in those sediment types/areas.

A SIMPER analysis of the similarities and dissimilarities between species abundance and composition in samples placed on the three different sediment types (1b – sand, 1a/1b – silty sand and a mix of these) were also conducted to identify, which species contributed most to the differences/similarity in infauna community composition observed between and within sediment types. The similarities of infauna abundances and composition within an area with the same sediment type and dissimilarities between areas with different sediment types are shown in Table 5-19. The lowest similarity in the infauna community was in NSI.1-OWF for samples consisting of sand (i.e. "OWF_1b", 18% similarity) and in NSI.1-ECC for samples in a mix of sand (mainly) and silty sand (1b and 1a/1b, respectively) (i.e. "ECC_Mix 1b and 1a/1b", 17% similarity). Highest similarity in the infauna community was found in NSI.1-OWF for samples collected in silty sand (51%). Thus, samples collected in silty sand were most similar and samples collected on sand most dissimilar as shown in Figure 5-29, where dissimilarity is seen as samples with highest variance (spread) and similarity as samples which overlap and are close together in the MDS plot.

Highest dissimilarities in the infauna community were observed between samples taken on sand and silty sand in area NSI.1-OWF (96%) and in NSI.1-ECC (96%). Also, high dissimilarities in the infauna community (>90%) were found between samples taken on silty sand and mixed sediment. Lowest dissimilarity in the infauna community (60%) was observed between samples from NSI.1-OWF and NSI.1-ECC on silty sand (Table 5-19), indicating somewhat similar and overlapping infauna communities between these two areas.

Table 5-19. Similarities (blue cells) and dissimilarities (white cells) in species composition and abundances between different substrate types as indicated in Figure 5-29.

Substrate Type	**OWF_1b**	**OWF_1a/1b**	**ECC_1a/1b**	**ECC_Mix (1b and 1a/1b)**
OWF_1b	18	96	96	86
OWF_1a/1b	96	51	60	91
ECC_1a/1b	96	60	39	90
ECC_Mix (1b and 1a/1b)	86	91	90	17

SIMPER showed that *Phoronis* sp. (horseshoe worm) was the species that contributed mostly (>25%) to the dissimilarities in the infauna community observed between samples taken at sediment type 1b and 1a/1b, respectively. This is evident in the data, as *Phoronis* sp. was observed in high numbers in HAPS samples taken on silty sand and only in a few samples taken in areas consisting of sandy sediment.

For samples taken in the two areas with sandy sediment (OWF_1b and ECC_mix (i.e. 2xsand and 1x silty sand)), the same species were present though in different abundances between the two areas. The bristle worm species *Nephtys cirrosa* and *Magelona mirabilis* both contributed ~10% to the dissimilarities observed in the infauna community between samples in these two areas, where *Magelona mirabilis* occurred in higher abundances in the mixed sediment type and *Nephtys cirrosa* in slightly higher abundances in the sandy sediment type. These two species were among the most dominating species in the western located stations within NSI.1-OWF – i.e. the stations located on sandy sediment.

For the two areas NSI.1-OWF and NSI.1-ECC with the same sediment type consisting of silty sand (1a/1b), the same species were present in the samples, but in different abundances. *Phoronis* sp. was the species contributng the most to the dissimilarities observed in the infauna community between samples in these two areas (18%), followed by the bristle worm species *Magelona mirabilis* (~6%) and *Owenia fusiformis* (6%), where all three mentioned species were present in higher abundances in NSI.1-OWF compared to NSI.1-ECC.

CONCLUSION FOR INFAUNA

Species numbers, abundances, biomasses, class and dominating species found in the two pre-investigation areas, NSI.1-OWF and NSI.1-ECC and subareas (OWF areas A1-3 and ECC1-3), are all comparable with other data sampled in the area (e.g. NOVANA, Thor OWF, Vesterhav Syd).

It is evident, that there is a high variation between samples both within and between the two pre-investigation areas with regard to number of species, abundance and biomass of infauna. When looking at overall average number of species, together with abundances and biomasses, the two pre-investigation areas are comparable to each other. Furthermore, class and species distribution of infauna in the two pre-investigation areas were similar, both in terms of abundance and biomass. The large, small-scale variance (between the 42 samples per infauna station) and the much lower, large-scale variance between infauna stations A_01-11, is typical of a very dynamic area, with a high degree of mixing and transportation of the seabed comparable to a bucket of sand being continually mixed. Furthermore, all benthic fauna (including infauna) spreads and re-colonize areas by larval drift. In the North Sea, larvae are transported along the West coast of Jutland, and it is thus, overall, the same benthic community that is seeded and lives along this dynamic coast.

Three different indices were applied to investigate biodiversity (H') and the quality of the marine ecosystem (AMBI and DKI) based on the composition and abundance of the infauna community in the area. Species diversity (Shannon-Wiener index, H') was similar in both pre-investigation areas (1.13 and 1.19 in NSI.1-OWF and NSI.1-ECC, respectively) and comparable to H' found for the closest NOVANA stations and for Thor OWF, but lower than the average H' reported for the inner Danish waters in 2022. A lower H' suggests an infauna community with fewer species (lower biodiversity) where some species dominate with high abundances (low evenness). The overall environmental health and quality of the marine ecosystem in the area is found by the AMBI index. The average AMBI values found in NSI.1-OWF and NSI.1-ECC was 1.35 and 1.20, respectively, which are comparable and within the range of AMBI values found in the surrounding area. The AMBI value in NSI.1-OWF classifies the overall area as slightly disturbed and the infauna community as unbalanced. The slightly lower AMBI in NSI.1-ECC classifies the overall area as undisturbed and an impoverished infauna community. The Danish Quality Index (DKI) combines factors such as Shannon-Wiener diversity and AMBI. The average DKI in NSI.1-OWF and NSI.1-ECC was 0.43 and 0.49, respectively, indicating a "moderate ecological status" of the marine area/water body ("Vandområde ID 133: Vesterhavet, Nord" (water body North Sea)). DKI in the two pre-investigation areas were comparable to DKI values calculated for the NOVANA stations in the area but, lower than DKI values reported for Thor OWF and for the inner Danish waters.

Multivariate statistical analysis showed that there is a large spatial and temporal variation between the 42 HAPS samples collected within an infauna station (= an area of 1x1 km^2) and between the 11 infauna stations due to the very dynamic conditions in the North Sea. Sediment type determined the infauna species abundance found at the 11 infauna stations. Lowest variance and most homogenous species composition (abundance of each observed species was more similar between samples) was found in the samples at infauna stations located on the sediment type 1a/1b – silty sand and highest variance and highest heterogeneity between samples was found at stations located on the sediment type 1b – sand. The multivariate statistical analysis showed there was an overall significant difference between species abundance and -composition at infauna stations between subareas and sediment types, but results from the multivariate analysis suggested that there is minimal ecological separation/difference of the infauna communities on the same sediment types in the two pre-investigation areas. The results thus indicate, that it is the same infauna community, which is present in the two pre-investigation areas and that, species abundance is determined by the distribution of silt (sediment type 1a/1b – silty sand) on the seabed, which again is likely caused by weather induced pulses of organic matter originating from the Wadden Sea, local fjords and the rivers in the Southern part of the North Sea.

6 CONCLUSION

This baseline study is comprised by a large, comprehensive sampling program providing detailed knowledge of sediment, benthic flora and fauna in the pre-investigation area for the North Sea I.1 OWF (NSI.1-OWF) and the pre-investigation area for the three export cable corridors (NSI.1-ECC) including subareas, i.e. three OWF areas (A1-3) and three export cable corridors (ECC1-3).

The sediment types in the two pre-investigation areas are dominated by “silty sand“ (sediment type 1a/1b) and “sand” (sediment type 1b), with very little area coverage of stones (<1.2%) (sediment types 2a, 2b, 3 and 4). "Silty sand” consists of sand with a surface layer of silt (few centimetres) and is more prevalent than previously found in existing studies from the area, indicating temporal and spatial variation in the silt area coverage in the area. The surface silt layer covering large parts of the sandy seabed in the two pre-investigation areas, likely originates from outflow from local fjords, the Wadden Sea and German river outlets.

Salinity, temperature and oxygen measurements in the water column showed an overall well mixed water column and a few stations with weak stratification in May 2023, and a more stratified water column in June 2023 except for the shallowest stations close to the coast, where wave mixing of the water column is more prevalent. Good oxygen conditions for benthic flora and fauna at the seabed were found in both months (>6.6 mgO_2/l). Oxygen deficiency is very rare in the North Sea on the West coast of Jutland due to the highly dynamic conditions.

Pollutants generally adsorb to fine-grained, organic-rich material. Accordingly, the highest number of exceedances of threshold values for pollutants were observed in samples collected on organic-rich silty sand (ECC2 and ECC3) and lower exceedances were observed on sand (OWF areas A1-3 and ECC1). No relationship between pollutant concentration and sample depth was observed. Furthermore, due to very low TOC contents (between 0.03 to 0.32 %), the estimated threshold for several of the pollutants based on the TOC measurements, was very low and often below the detection limit for the laboratory analysis. This makes it difficult not to exceed threshold values in marine areas with very low TOC content, as is the case for the North Sea. It is debatable whether this method is most appropriate, and exceedances of the pollutants were therefore compared with threshold values, where a TOC of 5 % was applied, as described in the Danish consolidation act BEK. no. 796 of 13/06/2023 (Miljøstyrelsen, 2023a). When applying a TOC of 5 %, only methylnaphthalenes (summed) and arsenic (the threshold is not calculated based on TOC) exceeded the threshold values in the three ECC areas. Within the three OWF areas (A1-3), only four pollutants (including arsenic) exceeded the threshold values, compared to the eight pollutants, when using the low average TOC of 0.17 %.

Observed benthic flora and fauna species and communities are all common for the North Sea and are similar to the results from other OWF areas in the Danish North Sea (Thor, Vesterhav Syd, Vesterhav Nord, Horns Rev III) regarding dominating species, benthic communities and area coverage. None of the observed species of benthic flora and fauna in the pre-investigation areas are considered threatened (Critically Endangered, Endangered or Vulnerable) according to the HELCOM red list (HELCOM, 2024a). However, the masked crab (*Corystes cassivelaunus*) is listed as Near Threatened (NT) (HELCOM, 2023b) and is commonly observed in the North Sea and was also observed in both pre-investigation areas. No evidence or indicators of biogenic reef structures from blue mussel (*Mytilus edulis*), European oyster (*Ostrea edulis*) or Sabellaria reef compositions were found.

Very few small spots of crust algae were observed in the pre-investigation area for NSI.1 (NSI.1-OWF), but none in the export cable corridors (NSI.1 -ECC). The general lack of macroalgae is mainly due to large depth and resulting light limitation in the pre-investigation areas for NSI.1 (NSI.1-OWF) and in the deeper part of the export cable corridors (NSI.1-ECC). Furthermore, the seabed is very dynamic with few larger stones (>10 cm) for attachment, which cause frequent scrubbing of the stones and covering of flora and fauna with sand.

Species number and area coverage for benthic fauna (epifauna and visible infauna) at ROV stations were determined mainly by sediment type and to a lesser degree by depth. It was observed that species number and area coverage was generally lower in OWF area A1 and ECC1, likely due to a larger area coverage of sediment type 1b – “sand”, compared to a larger coverage of sediment type 1a/1b – “silty sand” in OWF areas A2 and A3. Furthermore, OWF area A1 and ECC1 were shallower compared to the other subareas, and thus more dynamic with a coarser seabed. The same species were observed in the two pre-investigation areas and similar ranges of area coverages were observed, indicating that the species originates from the same pool of larvae being transported along the West coast of Jutland.

The same trend was also observed for abundances and biomasses of infauna species, which were comparable in the two pre-investigation areas (NSI.1-OWF and NSI.1-ECC). The largest differences were seen within the NSI.1-OWF area where fewer species, lower abundances and biomasses were found in the western part of the NSI.1-OWF, compared to the eastern part. The observed differences are due to the fact that the western part of NSI.1-OWF is dominated by "sand" and the eastern part is dominated by "silty sand" as is shown in the multivariate analysis below.

Three different indices were applied to investigate biodiversity (H') and the quality of the marine ecosystem (AMBI and DKI) based on the composition and abundance of the infauna community in the area. Species diversity (Shannon-Wiener index, H') was similar in both pre-investigation areas (1.13 and 1.19 in NSI.1-OWF and NSI.1-ECC, respectively) and comparable to H' found for the closest NOVANA stations and for Thor OWF, but lower than the average H' reported for the inner Danish waters in 2022. A lower H' suggests an infauna community with fewer species (lower biodiversity) where some species dominate with high abundances (low evenness). The overall environmental health and quality of the marine ecosystem in the area (determined by the AMBI index) is comparable with the surrounding area. The AMBI value (1.35) in NSI.1-OWF classifies the overall area as slightly disturbed and the infauna community as unbalanced. The slightly lower AMBI (1.20) in NSI.1-ECC classifies the overall area as undisturbed and an impoverished infauna community. The Danish Quality Index (DKI) combines factors such as Shannon-Wiener diversity and AMBI, where a high value (between 0.8 and 1) indicates "good environmental status". The average DKI in NSI.1-OWF and NSI.1-ECC was 0.43 and 0.49, respectively, indicating a "moderate ecological status" of the marine area/water body ("Vandområde ID 133: Vesterhavet, Nord" (water body North Sea)). DKI in the two pre-investigation areas were comparable to DKI values calculated for the NOVANA stations in the area but lower (i.e. worse status) than DKI reported for Thor OWF and for the inner Danish waters.

The multivariate statistical analysis showed, that there was a difference in infauna communities between sediment types (sand and silty sand), and that the lowest variance and most homogenous infauna species composition (abundance of each observed species was more similar between samples) was found in the samples at infauna stations located on silty sand and highest variance and highest heterogeneity between samples at stations located on sand. Furthermore, the analysis indicates that the same infauna community is present in the two pre-investigation areas, and that species abundance is determined by the distribution of silt on the seabed, which again is likely caused by weather induced pulses of organic matter originating from the Wadden Sea, local fjords and the rivers in the Southern part of the North Sea.

The observed benthic flora and fauna species in the two pre-investigation areas are robust species adapted to the very dynamic conditions in the North Sea. The observed benthic species are common along the West coast of Jutland and in this part of the North Sea (Køie & Kristiansen, 2023) and are expected to re-colonize a disturbed area (i.e. from digging, dredging and flushing project activities) within 2-5 years (Rambøll, 2020b; Vattenfall, 2020a; Essink, 1999; Essink et al., 1997). This is supported by experience from sand extraction areas in this part of the North Sea, that shows that re-colonization of benthic fauna and flora commences as soon as the dredging/disturbance in finished, and a full recovery is seen within a few years (Orbicon, 2014b; Orbicon, 2016).

Thus, the observed benthic communities of benthic flora and fauna in the two pre-investigation areas of North Sea I.1 are very common for the North Sea, widely distributed, with re-colonization times of 2-5 years and with a high recolonization potential from the surrounding similar populations and larvae drift along the West coast of Jutland.

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8 APPENDICES

Appendices are provided in a separate document.