ENERGINET

ENERGY ISLAND BORNHOLM

TECHNICAL REPORT - SEDIMENT, BENTHIC FLORA AND FAUNA

14-11-2023

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Abbreviation	Explanation
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**
Bird SPA site	New bird SPA site (Rønne Banke F129/DK00FC373) for long-tailed duck located between the two wind farm areas.
B1N	Bornholm I North subarea
B1S	Bornholm I South subarea
Bornholm I North (Nord)	Bornholm I is divided into two subsections i.e., Bornholm I North and Bornholm I South. Both areas are offshore wind farm areas. Also called Bornholm I Nord.
Bornholm I South (Syd)	Bornholm I is divided into two subsections i.e., Bornholm I North and Bornholm I South. Both areas are offshore wind farm areas. Also called Bornholm I Syd.
C°	Degree Celsius (temperature)
CC	Overlapping area of the two cable corridors in the Bornholm cable corridor section
CC1	Cable corridor from Bornholm I North wind farm area to Bornholm
CC2	Cable corridor from Bornholm II wind farm area to Bornholm
Cable corridor	Cable corridor between OWFs and Bornholm
Client	Energinet
CTDO	Conductivity-Temperature-Depth-Optical
Danish dredging manual	Den danske klapvejledning
DEA	Danish Energy Agency
DKI	The Danish Quality Index for benthic infauna used for assessment of infauna condition
DW	Dry weight
EIA	Environmental Impact Assessment
HAPS	Sediment core sampler. Samples a cylinder of sediment in soft to loose seabed sediments
INV	Station prefix for stations placed outside of the wind farm, cable corridor and SPA areas in the pre-investigation area for Energy Island Bornholm
Landfall	Is where the cable transfers from sea to land on the southern coast of Bornholm.
LOI	Loss of ignition
NSP2	North Stream 2 AG project
OWF	Offshore Wind Farm area
OWF1	Bornholm I, Offshore Wind Farm Area 1, is now divided into two subsections: Bornholm I North and Bornholm I South
OWF1 subarea	OWF1 subarea = B1N + B1S subareas
OWF2	Bornholm II, Offshore Wind Farm Area 2
Pre-investigation area	Gross area for the benthic survey including the three wind farm areas (Bornholm I North, Bornholm I South and Bornholm II) and the area in between in Danish waters
PA	Pre-investigation area
psu	Practical salinity unit
ROV	Remotely Operated Underwater Vehicle
Rønne Banke	Rønne Banke is a shallow bank area located in the middle third of the pre-investigation corresponding to the location of the SPA subarea
RBMP	River Basin Management Plan
SEA	Strategic Environmental Assessment
Shannon-Wiener index	The Shannon-Wiener Index gives a measure of the diversity of species in a community
SIMPER analysis	Similarity Percentage Analysis
SPA	Prefix for stations within the bird Special Protection Area (SPA) site
SSS	Side scan sonar
Subareas	Cable corridor area incl. CC, CC1, CC2, Bornholm I North and South (B1N and B1S), Bornholm II, SPA, INV, OWF2=Bornholm II, OWF1=B1N+B1S

Abbreviation	Explanation
TOC	Total Organic carbon given as % of DW
TR	Transect
WFD	Danish Water Framework Directive
WW	Wet weight

1 SUMMARY

INTRODUCTION

With the Climate Agreement for Energy and Industry of the 22nd of June 2020, the majority of the Danish Parliament decided that Denmark will become the first country in the world to develop two energy islands. One of these islands will be the island of Bornholm located in the Baltic Sea ("Energioe Bornholm"), with wind farms located south-west of Bornholm with an installed capacity of up to 3.8 GW. The designated wind farm areas consist of Bornholm I South (118 km^2), Bornholm I North (123 km^2) and Bornholm II (410 km^2). The wind farm areas will contain wind turbines with a maximum height of 330 m, maximum 7 transformer platforms, as well as subsea cables. The island of Bornholm will house the transformer station and serve to distribute the produced energy.

As a consequence of these political decisions a series of biological and scientific investigations will be carried out for a well-defined pre-investigation area as part of the baseline mapping of this part of the Baltic Sea. This also includes a baseline investigation of sediment, benthic flora and fauna (WP-E) in the pre-investigation area, which is presented in this technical report.

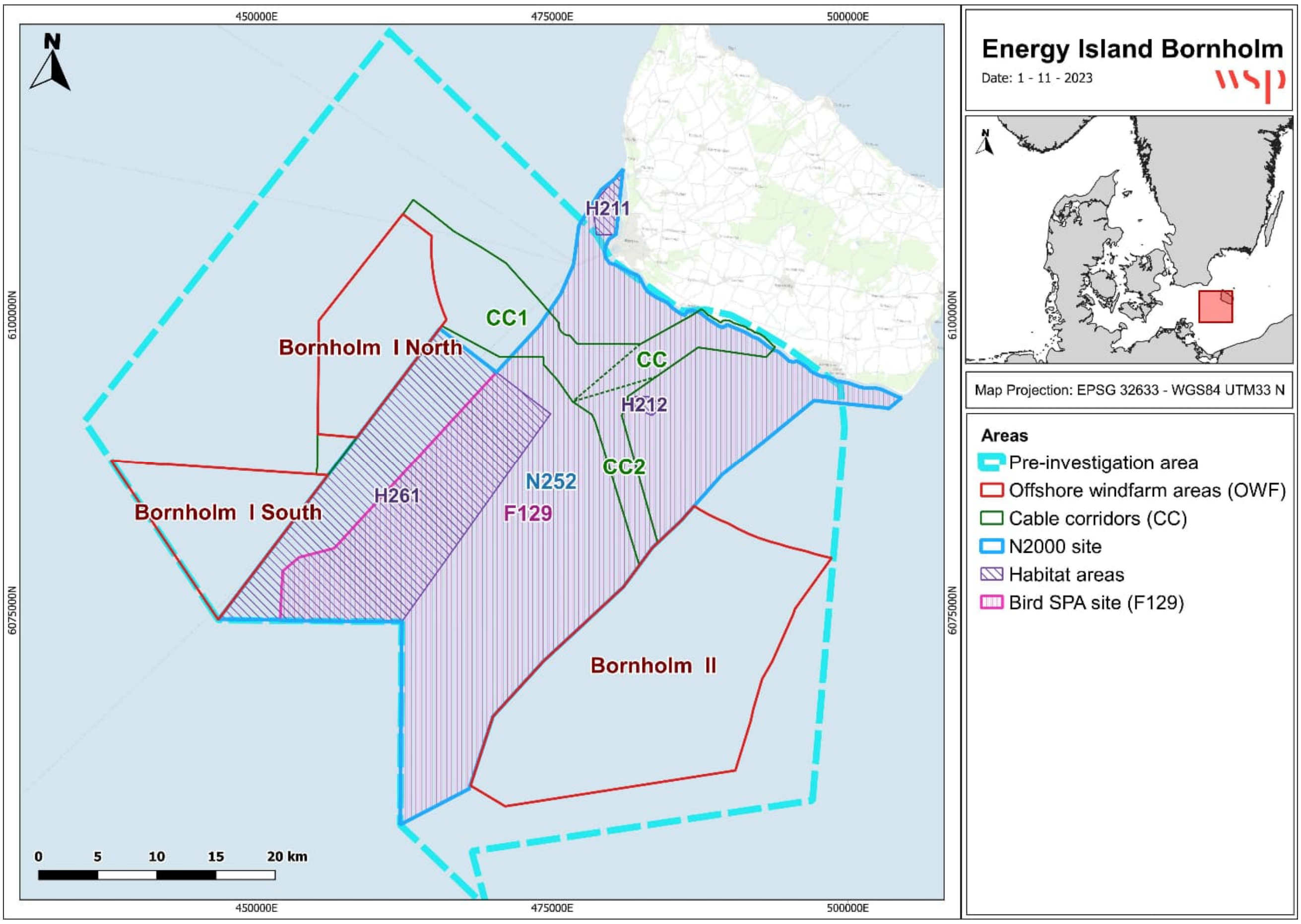


Figure 1-1. Energy Island Bornholm with indication of offshore wind farm areas (OWFs), cable corridor areas (CC), pre-investigation area, and Natura 2000 habitat areas and the new bird SPA area between the OWFs.

Figure 1-1 shows the pre-investigation area for Energy Island Bornholm with the wind farm areas Bornholm I (OWF1) North and South (B1N and B1S), Bornholm II (OWF2), cable corridor area (CC), Natura 2000 site "Adler Grund og Rønne Banke" (N252), habitat areas (H261, H212, H211) and the new bird SPA (Rønne Banke F129) within the Natura 2000 site N252. Conditions are compared between the subareas where relevant.

METHODOLOGY

Three benthic surveys were conducted during 2022 for work package WP-E Benthic flora and fauna in the pre-investigation area for Energy Island Bornholm. In total 450 stations were sampled within the pre-investigation area. Sampling activities at the stations included collection of ROV video of the seabed, CTDO-profiles of temperature, salinity, and oxygen along four transects across the pre-investigation area, HAPS sediment cores for chemical analysis and infauna analysis and, finally, Side Scan Sonar (SSS) was used to map sediment types in the OWF areas (Bornholm I and II) and the original cable corridor area within the pre-investigation area.

EXISTING DATA

Existing data were compiled from NOVANA stations, NOVANA monitoring reports, Natura 2000 basis analyses and baseline studies (Baltic Pipe and North Stream 2) from within or close to the pre-investigation area. 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

The CTDO-profiles show that the depth along the four CTDO-transects is lowest on Rønne Banke in the middle part of the transect and deepest along the outer parts of the pre-investigation area. The water column is fully mixed over the shallow Rønne Banke area (<30 meters of depth). In the deeper parts of the area on each side of Rønne Banke the water column is layered and a halocline (30-50 meters of depth) - and often also a thermocline (20-40 meters of depth) - is visible from the profiles of salinity and temperature. Additionally, a thermocline is found in the surface layers at some stations due to warming from the sun.

Bottom oxygen concentrations at the stations along the four transects ranged from 1.80 to 10 mgO_2/l. Oxygen deficiency with concentrations between 2-4 mgO_2/l was observed at 10 out of the total 46 CTDO-stations (22 %) and was observed at 41-57.9 meters of depth. Severe oxygen deficiency was observed at two stations (OWF2_22, INV_105) out of the total 46 stations (4 %) at 57.4 meters and 52.6 meters of depth, respectively.

One station within the Bornholm I South area (OWF1_11) showed moderate oxygen deficiency of 3.97 mgO_2/l. Oxygen deficiency was observed at five out of seven stations (OWF2_11, 22, 23, 26, 35) in the south-eastern part of the Bornholm II wind farm area. One station (OWF2_22) showed severe oxygen deficiency of 1.87 mgO_2/l. Only the two OWF2 CTDO-stations closest to Rønne Banke (OWF2_28 and _48) (see Figure 3-5) did not show oxygen deficiency indicating quite widespread moderate oxygen deficiency within the Bornholm II wind farm area. Oxygen deficiency was not observed in the cable corridor area.

SEDIMENT TYPES

The overall area coverage of the six observed sediment types in the pre-investigation area is presented in Figure 1-2 below. In general, the sediment type changes with depth and distance to the coast and the shallow Rønne Banke (corresponding to the Bird SPA subarea) and becomes muddier with higher organic content with distance to the bank (Figure 1-2).

The sediment types in the two wind farm areas Bornholm I (North and South) and Bornholm II differ with more muddy sediments (sediment type 1a) in the Bornholm II area. The Bornholm I areas have more area coverage of rocky sediment types (sediment type 2, 3 and 4) mainly in the part of the areas closest to the Rønne Banke area (Figure 1-2). In general, the sediment in the two cable corridors changes from “Sand” (sediment type 1b) very close to the coast, to hard “Sedimentary rock” (sediment type 4 and 3), and at 35-40 meters of depth finer sediment types such as mud and silt (sediment type 1a).

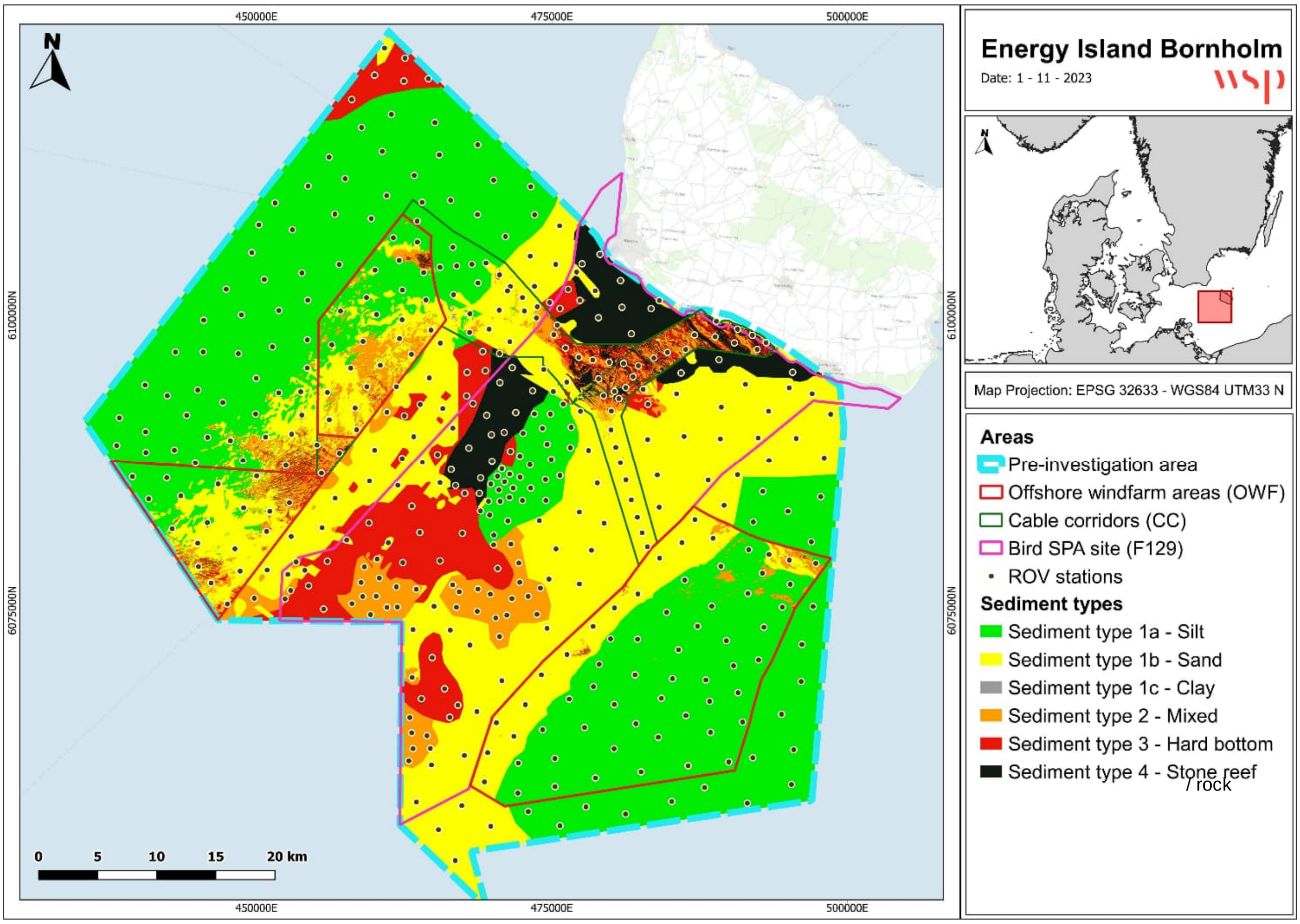


Figure 1-2. Map of sediment types in the pre-investigation area. Sediment types mapped by side scan sonar in the wind farm areas and cable corridor areas. Outside these, GEUS' sediment map is used including a few adjustments according to the ROV video of the actual sediment types observed on the seabed.

TOTAL ORGANIC CARBON (TOC)

Total organic content in the chemical HAPS samples was, generally, low, and comparable for Bornholm I South, Bornholm I North and Bornholm II with an average TOC of 1.47 % (0.30-3.6 %), 1.59% (0.97-2.8 %) and 1.60 % (0.27-5.6 %), respectively. TOC was generally lower in the cable corridor with an average of 0.15 % (<0.10-1.2 %). A few high TOC-levels were measured in all three OWF areas with maximum concentrations of 1.2 % in Bornholm I North, 2.8 % in Bornholm I South and 5.6 % in the Bornholm II wind farm area.

Measurements of TOC within the pre-investigation area showed a significant increase in TOC with increasing water depth.

NUTRIENTS

Total Nitrogen (TN) ranged from 150-5800 mg N/kg DW and Total Phosphorus (TP) ranged from 160-7700 mg P/kg DW within the pre-investigation area (Chemical HAPS stations). TN was similar to the range found in existing studies (NSP2 and Baltic Pipe) in the area (150-6000 mg N/kg DW), however, TP (170-1200 mg P/kg DW) was higher based mainly on one value of 7700 mg P/kg DW at the station CC2_06.

Concentrations of TN were generally higher in the deeper wind farm areas compared to the shallower cable corridor area. Whereas TP was generally higher at the shallower cable corridor stations compared to the deeper stations in the wind farm areas. TN and TP concentrations were within the same ranges in the two Bornholm I areas and slightly higher in the Bornholm II area.

Data from the pre-investigation area showed a significant correlation between TN and depth (p=0.00018) and TN and TOC (p<0.001) for all stations, however no significant correlation was found between TP, depth and TOC.

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), Total nitrogen (TN) and total phosphorus (TP) • Heavy metals (8): Arsenic (As), lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni) and zinc (Zn) • PAH compounds (9): Phenanthrene, anthracene, fluoranthene, pyrene, benz(a)anthracene, chrysene, benz(a)pyrene, indeno(123cd)pyrene and benzo(ghi)perylene • PCB compounds (7): 28, 52, 101, 118, 138, 153 and 180 • TBT and degradation products: DBT and MBT • Brominated flame retardants (5): PBDE 28, 47, 99, 100 and HBCDD – extra samples from 10 selected stations	1) NEQS: National Environmental Quality Standards, Danish EPA 2) EQS: Environmental Quality Standards, EU 3) EAC: The Environmental Assessment Criteria, OSPAR 4) ERL: Effect Range Low, US EPA 5) LAL: Lower Action Level, Danish Dredging Manual/Klapvejledningen

No exceedances of threshold values of the following pollutants were observed in the pre-investigation area: the heavy metals cadmium (Cd), chrome (Cr), mercury (Hg) and zink (Zn), the PAH-compounds phenanthrene, fluoranthene and pyrene as well as the seven PCB congeners. Detection limits from the laboratory analyses were, however, higher than the applied threshold values for some pollutants, which means that exceedances cannot be assessed at some stations.

In total, 11 pollutants (heavy metals (4), PAH-compounds (6) and organotin-compounds (1)) were found exceeding the applied threshold values in the pre-investigation area. Exceedances of threshold values were observed at 35 of 38 stations (92 %). This was primarily caused by the heavy metal arsenic, which was the only pollutant exceeding the NEQS threshold value at 16 of the 38 stations (42 %).

Looking at heavy metals other than arsenic, nickel exceeded threshold values at several stations (13 of 38 stations, 34 %) – however, exceedances were only of the NEQS, except for two stations that also exceeded the ERL. Lead and copper exceeded threshold values at two and five stations respectively (5 % and 13 %), but almost exclusively the LAL threshold, which is not applicable to normal sea-floor sediment (see 5.2.3 – Core indicators and threshold values). Excluding the LAL, lead did not exceed the other applied threshold values (NEQS, EQS or ERL) at any stations (0 %) and copper only exceeded other threshold values (ERL) at one station (3 %).

Exceedances were found in six PAH-compounds in the pre-investigation area: anthracene (8 % of stations), benzo(a)anthracene (5 %), chrysene (16 %), benzo(a)pyrene (34 %), indeno(1,2,3-cd)pyrene (26 %) and benzo(ghi)perylene (29 %).

Concentrations of the organotin-compound TBT exceeded threshold values at two stations (5 %).

The concentrations of five brominated flame retardants (PBDE 28, 47, 99, 100 and HBCDD) were measured at three selected stations in the cable corridor (CC_03, CC_09 and CC1_12). Only one threshold value exists for one of the brominated flame retardants, which is an EQS value for HBCDD. No exceedances of this compound were found at the three stations, and concentrations of all five compounds were below detection limits at all stations.

In general, pollutants were most prevalent in Bornholm II where also the highest concentrations of pollutants were found, compared to the two Bornholm I subareas (B1N+B1S) and the cable corridors.

BENTHIC COMMUNITIES (NATURE TYPES)

Nature type describes the distribution of benthic flora and fauna communities in an area i.e., the biology. 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 to relating to the benthic flora and fauna organisms present in the nature type.

Six different benthic communities/nature types were observed in the pre-investigation area and are listed in Table 1-2 and Table 1-3 below. Table 1-1 shows the area coverage in km^2 and % of the nature types in the cable corridor and wind farm areas.

Table 1-1. Area coverage (in km^2 and %) of the six nature types in the cable corridor and wind farm areas. * Part of another nature type (nature type 3 and 4) and not included in the total km^2 and % - e.g, Blue mussels are found mainly on hard sediment/substrate (rocks) in nature type 2, 3 and 4. Eelgrass beds were not observed. For Bornholm II and the cable corridor, Nature type 1c is part of Nature type 1a – Soft bottom community. Numbers are rounded to one or two determining decimals.

	Bornholm I North		Bornholm I South		Bornholm II		Cable corridor	
Nature type	**km^2**	%	**km^2**	**%**	**km^2**	%	**km^2**	%
1a – Soft bottom community	47.91	38.9	35.74	30.3	306.78	74.8	58.84	23.1
1b – Sand bottom community	45.75	37.1	57.30	48.6	93.13	22.7	101.44	39.9
2 – Mixed community	27.04	21.9	16.61	14.1	9.52	2.32	52.21	20.5
3 – Hard bottom community	1.97	1.6	7.66	6.5	0.83	0.20	25.77	10.1
4 – Stone reef/ rock	0.55	0.45	0.56	0.48	0.03	0.01	16.28	6.4
5 – Eelgrass beds	-	-	-	-	-	-	-	-
6 – Blue mussel beds*	2.52	2.05	8.22	7.0	0.85	0.21	33.02	13.0
Total	123.22	100.0	117.87	100.0	410.29	100.0	254.54	100.0

Note that sediment type 1a and 1c are merged into one nature type, i.e., nature type 1a – Soft bottom community. Nature type 6 – Blue mussel beds corresponds to the area of sediment type 3 and 4 with the highest coverage of blue mussels in the pre-investigation area (30-100 %). Blue mussels can be found in lower area coverage in other sediment types as well, mainly sediment type/nature type 1b and 2. Nature type 5 – eelgrass beds do occur in thin populations close to the coast of Bornholm but were not observed in the pre-investigation area.

Table 1-1 and the nature type map for the pre-investigation area (Figure 1-3) show dominance of hard bottom nature types close to Bornholm and in the shallow Rønne Banke area corresponding to the location of the Bird SPA area. Along the rims of the Rønne Banke area benthic communities connected to soft sediments such as sand “Sand bottom community” and at greater depth “Soft bottom community” on more silty sediment. The main difference in benthic communities between the mapped subareas (see Table 1-1) are a larger area coverage of soft sediments in Bornholm II wind farm area (nature type 1a) compared to the two Bornholm I areas (North and South) and the cable corridor area. Furthermore, the cable corridor area has a higher area coverage of the hard bottom benthic community compared to the wind farm areas.

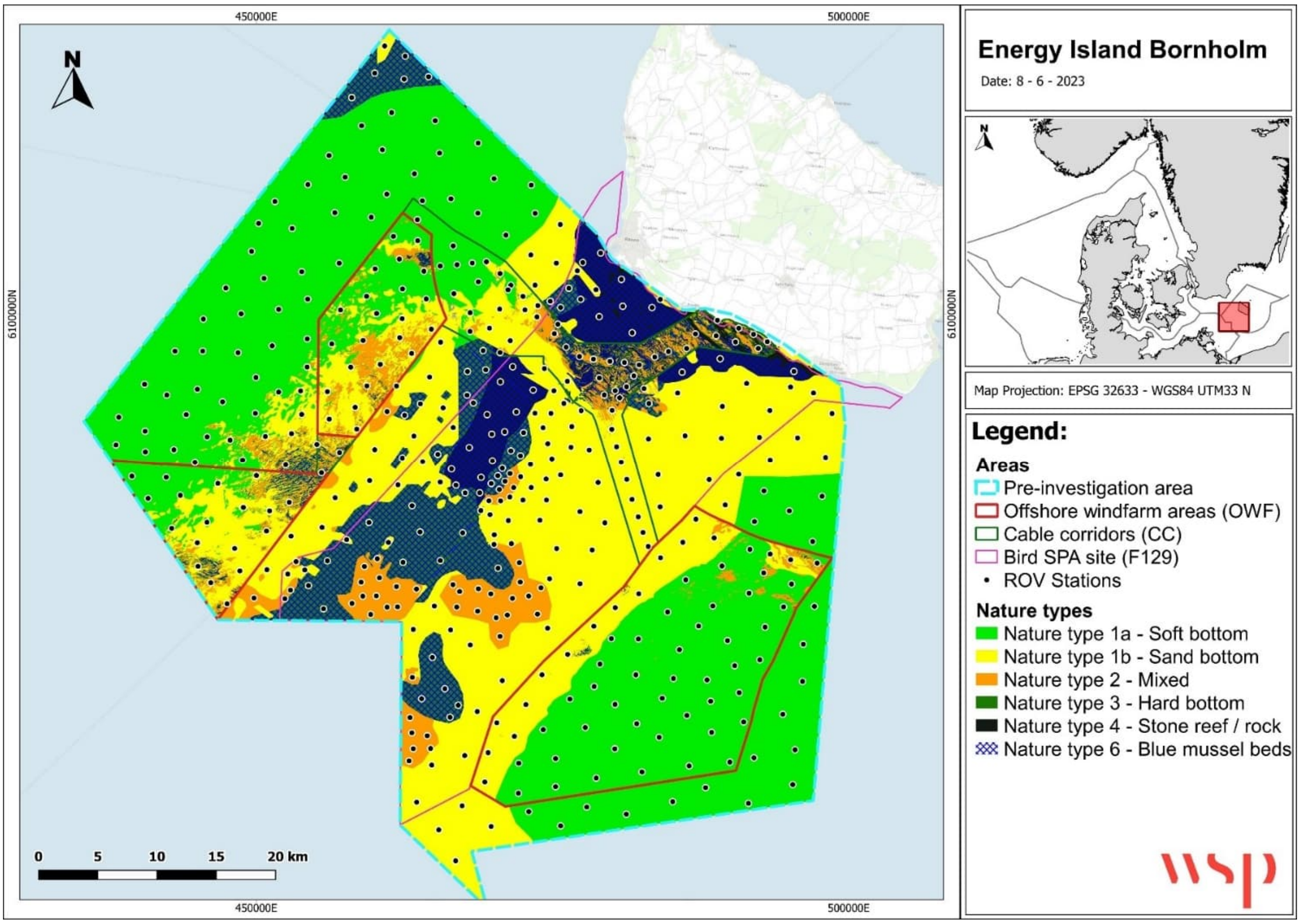


Figure 1-3. Nature type map. Based on sediment types in Figure 1-2 and observations of the associated benthic flora and fauna communities observed on the ROV video stations.

The dominating benthic flora and fauna species/taxa in each nature type are listed in Table 1-2 below.

Table 1-2. Benthic communities/nature types observed in the pre-investigation area and the dominating benthic flora and fauna species.

Nature type and community	Dominating fauna species	Dominating flora species
Nature type 1a – Soft bottom	The bristle worm *Pygospio elegans* and bivalves incl. *Arctica islandica*	None
Nature type 1b – Sand bottom	*Pygospio elegans*, Lugworm (*Arenicola marina*), and bivalves incl. blue mussels (*Mytilus* spp.)	Crust algae: red crust (*Hildenbrandia* spp.) and brown crusts
Nature type 2 – Mixed	On sand: *Pygospio elegans*, Lugworm (*Arenicola marina*) and bivalves. On rocks: blue mussels (*Mytilus* spp.), barnacles, hydrozoans, and calcareous worms	Crust algae: Red and brown crust
Nature type 3 – Hard bottom	Blue mussel (*Mytilus* spp.), calcareous worms, and barnacles	Red alga bushes and crust algae
Nature type 4 – Stone reef and sedimentary rock	Blue mussel (*Mytilus* spp.), and barnacles. Blue mussels dominate coverage at >9 m	Red alga bushes and crust algae
Nature type 5 – Eelgrass beds	-	*Zostera marina*
Nature type 6 – Blue mussel beds	*Mytilus* spp.	Red alga bushes and crust alga (*Hildenbrandia* sp.)

BENTHIC FLORA

Benthic flora in the pre-investigation area include only macroalgae as live seagrasses were not observed (dead eelgrass *Zostera marina* was observed). Observed macroalgae are summarized below.

In total 19 macroalgae species were observed on the total 434 ROV video stations. Highest species numbers were found in the cable corridor area (15 species, CC) and SPA site (14 species). One crust alga species were found in the Bornholm I area (*Hildenbrandia* sp.). No macroalgae were observed in the Bornholm II area. Macroalgae need hard substrate for attachment and light for photosynthesis. Macroalgae were, thus, observed mainly on hard sediment types (sediment type 2, 3 and 4) or on blue mussel beds (*Mytilus* spp.) and with highest coverage from 0-10 meters of depth.

Dominating species in the shallow part of the cable corridor area (CC) and the SPA area were the brown algae *Fucus vesiculosus*. In deeper waters red algae bushes such as *Polysiphonia* spp., *Ceramium* spp. and *Furcellaria lumbricalis* dominated. On the sedimentary rocks at Bornholm, *F. lumbricalis* often dominate and is overgrown by *Polysiphonia* spp. and other red algae bushes. At the deepest stations mainly red crust algae (*Hildenbrandia* sp.) and brown crust algae were observed in small patches on stones and single, small specimens of red algae bushes such as *Coccotylus truncatus* were observed.

Maximum depth for red alga bushes was 24.4 meters of depth (*Coccotylus truncatus*) (SPA_054) and 44.3 meters for crust algae (*Hildenbrandia* sp.) (INV_093). At depths deeper than 44.3 meters no macroalgae were observed due to light limitation. Macroalgae coverage was highest (100 %) close to land at 0-10 meters of depth within the cable corridor and SPA area (CC, SPA). At greater depths >10 meters within the pre-investigation area blue mussels generally dominated the hard sediment types.

BENTHIC FAUNA

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

EPIFAUNA

In total, 30 species were observed: 16 in the Bornholm I subareas and 14 in the Bornholm II wind farm area. Highest species number was observed in the SPA and INV areas with 23 and 24 species, respectively.

The dominating species on hard bottom (sediment type 2, 3 and 4), such as smaller and larger stones, was blue mussel (*Mytilus* spp.). Other common species observed on the hard bottom were barnacles, hydroids and calcareous tube worms.

On sand (sediment type 1b/nature type 1b) the bristle worm *Pygospio elegans* and lugworm (*Arenicola marina*) dominated and at greater depth (39-60 m) in the siltier sediment (sediment type 1a/nature type 1a) the bristle worm *Pygospio elegans* and the bivalve Ocean quahog (*Arctica islandica*) dominated.

Comparing the different subareas within the pre-investigation area (Figure 1-1) (CC, OWF1, OWF2, SPA and INV) fewest species and lowest area coverages (<1-50 %) are found in the wind farm areas (Bornholm I and II). The reason for this is that the OWFs are located in areas with greater water depths and with lower coverage of hard substrate/sediment types and, thus, a less varied substrate compared to the other areas (CC, SPA and INV). Highest area coverages and species numbers were found in the shallower cable corridor (CC) and bird SPA area (<1-100 %).

Blue mussels were observed to dominate on hard, rocky bottom (mainly in CC, SPA) in the pre-investigation area from 10 meters of depth and deeper.

INFAUNA

Infauna includes benthic fauna living burrowed in loose sediment. In total, 47 infauna species were found in the pre-investigation area. For the subareas within the pre-investigation area highest number of species were found in the INV and Bornholm I subareas (30 species), followed by 29 species in the CC area, 20 in SPA and 16 in the Bornholm II wind farm area.

Generally, species numbers, abundance and biomass were highest on Rønne Banke (SPA area) along its slopes and in the Bornholm I area at <40 meters of depth. Deeper than 40 meters, infauna species numbers, abundances and biomass decreased corresponding to the area where oxygen deficiency was observed (<4 mgO_2/l). In total, 28 stations out of a total of 319 stations sampled, had zero species present, and most of them (20 stations) were located in the deepest part of the pre-investigation area (= INV area). Species number, abundances and biomasses found in the present baseline study, are within the range found in other existing studies from the area, such as North Stream 2 and Baltic Pipe.

The number of infauna species found in the pre-investigation area ranged from 0-11 species per station. The number of species per station was on average 5 in Bornholm I North (B1N), 4.5 in CC area, 3.2 in the SPA area, 3.1 in Bornholm I Syd (B1S), 3.1 in Bornholm II (OWF2) and 2.3 in the INV area.

Abundances ranged from 0-39,860 individuals/m^2 per station in the pre-investigation area with average values of 2,736 in CC area, 873 in Bornholm II (OWF2), 836 in Bornholm I North (B1N), 804 in the SPA area, 618 in Bornholm I Syd (B1S), and 614 in the INV area.

Biomass is given in both wet weight (gWW/m^2) and dry weight (gDW/m^2) in the report and have similar distribution of high and low values within the pre-investigation area. Biomass given as dry weight (gDW/m^2) ranged from 0-574 gDW/m^2 in the pre-investigation area with average values of 75 in Bornholm I North (B1N), 36 in the CC area, 19 in the INV area, 14 in Bornholm I Syd (B1S), 10 in the SPA area, and 6 in Bornholm II (OWF2).

Infauna abundances (number of individuals/m^2) and biomass divided into classes, showed that bristle worms (polychaetes) dominated abundances, i.e., had highest individual numbers, in all subareas (B1N, B1S, OWF2, SPA and INV), except for the cable corridor area (CC), where bivalves dominated abundances. Biomass was dominated by bivalves in all subareas. The dominating infauna species in the total pre-investigation area (B1N, B1S, OWF2, CC, SPA, INV) based on abundances of the species were the bristle worm *Pygospio elegans,* the bivalve *Mytilus* spp., the bivalve species *Limecola balthica*, the bristle worm *Scoloplos armiger* and worms from the subclass *Oligochaeta*. The observed species are all common in Danish waters and in the Southwestern Baltic Sea around Bornholm. However, the amphipod *Pontoporeia femorata* (Amphipod) is on HELCOMs Red List and is listed as of Least Concern (LC) and was found in both the INV area (at 4 stations) and the Bornholm II (OWF2) area (at 11 stations).

The combination of the AMBI and Shannon-Wiener diversity indices (H') can be used to describe and to index the state of the environmental condition and can assess whether the infauna community is negatively impacted by eutrophication and oxygen depletion events. A low value of AMBI and high value of H' indicates good environmental conditions and vice versa. Species diversity in the pre-investigation area and the subareas within was investigated by the Shannon-Wiener diversity index (H'). The average H' for the whole pre-investigation area including all sampled stations was 0.78 ± 0.56. The highest species diversity was observed in the two Bornholm I subareas (1.07 ± 0.59), followed by the CC area (1.00 ± 0.55), and was lowest in the INV area (0.49 ± 0.55). The species diversity in the pre-investigation area given by the Shannon-Wiener diversity index shows, that the diversity is within the range found in Danish waters, though lower than the average (ranging between 0.2-3.1 with an average of 1.8 for Danish waters).

The AMBI index classified the infauna community and location as “unbalanced” and “slightly disturbed”, respectively, in all subareas within the pre-investigation area for Energy Island Bornholm. The average AMBI index found in the pre-investigation area using all data was 2.7, and comparable with the average AMBI index found in Danish waters (2.9). The dominating ecological fauna group was group III, which are defined as generalist species that are tolerant to excess organic matter enrichment.

Multi-Dimensional Scalling (MDS; based on Bray-Curtis similarity index), ANOSIM analysis and SIMPER analyses were used to analyse the similarity (within each subarea) and dissimilarity (between subareas) regarding infauna species composition and abundances/biomasses in the subareas of the pre-investigation area (B1S, B1N, OWF1, OWF2, CC, SPA and INV). Comparison between species and abundances between the subareas showed that the infauna communities were significantly different ($p<0.01$). This difference was caused by variance in the abundances of the species (number of individuals), not a difference in the species composition between the subareas, as it was the same species that dominated alle subareas. Comparison of the infauna species and abundances for 10-meter depth intervals showed similar infauna communities at all depths except when comparing the lowest (0-10 m) and deepest (50-60 m) depth intervals. This difference in infauna communities between the shallowest (0-10 m) and deepest samples (50-60 m) were likely caused by i) differences in sediment type (rocky sediment><soft sediment), ii) TOC content as TOC generally increases with depth and finally iii) more stations with moderate and significant oxygen deficiency at the deep soft sediment stations at >40 meters of depth (sediment type 1a), which correspond to very different living conditions for infauna when comparing shallow and deep stations.

BIRD FOOD PROGRAMME

A new Danish bird protection area (SPA site, F129) is placed in the middle of the pre-investigation area between the two wind farm areas. The SPA is designated to protect one bird species - long-tailed duck (*Clangula hyemalis*). The distribution of known food organisms for birds and especially long-tailed duck was, therefore, investigated in the pre-investigation area. A comprehensive program was conducted mapping the distribution of blue mussels and other bivalves, crustaceans, bristle worms and snails, which are preferred food organisms for long-tailed duck. The mapping showed that the most abundant food source available for long-tailed duck in the pre-investigation area is blue mussels and thereafter other bivalves (such as *Astarte* sp. followed by *Limecola balthica*, *Arctica islandica* and *Cerastoderma glaucum*), which are dominant in the SPA area and in the western part or the pre-investigation area, where the two Bornholm I areas are located. Other food sources such as bristle worms, crustaceans and snails occurred in low biomasses in the pre-investigation area.

CONCLUSION

This baseline study is comprised by a large, comprehensive sampling program and the acquired data material exceeds that used in the existing baseline studies for the big pipeline projects in the area (Baltic Pipe and North Stream 2).

The observed sediment types varied with depth, showing sand and then sedimentary rock and stony sediment (sediment type 4 and 3) in the cable corridors, bird SPA area and Bornholm I subareas close to land. At the deepest stations more silty and muddy sediment (sediment type 1a) was observed. The Bornholm II area had a higher area coverage of muddy sediments (sediment type 1a) compared to Bornholm I and the cable corridors and the Bornholm I areas had a higher area coverage of rocky sediment types (sediment type 2, 3 and 4) than that of the Bornholm 2 area as well as the cable corridors, mainly close to the shallower Rønne Banke area. Hence this; there is a higher area coverage of hard bottom communities in the cable corridors and the Bornholm I areas compared to Bornholm II, which instead was dominated by more soft bottom communities.

Abiotic data showed mixing and full oxygenation of the water column over the shallow Rønne Banke area and stratification of the water column in the deeper parts (>30 meters of depth) along with moderate (2-4 mgO$_2$/l) and severe oxygen deficiency (<2 mgO$_2$/l) at some stations at depths deeper than 41 meters of depth. Severe oxygen deficiency that causes death of benthic flora and fauna was observed at one station in the Bornholm II area (OWF2_22) at 57.4 meters of depth. Moderate oxygen deficiency was observed in most of the Bornholm II area but was only observed at one station in the Bornholm I area. Oxygen deficiency was not observed in the cable corridor area. The more widespread oxygen deficiency observed in the Bornholm II area compared to the Bornholm I areas was likely coursed by depth differences, with the Bornholm II wind farm area being deeper with a larger part of the area with depths below 41 m.

Chemical analyses of sediment samples from the pre-investigation area show that 11 pollutants (heavy metals (4), PAH-compounds (6) and organotin-compounds (1)) were found exceeding the applied threshold values in the pre-investigation area at 92 % of the sampled stations (HAPS Chem stations). Most exceedances of pollutants were found at >34 meters of depth, in sediment type 1a containing silt, mud and clay as pollutants generally adsorb to fine-grained, organic-rich material and accumulate with depth (Strand & Larsen, 2013). This is likely also the reason for more observed exceedances of threshold values for pollutants in the Bornholm II wind farm area compared to the Bornholm I subareas (B1N+B1S) and the cable corridors.

Observed benthic flora and fauna species and communities are all common for the Southwestern part of the Baltic Sea and observed with similar dominating species, abundances, biomasses, benthic communities, and area coverage as reported in the existing baseline studies for Baltic Pipe, North Stream 2, Natura 2000-baseline analyses and at NOVANA stations in the area.

The highest species numbers, area coverage (%) and biomass of both benthic flora (macroalgae) and benthic fauna (epifauna and infauna) were generally found where hard sediment types (sediment type 2,3 and 4) were present corresponding to areas with the most varying sediment types and to the shallower parts of the pre-investigation area (Rønne Banke area). Data show similar epifauna and infauna species composition in the wind farm areas, only abundance of the species varied. Very little macroalgae coverage (<1-1 %) was found in the Bornholm I wind farm subareas and none in the Bornholm II wind farm area.

The dominating macroalgae, epifauna and infauna species in the pre-investigation area are generalists that are able to recolonize a disturbed area within a few years (<1-5 years). This is based on the observed macroalgae, e.g. red algae bushes and large brown algae in the area, which can recolonize boulders within one to a few years. Bristle worms in the pre-investigation area have a relatively short life cycle/generation time and are expected to recolonize after one or two growth seasons. The observed bivalve species live longer and recolonization to baseline coverage will take longer. Baltic macoma (*Limecola balthica* formerly known as *Macoma balthica*) and blue mussels (*Mytilus edulis*) have a generation time of approximately 2-4 years, while sand gaper (*Mya arenaria*) and common cockle (*Cerastoderma edule*) have generation times of approximately 2-5 years. Barnacles (based on *Semibalanus balanoides*) have a generation time of approximately 1-2 years.

None of the observed species of benthic flora and fauna in the pre-investigation area are considered threatened (Critically Endangered, Endangered or Vulnerable) according to the HELCOM red list. The two brown algae species *Fucus serratus* and *Fucus vesiculosus* and the red algae species *Furcellaria lumbricalis* are, however, listed as Least Concern (LC). The infauna species *Pontoporeia femorata* (Amphipod) is on HELCOMs “Red List” and is listed as Least Concern (LC). *Pontoporeia femorata* was found in both the INV area (at 4 stations) and the Bornholm 2 area (at 11 stations, OWF2).

Thus, the observed benthic communities of benthic flora and fauna in the pre-investigation area for Energy Island Bornholm are very common for the Southwestern Baltic, widely distributed, with generations times of <1-5 years and with a high recolonization potential from the surrounding similar populations.

The bird food mapping in the pre-investigation area demonstrated, that the main food sources available for long-tailed duck in the area are blue mussels and other bivalves, which are dominant and with the highest biomasses in the SPA area and in the western part or the pre-investigation area, where the two Bornholm I areas (B1N and B1S) are located, respectively. Thus, the pre-investigation area provides a wide feeding area for long-tailed duck and other birds, with the main part of the food available for the birds consisting of dense coverages of blue mussels (up to 100 %) within the SPA area.

2 INTRODUCTION

2.1 BACKGROUND

With the Climate Agreement for Energy and Industry of the 22ndnd of June 2020, the majority of the Danish Parliament decided that Denmark will become the first country in the world to develop two energy islands. One of these islands will be the island of Bornholm located in the Baltic Sea ("Energioe Bornholm"), with wind farms south-west of Bornholm with an installed capacity of up to 3.8 GW. The designated wind farm areas consist of Bornholm I South (118 km^2), Bornholm I North (123 km^2) and Bornholm II (410 km^2). The wind farm areas will contain wind turbines with a maximum height of 330 m, maximum 7 transformer platforms, as well as subsea cables. The island of Bornholm will house the transformer station and serve to distribute the produced energy.

As a consequence of these political decisions a series of biological and scientific investigations will be carried out for a well-defined pre-investigation area as part of the baseline mapping of this part of the Baltic Sea. This also includes a baseline investigation of sediment, benthic flora and fauna (WP-E) in the pre-investigation area, which is presented in this technical report.

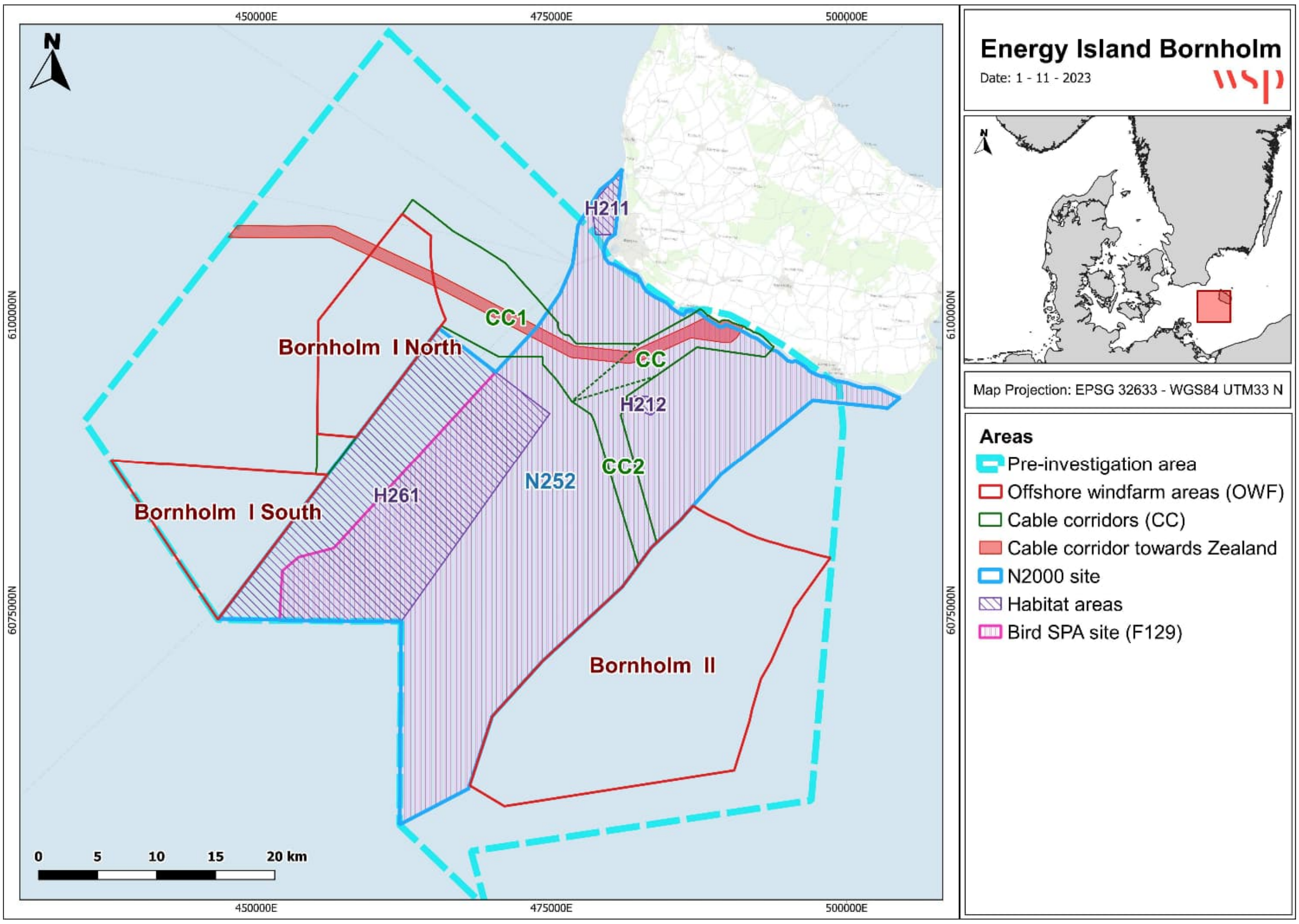


Figure 2-1. Energy Island Bornholm. The cable corridor to Zealand (red corridor) is not included in this technical report, which only concerns the pre-investigation area for Energy Island Bornholm.

Figure 2-1 shows the pre-investigation area for Energy Island Bornholm with wind farm areas Bornholm I North and South (B1N and B1S), Bornholm II, cable corridor area (CC), Natura 2000 site "Adler Grund og Rønne Banke" (N252), habitat areas (H261, H212, H211) and the new bird SPA (Rønne Banke F129) within the Natura 2000 site N252. Conditions are compared between the subareas where relevant.

The cable corridor from Bornholm to Zealand (see Figure 2-1) is reported in a separate report and not included in this report, which concerns only the pre-investigation area for Energy Island Bornholm.

2.2 AIM

This is the technical report for WP-E Sediment, Benthic flora and fauna for Energy Island Bornholm. This report presents existing data and survey data for the pre-investigation area for Energy Island Bornholm (see Figure 2-1), 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 concerns the pre-investigation area, including the two planned windfarm areas (Bornholm I North and South and Bornholm II) and the cable corridors from the wind farm areas to Bornholm (CC, CC1 and CC2) (see Figure 2-1).

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

- Abiotic parameters
- Seabed sediment characteristics
- Benthic flora
- Benthic fauna
- Bird food sources within the full pre-investigation area, the SPA site and the other subareas, e.g. OWF area and cable corridors

3 METHODOLOGY

In the following the sampling program, equipment and methods are described for WP-E Benthic flora and fauna. For more details on sampling see Appendix 1 or the Operational report (Energinet, 2022a). All station numbers are shown in Appendix 2, as station numbers have been excluded from some figures to increase readability of the figure.

3.1 SAMPLING PROGRAM

3.1.1 THREE SURVEYS

Three benthic surveys were conducted during 2022 for work package WP-E Sediment, benthic flora and fauna (Table 3-1). Sampling overview of the different surveys and stations are presented in Appendix 1.

Survey 1: Benthic survey for Energy IslandBornholm was conducted in March (3rd-20th) with the vessel Skoven and sampled most ROV-stations within the pre-investigation area for mapping and quantification of benthic flora and -fauna, and sediment samples with HAPS sampler for infauna quantification and for chemical analysis of pollutants.

Survey 2: Coastal survey was conducted in August (16th-17th) with the small vessel Sephia at the shallowest, most coast-near stations, which could not be reached by the bigger ship Skoven.

Survey 3: CTDO survey was conducted in November (2nd-3rd) with the vessel Skoven to collect CTDO-profiles that failed during survey 1. The relocation of the samples from August to November increased the value of the CTDO-data for determining oxygen deficiency in the pre-investigation area, which is more likely to be measurable late summer and autumn.

Table 3-1. Survey overview for the three surveys under WP-E Sediment, benthic flora and fauna.

Survey number	Ship	Survey name	Date	Activity
Survey 1	Skoven	Benthic survey	March 3rd-20th 2022	ROV, HAPS Infauna, HAPS Chem
Survey 2	Sephia	Coastal survey	August 16th-17th 2022	ROV, HAPS Infauna, HAPS Chem
Survey 3	Skoven	CTDO survey	November 2nd-3rd 2022	CTDO

3.1.2 SAMPLING STATIONS

The sampling program for the pre-investigation area, including the two wind farm areas (Bornholm I and Bornholm II), the cable corridors (CC, CC1 and CC2) and the bird SPA site (F129) are presented in Figure 3-1, Table 3-2 and in detail in Appendix 1. All sampling stations with station number are presented in Appendix 2 as station numbers can be difficult to see in the smaller figures in the report.

The sampling program is assembled to sufficiently cover and describe sediment and biological communities in all sediment types in the pre-investigation area. Stations have furthermore been placed within the shallow depth range (0-20 m) and deeper depth range (>20 m) and the 20 meters depth curve is shown in Figure 3-1. CTDO transects and stations are presented in Figure 3-5.

Observed epi-fauna and -flora and infauna species distribution, - coverage and - biomass (only infauna) are then used to describe and map the distribution of these groups in the pre-investigation area including the OWFs, cable corridors and the bird SPA site. Note that fish are not reported in this technical report for sediment, benthic flora and fauna but all observations of fish species are listed in the logbooks (see Appendix 3).

The number of HAPS, ROV and CTDO stations that are sampled within the two wind farm areas (Bornholm I North and - South and Bornholm II (Figure 3-2), the cable corridors (Figure 3-3), the bird SPA site (Figure 3-4) and the remaining part of the pre-investigation area are presented in Table 3-2 and in Figure 3-1. For more details see Appendix 1 and 2.

Some stations are situated within several subareas (e.g., OWF1, OWF2, CC, SPA and INV) and are only counted once in Table 3-2 below to get the correct total of each sampling type in the Table (HAPS Infauna, HAPS Chem, ROV stations and CTDO stations). However, all stations present in each subarea are listed in section 3.1.3 below and can be seen in Figure 3-1, Figure 3-2, Figure 3-3, Figure 3-4 and Figure 3-5 below and with station number in Appendix 2. Analyses of data within the subareas (= CC, Bornholm I North and South, Bornholm II, SPA and INV) in section 5 – Survey data, includes all stations within the subarea no matter the prefix.

Stations are named according to the following (Prefix_):

- **OWF1** stations are placed within the original Bornholm I area. This area has subsequently been divided into two subareas Bornholm I North and Bornholm I South. Thus, some OWF1 stations are now placed in the area between the two sub areas (see Figure 3-2).
- **OWF2** stations are placed within the Bornholm II wind farm area.
- **CC** stations are placed in the cable corridors/area between the wind farm areas and Bornholm. The cable corridors from Bornholm I and II to Bornholm are called CC1 and CC2, respectively. The stations in the overlapping part of the two cable corridors close to the coast are called CC. Stations in the small cable corridor area between Bornholm I North and South are called/have the prefix OWF1_.
- **SPA** stations are placed within the new Bird SPA area (F129).
- **INV** stations are the remaining stations placed outside the above subareas but within the pre-investigation area.

Table 3-2. Distribution of sampling stations within the offshore wind farm areas (OWF, e.i. Bornholm I and II), the cable corridors (CC, CC1 and CC2), the Special Protection Area (bird SPA site) and in the remaining pre-investigation area (INV). CC is where the cable corridors overlap. [1] number excl. OWF1 stations now placed outside Bornholm I North and South wind farm areas (see grey stations in Figure 3-2). [2] Including CC stations and OWF_59, excluding INV and SPA stations located in the CC area to avoid counting these twice. [3] Number of stations with SPA prefix excl. stations within cable corridor area to not count stations several times (see Figure 3-3) and Appendix 2. [4] Including 15 OWF1 stations between Bornholm I North and South and one OWF1 station north of Bornholm I North (OWF1_60). * The three OWF1 stations included.

Area	HAPS samples for infauna	HAPS samples for Chemical analyses	ROV stations	CTDO stations
Bornholm I North and South (OWF1)[1]	41	7	41	5
Bornholm II (OWF2)	60	10	60	7
Cable corridors (CC, CC1 and CC2)[2]	26	20*	44	0
SPA site (SPA) [3]	99	-	167	14
Remaining part of pre-investigation area (INV) [4]	93	1	122	20
Total	**319**	**38**	**434**	**46**

3.1.3 SAMPLING IN THE DIFFERENT AREAS

Sampling stations in the pre-investigation area detailed below and extra stations with other prefix are included here to give total numbers of stations within each subarea no matter the prefix (e.g., CC_, CC1_, CC2_, OWF1_, OWF2_ SPA_ and INV_).

The wind farm areas (Figure 3-2):

- 101 HAPS infauna samples – 41 in Bornholm I (North+South) and 60 in Bornholm II for sediment type description and infauna analysis.
- 17 HAPS samples for chemical analysis – seven in Bornholm I (North+South) and 10 in Bornholm II.
- 101 ROV-video stations (41 in Bornholm I and 60 in Bornholm II) i.e., one ROV station pr HAPS infauna station to verify sediment type and quantify epiflora, epifauna and fish (species and area coverage %).
- 12 CTDO stations - to describe temperature, salinity and oxygen profiles in the water column along four transects across the wind farm areas.

The cable corridors (Figure 3-3):

- Here the total number of stations within the cable corridor area is given including all CC/CC1/CC2 stations; OWF1_27, 28, 59; SPA_13, 33, 34, 36 and INV_028, 035, 036, 037, 061, 062, 063, 065.
- 32 HAPS infauna samples – distributed within the total cable corridor area for sediment type description and infauna analysis.
- 20 HAPS samples for chemical analysis - distributed within the total cable corridor area. Two samples from the original OWF1 area are now placed within the CC1 cable corridor (OWF1_59 and _28).
- 58 ROV-video stations - distributed within the total cable corridor area to verify sediment type and quantify epiflora, epifauna and fish species (species and area coverage %).
- No CTDO stations.

SPA site (Figure 3-4):

- Part of the cable corridor stations are also placed within the SPA area (all CC, CC2 stations and CC1_01-05)
- 111 HAPS infauna samples - for sediment type description and infauna analysis.
- 12 HAPS samples for chemical analysis.
- 194 ROV-stations - distributed within the total SPA area to verify sediment type and quantify epiflora, epifauna and fish (species and area coverage %).
- 14 CTDO stations to describe temperature, salinity and oxygen profiles in the water column along the four transects.

Rest of pre-investigation area (Figure 3-1 and Appendix 2 - map 4):

- 16 stations from the former OWF1 area are now located in the INV area; 15 OWF1 stations between the Bornholm I North and South wind farm area and one station (OWF1_60) north of Bornholm I North (see grey stations on Figure 3-2).
- 90 HAPS infauna samples - for sediment type description and infauna analysis.
- One HAPS sample for chemical analysis. Originally within Bornholm I area (OWF1) but after division of Bornholm I into two subareas, one station (OWF1_37) is located in the remaining part of the pre-investigation area outside the OWFs, cable corridors and SPA areas.
- 122 ROV-stations - distributed within the total INV area to verify sediment type and quantify epiflora, epifauna and fish (species and area coverage %).
- 20 CTDO stations to describe temperature, salinity and oxygen profiles in the water column along the four transects.

During the survey, station positions were changed if relevant to ensure the best possible mapping of the sediment types and biological community. If e.g. the ROV-video at a station showed, that it was not possible to take HAPS samples, the position was moved a maximum of three times = three attempts before sampling was abandoned (see section 3.2.2 and Appendix 3 - Logbooks).

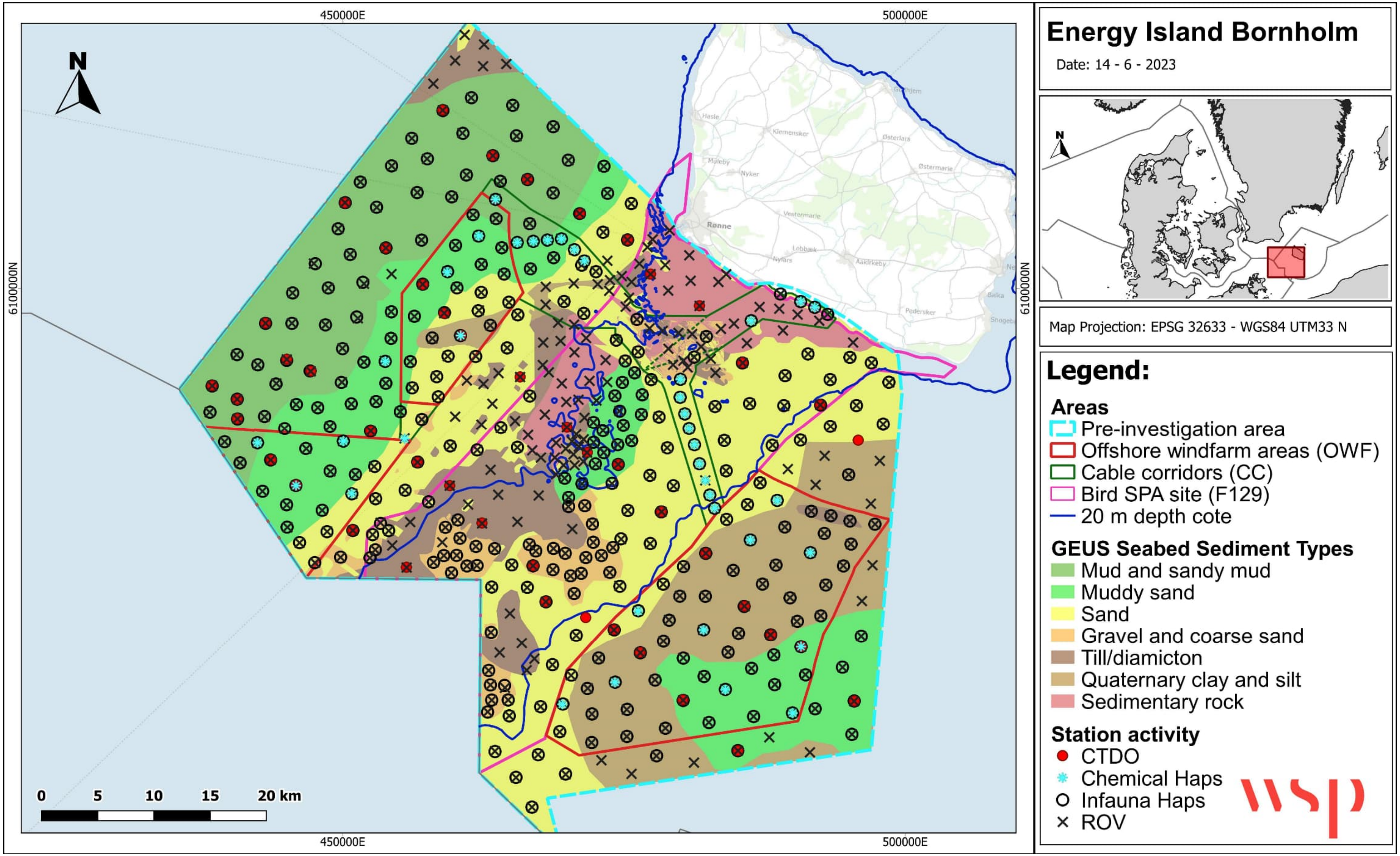


Figure 3-1. Sampling program for the pre-investigation area. The 20-meter depth curve is also shown. See station numbers for the specific subareas in Appendix 2. The background seabed sediment map is from GEUS, Marta-database. See Table 3-3 for conversion between GEUS sediment types and sediment types used in this report.

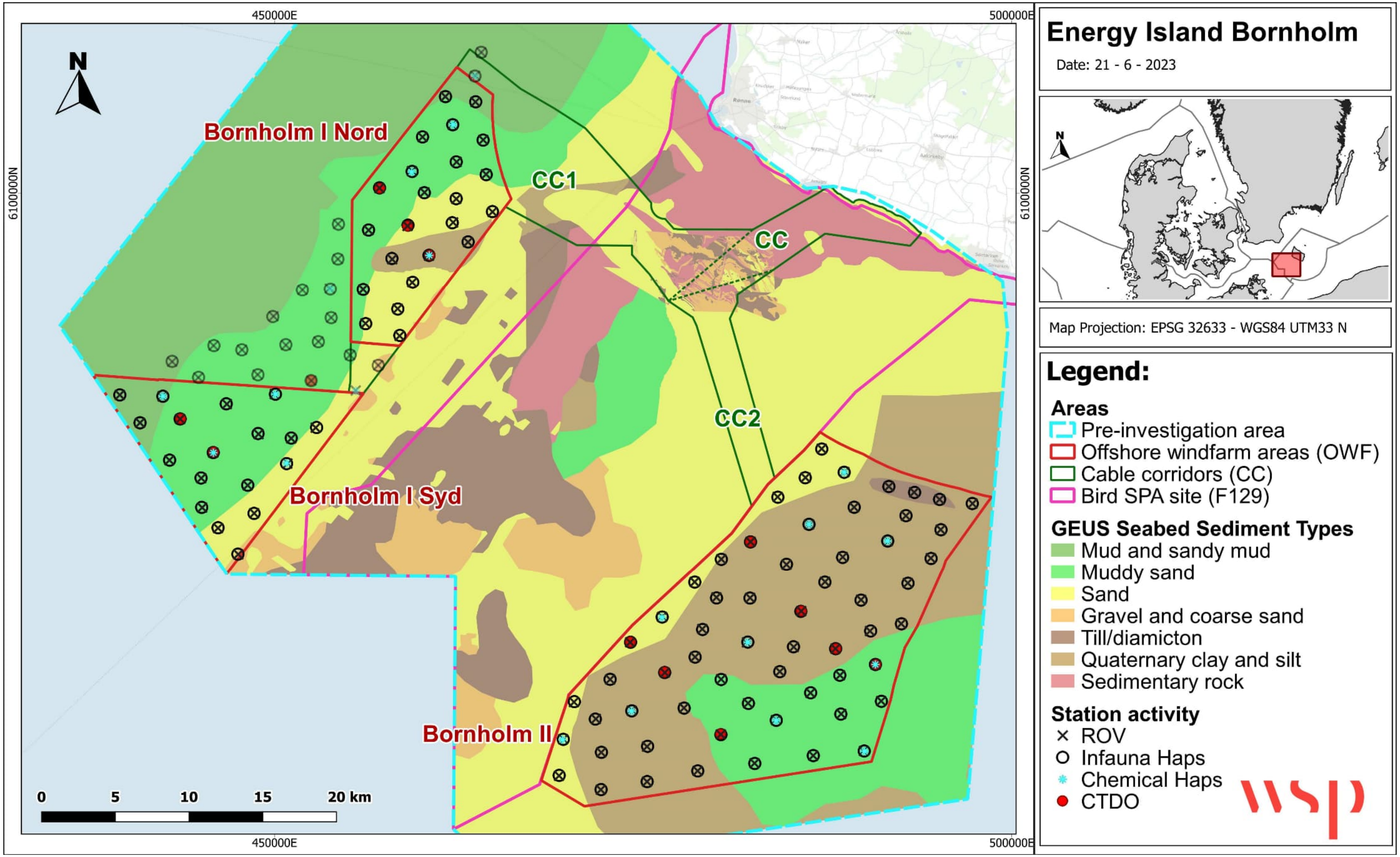


Figure 3-2. Sampling program for the two wind farm areas (OWF1 and OWF2). All stations from the original OWF1 area are shown. OWF1 are now divided into Bornholm I North (B1N) and Bornholm I South (B1S) and 17 stations are now outside the B1N and B1S areas (15 stations between the wind farm areas and two stations north of B1N) marked with grey. Naming is the original for OWF1 area. See station numbers in Appendix 2, Map 1. The background seabed sediment map is from GEUS, Marta-database.

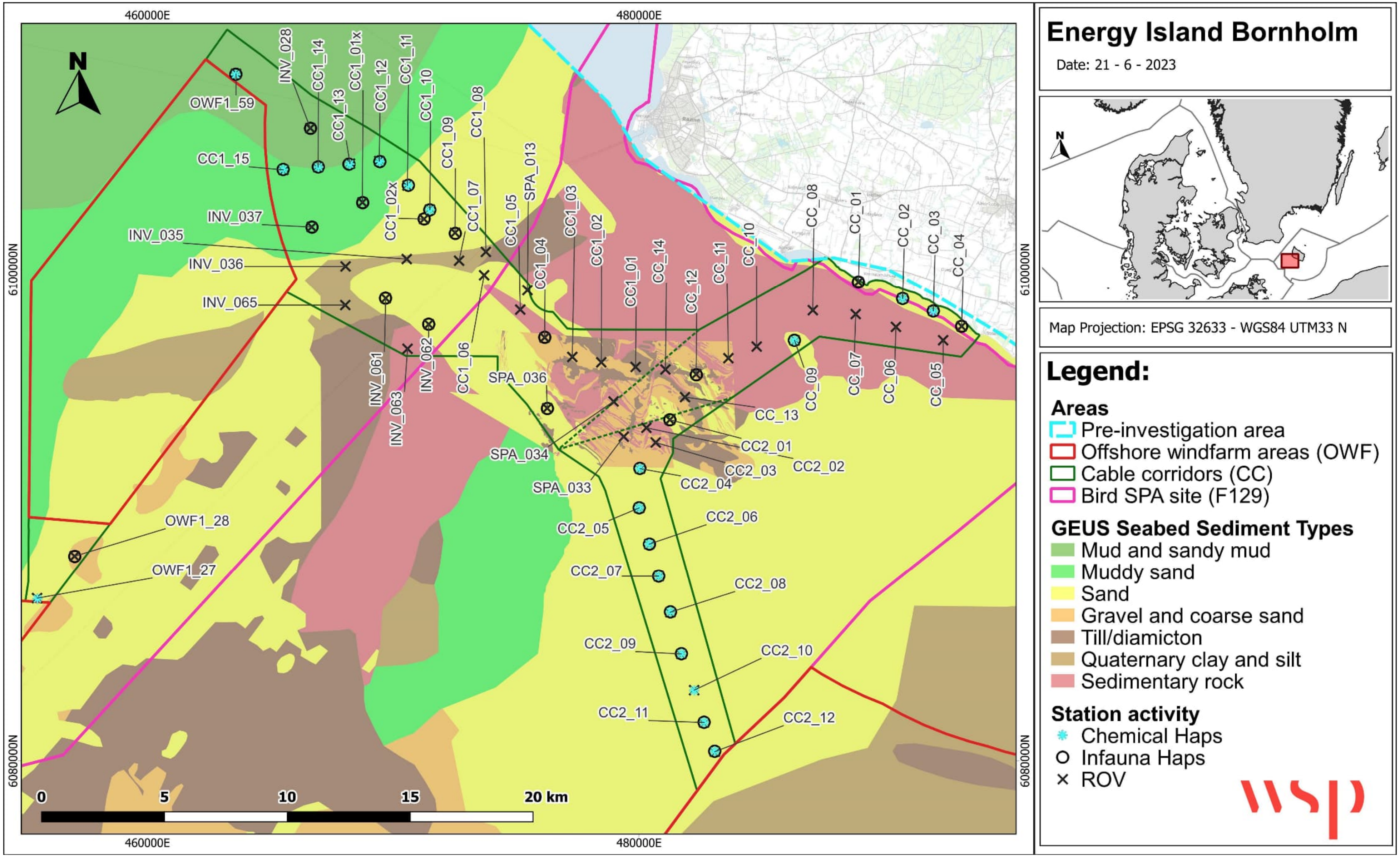


Figure 3-3. Stations placed within the cable corridor area. Where the pre-investigation area for the two cable corridors overlap stations are called CC. The cable corridor area has been expanded from the original placement and now includes stations with other prefixes e.g. OWF1_, SPA_ and INV_. The background seabed sediment map is from GEUS, Marta-database. SPA = Special Protection Area. See Table 3-3 for conversion between GEUS sediment types and sediment types used in this report.

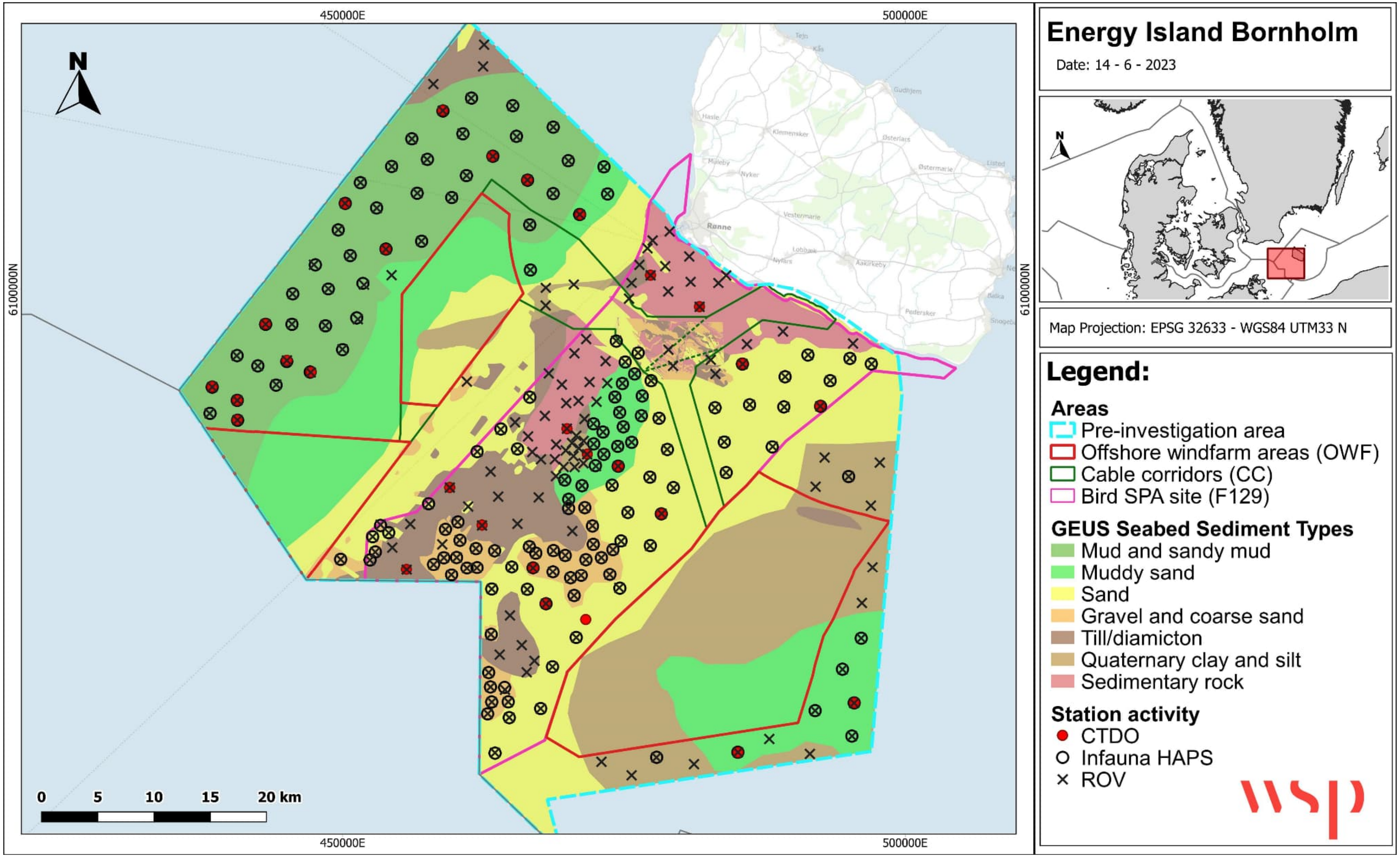


Figure 3-4. Sampling program for bird food mapping mainly in the bird SPA site but also in the rest of the pre-investigation area. See station numbers in Appendix 2. The background seabed sediment map is from GEUS, Marta-database. SPA=Special Protection Area. See Table 3-3 for conversion between GEUS sediment types and sediment types used in this report.

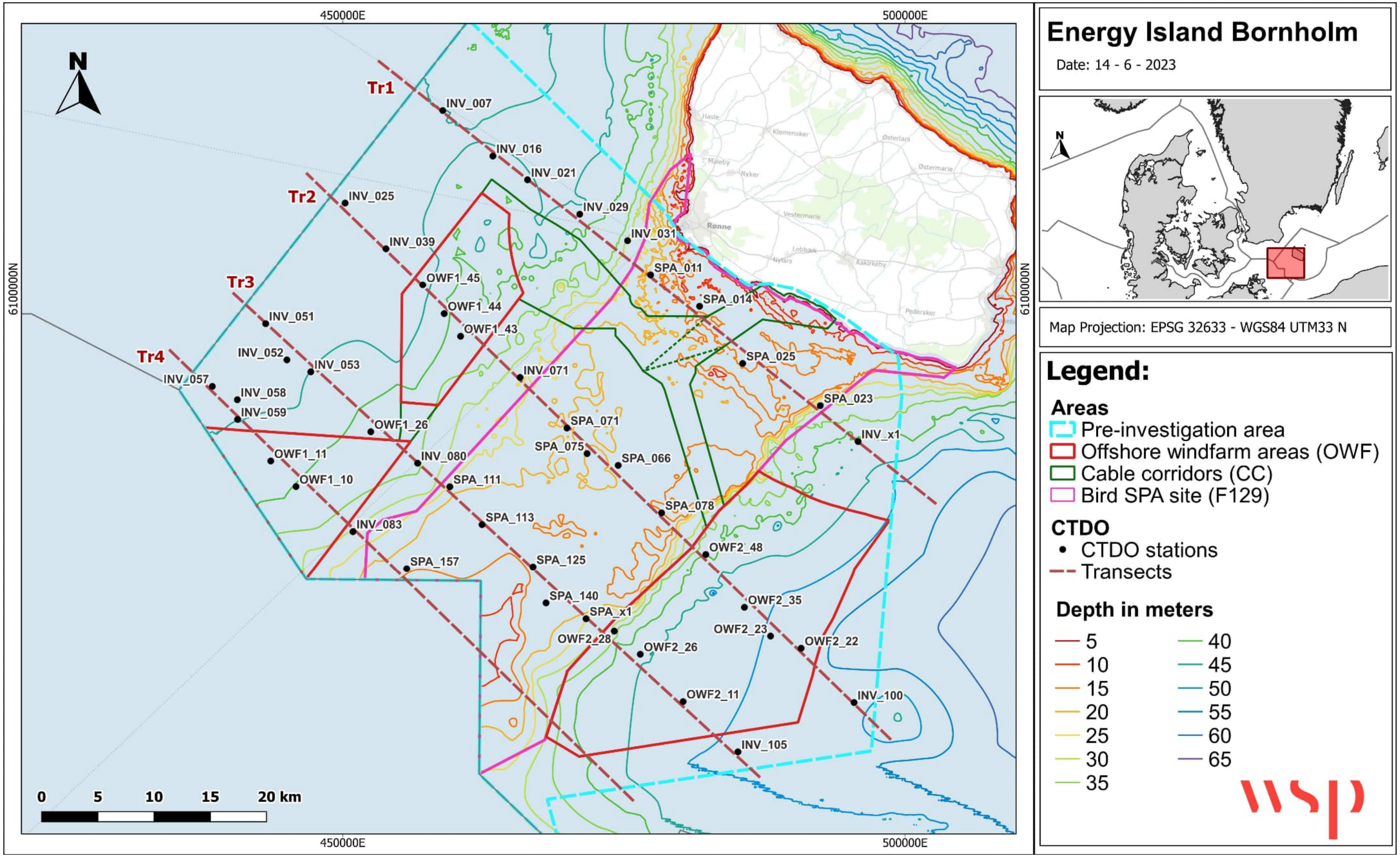


Figure 3-5. Four CTDO transects and stations crossing the pre-investigation area. The CTDO-samples describe temperature, salinity, and oxygen profiles in the water column along the four transects. SPA = Special Protection Area.

WIND FARM AREAS (OWF1 AND OWF2)

Sampling in the two offshore wind farm areas (OWFs, Bornholm I and Bornholm II) are presented in Table 3-2 and Figure 3-2. Stations are placed to ensure sufficient coverage of all sediment types in the wind farm areas. Station placement is based on GEUS Martha-database sediment types.

The Bornholm I wind farm area has been divided into two sub areas called Bornholm I North and Bornholm I South. Station numbers placed within the originally planned Bornholm I area, have the prefix OWF1_ and are now divided between the two subareas of Bornholm I (North and South) and some stations are placed outside and between the two subareas (see Figure 3-2).

Furthermore, the 10 chemical HAPS samples placed within the former OWF1 area are now placed in and between the two Bornholm I subareas (Bornholm I North and South) (see Figure 3-1). This is described in detail in section 3.2.4 – Chemical analysis.

CABLE CORRIDORS (CC, CC1 AND CC2)

The cable corridors from the two wind farm areas (Bornholm I and Bornholm II) to Bornholm are shown in Figure 3-3. The cable corridor area has been expanded from the original placement and now includes stations with other prefixes e.g., OWF1_, SPA_ and INV_ (see Figure 3-3).

The original 18 HAPS samples for chemical analysis of the sediment are divided between the two cable corridors according to the area of loose sediment. The area of loose sediment along the cable corridor is larger for CC2 than CC1. There are therefore appointed six HAPS samples and nine HAPS samples for chemical analysis respectively for CC1 and CC2 (see Figure 3-3). Along the coast of Bornholm in the landfall area, further three HAPS samples for chemical analysis are placed to assess chemical concentrations in this area as well. Two HAPS samples for chemical analysis could not be taken in the CC1 cable corridor due to rocky sediment (CC1_06 and CC1_09).

After subdivision of the original OWF1 area two extra HAPS samples for chemical analysis are now placed in the cable corridor area (OWF1_27 and OWF1_59) bringing the total samples for chemical analysis to 20 within the total cable corridor area.

BIRD FOOD PROGRAM

A new Danish bird protection area (Special Protection Area, SPA site, F129) is placed in the middle of the pre-investigation area between the two wind farm areas (Figure 3-4). This SPA is designated to protect one bird species - long-tailed duck.

Relevant for the scope of work of WP-E Sediment, benthic flora and fauna is, therefore, mapping and assessment of bird food in the SPA site and the pre-investigation area for long-tailed duck (and possibly other birds from the nearby Natura 2000 sites). Long-tailed duck feeds on different mussel types, snails, shrimps, small fish, and other benthic fauna including infauna such as bristle worms (Petersen et al, 2019). Sampling therefore includes HAPS samples for infauna and mussels and ROV for assessment of epifauna and blue mussels. Long tailed duck can dive to a depth of 100 meters while foraging. All depths in the SPA site and the pre-investigation area are, therefore, possible foraging areas for the birds. Samples and stations are therefore distributed at all depth intervals in the pre-investigation area.

The sampling program is assembled to sufficiently describe and map the biological communities and, thus, the bird food availability for the sediment types in the pre-investigation area including the bird SPA site (Figure 3-4).

42 HAPS samples pr loose sediment type in the bird SPA site were sampled according to the technical requirements for soft bottom fauna sampling in the NOVANA program (Hansen & Josefson, 2020) to ensure sufficient samples to describe infauna and epifauna community in each of the loose sediment types. One loose sediment type ("Mud and sandy mud") were not represented in the large-scale map of sediment types within the bird SPA site, and 42 stations were therefore placed in the area west of OWF1, to ensure sampling of this sediment type (Figure 3-4).

For the hard sediment types in the bird SPA site 25 ROV stations were sampled per hard sediment type to describe the sediment type (sand, silt, and rock coverage %) and epifauna community (Figure 3-1 and Figure 3-4). The epifauna community on hard sediment types is less diverse with fewer species compared to the infauna and epifauna community in loose sediment types, and fewer stations are therefore needed to sufficiently describe this community.

Where stations were too closely placed within a sediment type in the bird SPA site, some stations were distributed in areas with low-station coverage in the pre-investigation area outside of the bird SPA area (see Figure 3-4):

- This way 15 out of the 42 HAPS samples for "Muddy sand" were placed in the pre-investigation area outside the SPA site.
- 2 out of 42 HAPS samples for "Gravel and coarse sand" were likewise relocated.
- 15 out of 25 ROV stations for "Quarternary clay and silt" were relocated to ensure mapping of this sediment type in the eastern and western part of the pre-investigation area.
- "Mud and sandy mud" were only found outside the SPA site and the 42 HAPS sample stations were therefore placed in the western part of the pre-investigation area.

Bird food mapping is done using all stations sampled for infauna and epifauna in the pre-investigation area (see Figure 3-1) and the results are presented in section 5.6 – Bird food program.

3.2 EQUIPMENT AND METHODS

Equipment and vessels used for the three benthic surveys in the pre-investigation area are presented below.

3.2.1 VESSELS

Survey 1 and 3 were conducted from the vessel M/S Skoven and survey 2 from the small vessel Sephia, see description below.

The survey vessels M/S Skoven (Figure 3-6) and Sephia (Figure 3-7) were used to accommodate the technical requirements for WP-E. The smaller vessel Sephia was used specifically for the investigations in the shallow coastal area.

Skoven has excellent facilities regarding lifting equipment and deck area, as well as launch and recovery systems (LARS). The benthic survey for WP-E was 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 Baltic Sea and appropriate working space on deck for handling of relevant equipment and handling of samples.

Figure 3-6. Research vessel M/S Skoven.

The small vessel Sephia has excellent experience with seabed mapping and has been used in seabed investigations related to wind farms, pipelines and raw material extraction areas. In relation to previous seabed investigations Sephia has been HSE approved by Ørsted A/S and North Stream 2 AG (NSP2) and is IMCA/CMID approved. Sephia has been used in connection with a wide range of wind farms in the Danish Waters, i.e., diving inspections, ROV inspections, sediment samplings, navigation channels etc. Sephia was used for survey 3 in the coastal area from approximately 1 meters of depth.

Figure 3-7. Research vessel Sephia.

3.2.2 ROV – VISUAL VERIFICATION/QUANTIFICATION

A ROV was used for visual inspection of the seabed and quantification of seabed type and characteristics, benthic flora and fauna including species/taxa number and coverage (%) and the number of fish species and coverage (%). The first activity on each station was a ROV inspection showing the seabed characteristics, flora and fauna live on deck. Visual inspection of the seabed with ROV is always done before HAPS sampling to ensure sampling on loose sediment.

A BlueROV2 (Figure 3-8) 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. A complete Digital Video System was used, including all equipment, laptops, cabling, connections, screens, spares etc. The equipment is set up so both the helmsman and the camera operator can see the image/video in real time. A voiceover for the video was recorded as well as filling out a field log (logbook) for each station. The logbooks include position, depth, seabed sediment types/composition, habitat types and determination of species (flora and fauna) and coverage of species and biogenic structures observed on the seabed surface (e.g. sandworms, fish foraging holes in the seabed, mysids/shrimps etc.). Other parameter targets, at the same station were included in the logbook. Sufficient storage media was ensured, and back-up of all data was performed at least twice a day on two hard discs.

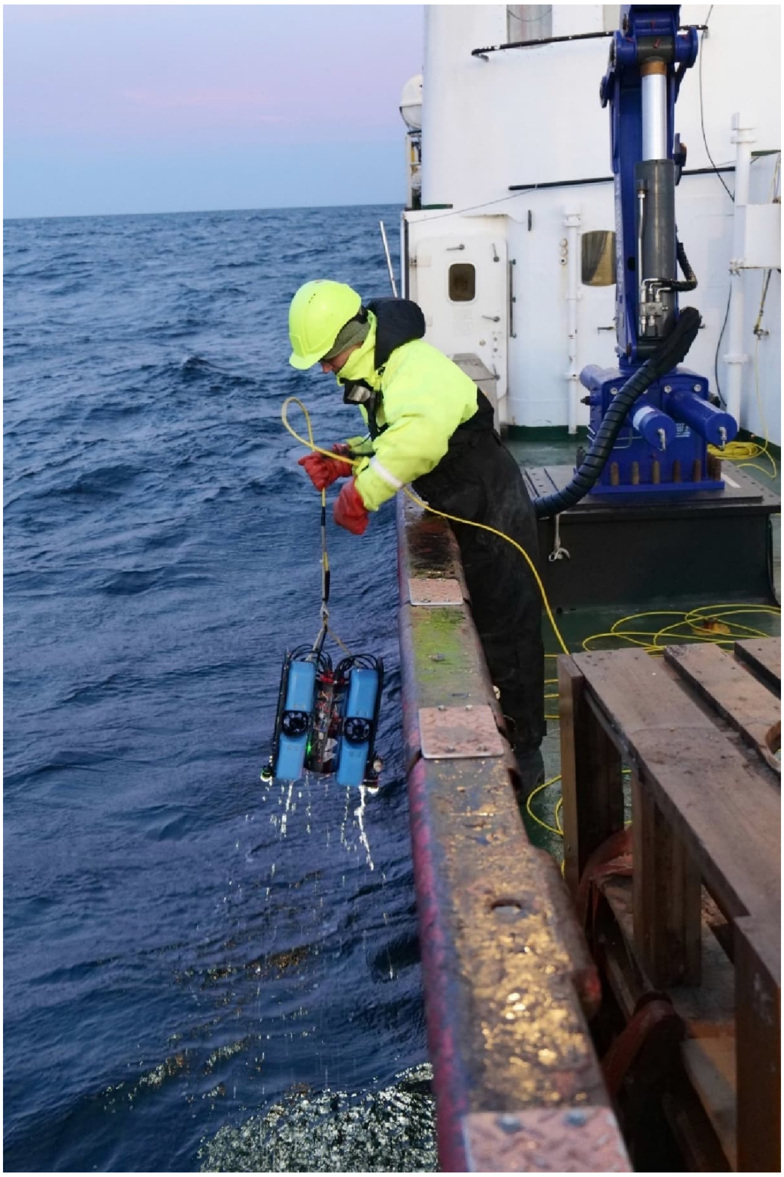


Figure 3-8. ROV being pulled out of the water.

3.2.3 CTDO – PROFILING IN THE WATER COLUMN

A CTDO was used for profiling of temperature, salinity and oxygen concentration and saturation in the water column. Based on previous good experiences, a CTDO with optional water sampler was used. This unit can be used as a standalone CTDO unit, or as an ROV integrated CTDO. The core element in the 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 were 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 and water sampling with a General Oceanics 1.7 L model 1010 Niskin Water Sampler.

CTDO data are presented in Appendix 7.

3.2.4 HAPS – SEDIMENT CORE SAMPLING

SAMPLING METHOD

A HAPS core sampler (Figure 3-9) was used for sampling of sediment characteristics, chemical analyses and infauna quantification. The HAPS core sampler samples a seabed area of 0.0145 m². This instrument complies with the technical requirements for soft bottom fauna sampling in the NOVANA program. Three attempts were made before moving to the next location including the use of a vibrating unit used to force the HAPS into the sediment.

Figure 3-9. HAPS core sampler.

The first activity at each station was a ROV inspection of the seabed showing the seabed characteristics, flora and fauna live on deck. If e.g. the ROV-video at a station showed, that it was not possible to take HAPS samples due to presence of hard sediment, the position was moved a maximum of three times = three attempts before sampling was abandoned. The number of HAPS samples collected in the pre-investigation area are listed in Table 3-2 and Appendix 1 and shown in Figure 3-1.

SEDIMENT CHARACTERISTICS

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 3).

CHEMICAL ANALYSIS

Chemical analysis of the concentration of nutrients and pollutants in the sediment was performed in the two wind farm areas (Bornholm I and Bornholm II) and the two export cable corridors, where sediment might be suspended due to digging, cable trenching, cable flushing or other sediment disturbing activities, that may bring nutrients and pollutants in suspension in the water column. Release of nutrients and pollutants through resuspension of sediment from wind farm activities are potential impacts for the environmental parameters.

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 the US EPA, which are used by HELCOM (see section 5.2.3 - Chemical Parameters/Pollutants).

Chemical parameters analysed:

- Total Organic Carbon (TOC) by LOI, Total nitrogen (TN) and total phosphorus (TP)
- Heavy metals (8): Arsenic (As), lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni) and zinc (Zn)
- PAH compounds (9): Phenanthrene, anthracene, fluoranthene, pyrene, benz(a)anthracene, chrysene, benz(a)pyrene, indeno(123cd)pyrene and benzo(ghi)perylene
- PCB compounds (7): 28, 52, 101, 118, 138, 153 and 180
- TBT and degradation products: DBT and MBT
- Brominated flame retardants (5): PBDE 28, 47, 99, 100 and HBCDD – extra samples from 10 selected stations

Analysed chemical pollutants were chosen on the basis of requirements in the Danish Dredging Manual (Miljøstyrelsen, 2008) and furthermore brominated flame retardants were added to the analysis.

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

Threshold values are prioritized in the following order:
1) NEQS: National Environmental Quality Standards, Danish EPA (Miljøstyrelsen, 2023a; Miljøstyrelsen, 2023b)
2) EQS: Environmental Quality Standards, EU (HELCOM, 2017)
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 within the pre-investigation area with emphasis on the wind farm areas and the cable corridors, are presented in this technical report (5.2.3 – Chemical Parameters) and compared to relevant existing data from the area (4.3.3 – Existing data/ Chemical parameters). All data for the chemical analysis are presented in Appendix 4.

Wind farm areas (Bornholm I and Bornholm II)

10 HAPS sediment samples were taken in Bornholm II for chemical analysis. After subdivision of Bornholm I, three chemical samples were placed within Bornholm I North and four samples within Bornholm I South. In total 17 chemical analyses for the two wind farm areas (Figure 3-2).

Cable corridors

Similarly, 18 HAPS samples were taken in the cable corridor area for chemical analysis (Figure 3-3). The area of loose sediment along the cable corridor is larger for CC2 than CC1. Sampling, therefore, included nine HAPS samples for chemical analysis in CC2 and six HAPS samples in CC1. Two samples in CC1 were not sampled due to rocky sediment (CC1_06, CC1_09). Along the coast of Bornholm in the overlapping cable corridor area (CC), further three HAPS samples for chemical analysis were sampled to assess chemical load in this area as well.

After subdivision of the original OWF1 area two extra HAPS samples for chemical analysis are now placed in the cable corridor area (OWF1_27 and OWF1_59) bringing the total samples for chemical analysis to 20 within the total cable corridor area.

INFAUNA QUANTIFICATION

Sample sieving (1 mm sieve) and storage/preservation of samples were carried out in accordance with technical requirements for soft bottom fauna. All samples were stored 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 dry weight after 105°C for 18-24 hours or until stable weight was reached. The polychaete *Pygospio elegans* was weighed along with its tube after prior removal of "excess tube material" without content. Barnacles were counted and indicated as being present, i.e. no biomass determination.

The infauna data for all stations are analysed and presented in the technical report as tables and maps of number of infauna species, abundance, and biomass (wet weight (WW) and dry weight (DW)).

Furthermore, statistical analysis is performed including species diversity (Shannon-Wiener index) as well as relevant index and plots if appropriate: AMBI and Multidimensional scaling plots (MDS-plot). See Appendix 5 for all infauna data and Appendix 6 for details related to calculation of indexes and statistics.

Infauna results from the pre-investigation area are presented in this technical report (section 5.5.2 – Infauna) and compared to relevant existing data (section 4.5.2 – Existing data/ Infauna) from the area.

3.2.5 SEDIMENT TYPE MAPPING

The sediment type map shows the distribution of sediment types within the cable corridor and is based on the geophysical mapping in the area.

First generation mapping – Side scan data interpretation

The 1st generation sediment map is based on the interpretation of side scan sonar data (SSS), 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). Further, the sediment may contain a few (<1 %) boulders (>10 cm).

- **Type 2 – Sand, gravel 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).

- **Type 3 – Sand, gravel, small rocks and several larger rocks (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 – Sedimentary rock, till and stone reef, 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. Also includes sedimentary rock as present around Bornholm.

Second generation mapping – Sediment type map

Second generation sediment type mapping is done when verifying the interpreted seabed sediment types from the side scan sonar mapping obtained from the first-generation mapping with the actual ROV-video recordings of the *in situ* seabed sediment type. The final product here is the sediment type maps of the OWF areas and cable corridors (see section 5.2.1 – Survey data/Sediment types and Table 3-3).

The placement of ROV-stations for the field survey program was appointed to ensure coverage of all identified sediment types from the first-generation mapping by SSS. This additionally ensures the identification of the local flora and fauna on the different sediment types used to determine the nature types (see section 3.2.6 – Nature type mapping below).

Sediment types in areas not mapped by side scan sonar (SSS) in this baseline study

In the SPA area and the remaining part of the pre-investigation area outside of the OWF and cable corridor areas (INV), the sediment type map is based on the GEUS maps of sediment types (GEUS, 2023), and verification of the sediment types on the seabed at the ROV stations. The GEUS map is used since side scan sonar mapping was not conducted outside of the OWF and cable corridor areas. More specifically the sediment types used by GEUS has been translated into the sediment types used for the ROV and side scan mapping in this study, which is approved by the Danish Environmental Agency (see sediment type mapping above) (Table 3-3).

Table 3-3. Conversion between GEUS sediment types and sediment types used in this report. Not always possibly to convert directly as e.g. till/diamiction can be several sediment types.

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

3.2.6 NATURE TYPE MAPPING (= BENTHIC COMMUNITIES)

Wind farm areas and cable corridor:
The nature type map is based on the second-generation sediment type map within the wind farm areas and the cable corridors as well as the flora and fauna communities observed from the ROV-videos in each of the sediment types. Each sediment type will be converted to the appropriate nature type according to the observed (ROV video) benthic flora and fauna community on the sediment type.

Other areas within the pre-investigation area (SPA and INV stations):
In the subareas within the pre-investigation area, which were not mapped with side scan sonar, the nature type map is based on the GEUS sediment type map and the observed flora and fauna species observed on ROV-video living on these sediment types.

The nature type maps shows the distribution of the dominating benthic flora and fauna communities within the OWF areas and the cable corridors, which have been surveyed by both side scan sonar and ROV video verification stations (see section 5.3 – benthic communities (Nature types)), see Figure 5-9 and Figure 5-10.

The nature type map is based on the sediment type map and the dominating benthic flora and fauna communities observed from the ROV-videos in each of the sediment types. Each sediment type will be converted to the appropriate nature type according to the observed (ROV video) benthic flora and fauna community on the sediment type.

When assigning the nature types based on the sediment type maps, several sediment types with the same benthic flora and -fauna communities observed on the ROV-videos are merged into one nature type representative for one benthic flora and -fauna community. This was done for nature type 6 - ”Blue mussel beds”, which is based on both sediment type 3 and sediment type 4 corresponding to the GEUS sediment type till/diamiction and sedimentary rock.

4 EXISTING DATA

This baseline study uses existing data sources in and close to the pre-investigation area and the important subareas within, e.g., wind farm areas and cable corridors. Existing data sources for each parameter included in this report are described separately below.

4.1 EXISTING DATA SOURCE

Existing data found within the pre-investigation area are based on the NOVANA program (Eelgrass, macroalgae and infauna stations), the Danish Environmental Portal, Natura 2000 basis analyses and from the two pipeline projects from the area (Baltic Pipe and North Stream).

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

In relation to pollutants in the sediment, NOVANA stations in and around the pre-investigation area were checked, but none of the chemical compounds tested in the present investigation were included in the analyzed pollutants at the NOVANA stations (stations: 99000116, 99000117, 99100012 and 99150003).

Regarding total organic content (TOC) in the sediment, existing data from Baltic Pipe is not used, because the data is not directly comparable to the data obtained in the present study.

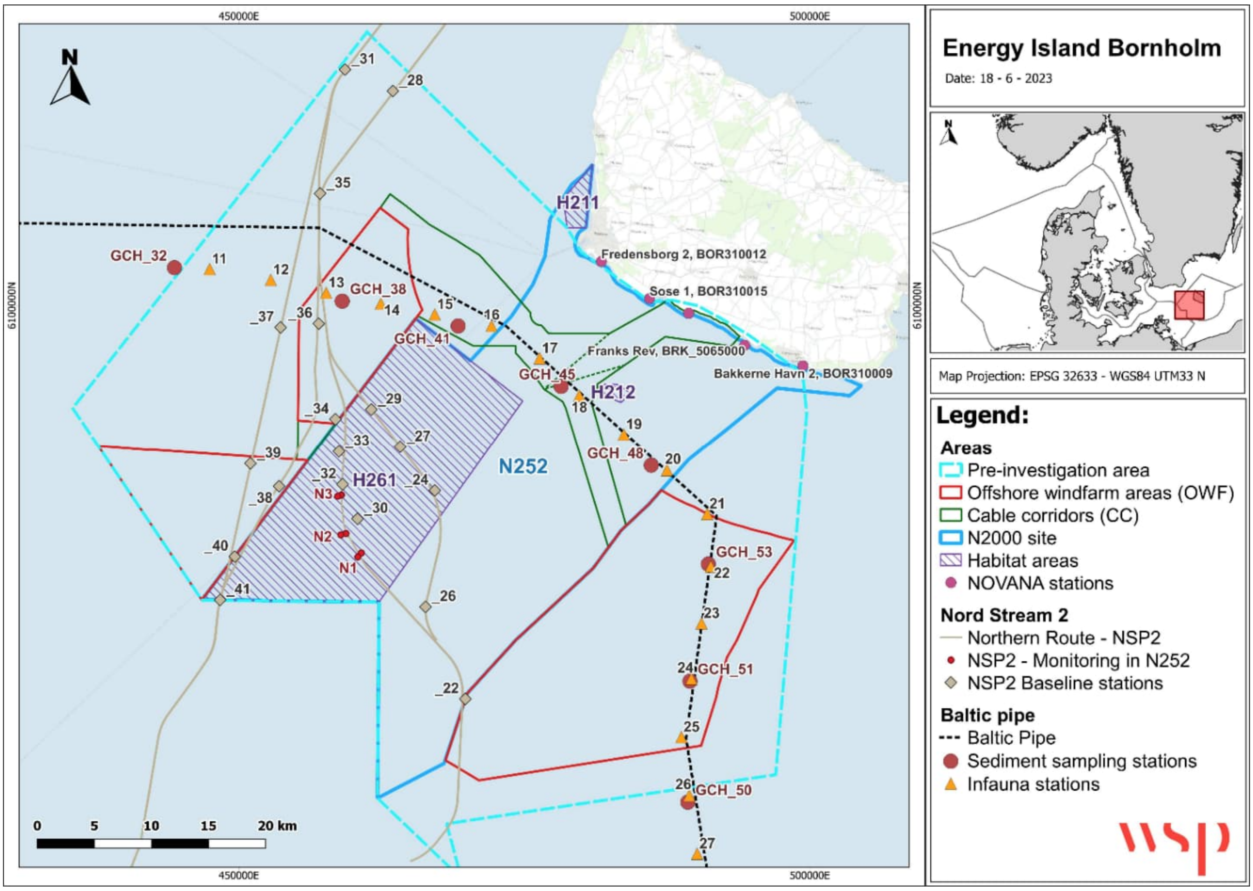


Figure 4-1. Existing data used for the pre-investigation area.

Table 4-1. Projects and stations used for description of existing data in the pre-investigation area. *Stations used from the EIA of Baltic Pipe has been digitized from existing maps as position data is unavailable. NSP2 = North Stream Project 2.

Bornholm existing data	Sampling date	Selected stations	Reference
Depth			
GEUS Dataverse			**(GEUS, 2023a)**
Sediment			
GEUS Martha database			(GEUS, 2023)
Pollutants + Nutrients + TOC + oxygen			
Baltic Pipe	February and March 2018	GCH_38, 41, 45, 48, 51, 53	(Baltic Pipe, 2019)
NSP2 - Northern route, Baseline study, Sediment	21-25 November 2017	D_EEZ_22, 24, 26, 28, 29, 30, 31, 34-39	(Nord Stream 2, 2018a)
NSP2 – Final Route	August and September 2018	SS-13, -14, -15, -16	(Nord Stream 2, 2019)
Eelgrass			
NOVANA stations	2017-2022	Fredensborg 2 (BOR310012) Sose 1 (BOR310015) Sose 2 (BOR310016) Bakkerne Havn 2 (BOR310009) Franks Rev (BRK_5065000)	(Danmarks Miljøportal, 2023a) (Odaforalle.dk, 2022)
Macroalgae			
NOVANA stations	2008-2020	Franks Rev (BRK_5065000)	(Danmarks Miljøportal, 2023b)
Natura 2000 basisanalyse 2022-2027 N252/H261 Adler Grund og Rønne Banke	2011-2018	No stations	(Miljøstyrelsen, 2020)
NSP2, N2000 monitoring in N252/H261	30 April to 1 May 2019	N1_1, N1_2, N1_3, N2_1, N2_2, N2_3, N3_1, N3_2, N3_3	(Orbicon, 2019)
Epifauna			
NSP2, Northern route, Baseline study, Biotope survey in N252/H261	7-8, 10-11 January 2018	D_EEZ_24, 26-27, 29-30, 32-34, 40-41	(Orbicon, 2018)
NSP2, N2000 monitoring in N252/H261	30 April to 1 May 2019	N1_1, N1_2, N1_3, N2_1, N2_2, N2_3, N3_1, N3_2, N3_3	(Orbicon, 2019)
Infauna			
NSP2 Northern route, Baseline study, infauna	21 November – 4 December 2017	D_EEZ_22, _24, _26, _28, _29, _30, _31, _34, _35, _36, _37, _38, _39, _41	(Nord Stream 2, 2018b)
NSP2, N2000 monitoring in N252/H261	30 April to 1 May 2019	N1_1, N1_2, N1_3, N2_1, N2_2, N2_3, N3_1, N3_2, N3_3	(Orbicon, 2019)
Baltic Pipe	February and March 2018	GCH32, _38, _41, _45, _48, _50, _51, _53	(Baltic Pipe, 2019)
Baltic Pipe*	July 2018	17 stations located near Bornholm (see Figure 4-14)	(Baltic Pipe, 2019)

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

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). For benthic fauna the importance of depth is mainly due to shifting sediment composition towards more soft sediment types at higher depths (>40-50 m, (Nord Stream 2, 2018a)) (see section 4.3.1 - Sediment types), higher salinity and lower oxygen concentrations below the halocline in the Baltic Sea (see section 4.2 – Abiotic data).

Depth in the pre-investigation area based on existing data is presented in Table 4-2 and Figure 4-2 and ranges from 0 to 58 meters depth. The shallowest parts are found in Bird SPA F129 close to the coast and in the Rønne Banke area between the two wind farm areas (Bornholm I and Bornholm II). The deepest parts of the pre-investigation area are found northwest of Bornholm I North and southeast of Bornholm II.

Table 4-2. Depth ranges in meters in the pre-investigation area based on existing data, the wind farm areas (OWF), the two cable corridors (CC1 and CC2) from the OWFs to Bornholm and the Bird SPA in the middle of the pre-investigation area. Depth data source is (GEUS, 2023a).

Depth ranges	Lowest (m)	Highest (m)
Pre-investigation area	0	58
Bornholm I North (B1N)	33.5	47.5
Bornholm I South (B1S)	28	45
Bornholm II	20	55
CC overlapping part near coast	0	20
CC1 (incl. CC area)	0	47
CC1 area between Bornholm I North and Bornholm I South	34.5	38
CC2 (incl. CC area)	0	36.5
Bird SPA F129	0	36.5

The depth range based on existing data is 33.5 to 47.5 meters and 28 to 45 meters in Bornholm I North and Bornholm I South, respectively. The largest depth variation and depths of 20 to 55 meters are found in Bornholm II.

The overlapping part of the cable corridors (CC) close to the coast of Bornholm has depths between 0 and 20 meters. The cable corridor from Bornholm to Bornholm I North (CC+CC1) has depths between 0 and 47 meters. The small part of the small cable corridor (CC1) between Bornholm I North and South has depths between 34.5 - 38 meters. The cable corridor (CC+CC2) from Bornholm to Bornholm II is slightly shallower with depths between 0 and 36.5 meters.

The depth range in Bird SPA F129 is between 0 to 36.5 meters.

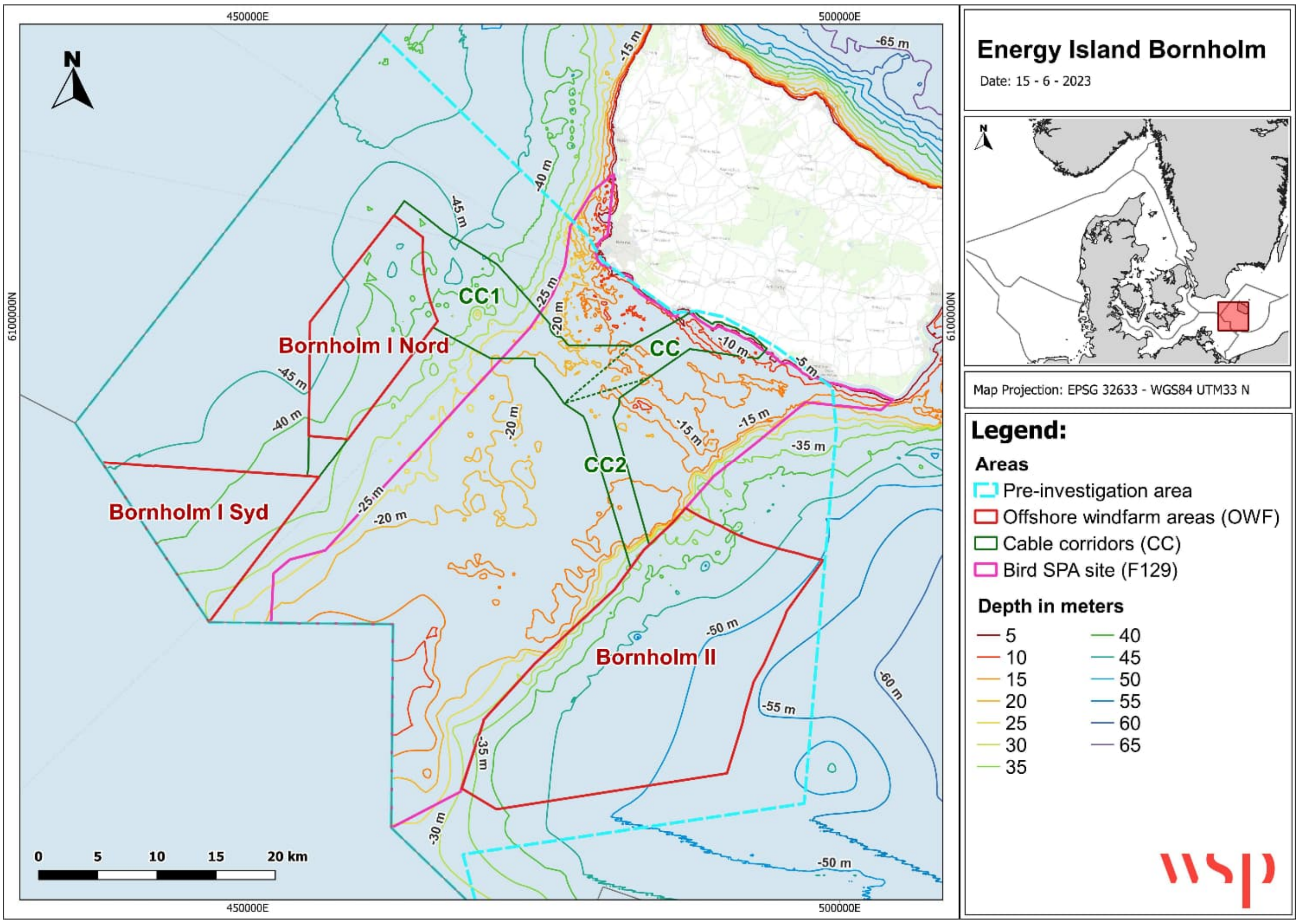


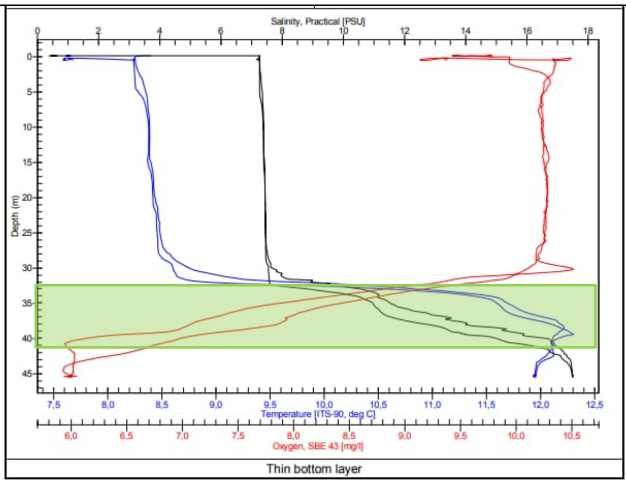
Figure 4-2. Depth map in the pre-investigation area. Source: (GEUS, 2023a).

4.2.2 SALINITY AND OXYGEN CONCENTRATION

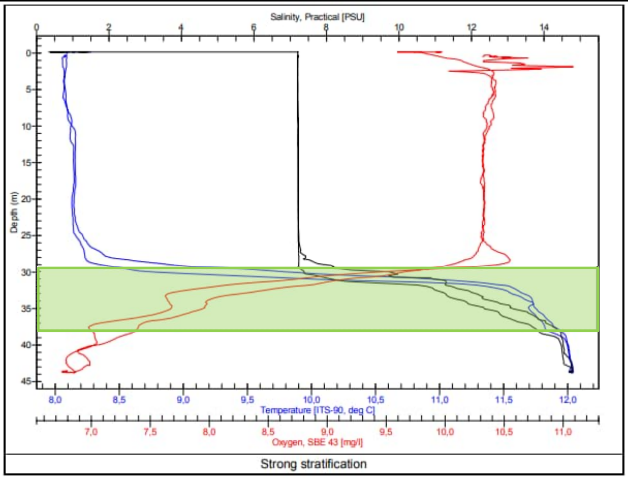
Salinity is one of the main parameters that determines species diversity for both benthic flora and fauna in the Baltic Sea (Gogina et al, 2016; Køie & Kristansen, 2014). Species diversity for benthic flora and fauna is reduced from The Sound to the Bothnian Bay due to a general decline in the salinity of the bottom water from a salinity of approximately 20 psu in The Sound to 2-3 psu in the Bothnian Bay (Perttilä, 2007). Bottom water in the pre-investigation area south of Bornholm, generally, has salinities between 7.5 to 18 psu (Perttilä, 2007; Nord Stream 2, 2018a; Baltic Pipe, 2019).

The salinity in the Baltic is affected by surface freshwater from the many river outflows and from irregular inflow of high-saline deep water from the North Sea through the Danish Straits (Perttilä, 2007). The inflow of saline and oxygen rich seawater to the deep basins in the Baltic Sea is very important for the oxygenation of the deep parts of the Baltic Sea and for the ability of benthic fauna to survive at greater depth. Inflows of high saline water to the Baltic Sea have been relatively rare since the 1980's but has had a slightly higher frequency from 2013 to 2016 resulting in recent improvements (HELCOM, 2018a). The most recent major Baltic inflow occurred in 2014, and moderate inflows were observed in 2018/19 (E.U. Copernicus Marine Service Information, 2020).

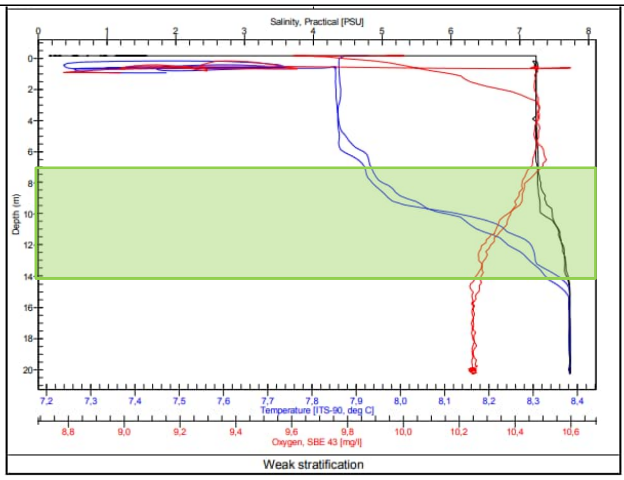
Oxygen deficiency is of particular concern and is especially pronounced in the summer when the spring algae bloom sediments to the seabed and is degraded by bacteria consuming the available oxygen, near and in the seabed. In areas with a strong stratification (halocline and/or thermocline) (see Figure 4-3 A,B) there is no or little oxygen exchange between the surface water mass and the bottom water mass. Without inflow of new oxygen to the bottom water mass bacterial degradation of the spring phytoplankton bloom is able to use up most or all oxygen at the seabed, which in turn limits the growth of benthic flora and benthic fauna in deeper areas, where the oxygen depletion is most severe (HELCOM, 2018a). Shallower stations have more wind and current mixing of the water column and, thus, better oxygen concentrations above the seabed (see Figure 4-3C). Oxygen deficiency (<4 mgO_2/l) is typically found in the period from late spring to late autumn in the pre-investigation area. Lowest oxygen levels are in general experienced at the end of summer, between August and October, due to decomposition of organic material on the seabed (HELCOM, 2018a).



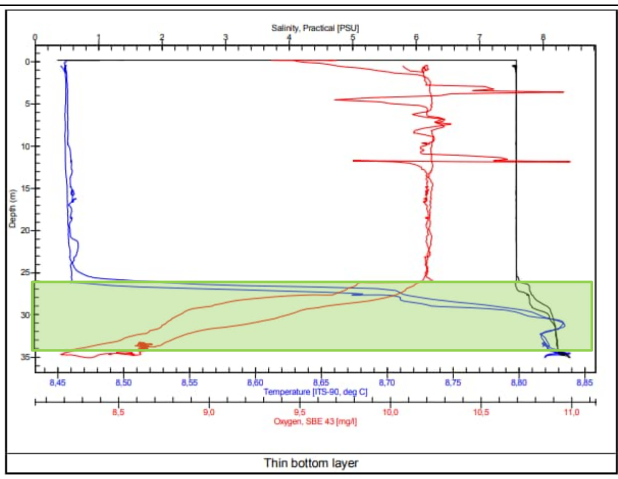
A) NSP2 st_35 - 47.5 m



B) Bornholm I North: NSP2 st_36 - 45.5 m



C) Bird SPA site: NSP2 st_30 - 21 m



D) Bornholm II: NSP2 st_22 – 37 m

Figure 4-3. CTDO-profiles of salinity, temperature and oxygen concentrations from November 21st to December 4th 2017 crossing the pre-investigation area from north (st_35), to Bornholm I North (st._36), south to the shallow Bird SPA area (st_30) and to the deeper Bornholm II area (st_22) (se stations in Figure 4-1). Green box illustrates the position of the halocline and/or thermocline (stratification) between an upper warmer, less-saline water mass and a water mass above the seabed characterized by a higher salinity, lower temperature and oxygen concentration. Source: (Nord Stream 2, 2018a; Orbicon, 2019).

The baseline study for North Stream 2's Northern route crossing the pre-investigation area (see Figure 4-3) found that low oxygen concentrations <4 mgO_2/l were generally found at depths deeper than 60 m. Moderate oxygen deficiency is defined as oxygen concentrations between 2-4 mgO_2/l and severe oxygen deficiency as <2 mgO_2/l. Less than 2 mgO_2/l occurred at most stations with a depth of more than 66 meters (Nord Stream 2, 2018a) and low numbers or no infauna (0-50 individuals/m^2) were found at these stations. The pre-investigation area for Energy Island Bornholm is maximally 58 meters deep and oxygen deficiency at the seabed is therefore possible but less likely.

CTDO-profiles from the deep and shallower part of the pre-investigation area are included to illustrate the profiles of salinity, temperature and oxygen concentration in the water column. The data are provided by the North Stream 2 – Northern route – Baseline study and were sampled in early winter (21st November to 4th December 2017) at four pipeline stations crossing the pre-investigation area from north to southeast (see Figure 4-3). The depth range is from 21 to 47.5 meters of depth. More mixing of the water column at the shallow Rønne Banke station (NSP2st_30, 21 meters depth) is evident from a weak stratification (see Figure 4-3C) and well oxygenated bottom water above the seabed.

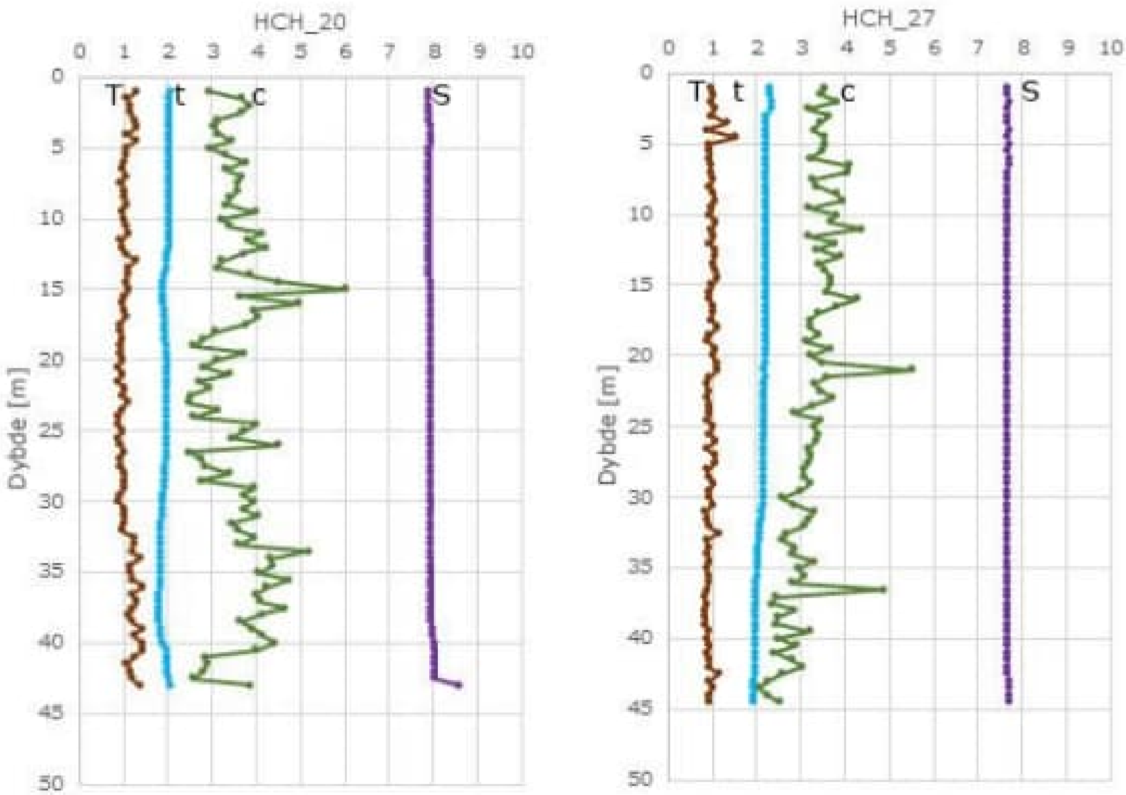


Figure 4-4. CTDO-profiles of temperature (t, °C), salinity (S, psu), turbidity (T, FTU) and chlorophyll-a (C, mg/m^3) in the water column, measured at station HCH_20 and HCH_27 within the pre-investigation area on the 24th to 26th of March 2018. Source: (Baltic Pipe, 2019).

For the Baltic Pipe project CTDO-profiles were taken in the period from 24th to 26th of March 2018, also crossing the pre-investigation area (see Figure 4-1). In this spring period salinities of 7.7 to 8.6 were found in the pre-investigation area and a more well-mixed water column with very little stratification. Oxygen concentrations at the two stations were 12.3 and 14.2 mg/l and no oxygen deficiency were found for any stations during that period (mgO_2/l) (Figure 4-4).

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 in the statistical analysis of infauna composition and distribution in the pre-investigation areas, wind farm areas, cable corridors and the Bird SPA site.

4.3.1 SEDIMENT TYPES

The overall distribution of seabed sediments in the pre-investigation area is presented below in Figure 4-5. The map is based on data from the national geophysical database provided by GEUS (Marta database, (GEUS, 2022)). The conversion between GEUS sediment types and the sediment types used in this baseline study are given in Table 3-3.

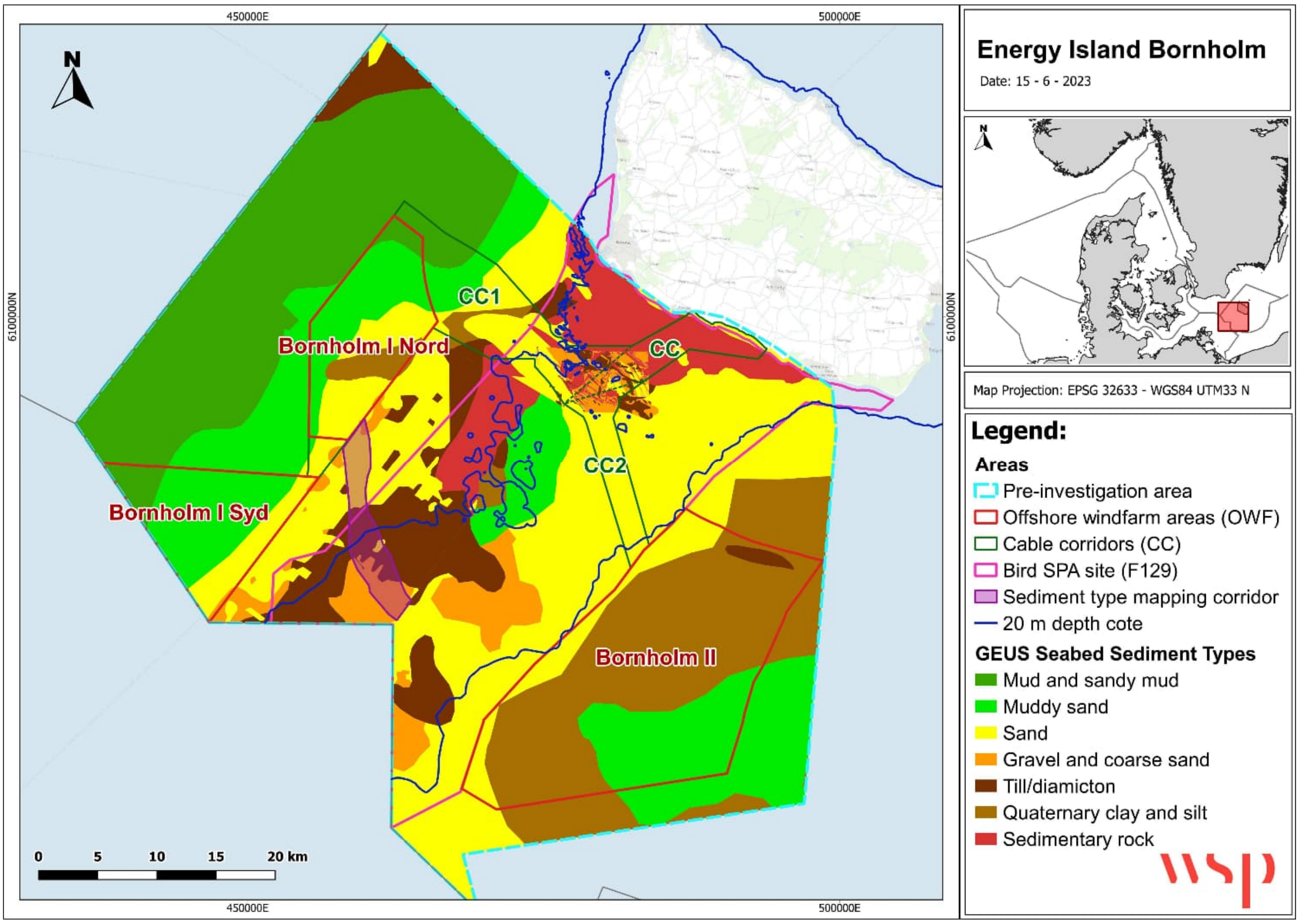


Figure 4-5. Seabed sediment types in the pre-investigation area based on GEUS´ sediment map. The sediment mapping corridor for the North Stream 2 project – Northern route – Monitoring in Natura 2000 site N252/H261 is included (purple line) and the fine-scale sediment mapping within part of this corridor is shown in (Figure 3-5) below. Sources: GEUS Marta database and (Orbicon, 2019). See Table 3-3 for conversion between GEUS sediment types and sediment types used in this report.

The seabed sediment types in the pre-investigation area are highly variable with exposed bedrock ("Sedimentary rock", see Figure 4-5), glacial deposits (stony sediment types) and post-glacial sand and gravel deposits (finer sediments) (Figure 4-5). The deeper parts of the pre-investigation area (furthest east and west) are dominated by finer post-glacial sediments, i.e., "Mud and sandy mud" and "Muddy sand" dominates the sediment.

The largest variation in sediment types within the pre-investigation area is observed in the Rønne Banke area between the wind farm areas. This area is characterized by shallow depth and more till and rocky areas. “Stone reefs” (sediment type 4) are mainly found in the sediment types: “Till/diamicton” and “Sedimentary rock” and are mainly found in the Rønne Banke area between the wind farm areas.

The GEUS map of sediment types in the pre-investigation area is relatively broad-scale and does not illustrate the high natural variation in the pre-investigation area. The high variation in sediment types in the Rønne Banke area is illustrated from the fine scale-mapping of NSP2 - Northern route - Monitoring through the Natura 2000 site “Adler Grund og Rønne Banke (N252/H261)” in 2017/2018 as shown in Figure 4-6 below (Orbicon, 2019). This area is mapped as “Till diamicton” (sediment type 3 and 4), “Gravel and coarse sand” (sediment type 2) and small patches of “Sand” (sediment type 1b).

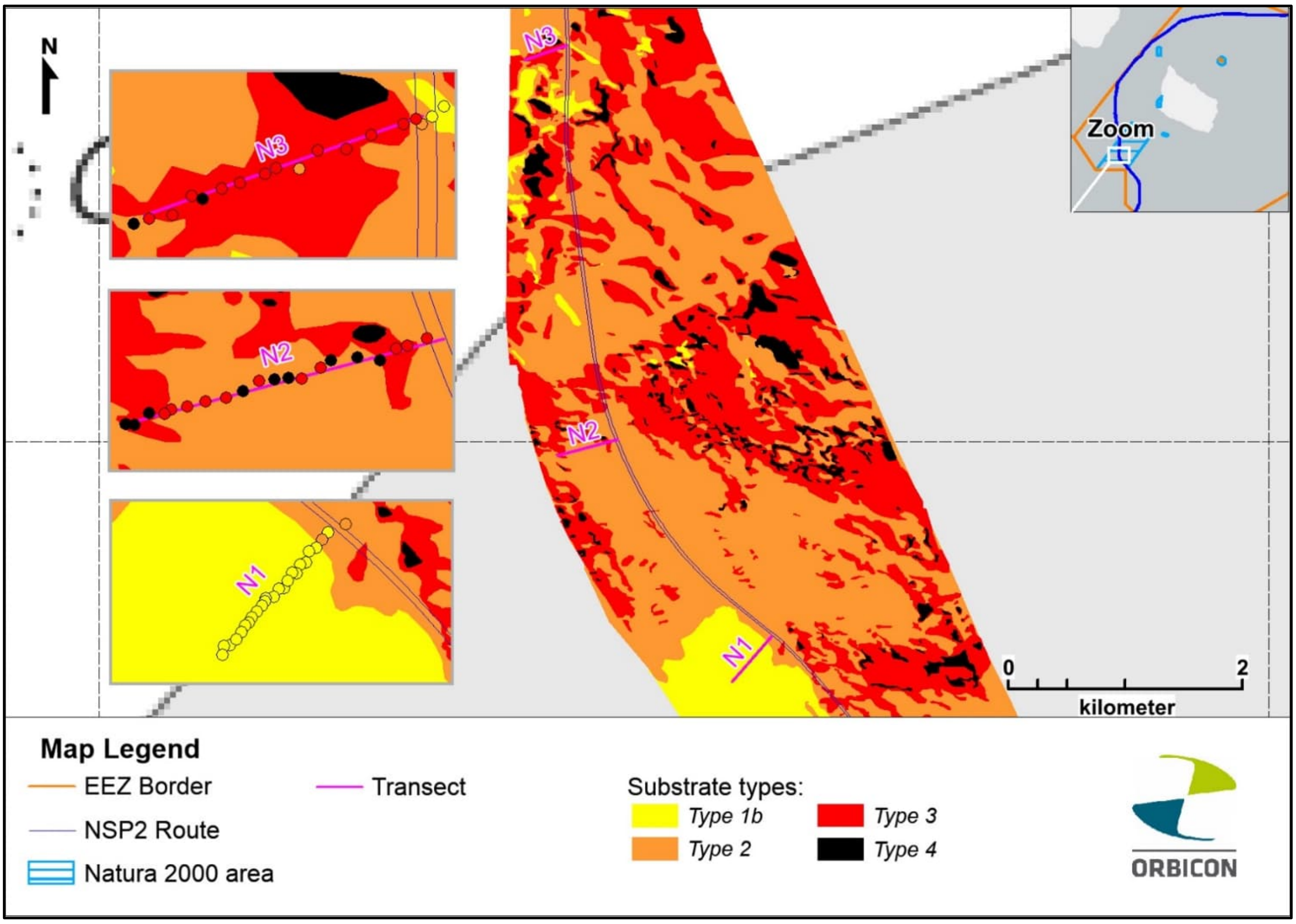


Figure 4-6. Small-scale variation in seabed sediment types in the Rønne Banke area. Fine-scale baseline mapping in the pipeline corridor for the Northern route through the Natura 2000 site “Adler Grund og Rønne Banke” (N252/H261) in 2017/2018 (Orbicon, 2019). Sediment type 1b is sand, Sediment type 2 is soft sediment, or gravel with up to 10 % coverage of large stones (>10 cm). Sediment type 3 is soft sediment with 10-25 % coverage of large stones (>10 cm) and finally sediment type 4 is stone reef with >25 % coverage of large stones (>10 cm). Source: (Orbicon, 2019). See Table 3-3 for conversion between GEUS sediment types and sediment types on this figure.

On the GEUS broad scale map (Figure 4-5) the “sediment type mapping corridor” contains larger areas of “Sedimentary rock” (sediment type 3 and 4), “Sand” and “Gravel and coarse sand” (sediment type 2 to 1b) (Figure 4-5). However, on the fine-scale map above the sediment types are shown as a highly varying mosaic of sediment types (Figure 4-6).

WIND FARM AREAS

Existing data shows that Bornholm I North is dominated by “Muddy sand”, “Sand”, and “Quarternary clay and silt” (Figure 4-5). Bornholm I South is dominated by “Muddy sand”, “Sand”, and “Mud and sandy mud”. Bornholm II is dominated by “Quarternary clay and silt”, “Muddy sand” and a smaller area with “Sand”. Bornholm II therefore has more “Quarternary clay and silt” compared to Bornholm I North and Bornholm I South with more sandy sediments. In general, the organic content of sediments in the area increases with depth (see section 4.3.2 below).

CABLE CORRIDORS

The cable corridors between the wind farm areas (OWFs) and Bornholm are shown in Figure 4-5 and Figure 4-7. In general, the sediment in the two cable corridors changes from “Sand” very close to the coast, hard “Sedimentary rock” and at more than 20 meters depth finer sediment types such as mud and silt.

The cable corridor overlap (CC) from landfall on Bornholm and the first 10-15 km towards the OWFs is dominated by “Sand” in the landfall area closest to the coast and in the rest of the overlapping corridor by “Sedimentary rock”, with smaller patches of “Gravel and coarse sand”, “Sand” and finer sediments.

In the CC1 corridor connecting Bornholm and Bornholm I North (OWF) at more than 20 meters depth the sediment changes from “Sedimentary rock” (CC1_01-05) to “Sand” (CC1_06 and CC1_09-11), a small area with “Till/diamicton” (CC1_07 and CC1_08) and closest to Bornholm I North “Muddy sand” and “Mud and sandy mud” (CC1_12-15).

The small cable corridor CC1 area between Bornholm I North and Bornholm South consists mainly of “Sand” (see Figure 4-5)

The CC2 corridor connecting Bornholm II (OWF) and Bornholm is dominated by “Till/diamicton” (CC2_01-03) in the first part of the corridor (from landfall) and “Sand” (CC2_04-12) in the rest of the cable corridor towards Bornholm II.

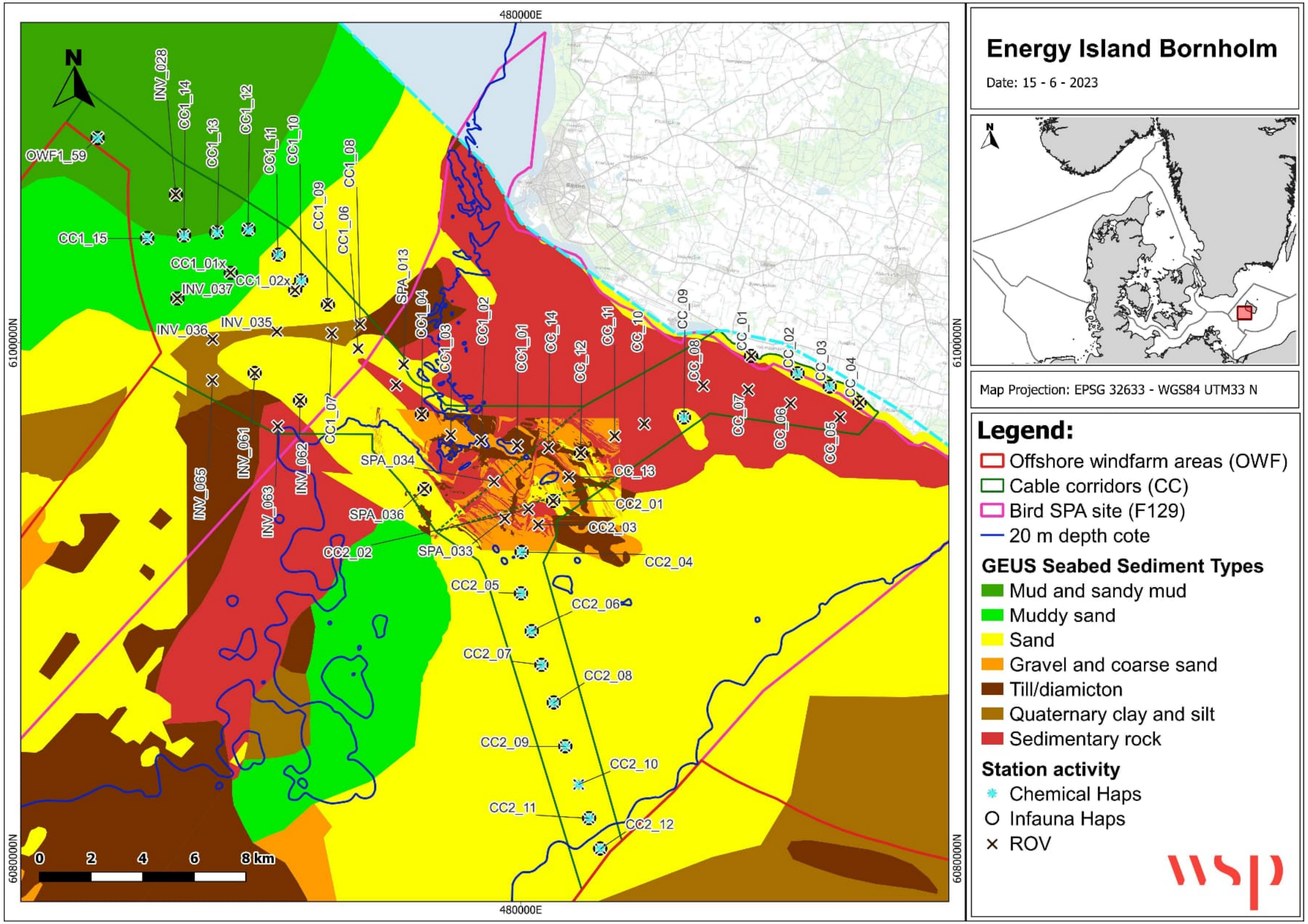


Figure 4-7. Seabed sediment types in the two cable corridors connecting the two OWFs to Bornholm (CC1 and CC2) (= cable corridor area). Overlapping area of the cable corridors close to the coast are called CC. Sampling stations in the cable corridors are presented in the figure. Different sampling types are also shown i.e., ROV-video, Chemical samples, CTDO profiles and HAPS sediment core samples. Source: GEUS´ Marta database.

4.3.2 PHYSICAL PARAMETERS

Grain size and organic content is determining for the habitat available to the benthic flora and fauna and for oxygen conditions.

Analyses of grain size and organic content along the NSP2 - Northern route showed that generally the organic content (TOC) and the silt and clay fraction increased with increasing water depth, whereas average grain size (D50) decreased with depth. Thus, high organic content and fine grain size was found in the deep parts of the pre-investigation area along the NSP2 – Northern route (Nord Stream 2, 2019). Whereas, in the shallow part of the pre-investigation area in the Rønne Banke area, generally, high grain size and low organic content was found (Nord Stream 2, 2019) (Table 4-3).

Table 4-3. Standard physical conditions at the surface sediment stations in the pre-investigation area. TOC = total organic carbon, D50 = average grain size. – no data. n = sample size. *Read from graph (Figure 7-18) (Nord Stream 2, 2019). Stations within Bornholm I North and Bornholm I South are marked with light and dark blue fill color, respectively. Bornholm II stations are marked with darker red fill color and stations within the cable corridor area with grey fill. Sources: (Baltic Pipe, 2019), (Nord Stream 2, 2019), (Nord Stream 2, 2018a). Station location is shown in Figure 4-1.

Project and sample number	Depth [m]	TOC [% of DW]	D50 [mm]	Silt & Clay fraction [%]
Baltic Pipe, February/March 2018				
GCH38	44	-	-	88.9
GCH41	28	-	-	1.0
GCH45	15	-	-	0.8
GCH48	17	-	-	0.2
GCH53	44	-	-	90.8
GCH51	53	-	-	100
GCH50	51	-	-	98.7
North Stream 2 – Northern Route, Baseline study, November/December 2017				
D_EEZ_22	37.0	0.42	0.188	4
D_EEZ_24	21.0	0.07	1.250	0
D_EEZ_26	21.0	0.05	0.500	0
D_EEZ_28	45.0	1.80	0.052	52
D_EEZ_29	35.0	0.10	0.438	0
D_EEZ_30	21.0	0.12	0.440	4
D_EEZ_31	45.0	0.73	0.350	14
D_EEZ_34	38.0	0.24	0.210	3
D_EEZ_35	47.5	5.00	0.016	89
D_EEZ_36	45.5	3.90	0.024	70
D_EEZ_37	47.0	2.60	0.015	94
D_EEZ_38	37.0	0.56	5.000	1
D_EEZ_39	40.0	3.00	0.290	10
D_EEZ_41	27.0	0.08	0.800	0
Average (n=27)	51.8	1.9	0.7	51.1
Standard deviation (±)	20.1	1.7	1.9	43.3
North Stream 2 – Final Route, August/September 2018				
SS-13	55.6	0.4*	-	75*
SS-14	52	2.7*	-	62*
SS-15	46.1	0.7*	-	50*
SS-16	30.2	0.5*	-	42*

For stations located within Bornholm I North and South (D_EEZ_34, _36, _38, _39 and GCH38), there was a similar trend that the deepest stations had the lowest grain size and the highest amount of organic content (Table 4-3). Comparing stations within Bornholm I North (D_EEZ_34, _36 and GCH38) and Bornholm I South

(D_EEZ_38, _39), both wind farm areas have very varying grain size and silt and clay fractions between stations within each wind farm area.

Two of the three stations within the Bornholm II (D_EZZ_22, GCH51, GCH53) were found at great depth (>98 m) with a very high silt and clay fraction (GCH51 and -53), whereas, the third, D_EEZ_22, bordering Rønne Banke, was a shallow station with a low silt and clay fraction (Table 4-3). Information on TOC and D50 was not available for comparison from Baltic Pipe stations. The silt and clay fraction differed to a great extend between stations in the wind farm areas (Bornholm I North, Bornholm I South and Bornholm II), and a further comparison of TOC and D50 would require more data.

Within the cable corridor area (CC, CC1, CC2) two stations from the Baltic Pipe project (GCH41 and GCH45) at depth between 15-28 meters of depth showed low silt and clay content of 0.8 and 1.0 % (Table 4-3). No data for TOC or D50 were available for these stations.

4.3.3 CHEMICAL PARAMETERS

Sediment that is suspended in the water column due to digging or flushing activities during construction of the 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 for 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 wind farm areas and cable corridors.

NUTRIENTS

Existing data for total nitrogen (TN) and total phosphorus (TP) in and close to the pre-investigation area show highest concentrations at deep stations >40 meters of depth corresponding to the presence of finer-grained and more organic-rich sediment dominated by silt and clay (Table 4-4). Station locations within the pre-investigation area are presented in Table 4-4 and Figure 4-8 below.

There are no threshold concentrations for TN and TP in sediment in the Baltic Sea.

North Stream 2 (NSP2) - Northern route – baseline study found concentrations between <100-5,700 mg N/kgDW and 170-1,100 mg P/kgDW for stations within the pre-investigation area (see Table 4-4).

Concentrations of sediment TN (150-5,000 mg N/kgDW) and TP (110-820 mg P/kgDW) measured for NSP2 – Final route in 2018 along the southern rim of the pre-investigation area were within the range found at the same depths for the NSP2 - Northern route - baseline study in 2017 (Table 4-4).

For Baltic Pipe, measurements of TN (<200-6,000 mg N/kgDW) and TP (240-1,200 mg P/kgDW) in the sediment were within the same range as found in both NSP2 - Northern Route – baseline study and NSP2 - Final Route, however, most measurements of TN were <200 mg/kgDW, i.e. below detection range (Table 4-4).

Looking at the stations located within Bornholm I North and South (D_EEZ_34, _36, _38, _39 and GCH38), the concentration of TN ranged between 700-4,900 mg N/kgDW, which is relatively high compared to the overall range in the pre-investigation area (<100-6,000 mg N/kgDW). The range of TP in Bornholm I North and South (170-1,100 mg P/kgDW) was similar to the overall range for all previous reports (110-1,200 mg P/kgDW).

Within Bornholm II (D_EZZ_22, GCH51, GCH53), concentrations of TN and TP ranged between <200-6,000 mg N/kgDW and 400-1,200 mg P/kgDW, which is comparable to the overall ranges, although TP is in the higher end (Table 4-4).

Within the cable corridor area (CC, CC1, CC2) two stations from the Baltic Pipe project (GCH41 and GCH45) showed TN concentrations of TN and TP ranged between <200 mg N/kgDW and 240-810 mg P/kgDW, which is low compared to the overall ranges (Table 4-4).

Table 4-4. Existing data for total nitrogen (TN) and phosphorus (TP) measured in sediment samples within the pre-investigation area. Data included from North Stream 2 – Northern route (Nord Stream 2, 2018a), North Stream 2 – Final Route (Nord Stream 2, 2019) and Baltic Pipe (Baltic Pipe, 2019). Stations within Bornholm I North and Bornholm I South are marked with light and dark blue fill, respectively. Bornholm II stations are marked with darker red fill color and stations within the cable corriodrs with grey fill. For station location see Figure 4-8.

Location ID shortcut	Total nitrogen (mg/kg DW)	Total phosphorus (mg/kg DW)	Depth (m)	Sediment type
North Stream 2 – Northern Route, November/December 2017				
D_EEZ_22	600	400	37	Fine sand and silt
D_EEZ_24	110	300	21	Sand
D_EEZ_26	<100	180	21	Sand
D_EEZ_28	2900	670	45	Silt on top of clay
D_EEZ_29	<100	180	35	Sand
D_EEZ_30	140	340	21	Sand
D_EEZ_31	520	580	45	Silt, sand and gravel on top of clay
D_EEZ_34	700	170	38	Sand and silt
D_EEZ_35	5700	1100	47.5	Silt
D_EEZ_36	4900	1100	45.5	Silt
D_EEZ_37	2900	290	47	Silt
D_EEZ_38	1000	260	37	Sand and silt
D_EEZ_39	2300	820	40	Silt and sand
D_EEZ_41	<100	260	27	Sand
North Stream 2 – Final Route, August/September 2018				
SS-13	5000	820	55.6	Grey and dark clay
SS-14	3600	740	52	Clay and some sand
SS-15	1000	490	46.1	Sand and dark clay
SS-16	150	110	30.2	Sandy
Baltic Pipe, February/ March 2018				
GCH38	1.000	640	44	Silt/clay (88.9 %), sand
GCH41	<200	240	28	Sand (98.8 %)
GCH45	<200	810	15	Sand (96.9 %), gravel
GCH48	<200	470	17	Sand (99.7 %)
GCH53	<200	550	44	Silt/clay (90.8 %), sand
GCH51	6000	1200	53	Silt/clay (100 %)
GCH50	1400	630	51	Silt/clay (98.7 %)

POLLUTANTS

Pollutants in the sediment have previously been investigated in the pre-investigation area in relation to the Baltic Pipe and North Stream Project 2 (NSP2) for the Final Route and the Northern Route (Baltic Pipe, 2019; Nord Stream 2, 2018a; Nord Stream 2, 2019). Existing data are presented below (see section 3.2.4 – Chemical Analysis for list of included pollutant parameters). Stations where pollutants exceeded the applied threshold values can be seen in Table 4-5 and station locations within the pre-investigation area are presented in Figure 4-8. Depth and sediment type for the selected stations can be seen in Table 4-6.

Detection limits of anthracene and TBT from the laboratory analyses from the previous investigations were higher than some of the applied threshold values. In the Baltic Pipe investigations, the detection limit for TBT was 0.01 mg/kg DW, but all three available threshold values (NEQS, EQS and LAL) were lower (see Table 4-5). In the baseline study for NSP2 – Northern Route, detection limit of anthracene was 0.005 mg/kg DW but the NEQS threshold value today is 0.0048 mg/kg DW (Table 4-5). This means that, at some stations, an assessment of these pollutants cannot be achieved according to the existing threshold values and therefore more exceedances might exist.

The majority of the measured pollutants at the selected stations within the pre-investigation area from these existing baseline studies were found in concentrations below threshold values, corresponding to background levels, which are considered to be harmless to marine life.

In total, 12 pollutants (heavy metals (4), PAH-compounds (6), PCB congeners (1) and organotin-compounds (1)) were found exceeding the applied threshold values (see Table 4-5). Of the 24 selected stations, arsenic exceeded the NEQS threshold value at all stations. Excluding arsenic, exceedances of threshold values were found at 16 out of 24 stations (67 %).

Looking at heavy metals other than arsenic, nickel also exceeded threshold values at several stations (11 of 24 stations, 46 %). Lead and copper were also found at exceeding concentrations at three stations each, and both compounds exceeded the ERL and the LAL values, but not the NEQS or the EQS values (see Table 4-5).

Exceedances were found in six PAHs in the previous investigations: anthracene (42 %), chrysene (25 %), benzo(ghi)perylene (38 %), benzo(a)anthracene (25 %), benzo(a)pyrene (50 %) and indeno(1,2,3cd)pyrene (42 %) (Table 4-5).

Concentrations of the PCB congener 118 exceeded threshold values at two stations (8 %) and the organotin-compound TBT exceeded threshold values at seven stations (29 %) (Table 4-5).

Baltic Pipe station GCH_38 and NSP2 – Northern Route stations D_EEZ_34 and _36 are located within Bornholm I North (see Figure 4-8). Of the 12 compounds that exceeded threshold values in the pre-investigation area in total, only lead and PCB were not found in exceeding concentrations within this OWF area. Contamination of the sediments at the three stations differ, however, where most exceedances of pollutants are found at station D_EEZ_36, whereas only two pollutants (arsenic and anthracene) are found at D_EEZ_34.

The NSP2 – Northern Route stations D_EEZ_38 and _39 are located within Bornholm I South (see Figure 4-8), and here exceedances are also found for most compounds, except for copper and PCB118. Again, the two stations differ, with D_EEZ_39 being the most contaminated.

Within the Bornholm II area, Baltic Pipe stations GCH_51 and _53 and the NSP2 – Northern Route station D_EEZ_22 are found. Similar to the two Bornholm I OWF areas, great differences were found between the stations, where GCH_51 had exceedances of all pollutants except for PCB118, whereas station GCH_53 and D_EEZ_22 had exceedances of only one and two compounds (Table 4-5).

Two stations are located within the cable corridors i.e., Baltic Pipe stations GCH_41 and _45. At both stations arsenic exceeded the NEQS threshold value, and at GCH_41, PCB118 was also exceeded.

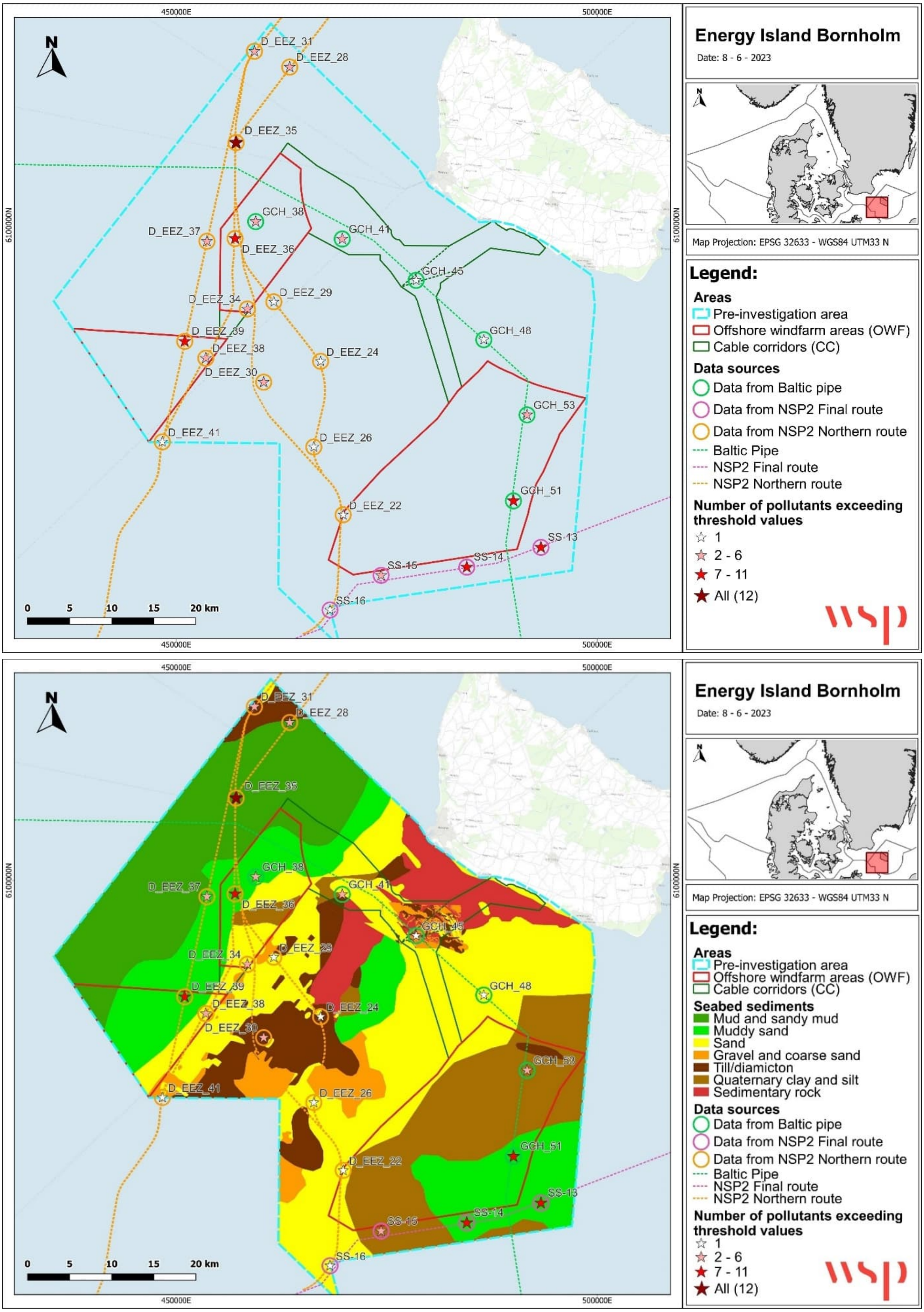


Figure 4-8. Stations from previous baseline studies located within the pre-investigation area, with exceedances of threshold values for pollutants marked with different star symbols. Map at the bottom includes sediment types. Data and data sources are shown in Table 4-5. Survey years are shown in for the existing studies in Table 4-4.

Table 4-5. Pollutants exceeding applied threshold values (heavy metals, TBT, PCB118 and PAH-compounds) in the sediment at stations from previous baseline studies within the pre-investigation area of the Energy Island Bornholm, showing concentrations and applied threshold values (in mg/kgDW). "-" indicate that the detection limit from the chemical analysis in the laboratory was higher than the lowest applied threshold value(s) and, thus, it is not possible to determine if the specific compounds exceed the threshold values at these stations. Empty cells indicate no exceedance of threshold values. Pollutants mostly exceeded the NEQS values represented by black numbers in the table, and blue numbers indicate which of the other threshold values were exceeded. Gray threshold values indicate that these have not been exceeded. Stations within Bornholm I North and Bornholm I South are marked with light and dark blue fill, respectively. Bornholm II stations are marked with darker red fill color. For station location see Figure 4-8. Data included from North Stream Project 2 (NSP2) – Northern route (Nord Stream 2, 2018a), NSP2 – Final Route (Nord Stream 2, 2019) and Baltic Pipe (Baltic Pipe, 2019). *Threshold value for anthracene is a statutory NEQS value (Miljøstyrelsen, 2023a). f_{oc} is the fraction of TOC in the sediment.

Sampling Station	Heavy metals				PAH						PCB	Organotin
	Arsenic (As)	Nickel (Ni)	Lead (Pb)	Copper (Cu)	Anthra-cene	Chry-sene	Benzo-(g,h,i)-perylene	Benz(a)-anthra-cene	Benz(a)-pyrene	Indeno-(1,2,3cd)-pyrene	PCB118	TBT
Threshold values												
NEQS	**0.4**	**6.8**	163		**0.096 x f_{oc}***	**0.0231**	**0.042**	**0.03**	**0.007**	**0.042**		**0.0013**
EQS			120									**0.0016**
EAC									0.625		**0.0006**	
ERL	**8.2**	20.9	**47**	34	0.078	0.384	**0.085**	0.261	0.43	**0.24**		
LAL	20	30	**40**	**20**	0.085							**0.007**
Baltic Pipe												
GCH_38	**12.0**	**29.0**		**22.0**					0.011	0.045		-
GCH_41	2.3										**0.0036**	-
GCH_45	1.3											-
GCH_48	1.3											-
GCH_53	5.0	17.0										-
GCH_51	**15.0**	**29.0**	**57**	**41**	0.009	0.062	**0.3**	0.046	0.062	**0.48**		**0.01**
NSP2 – Northern Route												
D_EEZ_22	1.7				-							
D_EEZ_24	2.5				-							
D_EEZ_26	1.1				-							
D_EEZ_28	**12**	18			0.016		**0.086**		0.039	0.11		
D_EEZ_29	1				-							
D_EEZ_30	2.9	11			-							
D_EEZ_31	6.1	9			0.0086		0.054		0.025	0.066		
D_EEZ_34	1.1				0.0029							
D_EEZ_35	**17**	**34**	**78**	**44**	0.05	0.099	**0.42**	0.12	0.17	**0.52**	**0.00093**	**0.0042**

Sampling Station	Heavy metals				PAH						PCB	Organotin
	Arsenic (As)	Nickel (Ni)	Lead (Pb)	Copper (Cu)	Anthra-cene	Chry-sene	Benzo-(g,h,i)-perylene	Benz(a)-anthra-cene	Benz(a)-pyrene	Indeno-(1,2,3cd)-pyrene	PCB118	TBT
Threshold values												
NEQS	**0.4**	**6.8**	163		**0.096 x f_{oc}***	**0.0231**	**0.042**	**0.03**	**0.007**	**0.042**		**0.0013**
EQS			120									**0.0016**
EAC									0.625		**0.0006**	
ERL	**8.2**	20.9	**47**	34	0.078	0.384	**0.085**	0.261	0.43	**0.24**		
LAL	20	30	**40**	**20**	0.085							**0.007**
D_EEZ_36	**8.4**	**21**			0.034	0.046	**0.19**	0.053	0.074	0.23		**0.003**
D_EEZ_37	2				0.014		0.058		0.027	0.077		**0.0017**
D_EEZ_38	2.6				0.012				0.014			
D_EEZ_39	**9.4**	**24**	**54**		0.015	0.024	**0.092**	0.031	0.044	0.12		**0.0029**
D_EEZ_41	1.7				-							
NSP2 – Final Route												
SS-13	**9.3**	19			0.016	0.049	0.23	0.057	0.08	0.32		**0.0029**
SS-14	5.8	13				0.029	0.11	0.035	0.049	0.15		**0.0023**
SS-15	2.3								0.012			
SS-16	2.9											

Most exceedances of pollutants were found at >37 meters of depth, in sediment type 1a containing silt, mud and clay. Stations within the pre-investigations area which contained the greatest number and concentrations of pollutants (GCH_51, D_EEZ_39 and D_EEZ_36), were found >45 meters of depth on a 1a sediment, whereas the least polluted stations with only one pollutant exceeding threshold values (see Table 4-5) were found at >37 meters of depth (often >20 m) primarily located on sandy sediments (Table 4-5 and Table 4-6). This was expected, since pollutants generally adsorb to fine-grained, organic-rich material and accumulate with depth (Strand & Larsen, 2013).

Pollutants mostly exceeded the NEQS threshold values, which are generally lower compared to the other applied threshold values (see Table 4-5). In fact, discarding the NEQS, exceedances were only observed at 10 out of 24 stations and no exceedances were found in 4 of 6 PAH-compounds (anthracene, chrysene, benz(a)anthracene and benz(a)pyrene) (Table 4-5).

Table 4-6. Depth and sediment type for included existing stations from baseline studies of Baltic pipe and North Stream 2 located within the pre-investigation area.

Sampling Station	Depth	Sediment Type
Baltic Pipe		
GCH_38	44	1a: Silt/clay (88.9 %), sand
GCH_41	28	1b: Sand (98.8 %)
GCH_45	15	1b/2: Sand (96.9 %), gravel
GCH_48	17	1b: Sand (99.7 %)
GCH_53	44	1a: Silt/clay (90.8 %), sand
GCH_51	53	1a: Silt/clay (100 %)
NSP2 – Northern Route		
D_EEZ_22	37	1a: Fine sand and silt
D_EEZ_24	21	1b: Sand
D_EEZ_26	20	1b: Sand
D_EEZ_28	45	1a/1c: Silt on top of clay
D_EEZ_29	35	1b: Sand
D_EEZ_30	21	1b: Sand
D_EEZ_31	45	2: Silt, sand, and gravel on top of clay
D_EEZ_34	38	1a/1b: Sand and silt
D_EEZ_35	47.5	1a: Silt
D_EEZ_36	45.5	1a: Silt
D_EEZ_37	47	1a: Silt
D_EEZ_38	37	1a/1b: Sand and silt
D_EEZ_39	40	1a: Silt and sand
D_EEZ_41	27	1b: Sand
NSP2 – Final Route		
SS-13	55.6	Dark gray clay
SS-14	52	Clay, some sand
SS-15	46.1	Sand with dark clay
SS-16	30.2	Sand

4.4 BENTHIC FLORA

Benthic flora in the Baltic Sea consists mainly of seagrasses and macroalgae. Seagrasses grow in sandy sediment types down to 2.7 to 6.3 meters depth (maximum depths) along the southern coast of Bornholm (see section 4.4.1 - Seagrasses below, Table 4-7). Macroalgae live attached to hard substrate/ rocky sediment within the photic zone. The photic zone is generally defined as depths, where more than 1 % of surface irradiance is present and typically encompasses the upper 0-20 meters of the water column in the Baltic Sea. Monitoring of North Stream 2 in the Natura 2000 site N252/H261 in the pre-investigation area found macroalgae down to 24.5 meters of depth in 2017 (crust algae) (Orbicon, 2019). At greater depths benthic flora, generally, cannot exist due to light limitation (Olsonen, 2006).

Depths within the photic zone (light green) and with rocky sediment (dark green) for macroalgae attachment in the pre-investigation area are shown in Figure 4-9 below. The figure illustrates that benthic flora is potentially present along the coast of Bornholm and in the shallow Rønne Banke area south of Bornholm between the wind farm areas where depths are 0-24.5 meters.

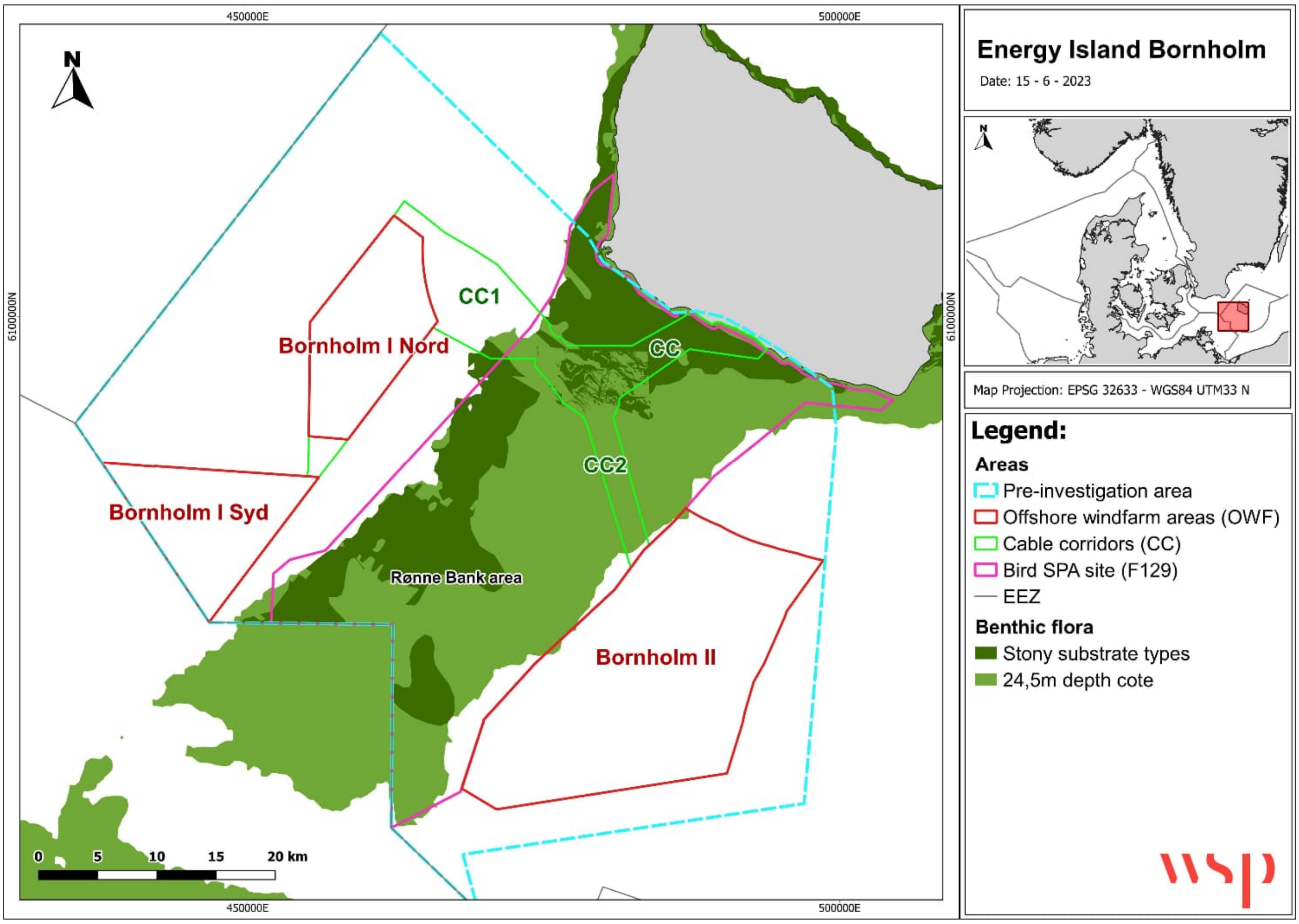


Figure 4-9. The map shows the photic zone (light green) and stony areas (dark green) where attachment is available for macroalgae in the pre-investigation area at depths from 0 to 24.5 meters, the wind farm areas and in the cable corridors.

Apart from hard substrate and light availability, macroalgae growth is limited by oxygen deficiency and low salinity (Olsonen, 2006; Køie & Kristansen, 2014). In general, species richness decreases with decreasing salinity concentration from the Danish Sound towards the northeastern part of the Baltic (Olsonen, 2006; Køie &

Kristansen, 2014). Macroalga species composition varies with succession during the year, from year to year, and can, therefore, vary between sampling years (Køie & Kristansen, 2014). Macroalgae compete with blue mussels (*Mytilus edulis*) for the hard substrate in the area, and in large parts blue mussels dominate the coverage of stones in the pre-investigation area creating biogenic reefs (Orbicon, 2019; Miljøstyrelsen, 2021b).

Benthic flora in the shallow-water, sandy seabed along the southern coast of Bornholm consists mainly of macroalgae on hard substrate and some seagrass (*Zostera marina*) in sandy substate.

4.4.1 SEAGRASSES

The depth limit of the main distribution (where coverage is ≥10 %) of eelgrass (*Zostera marina*) is used as an indicator of the water quality cf. the Danish River Basin Management Plans (RBMPs). The objective for the depth limit is targeted at 7.5 meters in the River Basin Østersøen (Baltic Sea), Bornholm DKCOAST56, defining the threshold between moderate and good ecological status (Miljøministeriet, 2023). The actual depth limit was latest assessed at 3.3 meter covering the monitoring period between 2014-2019, and the current status of the River Basin is assessed as poor with regard to eelgrass.

Several NOVANA stations monitoring eelgrass exist within the pre-investigation area (Table 4-7). Monitoring has been carried out in 2017 and 2022 (with the exception of station Sose 2, BOR310016 which was only monitored in 2022) and data are presented in the table below.

Table 4-7 Minimum, main and maximum depth limits (meter) of eelgrass found at NOVANA stations within the pre-investigation area in 2017 and 2022. Data from (Danmarks Miljøportal, 2023a). Station locations are shown in Figure 4-1.

Distribution depth (m)	Min		Main		Max	
Station no. and name	2017	2022	2017	2022	2017	2022
99110007 - Fredensborg 2, BOR310012	3.3	2.2	4.2	4.55	4.2	4.55
99150005 - Sose 1, BOR310015	1.7	1.6	4	6.3	-	6.3
99150006 - Sose 2, BOR310016	-	1.72	-	5.41	-	5.41
99150009 - Bakkerne Havn 2, BOR310009	3.8	1.9	-	2.67	3.80	2.67

Eelgrass along the west coast of Bornholm is found at depths between 1.6-6.3 m. The coverage degree is generally low (<10 %) with most observations showing 0 % coverage. Main and maximum distribution depths have been registered for station 99110007 - Fredensborg 2 (BOR310012), which showed a slight increase in both depth limits between 2017 and 2022. For station 99150005 - Sose 1 (BOR310015), only the main distribution depth has been registered both years showing an increase of 2.3 meters in the same period. For the remaining stations data on the main distribution depth only exists for 2022. For station 99150009 - Bakkerne Havn 2 (BOR310009) a slight decrease in the maximum distribution depth was registered between 2017 and 2022. As data only exists for 2017 and 2022, it is not possible to derive any tendency based on this dataset.

Additionally, at the macroalgae NOVANA station Franks Rev (BRK_5065000), eelgrass was also registered at depths between 2-4 meters, which corresponds to observations made at the surrounding eelgrass NOVANA stations within the pre-investigation area (Odaforalle.dk, 2022).

4.4.2 MACROALGAE

Macroalgae are divided into three groups including red algae (Rhodophyta), brown algae (Phaeophyta) and green algae (Chlorophyta). All three groups can be found along the coast of Bornholm (Table 4-8).

Existing data illustrated in Table 4-8, shows that macroalgae found on larger stones along the coast are dominated by the brown alga genus *Fucus* spp., green algae such as *Cladophora* spp., and red alga bushes such as *Ceramium* spp., *Polysiphonia* spp. and *Furcellaria lumbricalis*. At greater depth red algae bushes, crust algae and coralline red algae dominate (Figure 4-10). At even greater depths of 14-30 meters blue mussels (*Mytilus edulis*, up to 100 % coverage) was found to dominate the benthic communities in the NOVANA baseline study from 2011 in the Natura 2000 site N252/H261 (Miljøstyrelsen, 2021a) (Figure 4-10 lower figure).

In the shallow Rønne Banke area NSP2 - monitoring in Natura 2000 site “Adler Grund og Rønne Banke (N252/H261)” in 2017 at depths from 18-24.4 m, showed dominance of blue mussels on the hard substrate and low coverage of macroalgae (0-10 %) (Orbicon, 2019). The most common red algae species was the red bush *Callithamnion corymbosum* and red crust algae *Hildenbrandia* sp., which were observed at all but one station (Figure 4-10). Very few brown algae were observed. Most common was brown crust (Orbicon, 2019).

The cumulated coverage of macroalgae in coastal waters in the period NOVANA-monitoring period 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 in stone reefs (Hansen & Høgslund, 2023). The species diversity of macroalgae in the waters around Bornholm is generally low due to low salinities (Carstensen, 2020).

There are no benthic flora species on the Danish red list (Den danske rødliste, 2022). None of the observed species in the pre-investigation area (Table 4-8) are considered threatened (Critically Endangered, Endangered or Vulnerable) according to the HELCOM red list (HELCOM, 2023a). The two brown algae species *Fucus serratus*, *Fucus vesiculosus* and the red algae species *Furcellaria lumbricalis* are listed as Least Concern (LC).

Table 4-8. Macroalgae species found in the pre-investigation area. [1]: NOVANA-station Franks Rev 2008-2022 (Danmarks Miljøportal, 2023b). [2]: North Stream 2 – Northern route – monitoring in N2000 site N252/H261 (Orbicon, 2019). [3]: Baseline analysis Natura 2000 site N252/H261 (Miljøstyrelsen, 2021a). No benthic flora stations from Baltic Pipe were located within the pre-investigation area.

Macroaalgae taxa	Red algae (Rhodophyta)	Brown algae (Phaeophyta)	Green algae (Chlorophyta)
NOVANA st Franks Rev close to the coast[1] 2008-2022 **0-100 % coverage** **1-14 meters depth**	Crusts: *Red crust (Hildenbrandia rubra)* *Red calcified crust* Red algae bushes: *Aglaothamnion roseum* *Callithamnion sp.* *C. corymbosum* *Ceramium spp.* *C. diaphanum* *C. rubrum* *C. strictum* *C. tenuicorne* *C. virgatum* *Coccotylus truncates* *Cystoclonium purpureum* *Delesseria sanguinea* *Furcellaria lumbricalis* *Gaillona rosea* *Leptosiphonia fibrillosa* *Phyllophora pseudoceranoides* *Polysiphonia spp.* *P. fucoides* *P. stricta* *Rhodomela confervoides* *Vertebrata fucoides*	Crusts: *Brown crust* *Scytosiphon lomentaria crust* Brown algae bushes: *Chorda filum* *Desmarestia viridis* *Dictyosiphon foeniculaceus* *Ectocarpus sp.* *Eudesme virescens* *Fucus sp.* *Fucus serratus* *Halosiphon tomentosus* *Leathesia marina* *Pylaiella littoralis* *Scytosiphon lomentaria* *Stictyosiphon tortilis*	*Chaetomorpha linum* *Cladophora sp.* *C. glomerata* *C. rupestris* *Spongomorpha aeruginosa*
North stream 2 - N2000 monitoring in N252/H261 in 2019[2] **18-24.4 meters depth** **0-10 % coverage**	Crusts: *Red crust (Hildenbrandia sp.)* *Coralline red algae (Phymatolithon sp.)* Red algae bushes: *Callithamnion corymbosum* *Polysiphonia spp.* *Ceramium spp.* *Coccotylus truncatus*	Crusts: *Brown crust algae* Brown algae bushes: *Sugar kelp (Saccharina latissima)*	
Natura 2000 site N252/H261[3] 2016-2021	*Red algae bushes*	*Sugar kelp (Saccharina latissima)*	

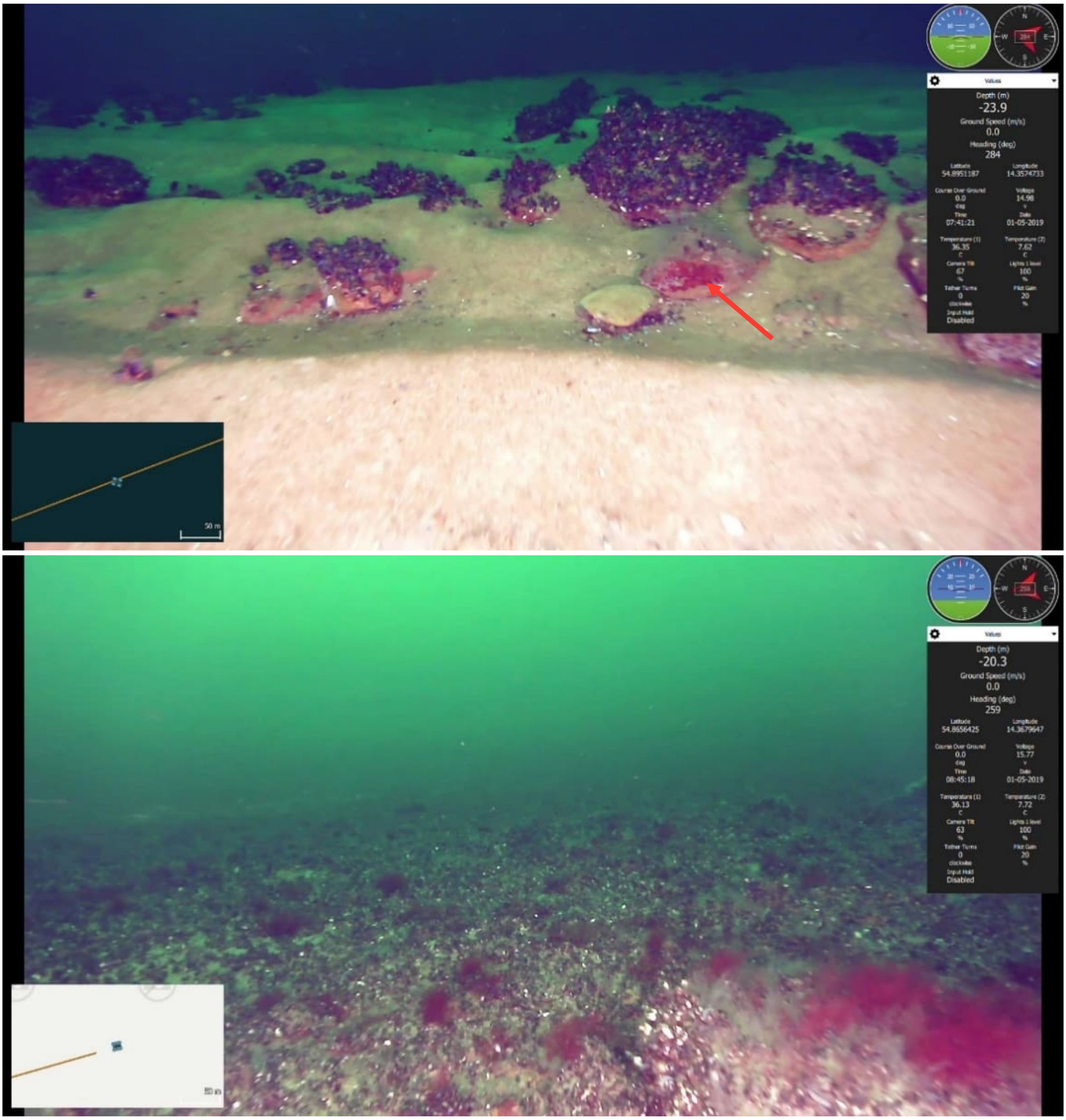


Figure 4-10. The dominating macroalgae species observed in the NSP2 – monitoring study in the habitat site N252/H261 in 2017 within the pre-investigation area. Upper figure: red crust alga *(Hildenbrandia* sp.) (red arrow). Lower figure: Red algae bush *Callithamnion corymbosum*. The panel in the lower left corner shows the ROV positions in relation to the NSP2 pipeline. Source: (Orbicon, 2019).

4.5 BENTHIC FAUNA

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

Benthic fauna in the open Baltic Sea is mainly determined by sediment type, salinity and oxygen concentration. The number of species which can be found, strongly depends on the ambient salt concentration, resulting in a generally higher species numbers in the south-western part of the Baltic Sea compared to the north-eastern part of the Baltic Sea in the Bothnian Bay. Oxygen deficiency (<4 mgO_2/l) results in a reduced number of benthic fauna species and abundance and is observed mainly at depths below 60 meters in the area (see section 4.2.2). 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). The pre-investigation area for Energy Island Bornholm is maximally 58 meters deep and oxygen deficiency at the seabed is therefore possible but likely rare.

In general, benthic fauna in the Baltic Sea belong to the so-called Macoma-community and are characterized by the bivalve *Limecola balthica* (formerly known as *Macoma balthica*) and a few other species, such as the common mussel *Mytilus* spp. (Figure 4-11 and Figure 4-12). The small, amphibian crustacean white Baltic pole flea *Pontoporeia (Monoporeia) affinis* living in brackish water, the isopoda crustacean *Saduria entomon* and the invasive bristle worm *Marenzellaria* are also characteristic species in the Baltic Sea. Furthermore, the benthic populations in the open waters of the central Baltic Sea are often characterized by the amphipod *Pontoporeia femorata* and the scale-worm *Bylgides sarsi* (Gogina et al, 2016), which are considered ice-age relics in the Baltic Sea.

Figure 4-11. The Macoma-community characteristic in the Baltic Sea between approximately 2-16 meters (Oeresundsvand.dk, 2023b) and deeper as seen in Figure 4-12 below.

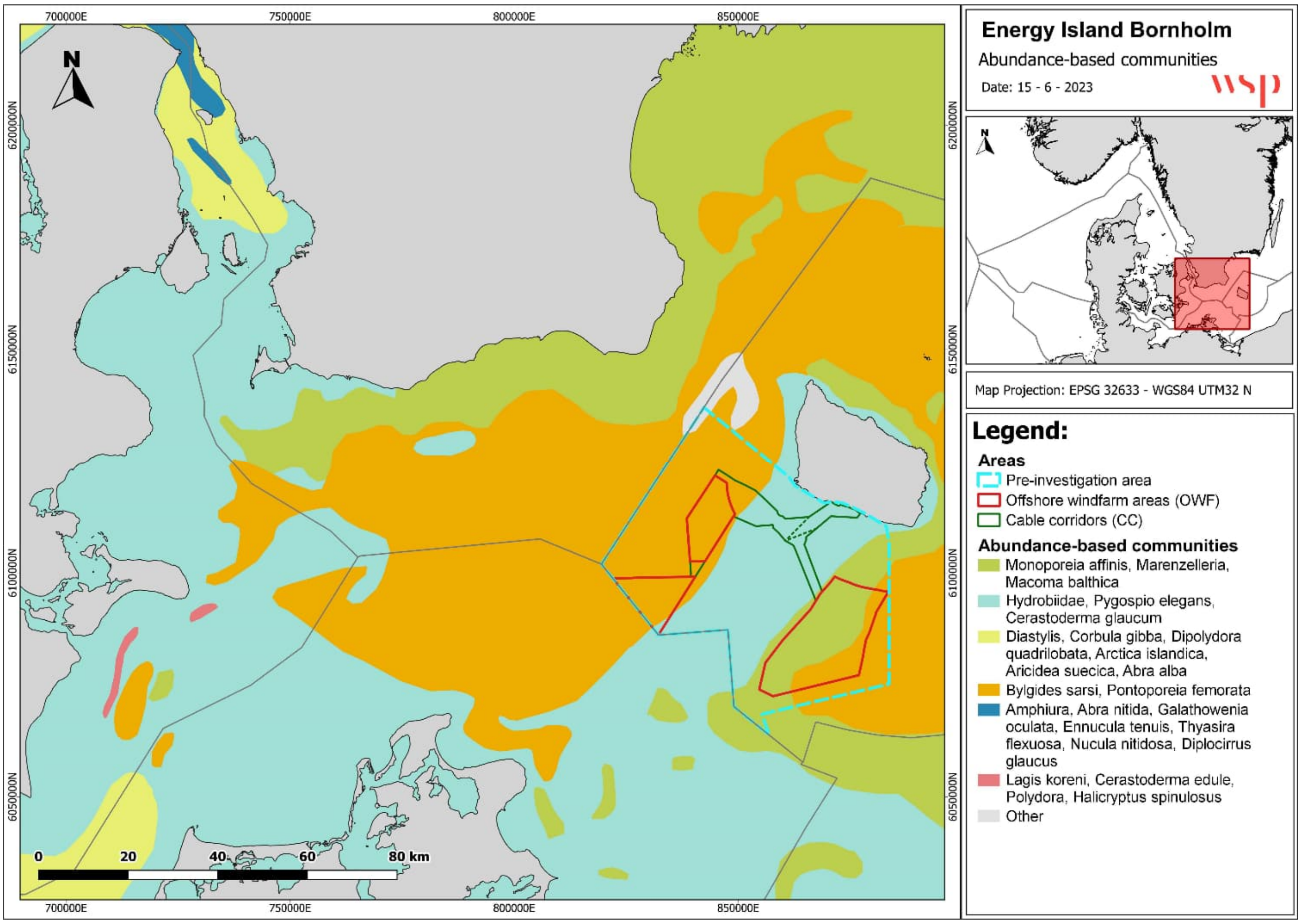


Figure 4-12. Benthic fauna communities in the southwestern Baltic Sea, based on abundance data from the period 2000-2013, showing the most abundant or characteristic species in the Baltic Sea (*Macoma baltica* = *Limecola balthica*). Source: WSP based on (Gogina et al, 2016).

4.5.1 EPIFAUNA

Epifauna observed by ROV is generally dominated by blue mussel (*Mytilus* spp.), both measured as individual numbers and biomass in the pre-investigation area (Nord Stream 2, 2018b; Orbicon, 2019; Miljøstyrelsen, 2021a; Miljøstyrelsen, 2021b). North Stream 2 (NSP2) - Northern route - Baseline studies and NSP2 - Northern route - Monitoring in Natura 2000 site N252 found highly variating blue mussel coverage of 0-100 % (Orbicon, 2019). Blue mussels dominated reef areas, whereas blue mussels and the small mud snail *Peringia ulvae* (*Hydrobiidae*) dominated sand areas (Orbicon, 2019). Hydrobiidae was observed as dominating in the sandbank and reef areas on sand in 2019 on the ROV-videos (Orbicon, 2019). In reef areas blue mussels are attached to larger stones. On sand banks blue mussels can be found as small ballistic (moving) balls/clumps consisting of small blue mussel communities that are moved along the sandbed with the current (Figure 4-13).

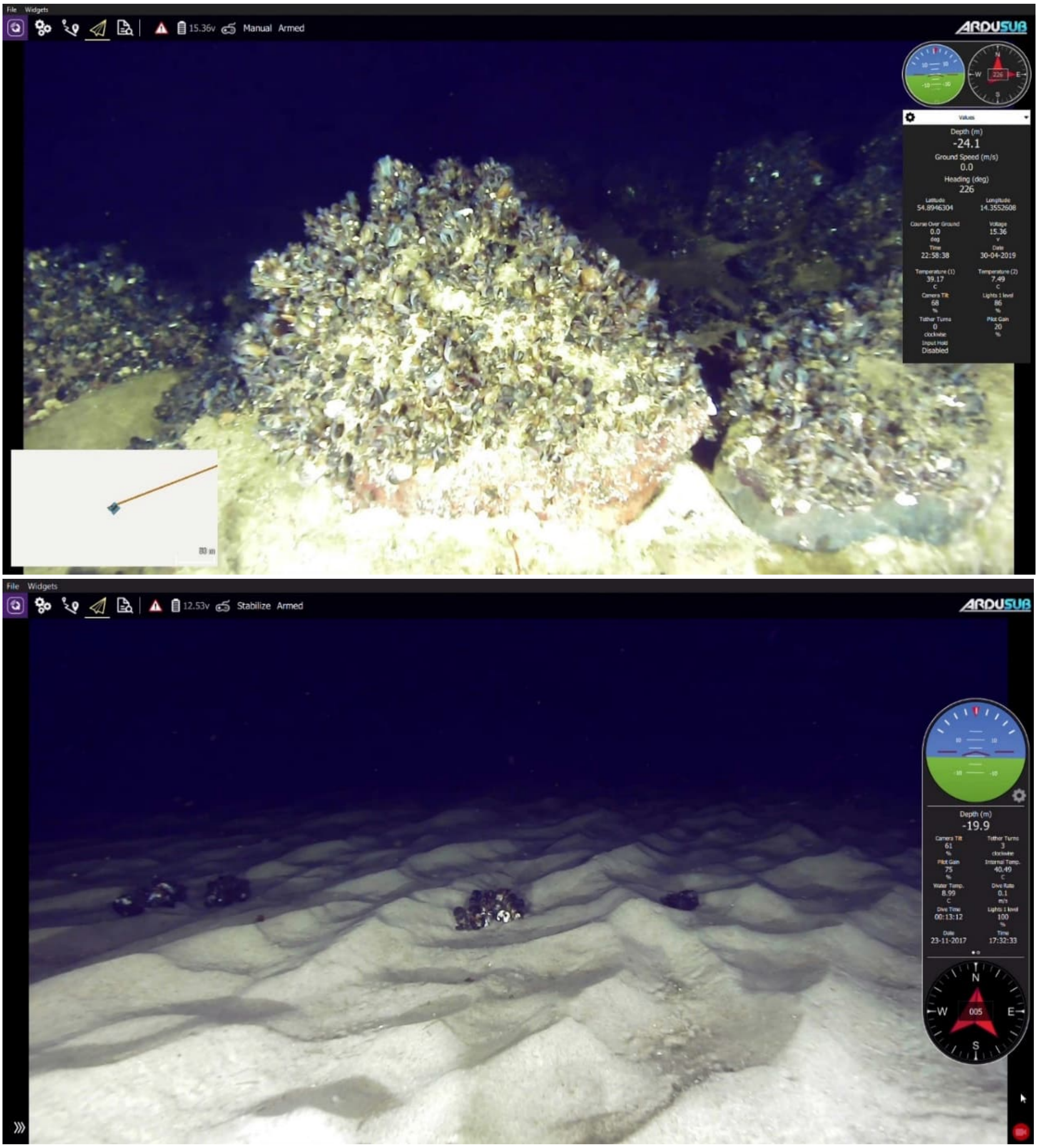


Figure 4-13. Blue mussel communities in the pre-investigation area. Upper figure: Blue mussels on large stones at station N3_3, NSP2 - monitoring in N252 in 2019. Source: (Orbicon, 2019). Lower figure: Mussels as small ballistic balls on the sandbed, that are moved along the seabed by the current at station D_EEZ_26, NSP2 - Northern route - Baseline study in 2018. Source: (Nord Stream 2, 2018a).

Other epifauna species observed in the North stream 2 monitoring of Natura 2000 site N252/H261 “Adler Grund og Rønne Banke” are listed in Table 4-9 below. In general, epifauna coverage was highly variable from 1 % to 90-100 %, *Mytilus* spp. comprised most of the coverage. Bristle worms as indicated by sand worm piles had a low coverage of 0-1 %.

Table 4-9. Epifauna and infauna observed on the seabed in Natura 2000 site N252/H261 "Adler Grund og Rønne Banke" in 2019. Source: (Orbicon, 2019).

Taxonomic group	Taxa/species and common name
Porifera	*Marine fungi* spp.
Cnidaria	*Hydrozoans* spp.
	Sea anemone sp.
Polychaeta/ bristle worms	*Spirobranchus triqueter* (Tube worms)
	Pygospio elegans
	Fabriacia stellaris
	Sand worm piles (Polychaeta spp.)
Bivalvia/ mussels and cockles	*Mytilus edulis* (Blue mussel)
Only shells observed	*Mya arenaria*
	Cerastoderma spp./cockle sp.
	Limecola balthica (Baltic macoma)
Gastropoda	*Mud snail (Hydrobiidae)*
Crustacea	*Balanidae spp.* (Barnacle)
	Amphipoda sp.

4.5.2 INFAUNA

Infauna was sampled in the pre-investigation area for Baltic Pipe in July 2018 and for the North Stream 2 baseline study in November/December 2017 and monitoring in the Natura 2000 site N252 in April/May 2019. Species numbers, abundance (individual numbers) and biomass are compared between the three studies in Table 4-10 below and illustrated for the Baltic Pipe and North Stream 2 project in Figure 4-14 and Figure 4-15, respectively.

Baltic Pipe generally found the highest abundance and biomass values in the pre-investigation area, compared to the baseline survey for NSP2 but lowest species numbers (Table 4-10). However, the high biomasses found at three of the stations (biomass >10-300 gWW/sample, see Figure 4-14C) was due to the presence of the mussel *Astarte borealis* which constituted 84-99 % of the total biomass at these stations. All other stations in the eastern part of the survey area for Baltic Pipe showed biomasses between 0-10 gWW/sample corresponding to 0-100 gWW/m^2. At the station showing >400-800 individuals/sample (see Figure 4-14B) approx. 50 % of all individuals were made up by the marine snail *Hydrobia* sp.

The baseline study for North Stream 2 - Northern route in 2017 included extensive sampling and statistical analysis of infauna at the stations within the pre-investigation area. This study found that high species numbers were positively correlated to oxygen concentration, lower depth and lower salinity. Salinity in the bottom waters was negatively correlated with species numbers, likely, due to low oxygen concentrations correlated to a strong halocline i.e., high salinity at the seabed (see section 4.2.2). A strong halocline hinders oxygen exchange with the surface layers and can cause oxygen deficiency for infauna species in the seabed. Species numbers were highest in areas with coarse and varying sediment types and lowest on stations with high silt and clay content. The silt and clay fraction is positively correlated to depth, which again is negatively correlated to oxygen concentrations (Nord Stream 2, 2018b).

Table 4-10. Comparison of species numbers, abundance (individual numbers) and biomass in the baseline study for Baltic Pipe (Baltic Pipe, 2019), North Stream 2 - Northern route (Nord Stream 2, 2018b) and North Stream 2 - monitoring in Natura 2000 site N252/H261 (Orbicon, 2019) within the pre-investigation area of this study. **: range minimum and maximum, *: average for all samples. Indv. = individuals. Note: sampling area in the baseline survey for Baltic Pipe was 0.1 m^2 and data has been extrapolated to show abundance and biomass per m^2 in the table below.

Previous studies	Sampling period	Species numbers pr. station	Abundance (Individuals/sample) (individuals/m^2)	Biomass Wet weight (WW)/Dry weight (DW)
Baltic Pipe	July 2018	0-15	0-8000 indv./m^2**	0-300 gWW/m^2**
NSP2 – Northern route, - Baseline study	Nov-dec 2017	5-22	0-2200 indv./m^2**	202.99 gWW/m^2 (incl. bivalves)* 15.03 gWW/m^2 (excl. bivalves)* 114.63 gDW/m^2 (incl. bivalves)* 5.61 gDW/m^2 (excl. bivalves)*
NSP2 – Northern route – monitoring N2000 site N252/H261	April-May 2019	7-8	107-347 indv./m^2**	1.17-12.37 gWW/m^2** 0.25-7.27 gDW/m^2**

Stations from NSP2 – Northern Route baseline study (Nord Stream 2, 2018b) and monitoring report (Orbicon, 2019) were located in the same area, and the latter only sampled three stations. Looking at the two previous investigations combined, infauna abundance (ranging from 0-2200 individuals/m^2) and species numbers (ranging from 5-22 species pr. station) were, generally, highest in the area between the bird SPA site (F129) and the Bornholm I wind farm areas (see Figure 4-15). The dominating infauna species in the NSP2 - baseline study in 2017 was blue mussel (*Mytilus* spp.), northern astarte (*Astarte borealis*) and Baltic macoma (*Limecola balthica*) (Nord Stream 2, 2018b). *Marenzelleria* sp., *Hediste diversicolour* and *Pygospio elegans* dominated in 2019 during NSP2's monitoring in the Natura 2000 site N252/H261 and approximately the same number of species were found pr sample in the two studies (Table 4-10) (Orbicon, 2019). In general, the most abundant infauna species in 2017 with more than 500 individuals in total (for all stations) were: blue mussel (*Mytilus edulis*), *Pygospio elegans*, *Scoloplos armiger*, Oligochaeta, mudsnail (*Peringia=Hydrobia ulvae*), northern astarte (*Astarte borealis*), *Marenzelleria*, Baltic macoma (*Limecola balthica*,), *Tubificoides benedii* and ragworm (*Hediste diversicolor*) (Nord Stream 2, 2018b).

Species biomass was highest at station D_EEZ_31 on the northern edge of the pre-investigation area and generally high in area between the bird SPA site (F129) and the Bornholm I wind farm areas. High biomass was related to the presence of bivalves. The highest average biomass was found for blue mussel (*Mytilus* spp.) (5.43 gDW/m^2), which was present at 73 % of the stations (Nord Stream 2, 2018b).

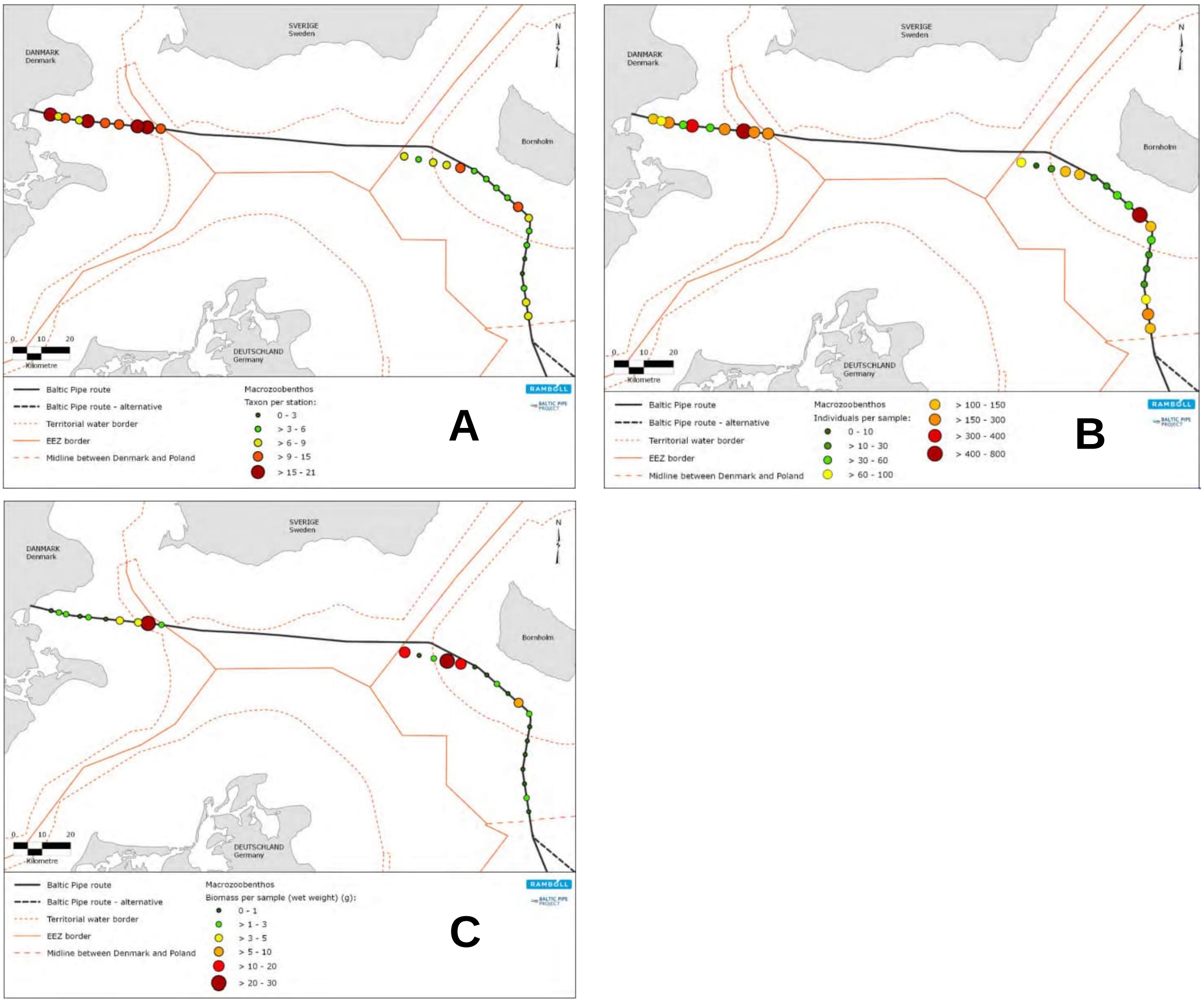


Figure 4-14. Infauna data from Baltic Pipe Project. A) Species (taxa) number of macrozoobenthos (sample size = 0.1 m^2), B) abundance of macrozoobenthos (sample size = 0.1 m^2) and C) biomass of macrozoobenthos (sample size = 0.1 m^2). Data is from the baseline survey conducted in July 2018 in relation to the Baltic Pipe project. Source: (Baltic Pipe, 2019).

There are no benthic fauna species on the Danish red list (Den danske rødliste, 2022). Two HELCOM red listed species (HELCOM, 2023a) the amphipods *Monoporeia affinis* (LC) and *Pontoporeia femorata* (LC) were observed in one sample from station D_EEZ_22 south of Rønne Banke on the border of Bornholm II (see station in Figure 4-15 below) (Nord Stream 2, 2018b).

Good ecological status is defined for benthic fauna at EQR 0.68 in the coastal waters of Bornholm. The DKI (Danish Quality Index) was last assessed in 2019 covering the period 2014-2019 and was found at 0.78, which means that coastal waters around Bornholm is currently in good condition with regard to benthic fauna and thus complies with the objectives of the Water Frame Work Directive (WFD) (Miljøministeriet, 2023).

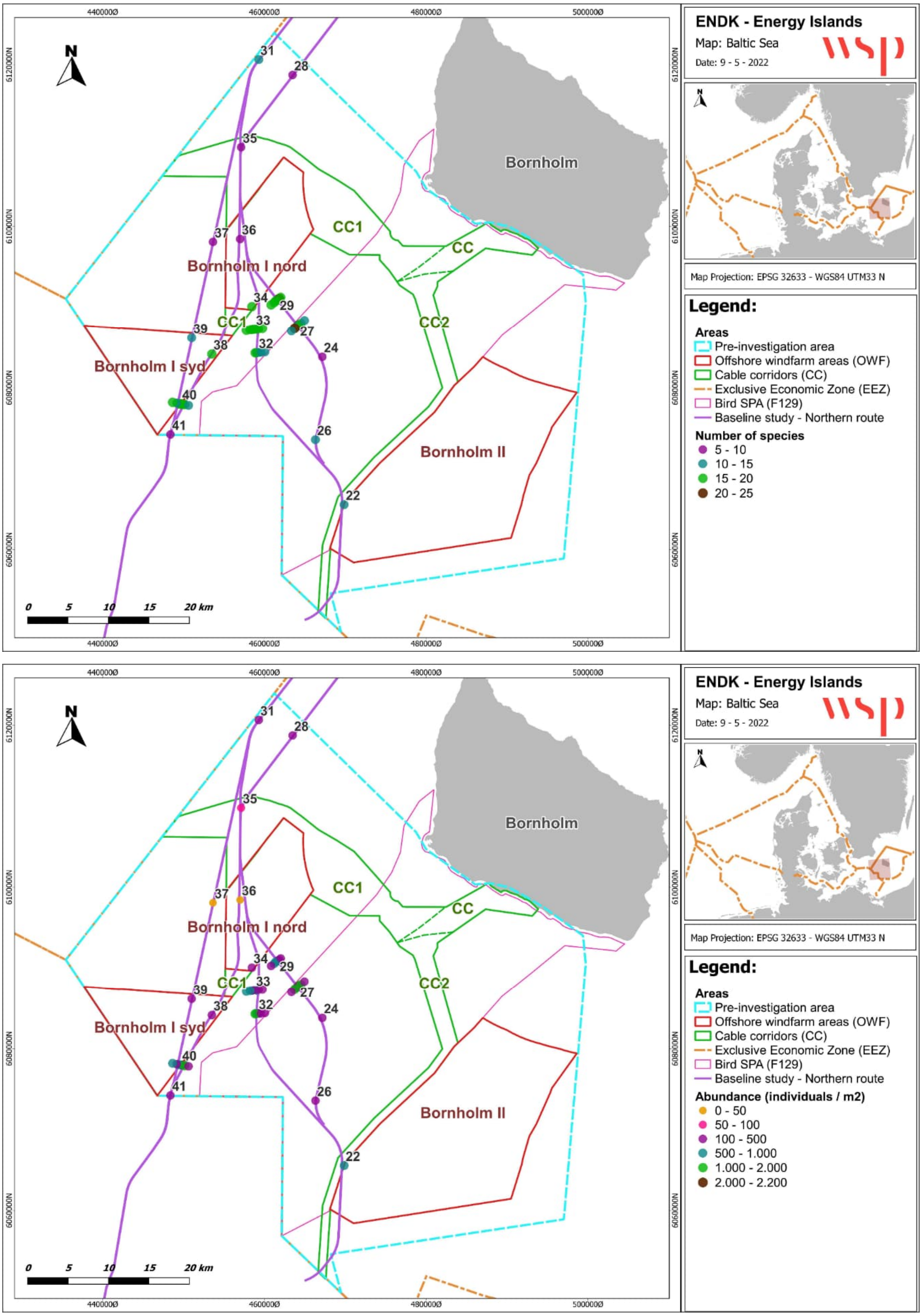


Figure 4-15. The number of infauna species found per station (upper figure) (sum of three replicates) and abundance (lower figure) (Individuals m^2) from the baseline study for North Stream 2 – Northern route. Prefix for stations is D_EEZ_ Source: (Nord Stream 2, 2018b).

5 SURVEY DATA

This technical report for sediment, benthic flora and fauna in the pre-investigation area of Energy Island Bornholm maps the distribution and composition of sediment, benthic flora and fauna. In this chapter survey data representing the results of the surveys and analyses of the data are presented for abiotic data, seabed sediments, benthic flora, benthic fauna and bird food program.

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

Depths were not specifically mapped during the surveys for this baseline report and are described only under section 4.2.1 – Existing data/Depth.

5.1.2 SALINITY, TEMPERATURE AND OXYGEN CONCENTRATION

CTDO profiles of salinity, temperature and oxygen concentrations were sampled along four transects crossing the pre-investigation area from west to east (see Figure 3-5). Data from the profiles across Rønne Banke are presented in Figure 5-1. The CTDO-profiles were sampled along the four transects during November 2nd-3rd 2022. The depth range along the transects are 14-58 meters of depth (see Table 5-1). The CTDO-profiles show the variation in salinity, temperature and oxygen down through the water column reaching from the sea surface to approximately 1 meter above the sea bottom, as the instrument risk damage if colliding with the seabed (see Figure 5-1). Generally, temperature and oxygen concentrations are highest in the sea surface and salinity is highest at the sea bottom.

CTDO profiles recorded across the pre-investigation area are illustrated for Transect 1 and 2 in Figure 5-1 and Figure 5-2, respectively. Profiles along all four transects are represented in Appendix 7B. The CTDO-profiles show that the depth along the transect is lowest on Rønne Banke in the middle of the transect and deepest along the outer parts of the pre-investigation area. The profiles in Figure 5-1 illustrates the layered quality of the water column (see layer number on the figure) at the deepest stations furthest from the shallow bank area (station INV_007, INV_016, INV_021, INV_029, NV_x1), whereas the water column is fully mixed over the shallow part of Rønne Banke (station INV_031, SPA_011, SPA_014, SPA_025, SPA_023).

The halocline representing the mixed layer between an upper less saline water layer and a lower more saline water layer, is generally found between approximately 30-50 meters of depth (see Figure 5-1 and Figure 5-2). The length/depth of the halocline varies and is generally longer and pushed slightly upwards close to Rønne Banke due to mixing along the slopes of the bank. The halocline disappears over the bank where the water column is shallow (< 30 meter deep) and fully mixed. This is in accordance with reported data from the baseline studies and North Stream 2 and Baltic Pipe from the area (Nord Stream 2, 2018a; Baltic Pipe, 2019) (see section 4.2.2 – Existing data/Salinity and oxygen concentration).

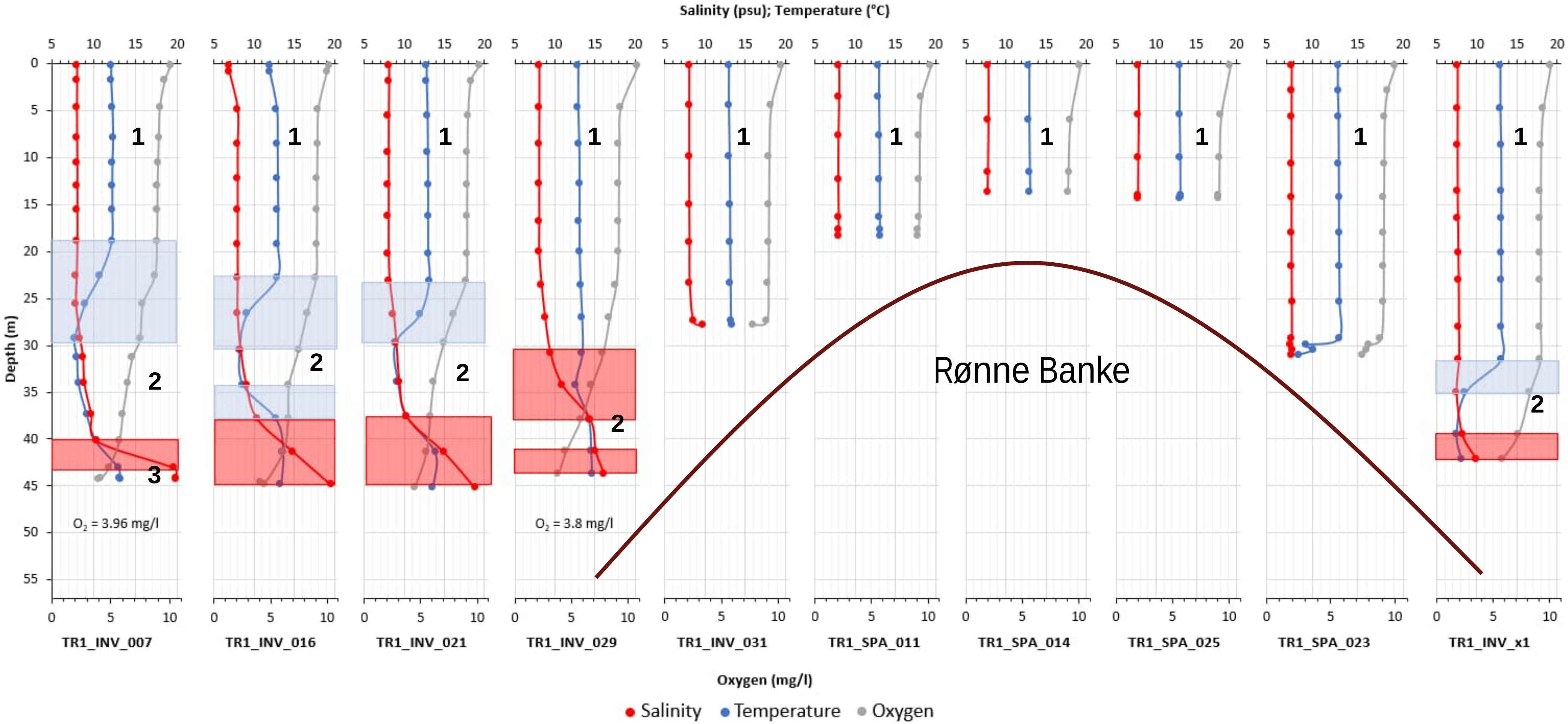


Figure 5-1. CTDO-profiles of salinity, temperature and oxygen across CTDO Transect 1 (T1). Rønne Banke is the shallow area in the middle of the pre-investigation area, which is also contained within the Bird SPA area. Blue areas indicate thermoclines (mixing zone between two water layers seen as rapid temperature change) and red areas indicate haloclines (mixing zone between two water layers seen as rapid salinity change). Oxygen concentrations below 4 mgO_2/l are indicated on the figure, which indicates presence of moderate oxygen deficiency. Moderate oxygen deficiency is defined as oxygen concentrations between 2-4 mgO_2/l and severe oxygen deficiency as <2 mgO_2/l. Numbers indicate number of water layers. Brown line indicates presence of Rønne Banke not precise depth.

TRANSECT 2A (LEFT PART)

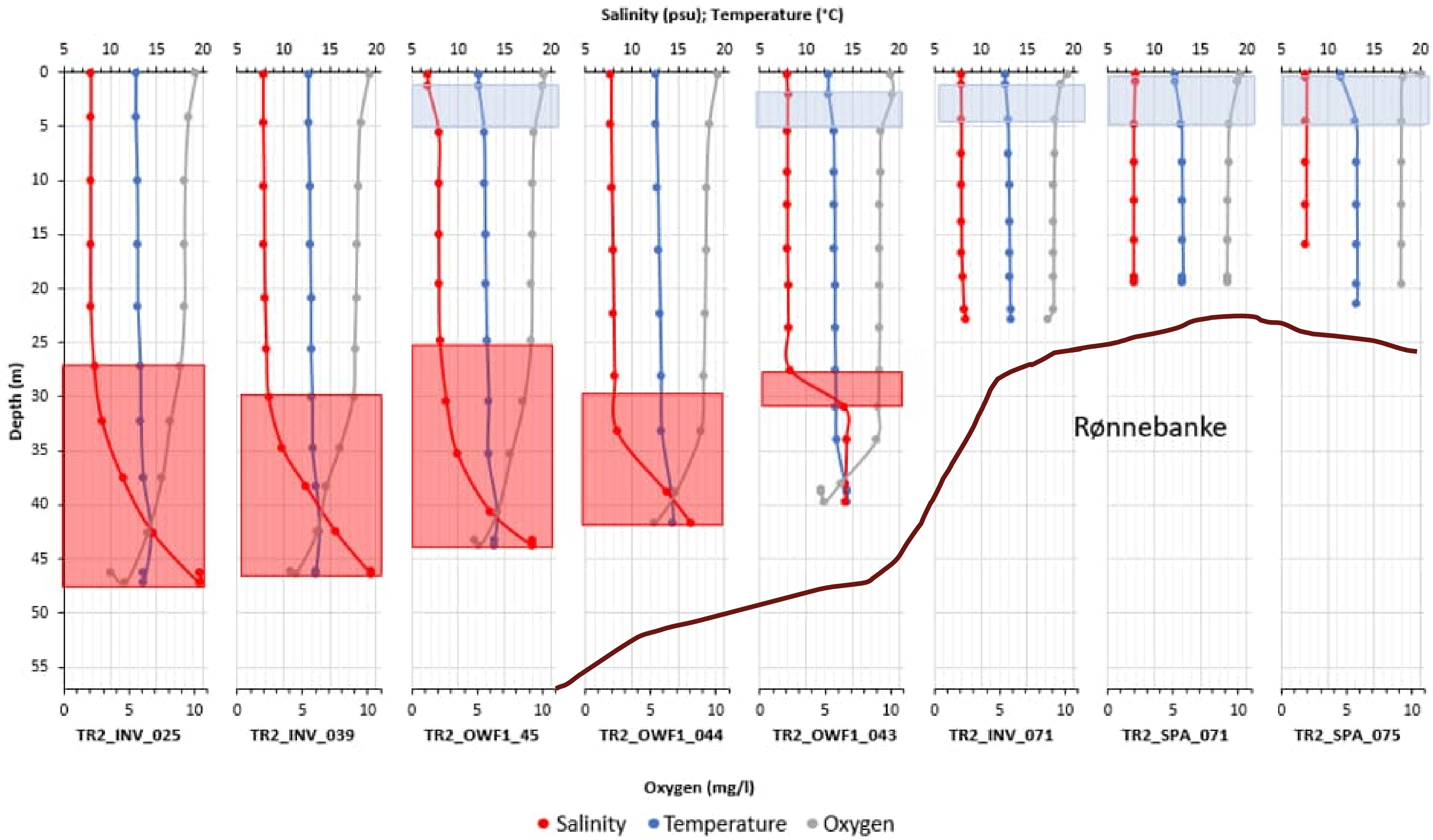


Figure 5-2. CTDO-profiles of salinity, temperature and oxygen across the left part of CTDO Transect 2 (T2). Rønne Banke is the shallow area in the middle of the pre-investigation area, which is also contained within the Bird SPA area. Blue areas indicate thermoclines (mixing zone between the two water layers seen as rapid temperature change) and red areas indicate haloclines (mixing zone between two water layers seen as rapid salinity change). Oxygen concentrations below 4 mgO_2/l are indicated on the figure, which indicates presence of moderate oxygen deficiency. Moderate oxygen deficiency is defined as oxygen concentrations between 2-4 mgO_2/l and severe oxygen deficiency as <2 mgO_2/l. Numbers indicate number of water layers. Brown line indicates presence of Rønne Banke not precise depth.

A thermocline is generally observed above and/or in the same depth range as the halocline (approximately 20-40 meters of depth) (see Figure 5-1 and Figure 5-2). Additionally, a thermocline is found in the surface layers at some stations due to warming from the sun (Figure 5-2).

Bottom measurements are presented in Table 5-1. Salinity at the sea bottom ranges between 7.4-19.8 psu and temperature between 7.4-19.6 °C, which is in accordance with other investigations in the area (Perttilä, 2007; Nord Stream 2, 2018a; Baltic Pipe, 2019) (see section 4.2.2 – Existing data/Salinity and oxygen concentration).

Well oxygenated bottom water is important for the survival of especially benthic fauna as flora is generally not present at the critical depths for oxygen deficiency. Moderate oxygen deficiency is defined as oxygen concentrations between 2-4 mgO_2/l and severe oxygen deficiency as <2 mgO_2/l. Oxygen deficiency (<4 mgO_2/l) generally results in a reduced number of benthic fauna species and abundance (see section 4.2.2). 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).

Bottom oxygen concentrations at the stations along the four transects ranged from 1.80 to 10 mgO_2/l (Table 5-1). Oxygen deficiency with concentrations between 2-4 mgO_2/l was observed at 10 out of the total 46 CTDO-stations (22 %) and was observed at 41-57.9 meters of depth. Severe oxygen deficiency was observed at two stations (OWF2_22, INV_105) out of the total 46 stations (4 %) at 57.4 and 52.6 meters of depth, respectively. Oxygen deficiency was found at all four transects at deep stations >40 meters on both sides of Rønne Banke. Stations with oxygen deficiency in the bottom water had a strong halocline, which reduces or hinders oxygen diffusion to the bottom water. In the baseline study for North Stream 2 oxygen deficiency was generally found at depths deeper than 60 m, thus, oxygen deficiency was more pronounced and found at lower depth in the present study. Oxygen concentrations are, thus, highly variable in the pre-investigation area depending on the presence of strong stratification or not (thermocline and/or halocline). In areas with a strong stratification (see Figure 4-3 A,B) there is no or little oxygen exchange between the surface water mass and the bottom water mass. This leads to reduced oxygen concentrations in the bottom water as bacterial degradation in the seabed consumes the available oxygen.

Oxygen deficiency was observed at five out of seven OWF2 stations (OWF2_11, 22, 23, 26, 35) in the south-eastern part of the Bornholm II wind farm area. OWF2_22 showed severe oxygen deficiency of 1.87 mgO_2/l. The two OWF2 CTDO-stations closest to Rønne Banke (OWF2_28 and _48) (see Figure 3-5) did not show oxygen deficiency indicating quite widespread moderate oxygen deficiency within the Bornholm II wind farm area. One OWF1 station within the Bornholm I South area (OWF1_11) showed moderate oxygen deficiency of 3.97 mgO_2/l. Oxygen deficiency was not observed in the cable corridor area. The more widespread oxygen deficiency observed in the Bornholm II area compared to the Bornholm I areas is likely coursed by depth differences, with the Bornholm II wind farm area being deeper with a larger part of the area with depths below 41 m.

Table 5-1. Bottom measurements of salinity, temperature and oxygen at the stations along the four transects crossing the pre-investigation area. Blue oxygen concentrations indicate moderate oxygen deficiency with concentrations between 2-4 mgO_2/l. Purple numbers indicate severe oxygen deficiency <2 mgO_2/l. C° is degree Celsius, psu is practical salinity unit. TR is Transect.

CTDO Transect	Station	Depth ROV depth	CTDO depth	Temperature C°	Salinity psu	Oxygen mg/l
TR1	INV_007	45.4	44.3	13.2	19.8	3.96
TR1	INV_016	46.5	44.9	13.3	19.6	4.44
TR1	INV_021	46.7	45.2	13.6	18.9	4.49

CTDO Transect	Station	Depth		Temperature C°	Salinity psu	Oxygen mg/l
		ROV depth	CTDO depth			
TR1	INV 029	44.9	43.8	14.7	16.1	3.84
TR1	INV 031	29.3	27.8	13.4	9.8	7.84
TR1	SPA 011	19.4	18.4	13.1	7.9	9.11
TR1	SPA 014	14.5	13.7	13.0	7.8	9.08
TR1	SPA 025	15.0	14.3	13.1	7.8	9.10
TR1	SPA 023	31.2	31.0	8.6	7.8	7.50
TR1	INV x1	No ROV	42.2	8.1	10.0	5.80
TR2	INV 025	47.8	47.2	19.6	13.5	4.71
TR2	INV 039	47.1	46.1	13.4	19.5	4.14
TR2	OWF1 45	44.9	43.9	13.8	18.1	5.16
TR2	OWF1 44	43.5	41.7	14.5	16.5	5.31
TR2	OWF1 43	41.4	39.7	14.4	14.4	4.96
TR2	INV 071	25.1	22.9	8.4	13.2	8.74
TR2	SPA 071	21.2	19.4	13.1	7.8	9.18
TR2	SPA 075	22.4	21.4	13.1	7.4	9.18
TR2	SPA 066	18.9	17.3	13.1	7.7	9.07
TR2	SPA 078	15.6	14.9	13.0	7.7	9.11
TR2	OWF2 48	39.2	38.5	7.6	8.7	6.57
TR2	OWF2 35	50.9	49.7	8.4	12.2	3.58
TR2	OWF2 23	55.5	53.4	8.8	12.1	2.33
TR2	OWF2 22	57.4	55.5	8.7	13.3	**1.87**
TR2	INV 100	57.9	56.4	9.1	13.2	2.33
TR3	INV 051	48.1	46.6	13.5	19.2	4.45
TR3	INV 052	46.5	40.1	13.7	12.8	6.96
TR3	INV 053	45.2	42.9	14.4	17.0	3.53
TR3	OWF1 026	38.8	36.5	13.9	13.6	5.79
TR3	INV 080	30.0	29.2	13.2	8.0	9.07
TR3	SPA 111	23.1	21.4	13.2	7.7	9.08
TR3	SPA 113	17.9	16.8	13.2	7.5	9.09
TR3	SPA 125	19.3	18.4	13.1	7.5	10.0
TR3	SPA 140	19.6	19.4	13.0	7.6	8.8
TR3	SPA x1	No ROV	29.2	9.9	7.7	7.64
TR3	OWF2 28	33.5	33.6	7.4	7.8	7.41
TR3	OWF2 26	43.2	41.9	8.2	11.3	3.97
TR3	OWF2 11	51.0	51.0	8.4	12.4	3.00
TR3	INV 105	52.6	51.3	9.0	13.2	**1.80**
TR4	INV 057	47.0	46.6	13.9	18.6	3.39
TR4	INV 058	46.0	43.7	14.0	16.9	4.88
TR4	INV 059	45.2	38.3	14.2	13.9	6.19
TR4	OWF1 11	41.1	39.6	14.5	15.9	3.97
TR4	OWF1 10	37.6	37.2	14.1	13.6	5.04

CTDO Transect	Station	Depth ROV depth	CTDO depth	Temperature C°	Salinity psu	Oxygen mg/l
TR4	INV_083	29.0	26.9	13.2	7.5	9.15
TR4	SPA_157	20.6	18.6	13.1	7.5	9.08

5.2 SEABED SEDIMENT CHARACTERISTICS

The seabed sediment types in an area determine the living conditions and habitats available for benthic fauna and flora in that area. Benthic flora e.g. macroalgae lives attached to hard substrate such as larger stones (>10 cm) and sedimentary rock, epifauna similarly 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.

5.2.1 SEDIMENT TYPES

The sediment type was mapped in the wind farm- and cable corridor areas within the pre-investigation area by side scan sonar in combination with ROV video verification of the seabed sediment type (see section 3.2.5 – Sediment type mapping). The rest of the pre-investigation area was not mapped and here GEUS sediment type map is used (see Figure 4-5 in section 4.3.1). Sediment types mapped in this baseline study are presented in Figure 5-3 below.

A combination of the mapping in this baseline study and the GEUS sediment type map are shown in Figure 5-4 below. In this figure a minor change has been made to the GEUS map based on ROV video verification, where the small area of “Muddy sand” and “Quaternary clay and silt” in the middle of the SPA area on the top of Rønne Banke (see Figure 4-5 in section 4.3.1) has been generally changed to sediment type 1b – Sand, some sediment type 2 gravel and single large stones (1-10 %), and two stations (SPA_050 and SPA_057) were changed to sediment type 4 – sedimentary rock, till and stone reef. This was done since the ROV videos in the area did not show muddy sand but instead sand, gravel and a few hard bottom stations. Furthermore, it seems unlikely for mud to accumulate on top of a dynamic bank unless a depression in the seabed is present. Normally finer sediments will sediment at calmer, deeper depths beyond the edges of the bank.

In general, the sediment type changes with depth and distance to the coast. The sediment type mapping shows hard bottom sediment types (sediment type 3 and 4) consisting of mixed rock and sand, sedimentary rock, till and stone reef with stone coverages >10 % close to the coast mainly in the cable corridor area (CC) (Figure 5-3 and Figure 5-4).

Further from the coast, sand (sediment type 1b) dominates and in the deepest parts of the pre-investigation area, more muddy sediments dominate (sediment type 1a) (see Figure 5-3 and Figure 5-4).

The overall area coverage of seabed sediment types in the mapped wind farm areas and cable corridor area is presented in Table 5-2 below. The remaining part of the pre-investigation area is not included since specific mapping, apart from GEUS more large-scale mapping, is not available.

Table 5-2. Sediment type distribution in the mapped wind farm - (Bornholm I North, Bornholm I South and Bornholm II) and cable corridor areas (CC, CC1, CC2). Note that the cable corridor area is not fully mapped and that only the mapped area is included in the estimates below (See Figure 5-3 below). Numbers are rounded to one or two determining decimals.

	Bornholm I North		Bornholm I South		Bornholm II		Cable corridor	
Sediment type	**km^2**	%	**km^2**	**%**	**km^2**	%	**km^2**	%
1a - Silt	47.91	38.9	35.74	30.3	305.49	74.5	58.31	22.9
1b – Sand	45.75	37.1	57.30	48.6	93.13	22.7	101.44	39.9
1c - Clay	-	-	-	-	1.30	0.32	0.53	0.21
2 - Mixed	27.04	21.9	16.61	14.1	9.52	2.31	52.21	20.5
3 - Hard bottom	1.97	1.6	7.66	6.5	0.83	0.20	25.77	10.1
4 - Stone reef/ rock	0.55	0.45	0.56	0.48	0.03	0.01	16.28	6.4
Total	123.22	100.0	117.87	100.0	410.30	100.0	254.54	100.0

WIND FARM AREAS

The sediment types in the two wind farm areas Bornholm I (North and South) and Bornholm II differ with more muddy sediments (sediment type 1a) in Bornholm II (Figure 5-3). The Bornholm I areas have more area coverage of rocky sediment types (sediment type 2, 3 and 4) mainly in the part of the areas closest to the Rønne Banke area (see Table 5-2).

The sediment types present in Bornholm I North and Bornholm I South are quite similar with more varying sediment types compared to the Bornholm II area (Figure 5-3).

The area coverage of Sediment type 4 – "Stone reef" is very limited in the wind farm areas with <1 % (see Table 5-2).

CABLE CORRIDORS

The cable corridors between the wind farm areas (OWFs) and Bornholm are shown in Figure 5-3. In general, the sediment in the two cable corridors changes from "Sand" (sediment type 1b) very close to the coast, to hard "Sedimentary rock" (sediment type 4 and 3), "Sand" (sediment type 1b) and at 35-40 meters depth finer sediment types "Soft bottom" (sediment type 1a) such as mud and silt.

The cable corridor overlap (CC) from the landfall on Bornholm and the first 10-15 km towards the OWFs is dominated by mostly hard sediment types (sediment type 3 and 4). In a thin line along the coast of Bornholm corresponding to the landfall area sediment type 1b – "Sand" dominates. In the rest of the overlapping corridor area (CC), hard sediment types dominate such as "till/diamiction" (sediment type 3) and "Sedimentary rock" (sediment type 4), with smaller patches of "Gravel and coarse sand", "Sand" and finer sediments (sediment types 2 and 1) (Figure 5-3).

In the CC1 corridor connecting Bornholm and Bornholm I North (OWF) at more than 20 meters depth the sediment changes from Sediment type 4 and 3 "Sedimentary rock" and "Till diamiction" (CC1_01-05) to sediment type 2 "Sand, gravel and single large stones" and sediment type 1b "Sand" (CC1_06 and CC1_09-11) and closest to Bornholm I North (CC1_10-15) more muddy sediment called sediment type 1a (Soft bottom) .

The small cable corridor CC1 area between Bornholm I North and Bornholm South consists mainly of sand, gravel (sediment type 2) and mixed sediments with sand and rocks of varying rock coverage >10 % (sediment type 3) (Figure 5-3).

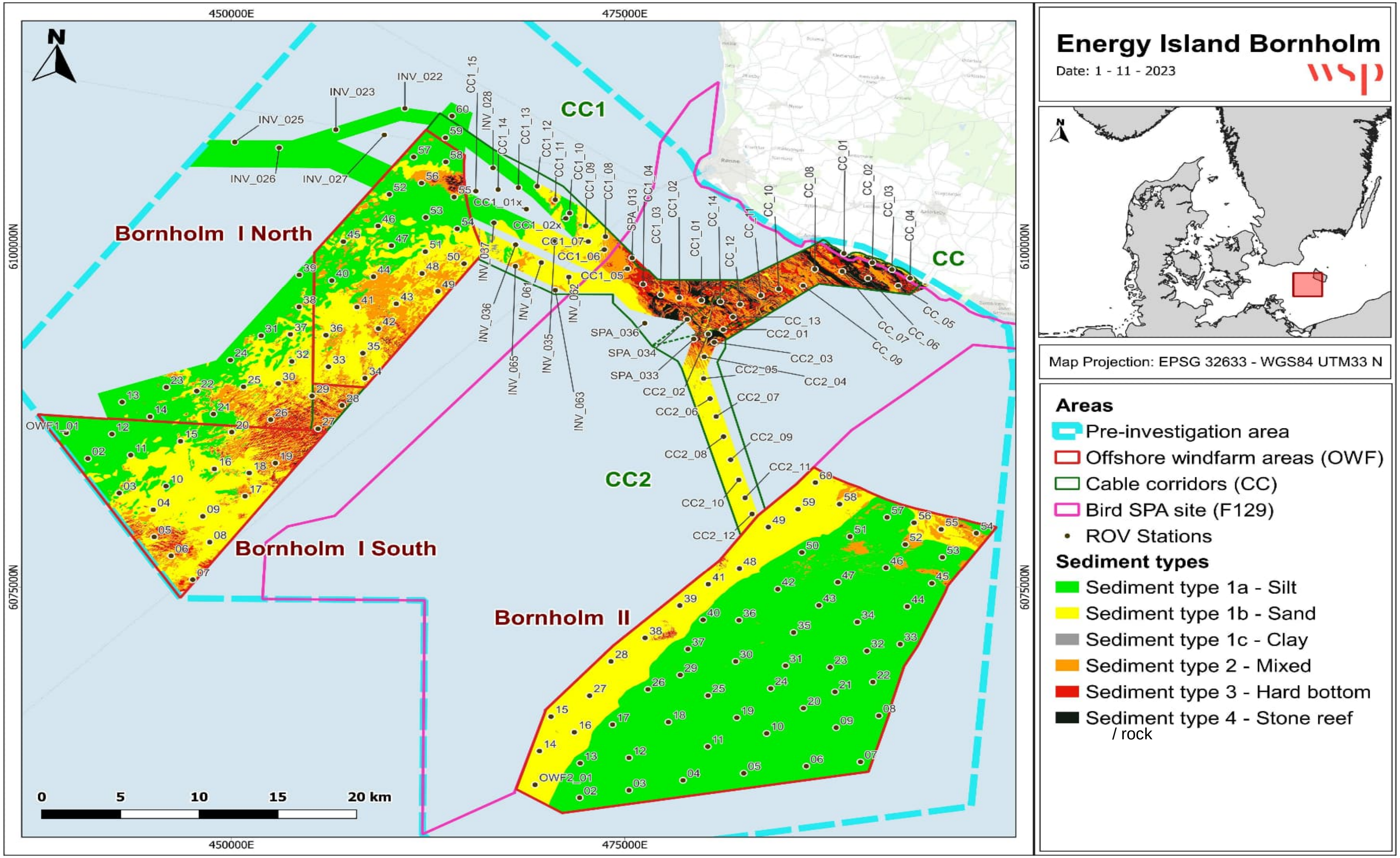


Figure 5-3. Sediment type map for the pre-investigation area. The map shows the baseline side scan sonar mapping done in the wind farm areas (OWF) and cable corridor areas for the present study.

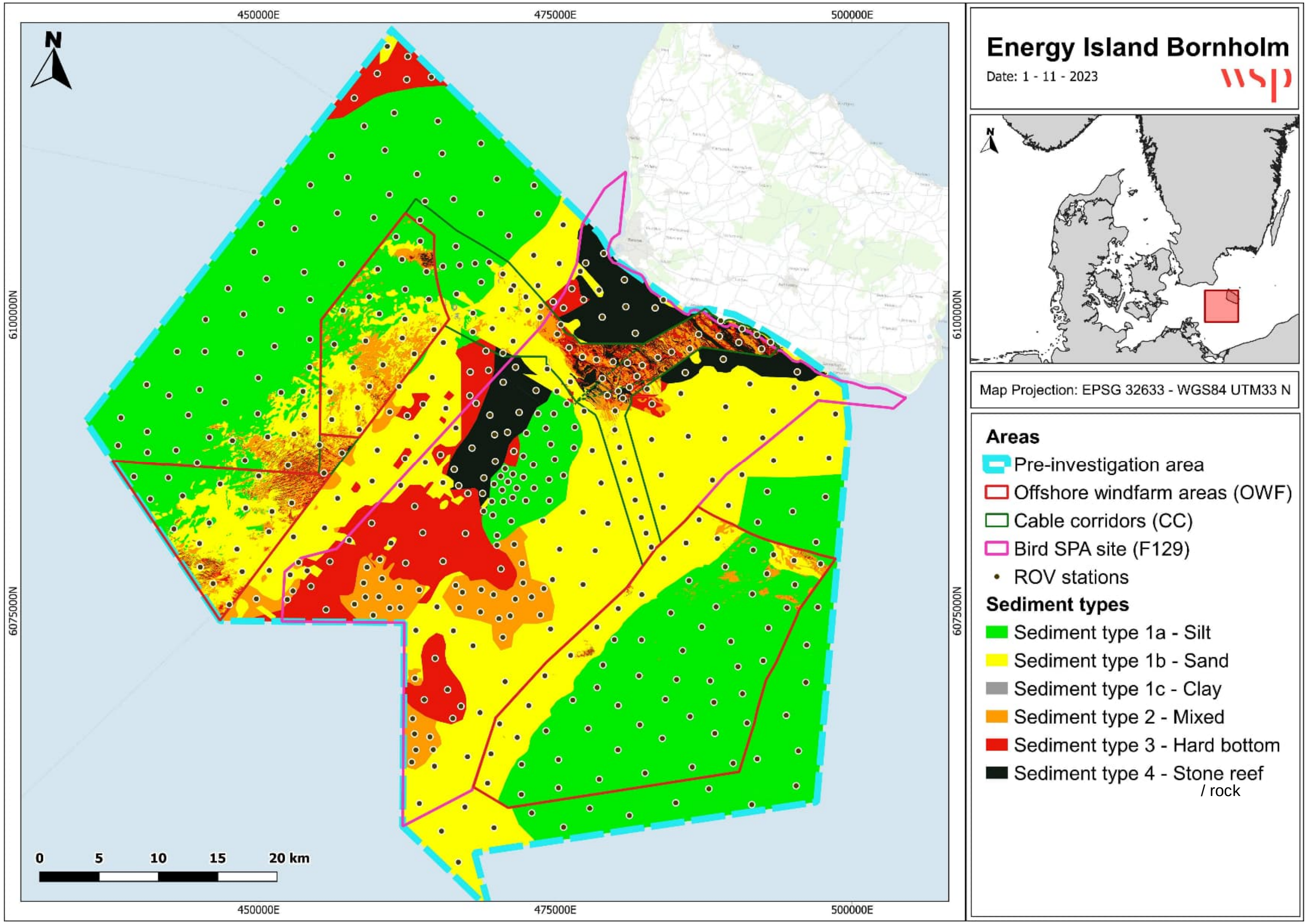


Figure 5-4. Sediment type map for the pre-investigation area. The map represents the baseline side scan sonar mapping done in the wind farm areas (OWF) and cable corridor area for the Energy Island Bornholm project. In the remaining part of the pre-investigation area GEUS´s sediment type map is used with minor adjustments based on the ROV videos (see explanation in text above).

The CC2 corridor connecting Bornholm II (OWF) and Bornholm is dominated by "Till/diamiction" (CC2_01-03) (sediment type 3 and 4) in the first part of the corridor (from landfall), then a small area with sediment type 2 "Sand, gravel and single large stones" and in the rest of the cable corridor towards Bornholm II sediment type 1b "Sand" dominates (CC2_05-12).

5.2.2 PHYSICAL PARAMETERS

Organic content (TOC) is one of the determining parameters for the habitat available to the benthic flora and fauna and for oxygen conditions and is presented below for the pre-investigation area for the Energy Island Bornholm. Oxygen deficiency arises when bacteria degrade organic matter on the seabed using oxygen in the process and thereby decreasing the available oxygen for benthic flora and fauna.

TOTAL ORGANIC CARBON CONTENT (TOC)

TOC was measured in the HAPS samples for chemical analysis (see stations in Figure 3-1) and are presented in Table 5-3 below.

Table 5-3. Total organic carbon (TOC) in the sediment in the pre-investigation area. Furthermore, depth and sediment type are indicated. Stations within Bornholm I North and Bornholm I South are marked with light and dark blue fill, respectively and Bornholm II stations are marked with darker red fill color. Stations within the cable corridor are marked with white, and the single INV station (OWF1_37) is marked with grey. Note that OWF1_37 is located in the INV area and OWF1_27 and _59 are located within the cable corridor. For station location see Figure 3-1.

Station ID	TOC (% of DW)	Depth (m)	Sediment type*
CC_02	0.10	3.4	1b
CC_03	<0.10	4.1	2
CC_09	0.14	12.0	2
CC1_10	0.49	38.8	1a
CC1_11	0.28	39.3	2
CC1_12	0.72	44.1	1a
CC1_13	0.94	45.3	1a
CC1_14	1.2	47.0	1a
CC1_15	0.90	39.4	2
CC2_04	<0.10	18.9	2
CC2_05	0.24	18.7	1b
CC2_06	<0.10	17.8	1b
CC2_07	<0.10	16.1	1b
CC2_08	<0.10	15.1	1b
CC2_09	0.14	14.7	1b
CC2_10	<0.10	14.3	1b
CC2_11	<0.10	14.2	1b
CC2_12	0.23	32.0	1b
OWF1_27	<0.10	34.7	2
OWF1_59	0.57	47.5	1a
Average	*0.15*	*25.9*	
OWF1_10	1.2	37.0	1a
OWF1_12	3.6	42.1	1a
OWF1_17	0.30	34.5	1b
OWF1_20	0.78	38.7	1a
Average	*1.47*	*38.1*	
OWF1_43	1.0	41.4	1a
OWF1_46	0.97	44.7	1a
OWF1_56	2.8	45.9	1a
Average	*1.59*	*44.0*	
OWF2_07	3.3	55.5	1a
OWF2_10	3.6	53.9	1a
OWF2_14	0.27	38.2	1a

Station ID	TOC (% of DW)	Depth (m)	Sediment type*
OWF2_17	0.43	43.2	1a
OWF2_22	5.6	57.4	1a
OWF2_30	1.1	49.0	1a
OWF2_38	0.43	34.9	1b
OWF2_46	0.75	48.0	1a
OWF2_50	0.50	42.4	1a
OWF2_58	0.46	40.0	1a/1b
Average	*1.60*	*46.3*	
OWF1_37	1.2	43.3	1a

Total organic content in the chemical HAPS samples was, generally, low and comparable for Bornholm I South, North and Bornholm II with an average TOC of 1.47 % (0.30-3.6 %), 1.59% (0.97-2.8 %) and 1.60% (0.27-5.6 %), respectively. TOC was generally lower in the cable corridor with an average of 0.15 % (<0.10-1.2 %) (Table 5-3). A few high TOC-levels were measured in all three OWF areas with maximum concentrations of 1.2 % in Bornholm I North, 2.8 % in Bornholm I South and 5.6 % in the Bornholm II wind farm area and form a group of outliers (see Figure 5-5).

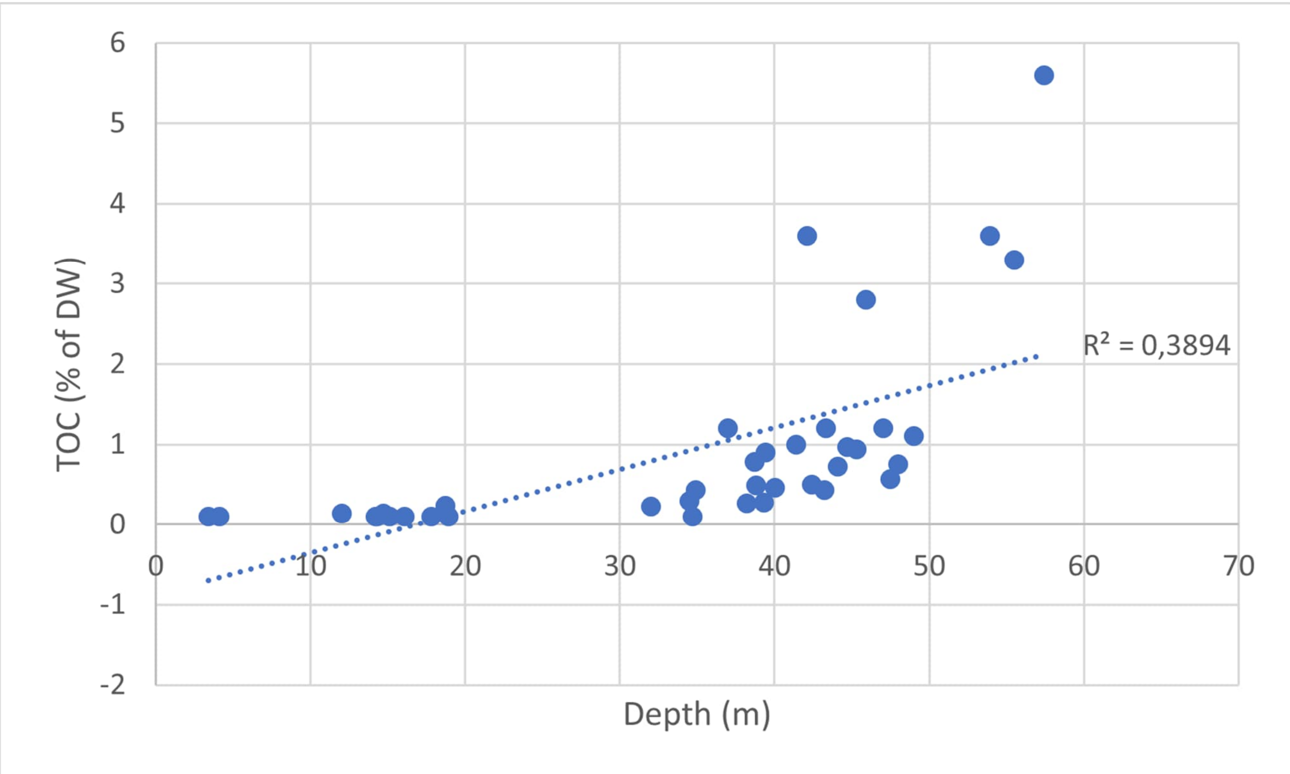


Figure 5-5. Relationship between TOC (% of DW) and depth, including data from all stations where TOC has been analysed. TOC increases with depth (linear regression model, p=0.0000283).

Measurements of TOC within the pre-investigation area showed a significant increase in TOC with increasing water depth (see Figure 5-5 and Table 5-3). Thus, the highest organic content was found at the deeper stations. Sediment types as visually determined from the HAPS sediment cores were not precise enough to be able to describe the relationship between sediment type and TOC concentrations for the data in this investigation. This would most likely require analysis of grain size in the same sediment samples.

Comparing with existing data TOC concentrations were within the range measured in the North Stream 2 baseline study (Nord Stream 2, 2018) but much lower than measured in the Baltic Pipe study. As seen for both the North stream 2 and Baltic Pipe baseline studies, TOC (or LOI) increased with depth as the sediment contains more silt and mud (e.g. higher organic content) with depth.

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. High concentrations of pollutants in the seabed may be determining for the abundance and distribution of infauna in the seabed.

Chemical parameters incl. both nutrients and pollutants were measured in the HAPS samples for chemical analysis (see stations in Figure 3-1 and Figure 3-3).

NUTRIENTS

The primary input of nutrients (nitrogen and phosphorous), to the Baltic Sea comes from rivers, diffuse run-off in coastal areas, discharge from ships or from atmospheric deposits of nitrogen. An exchange of water is continually happening between the Baltic Sea and the adjacent sea through the Danish channels. In the marine environment nitrogen and phosphorous are used by plants and algae, but the surplus is sequestered in the sea-floor sediment. Excessive input of nutrients to the marine environment enhances the growth of phytoplankton, leading to reduced light conditions in the water, oxygen deficiency at the seafloor, altered species composition and food web interactions and a cascade of other ecosystem changes. At least 97 % of the Baltic Sea was assessed as eutrophic in 2011–2016. Nutrient inputs from land have decreased as a result of regionally reduced nutrient loading, but the effect of these measures has not yet been detected (HELCOM, 2018).

There are no threshold values for total nitrogen (TN) and total phosphorus (TP) in sediment in the Baltic Sea, and therefore measured concentrations are assessed by comparison with existing data from comparable baseline studies in the area, such as the Baltic Pipe and North Stream 2 baseline studies (see section 4.3.3 – Existing data/Chemical parameters).

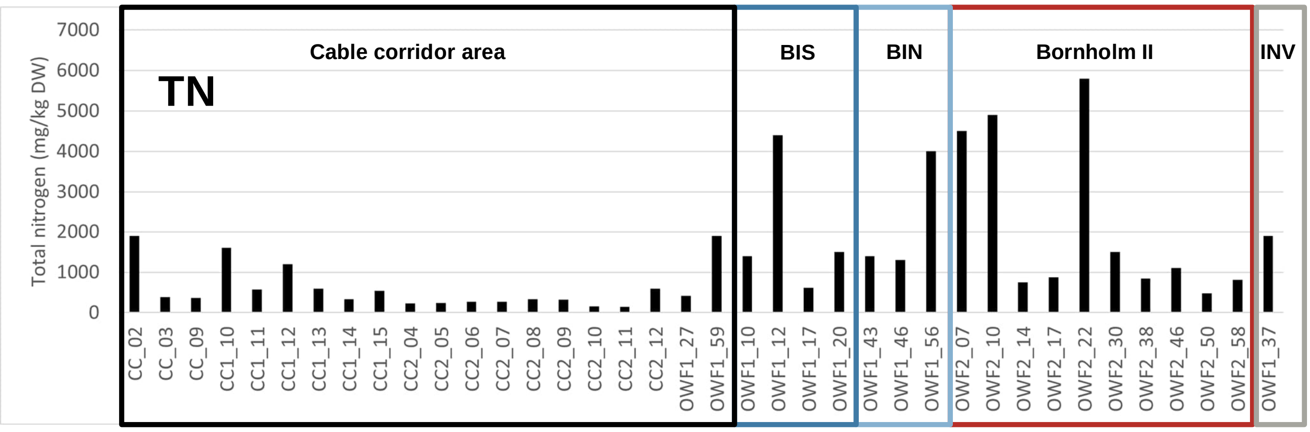
Concentrations of TN and TP in the sediment in the pre-investigation area are shown in Figure 5-6 and listed in Table 5-4 below.

TN ranged from 150 - 5800 mg N/kg DW and TP ranged from 160 – 7700 mg P/kg DW at depths between 3.4 - 57.4 meters of depth at the stations analysed for nutrient content within the pe-investigation area (Chemical HAPS stations) (Table 5-4 and Figure 5-6). TN was similar to the range found in existing studies (NSP2 and Baltic Pipe) in the area (150-6000 mg N/kg DW), however, TP (170-1200 mg P/kg DW) was much higher based on one value of 7700 mg P/kg DW at the station CC2_06 in Table 5-4 (see section 4.3.3 Existing data/Nutrients, Table 4-4).

Table 5-4. Total nitrogen (TN) and phosphorus (TP) measured in the sediment in the pre-investigation area. Furthermore, depth and sediment type are indicated. Stations within Bornholm I North and Bornholm I South are marked with light and dark blue fill, respectively, and Bornholm II stations are marked with darker red fill color. Stations within the cable corridor are marked with white, and the single INV station (OWF1_37) is marked with grey. Note that OWF1_37 is located in the INV area and OWF1_27 and _59 are located within the cable corridor. For station location see Figure 3-1.

Station ID	Total nitrogen (mg/kgDW)	Total phosphorus (mg/kgDW)	Depth (m)	Sediment type*
CC_02	1900	460	3.4	1b
CC_03	390	990	4.1	2
CC_09	360	740	12.0	2
CC1_10	1600	210	38.8	1a
CC1_11	570	740	39.3	2
CC1_12	1200	310	44.1	1a
CC1_13	590	390	45.3	1a
CC1_14	330	550	47.0	1a
CC1_15	540	2500	39.4	2
CC2_04	230	1500	18.9	2
CC2_05	240	630	18.7	1b
CC2_06	270	7700	17.8	1b
CC2_07	270	1500	16.1	1b
CC2_08	330	290	15.1	1b
CC2_09	320	250	14.7	1b
CC2_10	160	220	14.3	1b
CC2_11	150	180	14.2	1b
CC2_12	590	590	32.0	1b
OWF1_27	420	260	34.7	2
OWF1_59	1900	400	47.5	1a
Average			*25.9*	
OWF1_10	1400	330	37.0	1a
OWF1_12	4400	680	42.1	1a
OWF1_17	610	160	34.5	1b
OWF1_20	1500	390	38.7	1a
Average			*38.1*	
OWF1_43	1400	340	41.4	1a
OWF1_46	1300	500	44.7	1a
OWF1_56	4000	710	45.9	1a
Average			*44.0*	
OWF2_07	4500	680	55.5	1a
OWF2_10	4900	740	53.9	1a
OWF2_14	750	390	38.2	1a
OWF2_17	870	570	43.2	1a
OWF2_22	5800	970	57.4	1a
OWF2_30	1500	660	49.0	1a
OWF2_38	840	590	34.9	1b
OWF2_46	1100	240	48.0	1a
OWF2_50	480	310	42.4	1a
OWF2_58	810	460	40.0	1a/1b
Average			*46.3*	
OWF1_37	1900	310	43.3	1a

Concentrations of TN were generally higher in the deeper wind farm areas and INV area compared to the shallower cable corridor area. Whereas TP was generally higher in the shallower cable corridor stations compared to the deeper OWF1 and OWF2 stations (Figure 5-6). TN and TP concentrations were within the same ranges in the two Bornholm I areas and slightly higher in the Bornholm II area (Figure 5-6).



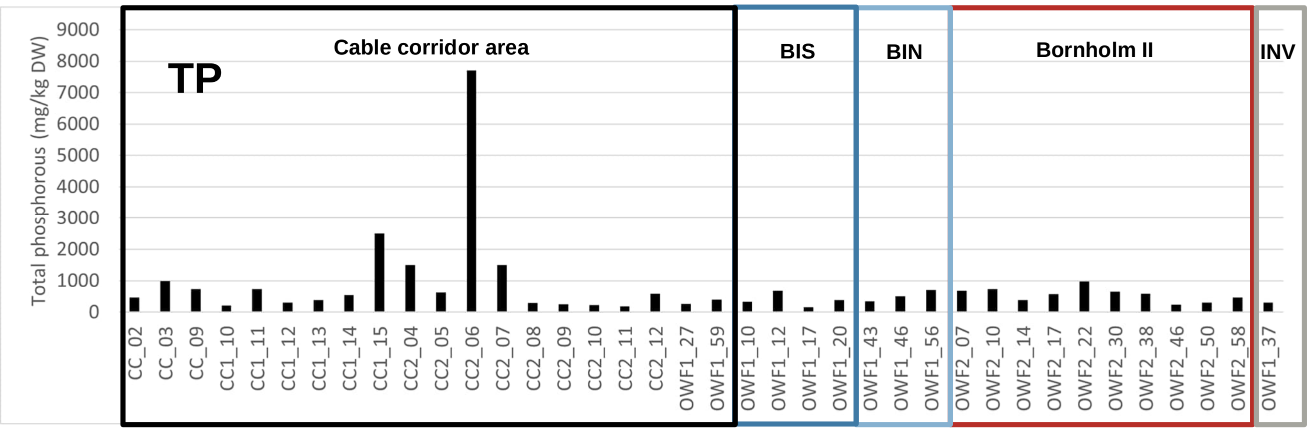
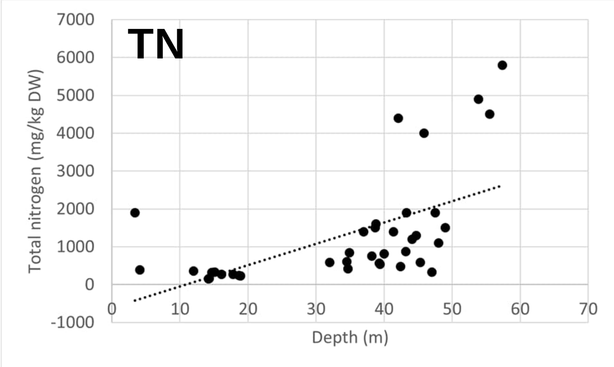


Figure 5-6. Total Nitrogen (TN) and total Phosphorus (TP) concentrations measured in the sediment at stations in the pre-investigation area. Upper figure: TN, Lower figure: TP. The colored areas on the figure indicate in which subarea the stations are located. BIN = Bornholm I North OWF area. BIS = Bornholm I South OWF area. INV = stations outside the subareas in the pre-investigation area (see section 3.1.3).

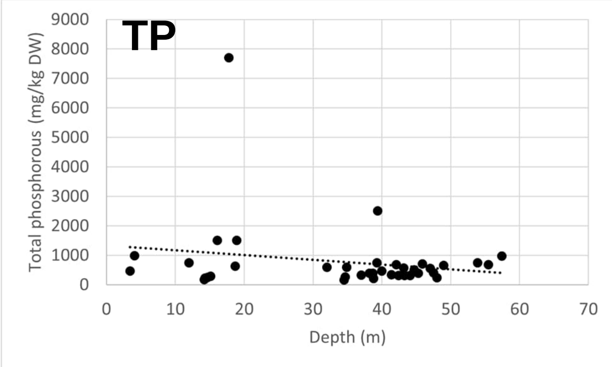
Nutrients and pollutants tend to adsorb to fine-grained sediment and accumulate with depth as is the case for the existing data (depth range 21-47,5 m, Table 4-4), where the highest concentrations for both TN and TP are found at depths >40 meters of depth corresponding to the presence of finer-grained and more organic-rich sediment dominated by silt and clay in the pre-investigation area south of Bornholm (see section 4.3.3 – Existing data/Chemical parameters/Nutrients). A positive correlation between depth and TOC was also found in the existing studies (see section 4.3.2 – Existing data/Physical parameters).

Data from the pre-investigation area showed a significant correlation between TN and depth ($p=0.00018$) and TN and TOC ($p<0.001$) for all stations (Figure 5-7), however no significant correlation was found between TP, depth and TOC (Figure 5-7).

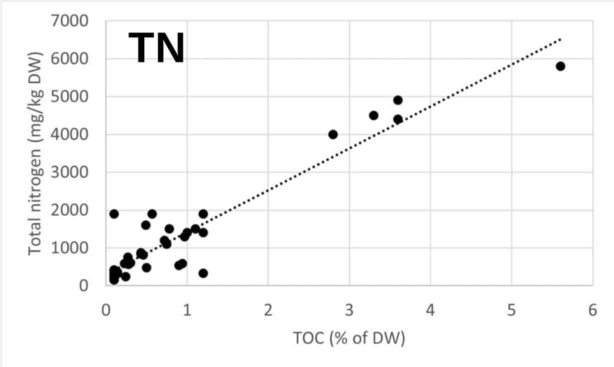
Sediment types as visually determined from the HAPS sediment cores were not precise enough to be able to describe the relationship between sediment type and nutrient concentrations for the data in this investigation. This would most likely require analysis of grain size and nutrient concentrations in the same sediment samples.



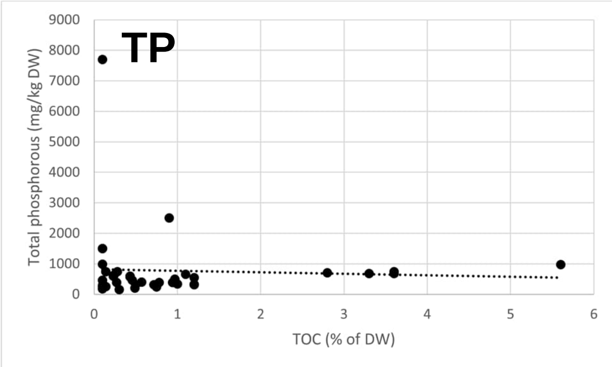
Correlation between total nitrogen (TN, mg/kg DW) and depth. Total N increases with depth (linear regression model, p=0.00018, R^2=0.3267).



Correlation between total phosphorous (TP, mg/kg DW) and depth. There is no significant relationship between depth and total P (linear regression model, p=0.24, R^2=0.0375).



Correlation between total nitrogen (TN) and TOC. There is a significant correlation between TN and TOC (linear regression model, p<0.001; R^2=0.89).



Correlation between total phosphorous (TP) and TOC. There is no significant correlation (linear regression model, p=0.77; R^2=0.0024).

Figure 5-7. Correlations between TN, TP and depth and TOC content for the chemical HAPS stations inside the pre-investigation area. Data from Table 5-4 above.

WIND FARM AREAS

Nutrient concentrations were generally very similar within the two Bornholm I areas (South and North) ranging from TN concentrations of 610-4400 mg N/kg DW and TP concentrations of 160-710 mg P/kg DW (Table 5-4). Existing data from North stream 2 and Baltic Pipe measured at stations within the two OWF areas were generally slightly higher than measured in the present baseline study (TN concentrations of 700-4900 mg N/kg DW and TP concentrations of 170-1100 mg P/kg DW) (see section 4.3.3 – Existing data/ Chemical data/Nutrients).

Nutrient concentrations were slightly higher in the Bornholm II area compared to the two Bornholm I areas ranging from TN concentrations of 480-5800 mg N/kg DW and TP concentrations of 240-970 mg P/kg DW (Table 5-4). Furthermore, existing data from North stream 2 and Baltic Pipe measured at stations within the Bornholm II area were generally slightly lower than measured in the present baseline study (TN concentrations of <200-6000 mg N/kg DW and TP concentrations of 400-1200 mg P/kg DW) (see section 4.3.3 – Existing data/ Chemical data/Nutrients).

CABLE CORRIDOR AREA

Nutrient concentrations measured in the cable corridor area (CC, CC1, CC2) ranged from TN concentrations of 150-1900 mg N/kg DW and TP concentrations of 180-7700 mg P/kg DW (Table 5-4). Especially, one TP concentration at stations CC2_06 was much higher 7700 mg P/kg DW compared to other cable corridor stations (≤2500 mg P/kg DW) and compared to all other measured TP concentrations (≤970 mg P/kg DW) at the Chemical HAPS stations within for OWF1 and OWF2 stations. This illustrates that the TP concentrations in general were much higher in the cable corridor area compared to the other areas (see Figure 5-6), whereas, the opposite was seen for TN (see Figure 5-6).

Existing data from North stream 2 and Baltic Pipe measured at stations within the cable corridor area were lower than measured in the present baseline study (TN concentrations of <200 mg N/kg DW and TP concentrations of 240-810 mg P/kg DW) (see section 4.3.3 – Existing data/ Chemical data/Nutrients).

POLLUTANTS

Man-made chemicals and heavy metals enter the Baltic Sea via numerous sources, including waste-water treatment plants, leaching from household materials, leaching from waste deposits, and atmospheric deposition from industrial plant emissions, amongst others. Once in the Baltic Sea, they can cause various types of damage to the ecosystem (HELCOM, 2018). The Baltic Sea has been exposed to pollutants since the beginning of the industrialization and has been called the most polluted sea in the world (HELCOM, 2010).

Chemical pollutants were measured in the sediment at a total of 38 stations in the pre-investigation area for Energy Island Bornholm, and the results are presented below. Chemical pollutants analysed in the sediment samples (Chemical HAPS) are listed in section 3.2.4 – Chemical analysis. Pollutants exceeding applied threshold values are listed in Table 5-6 and locations of chemical HAPS stations are presented in Figure 5-8 and Appendix 2. All chemical analysis data are presented in Appendix 4.

CORE INDICATORS AND THRESHOLD VALUES

HELCOM uses core indicators with quantitative threshold values to evaluate progress towards the goal of achieving good environmental status in the Baltic Sea. Core-indicator evaluations are regularly updated and published as core-indicator reports (HELCOM, 2018b).

In order to assess pollutants in marine waters, seabed sediments and biota (matrices), different threshold values are used around the world. Focus, in the present report, will be on sediments, since this is the matrix of investigation.

Nationally, the Danish EPA has determined National Environmental Quality Standards (NEQS) for specific hazardous substances (pollutants) in order to secure good chemical status in Danish waters (Miljøstyrelsen, 2023a; Miljøstyrelsen, 2023b). The European Union has determined Environmental Quality Standards (EQS) used by HELCOM countries, for the classification of chemical status of water bodies and sediments under the Water Framework Directive. The EQS and NEQS threshold values are legal requirements based on risk assessments. Concentrations of pollutants below threshold values are considered not to cause harm to the marine environment.

The statutory NEQS-values for hazardous substances are specified in the BEK. no. 796 of 13th of June 2023 (Miljøstyrelsen, 2023a). However, only a few NEQS-values are included for pollutants in sediment (Miljøstyrelsen, 2023a). Several more sediment NEQS-values have been developed and can be found at the Danish EPA’s website and are also used in the following assessment (Miljøstyrelsen, 2023b).

The Environmental Assessment Criteria (EAC) are OSPAR’s standards based on a similar risk assessment but is an assessment tool and not a legal requirement. The EAC threshold values are defined for each hazardous substance, as the concentration below which no chronic effect is expected to occur in the most sensitive marine species (OSPAR, 2009). The OSPAR standards are, however, not applicable to the Baltic Sea, but since no specific threshold values for the Baltic Sea exists, HELCOM uses the OSPAR standards for assessment of xenobiota (chemicals foreign to a biological system) in the Baltic Sea (HELCOM, 2010).

Threshold values used in other countries include the Effect Range Low (ERL), which has been developed by the US EPA (see (OSPAR, 2009; Nyberg et al., 2013). The ERL represents a chemical threshold below which, the likelihood of direct adverse effects from the chemical on aquatic life is low. OSPAR uses the ERL as a proxy for the EAC, and like the EAC, the ERL is a recommendation, not a legal requirement.

The Lower Action Level (LAL) for specified chemical substances is defined in "the Danish guideline for disposal of dredged material" (Klapvejledningen) (Miljøstyrelsen, 2008). This standard is a legal requirement, but only applies to sediment dumping, and therefore does not directly relate to the concentration of hazardous substances in normal sea-floor sediment. Therefore, this threshold should only be used in the absence of the quality standards and threshold values mentioned above.

Observed exceedances of pollutants in the sediment within the pre-investigation area are shown in Table 5-6 below and station location is shown in Figure 5-8. Pollutants are evaluated based on the available quality standards and threshold values specifically for sediments, prioritized according to recommendations from the Danish Centre for Environment and Energy, Aarhus University (DCE) (Strand & Larsen, 2013). Since the NEQS are now our national standards, and statutory threshold values are determined in the BEK. no. 796 of 13th of June 2023 (Miljøstyrelsen, 2023a), the NEQS are the primary assessment tool in the present report.

Applied threshold values are prioritized in the following order:
1) NEQS: National Environmental Quality Standards, Danish EPA (Miljøstyrelsen, 2023a; Miljøstyrelsen, 2023b)*****
2) EQS: Environmental Quality Standards, EU (HELCOM, 2017)*
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)

* Statutory threshold values (1+2). The rest (3-5) are only indicative.

RESULTS

For some of the measured pollutants, applied threshold values were below detection limits of the laboratory analyses, which means that an assessment of these pollutants cannot be achieved at some stations. Therefore, more exceedances might exist at some stations (see all measured concentrations in Appendix 4). The affected compounds are arsenic, anthracene, benzo(a)pyrene and different PCB's listed in Table 5-5.

Only anthracene has a statutory NEQS threshold value for sediment specified in BEK. no. 796 of 13th of June 2023 (Miljøstyrelsen, 2023a), whereas arsenic, benzo(a)pyrene and the PCB's are not listed as statutory compounds.

Table 5-5. Pollutants where lowest applied threshold value is below the detection limit of the laboratory analyses conducted for this study. See Appendix 4 for measured concentrations and the laboratory detection limits of the analyses. *For pollutants PCB28, PCB52, PCB101, PCB138, PCB180 and Sum of 7 PCB's, detection limit (0.020 mg/kg DW) is only above the relevant threshold values at one station (CC_02) – detection limit in the laboratory analysis for the remaining stations (0.0010 mg/kg DW) is below threshold values.

Pollutant	Detection limit of laboratory analyses (mg/kg DW)	Lowest applied threshold value (mg/kg DW)	Detection limit applies to samples
Arsenic (heavy metal)	0.50	0.4 (NEQS)	All
Anthracene (PAH)	0.010	0.0048 (NEQS)	All
Benzo(a)pyrene (PAH)	0.010	0.007 (NEQS)	All
PCB-compounds*			
PCB118	0.0010/0.020	0.0006 (EAC)	All
PCB28	0.020	0.0017 (EAC)	1: CC_02
PCB52	0.020	0.0027 (EAC)	1: CC_02
PCB101	0.020	0.003 (EAC)	1: CC_02
PCB138	0.020	0.0079 (EAC)	1: CC_02
PCB180	0.020	0.012 (EAC)	1: CC_02
Sum of 7 PCB's	0.14	0.023 (EAC)	1: CC_02

Pollutants that exceed threshold values in the pre-investigation area are listed in Table 5-6 below including station depth and sediment type, and location of stations where exceedances were found are shown in Figure 5-8. Note that OWF1_37 is located in the INV area and OWF1_27 and _59 is located within the cable corridor area.

No exceedances of the following pollutants were observed in the pre-investigation area: the heavy metals cadmium (Cd), chrome (Cr), mercury (Hg) and zinc (Zn), the PAH-compounds phenanthrene, fluoranthene and pyrene as well as the seven PCB congeners. Detection limits from the laboratory analyses were, however, higher than the applied threshold values for some pollutants, which means that exceedances cannot be assessed at some stations (see Table 5-5 and Appendix 4 for full data set).

In total, 11 pollutants (heavy metals (4), PAH-compounds (6) and organotin-compounds (1)) were found exceeding the applied threshold values in the pre-investigation area. Exceedances of threshold values were observed at 35 of 38 stations (92 %). This was primarily caused by the heavy metal arsenic, which was the only pollutant exceeding the NEQS threshold value at 16 of the 38 stations (42 %) (Table 5-6).

Looking at heavy metals other than arsenic, nickel exceeded threshold values at several stations (13 of 38 stations, 34 %) – however, exceedances were only of the NEQS, except for two stations that also exceeded the ERL. Lead and copper exceeded threshold values at two and five stations respectively (5 % and 13 %), but almost exclusively the LAL threshold, which is not applicable to normal sea-floor sediment (see 5.2.3 – Core indicators and threshold values). Excluding the LAL, lead did not exceed the other applied threshold values (NEQS, EQS or ERL) at any stations (0 %) and copper only exceeded other threshold values (ERL) at one station (3 %) (see Table 5-6).

Exceedances were found in six PAH-compounds in the pre-investigation area: anthracene (8 % of stations), benzo(a)anthracene (5 %), chrysene (16 %), benzo(a)pyrene (34 %), indeno(1,2,3-cd)pyrene (26 %) and benzo(ghi)perylene (29 %) (Table 5-6).

Concentrations of the organotin-compound TBT exceeded threshold values at two stations (5 %).

Table 5-6. Pollutants exceeding applied threshold values in the sediment within the pre-investigation area, showing concentrations and applied threshold values (both in mg/kg DW) as well as depth and sediment type for the HAPS sample for chemical analysis. "-" indicate that the detection limit from the chemical analysis in the laboratory was higher than the lowest applied threshold value(s) and, thus, it is not possible to determine if the specific compounds exceed the threshold values at these stations. Empty cells indicate no exceedance of threshold values. Pollutants mostly exceeded the NEQS values represented by black numbers in the table, and red numbers indicate which of the other threshold values were exceeded. Gray threshold values indicate that these have not been exceeded. Stations within Bornholm I North and Bornholm I South are marked with light and dark blue fill, respectively and Bornholm II stations are marked with darker red fill color. Stations within the cable corridor are marked with white, and the single INV station (OWF1_37) is marked with grey fill. Note that OWF1_37 is located in the INV area and OWF1_27 and _59 are located within the cable corridor area. For station location see Figure 5-8. *Threshold values for lead and anthracene are statutory NEQS values (Miljøstyrelsen, 2023a). f_{oc} is the fraction of TOC in the sediment.

Station	Heavy metals				Tributyltin-cation (TBT)	PAH						Depth (m)	Sediment type
Threshold values	Arsenic (As)	Lead (Pb)	Copper (Cu)	Nickel (Ni)		Anthracene	Benzo(a)-anthracene	Chrysene	Benzo(a)-pyrene	Indeno(1,2,3-cd)pyrene	Benzo(ghi)-perylene		
NEQS	0.4	163*		6.8	0.0013	0.096 x f_{oc}*	0.03	0.0231	0.007	0.042	0.042		
EQS		120			0.0016								
EAC						0.78			0.625				
ERL	8.2	47	34	20.9		0.085	0.261	0.384	0.43	0.24	0.085		
LAL	20	40	20	30	0.007								
CC_02	-					-			-			3.4	4
CC_03	2.0					-			-			4.1	3
CC_09	0.81					-			-			12.0	2
CC1_10	1.1					-			-			38.8	1a
CC1_11	2.8					-			-			39.3	2
CC1_12	2.3					-			0.021			44.1	1a/1b
CC1_13	5.4			10		-			0.022	0.055	0.058	45.3	1a
CC1_14	21			18		-		0.025	0.052	0.14	0.15	47.0	1a
CC1_15	6.7					-			-			39.4	2a
CC2_04	2.3					-			-			18.9	2
CC2_05	2.7					-			-			18.7	1b
CC2_06	4.4					-			-			17.8	1b
CC2_07	1.8					-			-			16.1	1b
CC2_08	-					-			-			15.1	1b
CC2_09	-					0.026	0.036	0.048	0.062	0.048	0.049	14.7	1b
CC2_10	-		30			-			-			14.3	1b

Station	Heavy metals				Tributyltin-cation (TBT)	PAH						Depth (m)	Sediment type
Threshold values	Arsenic (As)	Lead (Pb)	Copper (Cu)	Nickel (Ni)		Anthracene	Benzo(a)-anthracene	Chrysene	Benzo(a)-pyrene	Indeno(1,2,3-cd)pyrene	Benzo(ghi)-perylene		
NEQS	0.4	163*		6.8	0.0013	0.096 x f_{oc}*	0.03	0.0231	0.007	0.042	0.042		
EQS		120			0.0016								
EAC						0.78			0.625				
ERL	8.2	47	34	20.9		0.085	0.261	0.384	0.43	0.24	0.085		
LAL	20	40	20	30	0.007								
CC2_11	-					-			-			14.2	1b
CC2_12	0.96					-			-			32.0	1b
OWF1_27	0.96					-			-			34.7	2
OWF1_59	3.7			10		-			0.024	0.055	0.063	47.5	1a
OWF1_10	9.8			9.0		-			-			37.0	1a
OWF1_12	14		21	21		-			0.020		0.052	42.1	1a
OWF1_17	0.85					-			-			34.5	1b
OWF1_20	4.5			7.2		-			-			38.7	1a
OWF1_43	3.5					-			0.032	0.074	0.082	41.4	1a
OWF1_46	5.8			20		-			-			44.7	1a
OWF1_56	12			17		-		0.039	0.062	0.16	0.16	45.9	1a
OWF2_07	7.8		23	17	0.00263	0.011		0.047	0.071	0.19	0.19	55.5	1a
OWF2_10	10	46	24	18	0.00158	0.011	0.031	0.053	0.088	0.24	0.24	53.9	1a
OWF2_14	1.1					-			-			38.2	1a
OWF2_17	2.8					-			0.011			43.2	1a
OWF2_22	13	44	39	32		-		0.029	0.053	0.13	0.14	57.4	1a
OWF2_30	4.7					-			0.033	0.076	0.084	49.0	1a
OWF2_38	1.3					-			-			34.9	1b
OWF2_46	1.3			8.7		-			-			48.0	1a
OWF2_50	4.7					-			-			42.4	1a
OWF2_58	2.0					-			-			40.0	1a/1b
OWF1_37	14			8.9		-			-			43.3	1a

Station OWF1_37 formerly located in the Bornholm I area, is now located in the INV area. The heavy metals arsenic and nickel were the only pollutants exceeding threshold values at the station, which was found at 43 meters on a 1a sediment (see Table 5-6 and Figure 5-8).

In general, pollutants were most prevalent in Bornholm II where also the highest concentrations of pollutants were found, compared to Bornholm I and the cable corridors.

The concentrations of five brominated flame retardants (PBDE 28, 47, 99, 100 and HBCDD) were measured at three selected stations in the cable corridor (CC_03, CC_09 and CC1_12) and these data can be seen in Appendix 4. Only one threshold value exists for one of the brominated flame retardants, which is an EQS value for HBCDD. No exceedances of this compound were found at the three stations, and concentrations of all five compounds were below detection limits at all stations.

Most exceedances of pollutants were found at >34 meters of depth, in sediment type 1a containing silt, mud and clay. This was expected, since pollutants generally adsorb to fine-grained, organic-rich material and accumulate with depth (Strand & Larsen, 2013). A notable outlier, however, was cable corridor station CC2_09, where exceedances were found in all six PAHs, although the station was located on a 1b sandy sediment at only 15 meters of depth (Table 5-6).

Pollutants mostly exceeded the NEQS threshold values, which are generally lower compared to the other applied threshold values (see Table 5-6). In fact, excluding the NEQS, exceedances were only observed at 7 out of 38 stations (18 %), exceedances were only found in one PAH-compound (benzo(ghi)perylene) and arsenic only exceeded at one station – and only the non-applicable LAL-value (Table 5-6).

Comparing the above findings to the existing data in the pre-investigation area (see 4.3.3 – Existing data/ Pollutants) several differences are apparent. Besides the 11 pollutants that exceeded threshold values in the present study, PCB congener 118 was also found at exceeding concentration in both the baseline studies for Baltic Pipe and NSP2 – Northern Route. 8 pollutants exceeded threshold values other than the NEQS in the existing baseline studies, compared to 7 pollutants in the present study. Furthermore, the baseline studies for Baltic Pipe and NSP2 had exceedances of threshold values other than the NEQS at 10 out of 24 stations (42 %), compared to 7 out of 38 stations (18 %) in the present study (Table 5-6 and Table 4-5), which means that concentrations of pollutants in the existing baseline studies for Baltic Pipe and NSP2 were generally higher than in this study.

WIND FARM AREAS

Four stations were sampled for chemical analyses of the sediment (HAPS chem samples, Appendix 1 and Appendix 4) within the Bornholm I South wind farm area and three stations within Bornholm I North, whereas more stations (10) were sampled within Bornholm II (Figure 5-8).

In Bornholm I South, concentrations of five pollutants (heavy metals and PAHs) were observed to exceed threshold values: arsenic, copper (only LAL), nickel, benzo(a)pyrene and benzo(ghi)perylene (Table 5-6). Exceedances of PAH-compounds and copper were only found at one station (OWF1_12).

In Bornholm I North, six pollutants (heavy metals and PAHs) exceeded threshold values: arsenic, nickel, chrysene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene and benzo(ghi)perylene (Table 5-6)South. Most exceedances were found at station OWF1_56.

In the Bornholm II wind farm area concentrations of 11 pollutants exceeded threshold values (Table 5-6). In fact, exceedances of all 11 pollutants were found at one station (OWF2_10) in the area. Bornholm II was the only area where concentrations of lead were found at exceeding levels, however, only exceeding the non-applicable LAL-value (see 5.2.3 – Core indicators and threshold values).

Most exceedances in the Bornholm II wind farm area were found in the deep, muddy south-eastern area. Exceedances in the two Bornholm I OWFs (North and South) were also found at the deepest stations in areas with muddy sediment (type 1a) (see Figure 5-8).

CABLE CORRIDORS

20 stations were analysed for pollutants within the cable corridor area including OWF1_27 and _59 formerly located in the Bornholm I area (OWF1). In the cable corridor area nine pollutants were observed to exceed threshold concentrations (see Table 5-6). Exceedances were primarily found at stations in the deep, muddy area north/northeast of Bornholm I North in the CC1 cable corridor section (CC1_12, _13, _14, OWF1_59 and OWF1_27) (see Figure 5-8). A notable outlier, however, was cable corridor station CC2_09, where exceedances were found in all six PAHs, although the station was located on a 1b sandy sediment at only 15 meters of depth (Table 5-6). Apart from this station, exceedances within the cable corridor area were generally found at deep stations (>35 m) on muddy sediments.

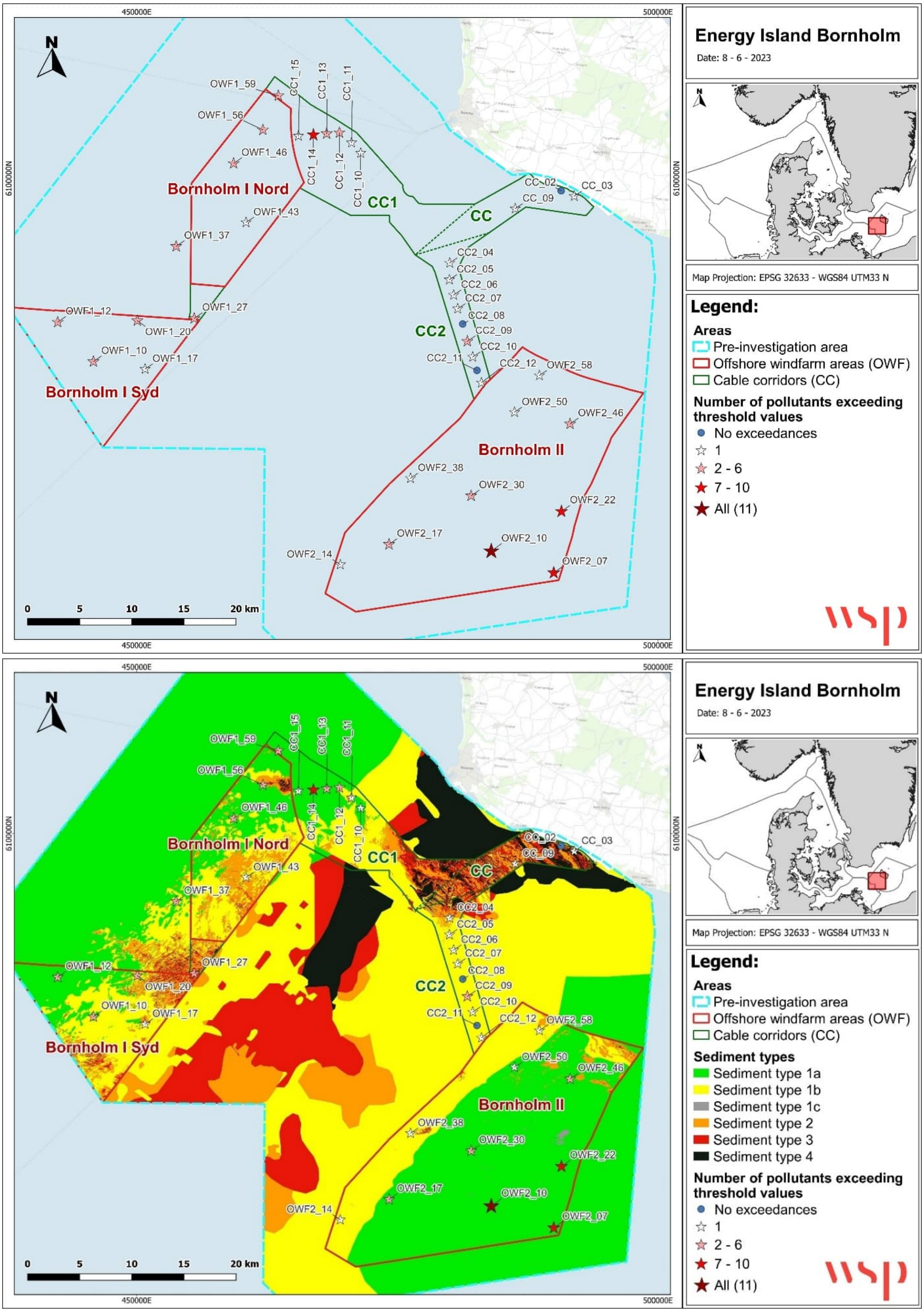


Figure 5-8. Exceedances of threshold values for pollutants in the pre-investigation area and subareas (CC, Bornholm I North and South and Bornholm II). Stations with exceedances of threshold values are marked with different star symbols. Data from Table 5-6.

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 in the pre-investigation area. This section gives a description of dominating species/groups for the observed benthic communities. For greater details on species and groups see sections on benthic flora and fauna below.

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 benthic communities and, thus habitat types, are therefore mainly determined from the epibenthic communities living on the sediment. However, visible infauna and signs of infauna activity such as mussel shells, bivalve wholes, bristle worm piles and tubes, are also included in the taxa list as well as percentage of coverage. Infauna is described in more detail in section 5.5.2 – Infauna.

Six different benthic communities/habitat types were found in the pre-investigation area for Energy Island Bornholm. The specifics of each nature type are listed in Table 5-7 and Table 5-8 below. Nature type 5 - Eelgrass beds are included to allow comparability with the technical report for the cable corridor from Energy Island Bornholm to Zealand and the numbering of nature types in that report.

Nature types mapped in the pre-investigation area are listed in Table 5-7, which shows the area coverage in km^2 and % coverage. The nature types in the pre-investigation area are, furthermore, shown in Figure 5-9 and Figure 5-10 below. Each benthic community (nature type) is described in Table 5-8 below and in more detail in the sections below.

Table 5-7. Percent area coverage of the nature types in the mapped wind farm areas (Bornholm I North, Bornholm I South and Bornholm II) and cable corridor area (CC, CC1, CC2). See Figures below. Note that the cable corridor area is not fully mapped and that only the mapped area is included in the estimates below. * Part of another nature type (nature type 3 and 4) and not included in the total km^2 and %.

	Bornholm I North		Bornholm I South		Bornholm II		Cable corridor	
Substrat type	**km^2**	%	**km^2**	**%**	**km^2**	%	**km^2**	%
1a – Soft bottom community	47.91	38.9	35.74	30.3	306.78	74.8	58.84	23.1
1b – Sand bottom community	45.75	37.1	57.30	48.6	93.13	22.7	101.44	39.9
2 – Mixed community	27.04	21.9	16.61	14.1	9.52	2.32	52.21	20.5
3 - Hard bottom community	1.97	1.6	7.66	6.5	0.83	0.20	25.77	10.1
4 - Stone reef/ sedimentary rock	0.55	0.45	0.56	0.48	0.03	0.01	16.28	6.4
5 - Eelgrass beds	-	-	-	-	-	-	-	-
6 – Blue mussel beds*	2.52	2.05	8.22	7.0	0.85	0.21	33.02	13.0
Total	123.22	100.0	117.87	100.0	410.29	100.0	254.54	100.0

Table 5-7 and the nature type maps for the pre-investigation area shows dominance of hard bottom nature types close to Bornholm and in the shallow Rønne Banke area corresponding to the location of the Bird SPA area. Along the rims of the Rønne Banke area benthic communities connected to soft sediments such as sand (Sand bottom community) and at greater depth finer, more organic rich soft sediments such as silt, clay and mud (soft bottom community). The main difference in benthic communities between the mapped subareas (see Table 5-7) are a larger area coverage of soft sediments in Bornholm II wind farm area (nature type 1a) compared to the two Bornholm I areas (North and South) and the cable corridor area. Furthermore, the cable corridor area is covered by a higher area coverage of the hard bottom benthic community (nature type 3+4) compared to the wind farm areas.

Generally, observed fauna species number and coverage on the seabed decreases with depth and is lowest in the deepest, muddy outer parts of the pre-investigation area (Table 5-8).

Table 5-8. Benthic communities (nature types) found in the pre-investigation area for Energy Island Bornholm. % indicates area coverage in percent. *Area distribution determined from Side scan sonar data. Boulders are > 10 cm. Stations with intermediate sediment types are not included e.g. 1a-1b. Depths are rounded to the nearest whole number. * only one station. "–" No ROV stations on this sediment type.

Nature type	Benthic community	Depth (m)	Corresponding sediment type	Dominating fauna species	Fauna coverage (%)	Dominating flora species	Flora coverage (%)
Nature type 1a	Soft bottom	OWF1: 39-48 m OWF2: 41-57 m CC: 39-47 m SPA: - INV: 41-60 m	Sediment type 1a – silt and 1c clay	*Pygospio elegans* and bivalves incl. *Arctica islandica*	OWF1: <1-10 % OWF2: <1-40 % CC: 1-15 % SPA: - INV: <1-30 %	Crust algae: red crust (*Hildenbrandia* spp.)* (one station)	0% INV: 0-<1 %*
Nature type 1b	Sand bottom	OWF1: 28-44 m OWF2: 33-43 m CC: 14-38 m SPA: 12-35 m INV: 22-42 m	Sediment type 1b - sand	*Pygospio elegans,* Lugworm (*Arenicola marina*) and bivalves incl. blue mussels *(Mytilus spp.)*	OWF1: <1-50 % OWF2: <1-25 % CC: <1-15 % SPA: <1-50 % INV: <1-40 %	Crust algae: red crust (*Hildenbrandia* spp.) and brown crust	OWF1: 0-<1 % OWF2: 0 % CC: 0 % SPA: 0-<1 % INV: 0-<1 %
Nature type 2	Mixed	OWF1: 32-39 m OWF2: 49 m* CC: 5-40 m SPA: 9-25 m INV: 21-45 m	Sediment type 2 - boulders 1-10%	On sand: *Pygospio elegans*, Lugworm (*Arenicola marina*) and bivalves. On rocks: blue mussels (*Mytilus* spp.), barnacles, hydrozoans and calcareous worms	OWF1: 1-30 % OWF2: 2-7 %* (one station) CC: 1-40 % SPA: <1-60 % INV: <1-70 % (*P. elegans*)	OWF1: red and brown crust OWF2: None CC: red and brown crust SPA: red and brown crust and red bushes INV: red and brown crust	OWF1: 0-2 % OWF2: 0 %* CC: 0-80 % SPA: 0-5 % INV: 0-1 %
Nature type 3	Hard bottom	OWF1: - OWF2: - CC: 4-23 m SPA: 11-29 m INV: 24-32 m	Sediment type 3 – boulders 10-25%	Blue mussel (Mytilus spp.), calcareous worms and barnacles	OWF1: - OWF2: - CC: 2-50 % SPA: 1-80 % INV: 15-30 %	OWF1: - OWF2: - CC, SPA: Red algae bushes and crust algae INV: red and brown crust	OWF1: - OWF2: - CC: 0-100 % SPA: <1-15 % INV: <1-2 %
Nature type 4	Stone reef and sedimentary rock	OWF1: - OWF2: - CC: 2-18 m SPA: 8-25 m INV: -	Sediment type 4 – boulders >25% and sedimentary rock	Blue mussel (Mytilus spp.), and barnacles Blue mussels dominate coverage at >9 m	OWF1: - OWF2: - CC: 1-100 % SPA: 2-90 % INV: -	*Fucus vesiculosus* (2 m depth) and deeper red algae bushes and crust algae Macroalgae dominate coverage at 0-9 m	OWF1: - OWF2: - CC: 0-100 % SPA: <1-100 % INV: -
Nature type 5	Eelgrass beds	-	Sediment type 1b – sand	-	-	*Zostera marina*	0 %
Nature type 6	Blue mussel beds	2-32 m	Sediment type 3 and 4	*Mytilus* spp.	Mytilus spp. 30-100 %	Red alga bushes and crust alga (*Hildenbrandia* sp.)	0-5 %

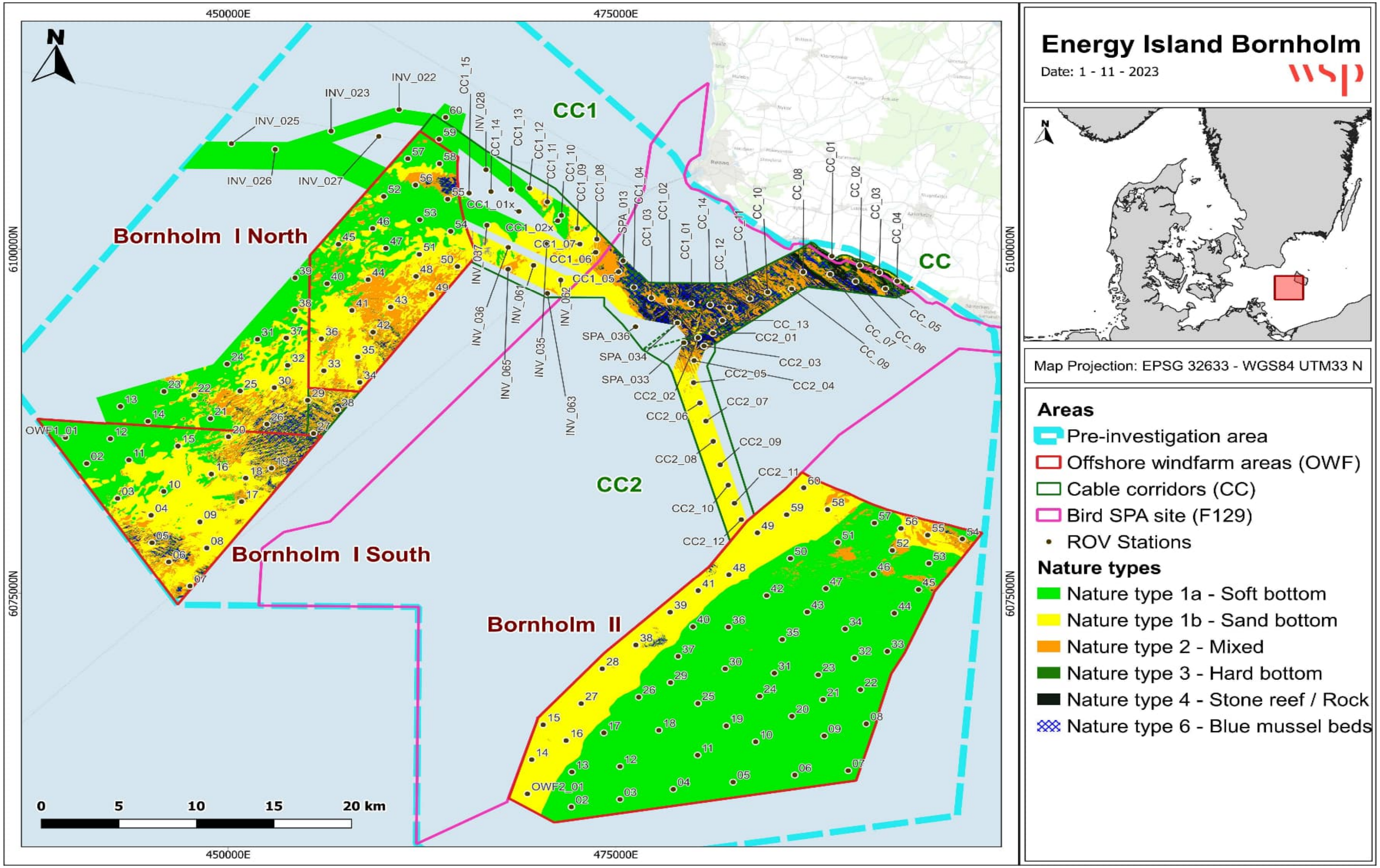


Figure 5-9. Nature type map of benthic communities in the side scan sonar mapped wind farm and cable corridor areas within the pre-investigation area. SPA = Special Protection Area.

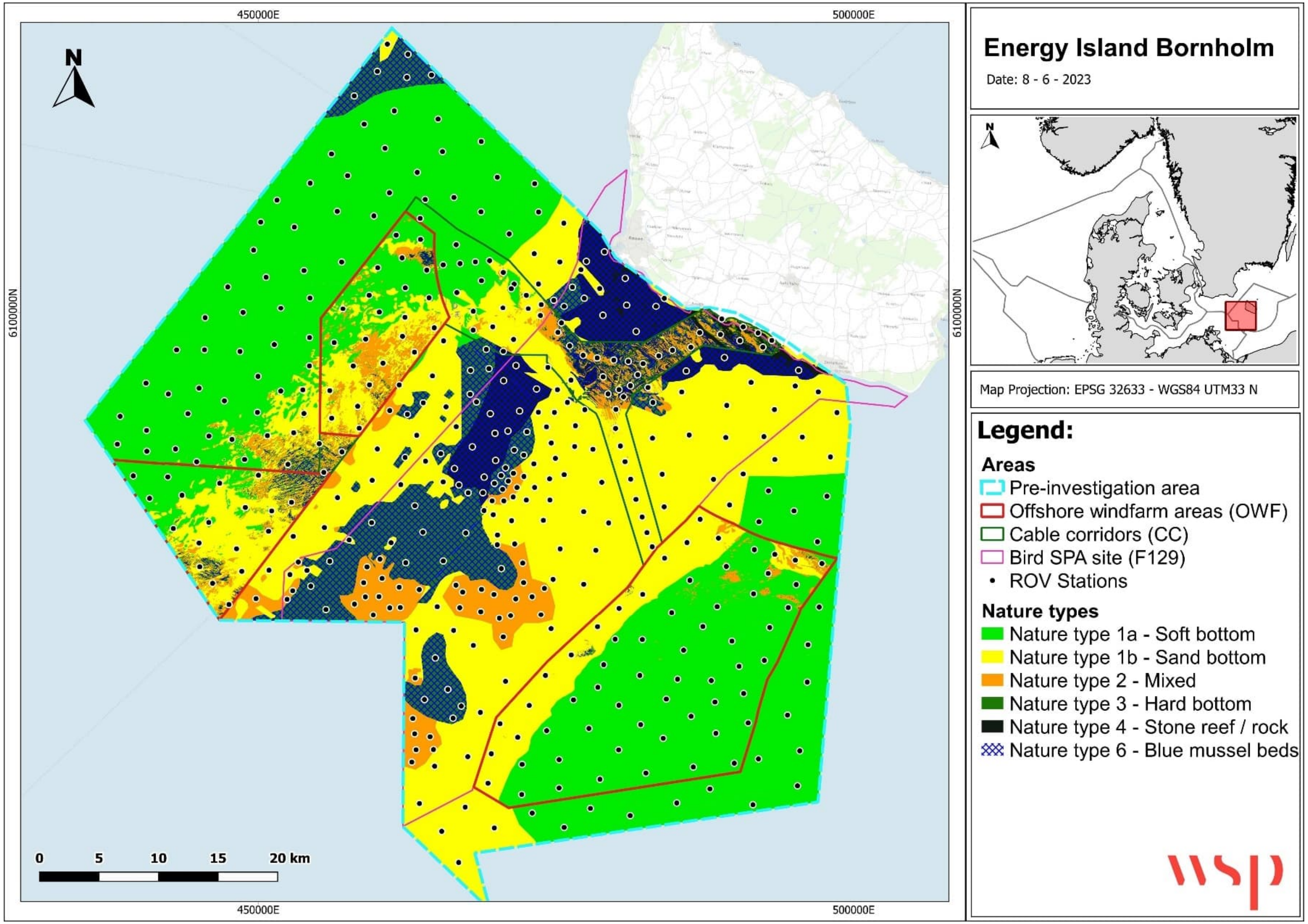


Figure 5-10. Nature type map of benthic communities in the total pre-investigation area based on side scan sonar mapping in the sub areas (CC, CC1, CC2, OWF1, OWF2) and the adjusted GEUS sediment map (see section 5.2.1). SPA = Special Protection Area.

5.3.1 NATURE TYPE 1A– SOFT BOTTOM COMMUNITY

Nature type 1a - Soft bottom community corresponds to sediment type 1a and 1c (Figure 5-3). Nature type 1a is present in the deeper outer parts of the pre-investigation area generally at depths >39 meters of depth (Figure 5-9, Figure 5-10). Generally, no benthic flora species were observed, however one specimen of red crust algae was found at station INV_110 (0-<1 % coverage). The benthic fauna generally has low coverages between <1-15 % (Figure 5-11). However, in the OWF2 and INV area south of OWF2 fauna coverages of up to 40 % are found at a few stations with relative dense coverage of *Pygospio elegans* tubes (see Figure 5-12 upper figure).

Benthic fauna in nature type 1a is dominated by the bristle worm *Pygospio elegans* and bivalves incl. *Arctica islandica* (Figure 5-12). The highest coverages observed in OWF2 and INV areas are caused by populations of *Pygospio elegans*.

Figure 5-11. Nature type 1a - Soft bottom community. A smooth, soft, and silty seabed dominated by low coverage of benthic fauna and no flora. ROV station OWF2_19.

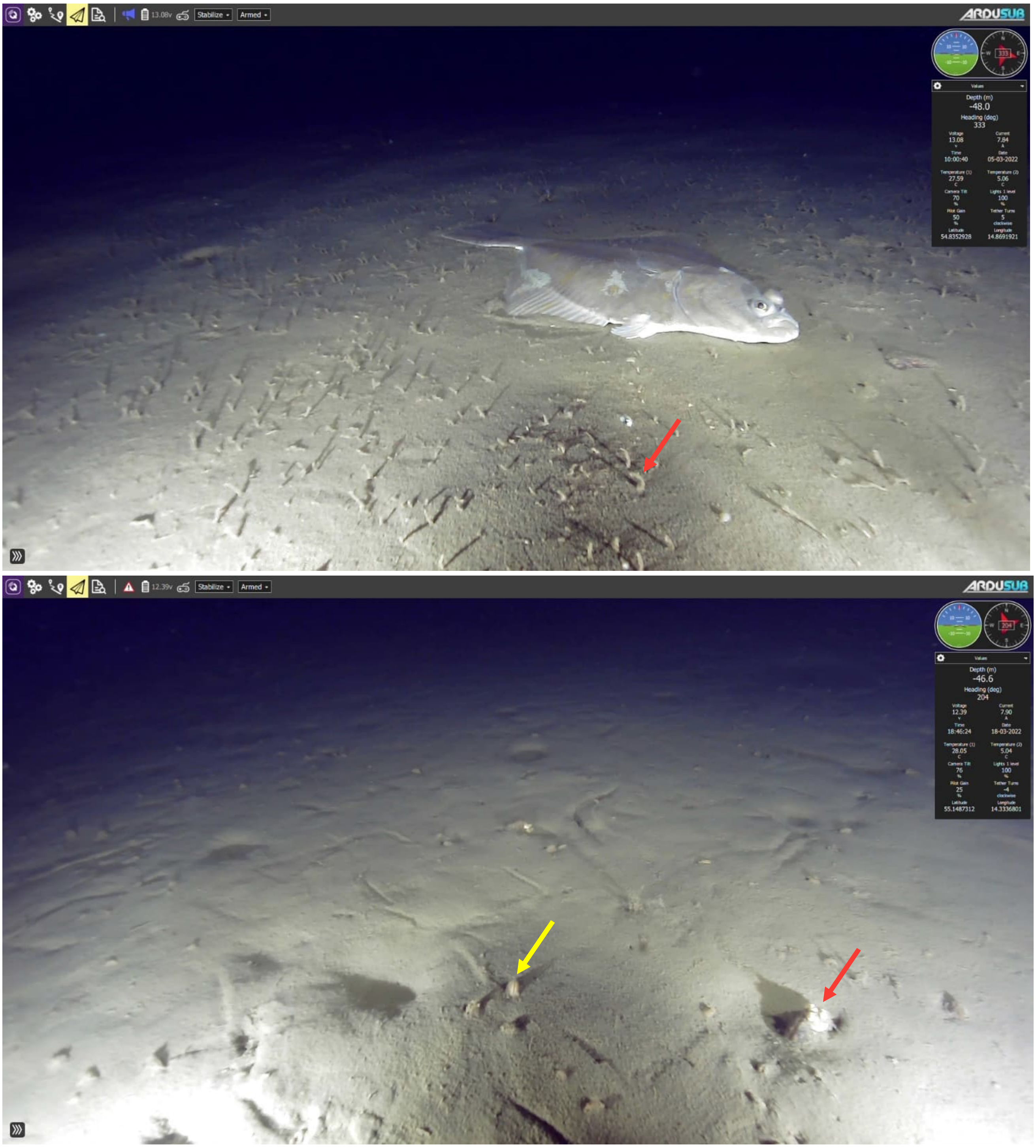


Figure 5-12. Nature type 1a – Soft bottom community. Upper figure: Nature type 1a in OWF2 with high coverage of *Pygospio elegans* tubes (red arrow) and a European flounder (ROV station OWF2_46). Lower figure: An adult *Arctica islandica* mussel is seen partly buried in the seabed (red arrow) surrounded by smaller juvenile specimens (yellow arrow) (ROV station INV_19).

5.3.2 NATURE TYPE 1B– SAND BOTTOM COMMUNITY

Nature type 1b - ”Sand bottom community” is present in the middle part of the pre-investigation area for Energy Island Bornholm at depths between 12 and 44 meters of depth (Figure 5-9) corresponding to sediment type 1b

(Figure 5-3). Benthic flora was observed on a few stones and blue mussel shells and was dominated by red crust alga (*Hildenbrandia* spp.) and brown crusts with very low coverage (0 - <1 %). The benthic fauna is dominated by the bristle worms *Pygospio elegans*, Lugworm (*Arenicola marina*) and blue mussels (*Mytilus* spp.) with area coverages of <1-50 % (Figure 5-13).

Blue mussels on the sandbed are often seen as mobile clusters of mussels being transported over the sandbed by the currents (Figure 5-14 upper figure). Blue mussel clusters are, occasionally, seen with hydroids, barnacles and single macroalgae attached to the mussels in the cluster.

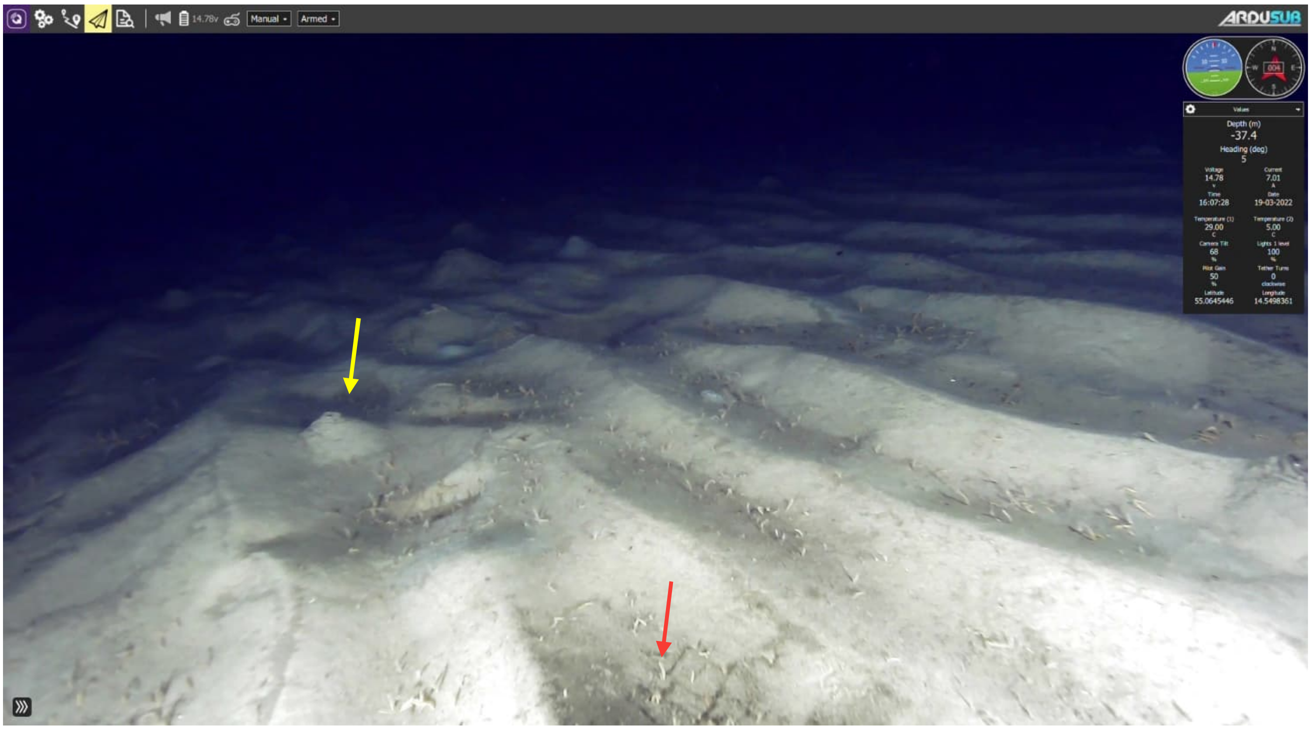


Figure 5-13. Nature type 1b – Sand bottom community. Sandy seabed with lugworm (*Arenicola marina*) (yellow arrow) and the brown-orange tubes of the bristle worm *Pygospio elegans* (red arrow) (ROV station CC1_02x).

Figure 5-14. Nature type 1b – Sand bottom community. Upper figure: sand with a mobile blue mussel cluster (red arrow) and assorted white bivalve shells visible on the seabed (ROV station CC2_09). Lower figure: more dynamic sandbed with wave ripples and a few mussel shells including white cockle shell (*Cerastoderma* sp., red arrow) (ROV station SPA_17).

5.3.3 NATURE TYPE 2 – MIXED COMMUNITY

Nature type 2 – “Mixed community” is present in local patches at depths between 5 to 49 meters of depth and consists of sediment type 2, which is a mixed sediment with sand, gravel, pebbles and large stones with 1-10 % coverage (Figure 5-9). This benthic community and the characteristic/dominating species are a mix of nature type 1 - sand community and nature type 3 hard bottom community (on stones) with an overall coverage of benthic fauna of <1-70 % and flora of 0-5 % - in the cable corridor up to 80 %. The benthic community on the sandbed between the stones is therefore dominated by the bristle worms *Pygospio elegans,* Lugworm (*Arenicola marina*) and bivalves (Figure 5-16).

On smaller and larger stones blue mussels (*Mytilus* spp.), barnacles, hydrozoans and calcareous worms dominate (specific coverage on stones 5-80 %) (Figure 5-15 and Figure 5-16). Blue mussel beds are described, separately, as a nature type 6 – Blue mussel beds in section 5.3.7 and in section 5.5.1 – Epifauna/Blue mussels below.

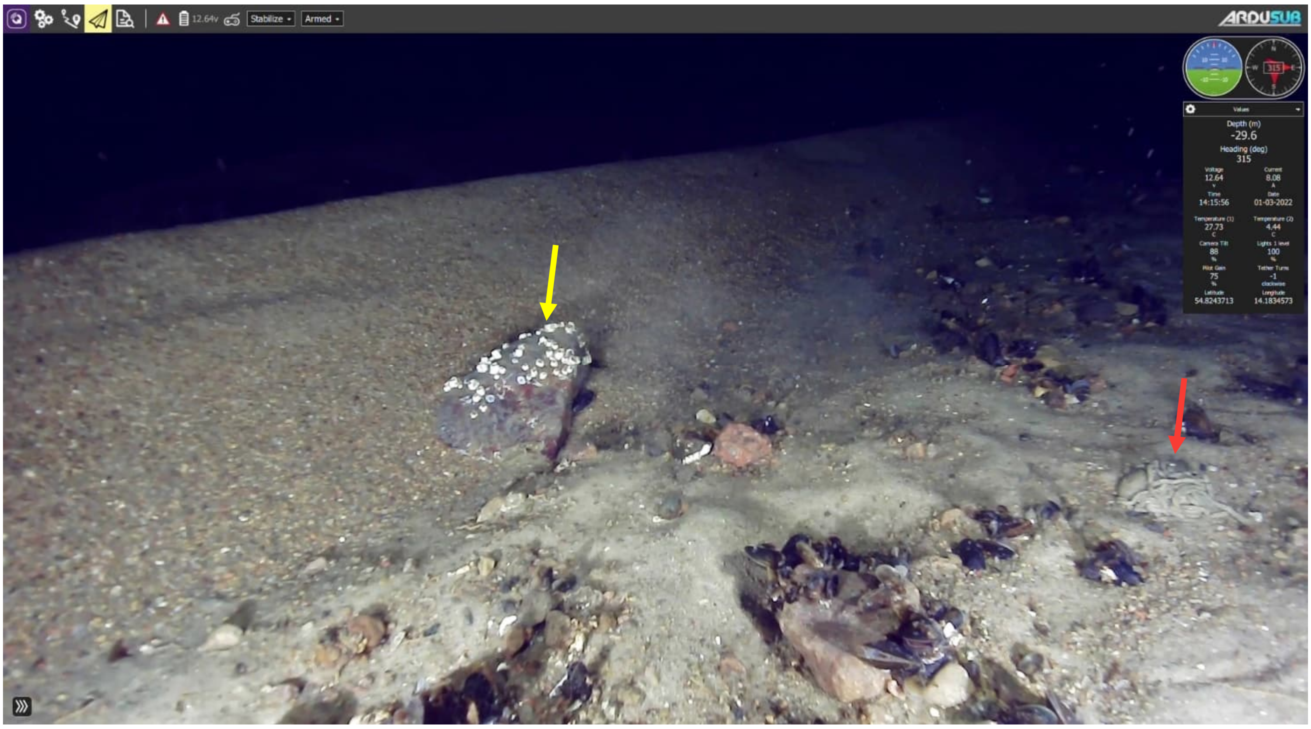


Figure 5-15. Nature type 2 – Mixed community with sandbed, small stones and a single larger stone (>10 cm). Bristle worm pile (red arrow) in the sandbed and blue mussels and barnacles (yellow arrow) on the stones (ROV station OWF1_07).

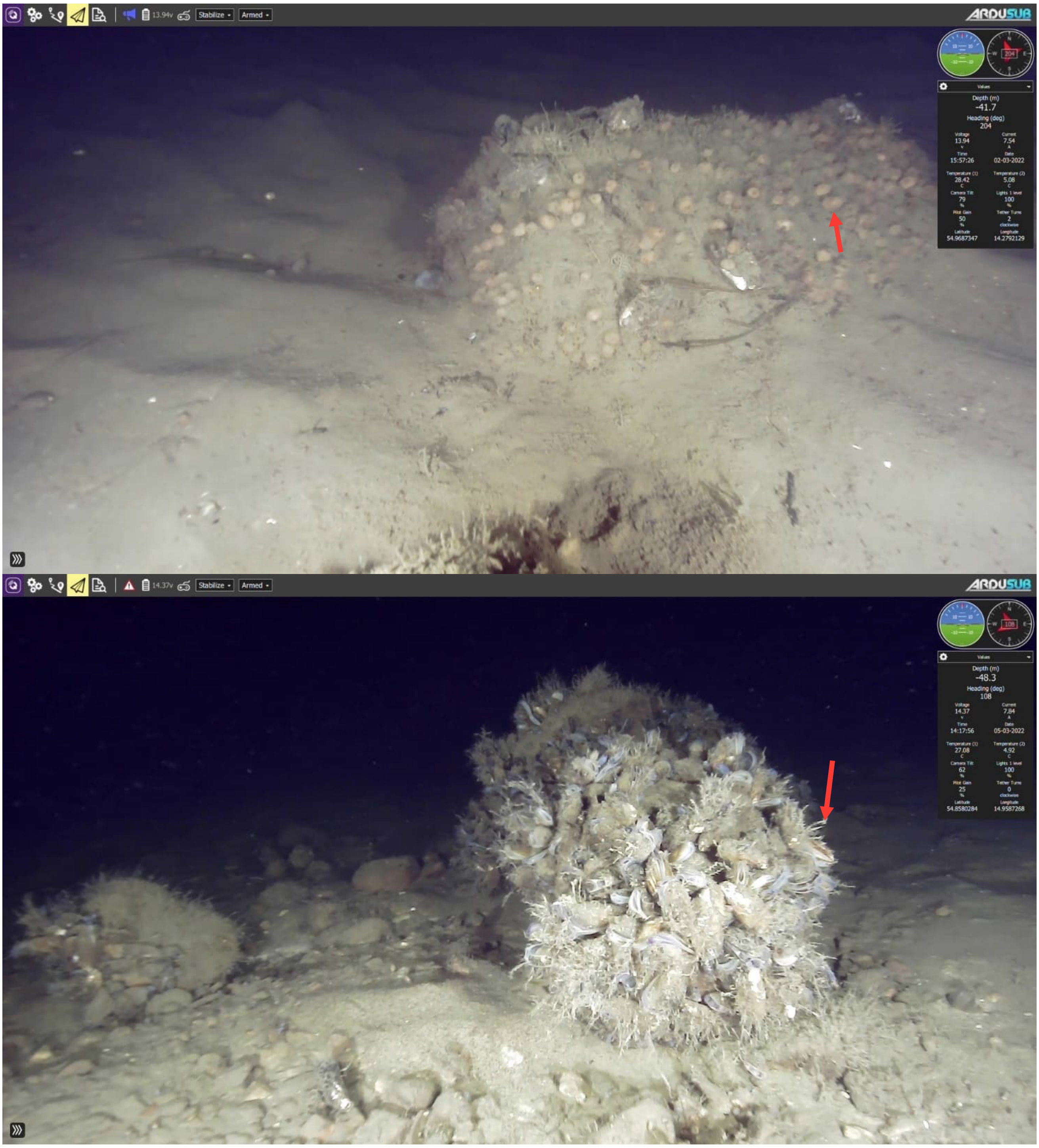


Figure 5-16. Nature type 2 – Mixed community consisting of sandbed, silty bed, stony bed (small stones) with a few large rocks (>10 cm). Upper figure: Large rock covered by tunicates (red arrow) (ROV station OWF1_32) and lower figure: blue mussels and hydroids (red arrow) on the larger rocks (>10 cm) (ROV station OWF2_54).

5.3.4 NATURE TYPE 3 – HARD BOTTOM COMMUNITY

Nature type 3 – "Hard bottom community" is present mainly in the SPA area in the middle part of the pre-investigation area at 4-32 meters of depth (Figure 5-9, Figure 5-17). Smaller areas in a mosaic with nature type 1b and 2 are present in the two OWF areas (see Figure 5-9). Nature type 3 is based on sediment type 3 with a coverage of large stones of 10-25 % (see sediment type maps in Figure 5-3). In general, benthic fauna had coverages of <1-80 % and macroalgae coverage of <1-15 % (In CC up to 100 %).

Benthic flora is dominated by red algae bushes and at greater depth crust algae (incl. *Hildenbrandia* spp.) with coverages of up to 100 % in the coast-near parts of the cable corridor and pre-investigation area (Figure 5-18). Substrate specific coverage (coverage on stones/rock) was up to 100 % dependent on depth. See section 5.4 – Macroalgae for further details on macroalgae species, coverages, depth limits etc.

Figure 5-17. Nature type 3 – Hard bottom community, here sandbed with large stones (>10 cm) with coverage of mainly blue mussels (ROV station SPA_56).

Benthic fauna on hard sediment was dominated by blue mussels (*Mytilus* spp.) with up to 50 % coverage and substrate specific coverage on stones of up to 100 % (see section 5.5.1 – Blue mussels for further details). Between and on the blue mussels, barnacles, calcareous tube worms and hydroids are observed (Figure 5-18).

Macroalgae dominated the hard substrate down to approximately 10 meters of depth, whereafter, blue mussels dominated (see section 5.4 – Macroalgae and 5.5 – Blue mussels for further details).

Figure 5-18. Nature type 3 – Hard bottom community. Upper panel: Large stones (>10 cm) with blue mussels, barnacles, hydroids, calcareous tube worms, red algae bushes (red arrow) and brown algae bushes (*Pylaiella/Ectocarpus*) (yellow arrow) (ROV station SPA_009, see Appendix 2, Map 3.3). Lower panel: Large stone (>10 cm) covered with blue mussels, barnacles, hydroids, calcareous tube worms, red algae bushes, and red algae crust (*Hildenbrandia* sp., red arrow) (ROV station CC_07).

5.3.5 NATURE TYPE 4 – STONE REEF AND SEDIMENTARY ROCK

Nature type 4 – “Stone reef and sedimentary rock” is present between 2-25 meters of depth in the pre-investigation area mainly in the cable corridor area (CC), the SPA area and with low areas coverage in the OWF areas (<0.5 %) (Figure 5-9, Table 5-7). Nature type 4 is based on sediment type 4, which includes stone coverage of large stones of >25 % and sedimentary rock (see sediment type map in Figure 5-3).

Benthic flora and -fauna consisted of the same species as described for nature type 3, with the only difference being a higher coverage due to a higher coverage of hard substrate/rocks (Figure 5-19, Figure 5-20). Benthic flora, represented only by macroalgae species, was observed to have coverages between 0-100 % and benthic fauna 1-100 %. Se sections 4.4 – Macroalgae and 4.5 – Benthic epifauna for further details on species, coverage and depth limits.

Figure 5-19. Nature type 4 – Stone reef and sedimentary rock, here larger stones and sedimentary rock with coverage of red algae bushes, blue mussels and barnacles (ROV station SPA_15, see Appendix 2, Map 3.3).

Macroalgae dominated the hard substrate down to 10 meters of depth whereafter blue mussels dominated (see section 5.4.2 – Macroalgae and 5.5.1 – Blue mussels for further details).

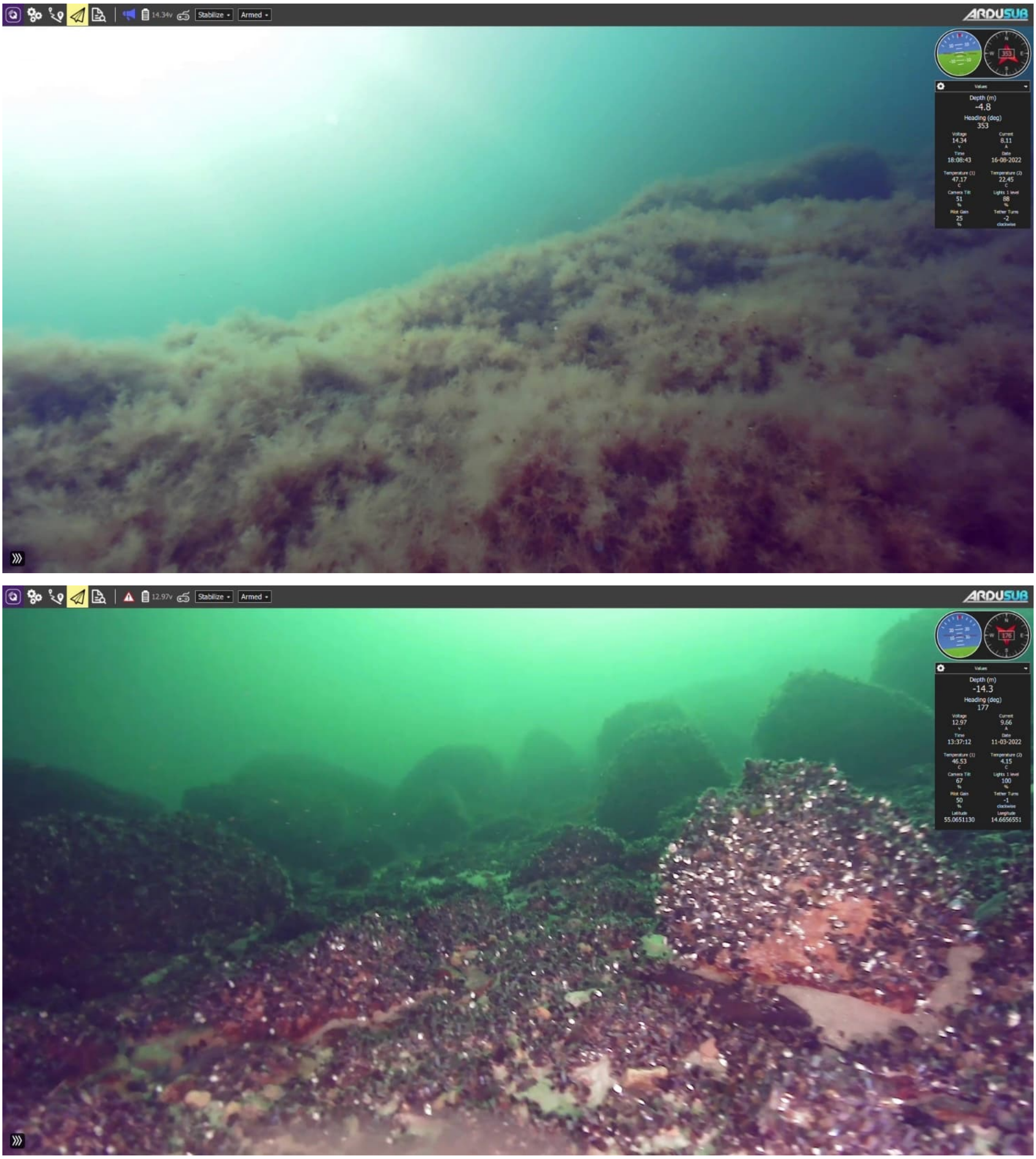


Figure 5-20. Nature type 4 – Stone reef and sedimentary rock in the pre-investigation area. Upper panel: Shallow water (4.8 meters of depth) with stone reef/rock dominated by macroalgae coverage (100 % coverage) including *Furcellaria lumbricalis* with overgrowth of *Polysiphonia* spp. and other red algae bushes (ROV station CC_02). Lower panel: Stone reef/rock at 10 meters of depth dominated by blue mussels (85-90 %) and barnacles, with low coverage of macroalgae (1-3 %) and the red crust algae *Hildenbrandia rubra* (dark red) along the lower rim of the boulders (ROV station SPA_005, see Appendix 2, Map 3.3).

5.3.6 NATURE TYPE 5 – EELGRASS BEDS

Nature type 5 – "Eelgrass beds" was not found in this baseline study in the pre-investigation area for Energy Island Bornholm. Eelgrass observed at NOVANA stations within the pre-investigation area are described in section 4.4 Existing data/ Benthic flora.

5.3.7 NATURE TYPE 6 – BLUE MUSSEL BEDS

This nature type consists mainly of blue mussels (*Mytilus* spp.) attached to hard substrate (stones and rock). The densest coverages of blue mussels are found on larger stones and sedimentary rock in the SPA area (Figure 5-21) (see 5.5.1 - Epifauna). However, blue mussels are observed on stones and sedimentary rock at all depths except at lower depths (0-10 m) where macroalgae dominate the hard substrate. Blue mussel distribution and coverage % are described in detail in section 5.5.1 – Epifauna/Blue mussels below.

In the Baltic region the genus *Mytilus* is comprised by *M. edulis* and *M. trossulus* (or hybrids between the two). As these two species are difficult to distinguish morphologically, they are called *Mytilus* spp. in this report.

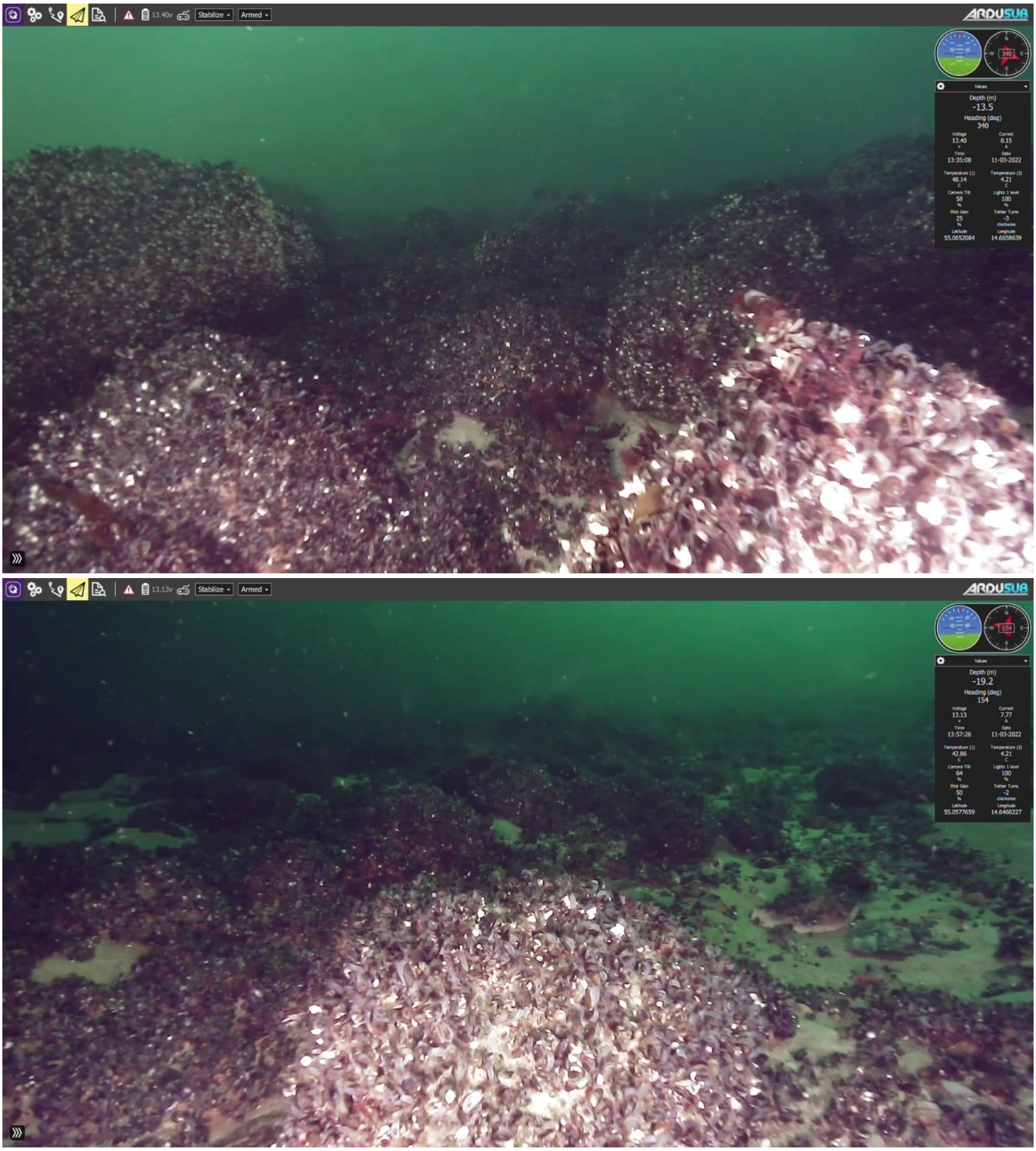


Figure 5-21. Nature type 6 – Blue mussel beds on large and small stones (sediment type 2, 3 and 4). Upper figure: till and sedimentary rock covered with blue mussels (ROV station SPA_005). Lower figure: Mosaic mussel coverage on less dense stone coverage (ROV station SPA_011).

5.4 BENTHIC FLORA

Benthic flora observed in the pre-investigation area are presented in Table 5-9 below. In total 19 macroalgae species and no seagrass species were observed on ROV video at the stations in pre-investigation area, including wind farm areas and cable corridor areas (see stations in Figure 3-1 and Appendix 2).
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.

Seagrasses and macroalgae are presented separately below.

There are no benthic flora species on the Danish red list (Den danske rødliste, 2022). None of the observed species in the pre-investigation area (Table 5-9) are considered threatened (Critically Endangered, Endangered or Vulnerable) according to the HELCOM red list (HELCOM, 2023a). The two brown algae species *Fucus serratus* and *Fucus vesiculosus* and the red algae species *Furcellaria lumbricalis* are, however, listed as Least Concern (LC).

5.4.1 SEAGRASSES

No seagrasses were observed at stations sampled in this baseline study (ROV stations, see Figure 3-1). However, dead eelgrass (*Zostera marina*) was observed on the seabed.

According to existing data seagrasses can be found along the coast of Bornholm in the depth range of 1.6-6.3 meters with generally very low area coverage (see section 4.4.1 – Existing data/Seagrasses).

5.4.2 MACROALGAE

Macroalgae species observed in the pre-investigation area are summarized in Table 5-9 below. In total 19 macroalgae species were observed on ROV video stations within the pre-investigation area (Table 5-9). Highest species numbers were found in the cable corridor area (15 species, CC) and SPA site (14 species). Macroalgae need hard substrate for attachment (stones and rock). Macroalgae were, thus, observed mainly on hard substrate (sediment type 2, 3 and 4, Figure 5-3) or in low coverage on blue mussel beds (*Mytilus* spp.) within the pre-investigation area.

Dominating species in the shallow part of the cable corridor area (CC) and the SPA area were the brown algae *Fucus vesiculosus* (Figure 5-22). In deeper waters red algae bushes such as *Polysiphonia* spp., *Ceramium* spp. and *Furcellaria lumbricalis* dominated. On the sedimentary rocks *F. lumbricalis* often dominate and is overgrown by *Polysiphonia* spp. and other red algae bushes (see Figure 5-22). At the deepest stations (down to 39.4 m) mainly red crust algae (*Hildenbrandia* sp.) and brown crust algae were observed in small patches on stones and single, small specimens of red algae bushes such as *Coccotylus truncatus* are observed (Figure 5-22 lower figure). The dominating macroalgae taxa and species and all observed species or taxa are listed in Table 5-9 below.

Existing data from the pre-investigation area show dominance of red algae bushes (*Ceramium* spp., *Polysiphonia* spp. and *Furcellaria lumbricalis)* and *Hildenbrandia* sp. and brown crust (see section 4.4.2 – Existing data Macroalgae). The observed species are common for the Baltic Sea and present in normal coverages for the pre-investigation area as determined from other studies in the area.

There are no benthic flora species on the Danish red list (Den danske rødliste, 2022). None of the observed species in the pre-investigation area (Table 5-9) are considered threatened (Critically Endangered, Endangered or Vulnerable) according to the HELCOM red list (HELCOM, 2023a). The two brown algae species *Fucus serratus and Fucus vesiculosus* and the red algae species *Furcellaria lumbricalis* are listed as Least Concern (LC).

Table 5-9. Benthic flora species (attached and alive, not drifting) observed at ROV stations in the different areas within the pre-investigation area. 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. D = Dominating. [1] Include INV and SPA stations within the CC areas (Appendix 2 map 2). [2] Include CC stations which are located within the SPA area. [3] Include OWF1 stations now located outside OWF stations but within the same depth range. Data from Appendix 3 – Logbooks.

Class	Order	Genus/species	OWF1	OWF2	CC	SPA	INV
Number of ROV stations			41	60	58[1]	194[2,3]	121[3]
Average coverage (%)			0-2%	0%	0-100%	0-100%	0-2%
Green algae:							
Chlorophyceae	Cladophorales	*Cladophora sp.*			x		
Red algae:							
Rhodophyceae	Hildenbrandiales	*Hildenbrandia sp.*	x		x	x	x
Rhodophyceae	Ceramiales	*Callithamnion corymbosum*			x	x	
Rhodophyceae	Ceramiales	*Ceramium spp.*			x		
Rhodophyceae	Ceramiales	*Desmarestia aculeata*				x	
Rhodophyceae	Ceramiales	*Delesseria sanguinea*				x	
Rhodophyceae	Ceramiales	*Polysiphonia spp.*			D	D	
Rhodophyceae	Ceramiales	*Polysiphonia stricta*				x	
Rhodophyceae	Ceramiales	*Phycodrys rubens*				x	
Rhodophyceae	Gigartinales	*Coccotylus truncatus*			x	x	x
Rhodophyceae	Gigartinales	*Furcellaria lumbricalis*			D	D	x
Brown algae:							
Phaeophycea	Fucales	*Fucus sp.*			x	x	
Phaeophycea	Fucales	*Fucus vesiculosus*			D		
Phaeophycea	Fucales	*Fucus serratus*			x		
Phaeophycea	Laminariales	*Chorda filum*			x		
Phaeophycea	Laminariales	*Saccharina latissima*			x	x	
Phaeophycea	Ectocarpales	*Ectocarpus silicolosus*			x	x	
Phaeophycea	Ectocarpales	*Pylayella littoralis*			x	x	
Phaeophycea		*Brown crust*	x		x	x	x
Total number			**2**	**0**	**15**	**14**	**4**

Figure 5-22. Macroalgae in the pre-investigation area. Upper figure: Macroalgae coverage at low depth <5 meters in the landfall zone (ROV station CC_01). Middle figure: *Furcellaria lumbricalis* with epiphytic (grows on other macroalgae) overgrowth of *Polysiphonia* spp. (ROV st. CC_02). Lower figure: Red crust algae (*Hildenbrandia* spp., red arrow) and *Coccotylus truncatus* at deep station (ROV station SPA_083).

Maximum depth distribution for red algae bushes (*Polysiphonia* spp. and *F. lumbricalis*) and crust algae was 17.3 meters (CC_13) and 44.3 meters (INV_093), respectively. *Saccharina latissima* and *Coccotylus truncatus* were observed down to 21.8 meters (CC1_03) and 24.4 meters (SPA_054) of depth, respectively. The red crust algae *Hildenbrandia* spp. was found at the greatest depth of 44.3 meters in the INV area outside the OWF and CC areas (INV_093). At depths greater than 44.3 meters no macroalgae were observed due to light limitation.

Macroalgae coverage was highest (100 %) close to land at 0-10 meters depth within the pre-investigation area (see Figure 5-23 below). At greater depths >10 meters blue mussels generally dominated the hard substrate (stones and rock) (see section 5.5.1 – Blue mussels). Macroalgae, thus, win the competition for hard substrate at lower depth with optimal light availability but were outcompeted by blue mussels at greater depths >10 meters of depth.

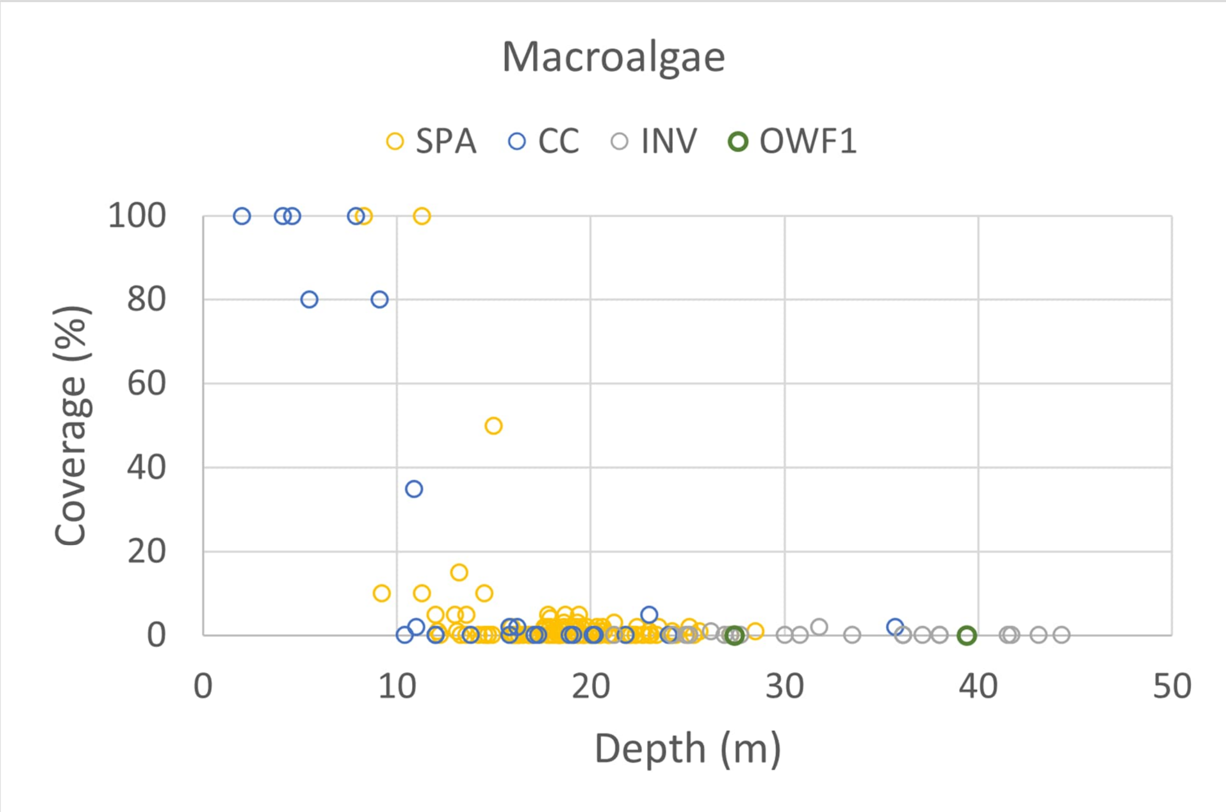


Figure 5-23. Overall macroalgae coverage (%) (coverage on total visible ROV video seabed area) at ROV stations in the CC-area (pooled stations within CC, CC1 and CC2), OWF1, SPA and INV areas (see Figure 5-24 or Appendix 2). The maximum coverage in the observed overall macroalgae coverage % range for each ROV station is used. Note that macroalgae were not observed within the OWF2 area (Bornholm II), thus, this area is not included in the figure. Data with zero values are not included and lowest values displayed in the Figure is a coverage of 0.1 % = <1 % in logbooks (see Appendix 3).

Macroalgae coverage at each station are presented in Figure 5-24 below. Maximum macroalgae coverage is found on hard sediment types (sediment type 2, 3 and 4) close to the coast at depths between 0-10 meters of depth. Below 10 meters of depth blue mussel dominate.

Comparing the macroalgae coverage (%) for the subareas, it is obvious that macroalgae have the highest coverages in the SPA area, which has the largest area of hard sediment types and is the shallowest part of the pre-investigation area and, thus, with more optimal light conditions (see Figure 5-24). Some macroalgae coverage is also found on the slopes of Rønne Banke between the SPA area and the wind farm areas especially the two Bornholm I subareas. A small area in the northwestern corner of the pre-investigation areas has low coverage of macroalgae corresponding to an area with hard sediment type 3 (see Figure 5-4).

WIND FARM AREAS

Macroalgae coverage was not found in Bornholm II (OWF2) and only at two stations in Bornholm I – one station in each of the two Bornholm I areas had very low macroalgae coverage of <1-1 %. Small spots of crust algae (red and brown crust) were found on one ROV station in Bornholm I South (OWF1_07) and Bornholm I North (OWF1_50) with coverage of <1 %. No larger macroalgae (bush algae) were observed in the OWF areas.

CABLE CORRIDORS

In the cable corridor areas macroalgae coverage is determined by the presence of hard substrate for attachment and light. Macroalgae coverage was highest, with up to 100 % coverage, in the shallow area closest to the coast dominated by sedimentary rock and till (0-10 m) (see Figure 5-24). Deeper than 10 meters blue mussels covered rocks and sedimentary rock with low coverage of macroalgae, generally, attached to the mussel shells (≤10 %) of the blue mussels covering the rocks and hard substrate (stones >10 cm).

Close to the coast <5 meters of depth *Fucus* spp. and *Fucus vesiculosus* dominated (Figure 5-22). Areas with dense coverage of macroalgae were dominated by the red algae bush *Furcellaria lumbricalis* with overgrowth of mainly *Polysiphonia* spp. (Figure 5-22). The deepest growing macroalgae were the red crust algae (*Hildenbrandia* sp.) and brown crusts (Figure 5-22 lower figure).

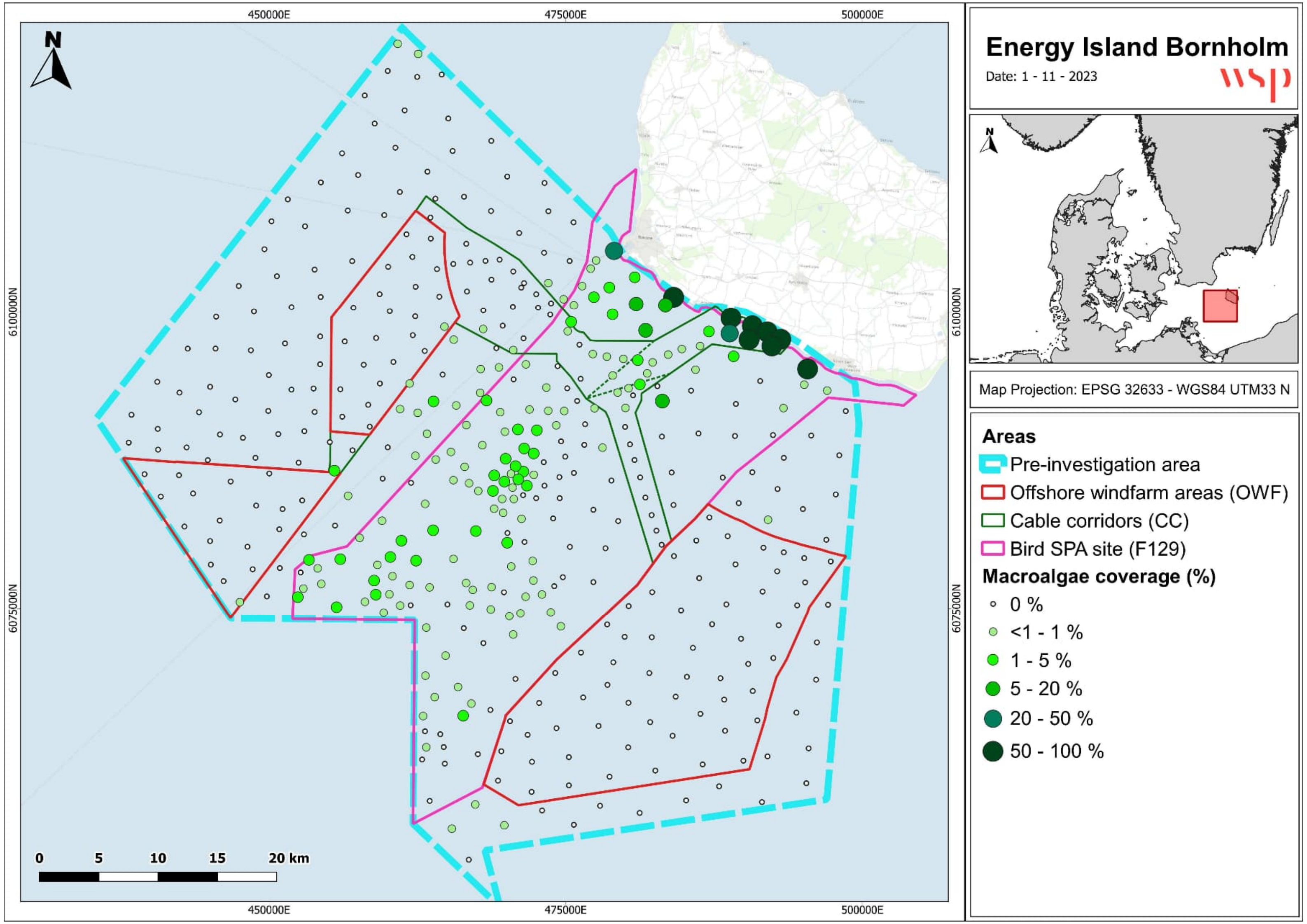


Figure 5-24. Overall coverage (%) of macroalgae at stations in the pre-investigation area. Overall coverage % is the coverage of the total video view of the seabed often given as a range in the logbooks in Appendix 3. The maximum coverage % in the range is shown in this figure.

5.5 BENTHIC FAUNA

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

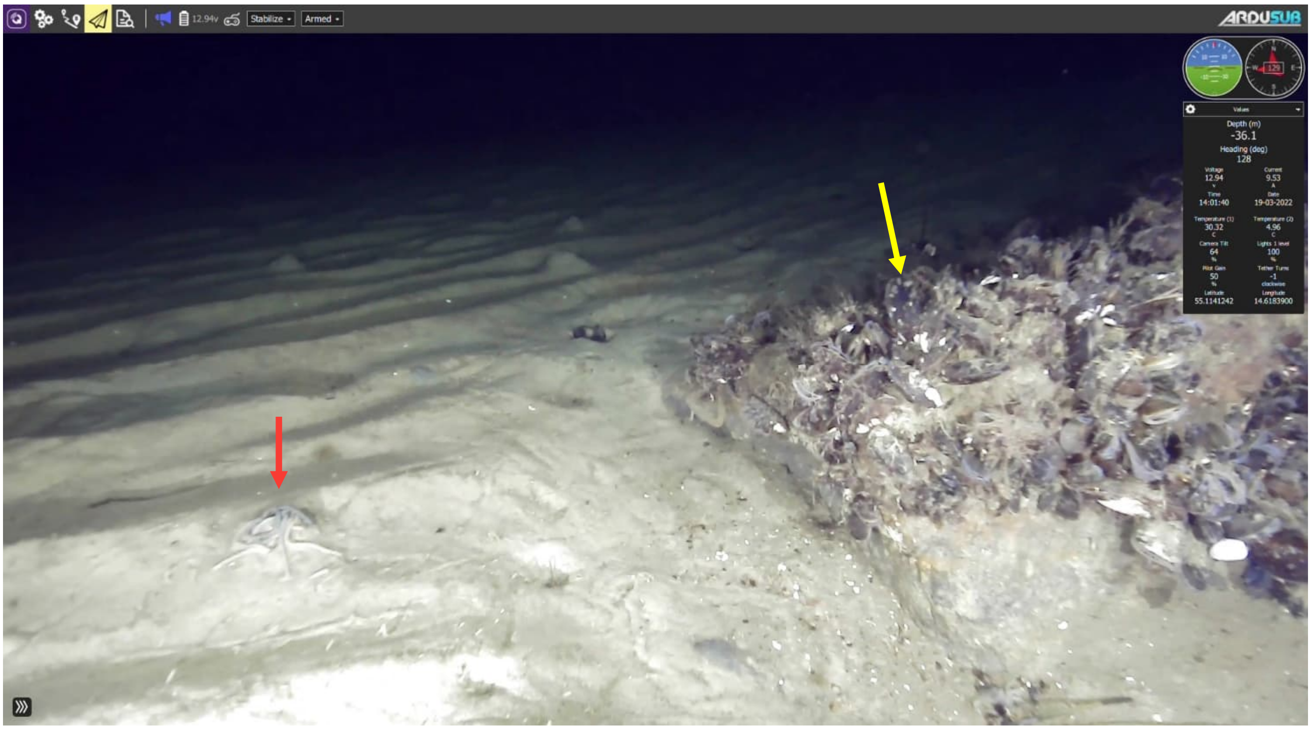


Figure 5-25. Benthic fauna in the pre-investigation area. Picture shows stone with hard bottom fauna incl. blue mussels (yellow arrow) and sandy seabed with lugworm piles (red arrow) (ROV station INV_030).

5.5.1 *EPIFAUNA*

In this section species observed on ROV video are presented, which include epifauna and visible infauna such as mussel shells, bivalve wholes, bristle worm piles and tubes. Epifauna coverage % therefore includes all observed benthic fauna.

Epifauna species observed in the different subareas of the pre-investigation area are summarized in Table 5-10 below. In total 30 species/taxa were observed. 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. a diver inspection or microscope species determination.

The dominating species on hard substrate (sediment type 2, 3 and 4) such as smaller and larger stones was blue mussel (*Mytilus* spp.) (Table 5-10). See section on blue mussels below. Other common species observed on the hard substrate were barnacles, hydroids and calcareous tube worms.

On sand (sediment type 1b/nature type 1b) the bristle worms *Pygospio elegans* and lugworm (*Arenicola marina*) dominated and at greater depths (39-60 m) in the more muddy sediments (sediment type 1a/nature type 1a) the bristle worm *Pygospio elegans* and the bivalve ocean quahog (*Arctica islandica*) dominated, see also nature type sections (section 1) (Table 5-8).

Existing data from the pre-investigation area confirm the dominance of *Mytilus* spp. and the bristle worms lugworm (*Arenicola marina*) and *Pygospio elegans* (see section 4.5.1 – Existing data Epifauna). However, mudsnail (*Hydrobia* spp.) was less dominant in the present baseline study. The observed epifauna species in the pre-investigation area are, thus, common for the Baltic Sea and present in normal coverages for the pre-investigation areas as determined from other studies in the area.

There are no benthic fauna (invertebrates) species on the Danish red list (Den danske rødliste, 2022). None of the observed species in the pre-investigation area (Table 5-10) are considered threatened (Critically Endangered, Endangered or Vulnerable) according to the HELCOM red list (HELCOM, 2023a).

Table 5-10. Epifauna and visible infauna species observed at ROV stations in pre-investigation area for Energy Island Bornholm. 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. [1] exclude OWF1 stations now located outside Bornholm I. [2] Include INV and SPA stations within the CC areas (Appendix 2,2). [3] Include CC stations which are located within the SPA. [4] Include OWF1 stations now located outside Bornholm I. ** On leaves of macroalgae. Data from Appendix 3.

Class	Genus/species	English name (Danish name)	OWF1	OWF2	CC	SPA	INV
Number of stations			41[1]	60	58[2]	194[3]	121[4]
Coverage (%)			<1-50 %	<1-40 %	<1-100 %	<1-100 %	<1-70 %
Gastropoda	*Hydrobia* spp.	Mudsnail (Dyndsnegl)			x	x	
Bivalvia		Bivalvia spp.	x	x	x	x	x
Bivalvia	Mytilus spp.	Blue mussel (Blåmusling)	x	x	D	D	x
Bivalvia	Astarte sp.	Astarte (Astarte musling)	x	x			x
Bivalvia	*Macoma balthica*	Baltic macoma (Østersømusling)					x
Bivalvia	*Cerastoderma sp.*	Cockle (Hjertemusling)			x	x	x
Bivalvia	*Arctica islandica*	Ocean quahog (Molboøsters)			x	x	D
Bivalvia	*Mya arenaria*	Sand gaper (Sandmusling)			x	x	x
Bivalvia	*Phaxas pellucidus*	Razor clam (Lille knivmusling)					x
Crustacea	*Balanus spp.*	Barnacles (Rurer)	x	x	x	x	x
Crustacea	*Mysidae*	Shrimps spp.	x	x	x	x	x
Crustacea	*Palaemon spp.*	Shrimp (Reje sp.)			x	x	
Crustacea	*Crangon crangon*	Brown shrimp (Alm. Hestereje)	x		x	x	
Crustacea		Amphipod sp.				x	x
Asteroidea	*Spp.*	Starfish (Søstjerne)	x	x	x	x	x
Asteroidea	*Asterias rubens*	Common starfish (Alm. Søstjerne)	x				x
Echinoidea	*Echinocardium sp.*	Sea potato (Sømus)				x	

Class	Genus/species	English name (Danish name)	OWF1	OWF2	CC	SPA	INV
Polychaeta	*Spp.*	Bristle worms (havbørsteorme)	D	D	x	x	D
Polychaeta	*Arenicola marina*	Lugworm (Sandorm)	D	x	x	x	x
Polychaeta	*Pygospio elegans*	-	D	D	x	x	D
Polychaeta	*Scoloplos armiger*	Armoured bristle worm		x	x	x	x
Polychaeta	*Spp.*	Calcareuos tube worms/kalkrørsorme	x	x	x	x	x
Polychaeta	*Spirobranchus*	Keel worm (Trekantorm)	x	x	x	x	x
Bryozoa	*Spp.*	Bryozoans (Mosdyr)**		x	x	x	x
Anthozoa	*Metridium senile*	Sea anemone (søanemone)	x				x
Hydrozoa	*Spp.*	Hydroids (Hydroider)	x	x	x	x	x
Hydrozoa	*Sertularia cuppressina*	White weed					x
Ascidiacea	*Spp.*	Tunicates (sækdyr)	x				x
Porifera	*Spp.*	Sea sponges (havsvampe)				x	
Porifera	*Halichondria panicea*	Breadcrumb sponge (Brødkrummesvamp)				x	
Total number			**16**	**14**	**19**	**23**	**24**

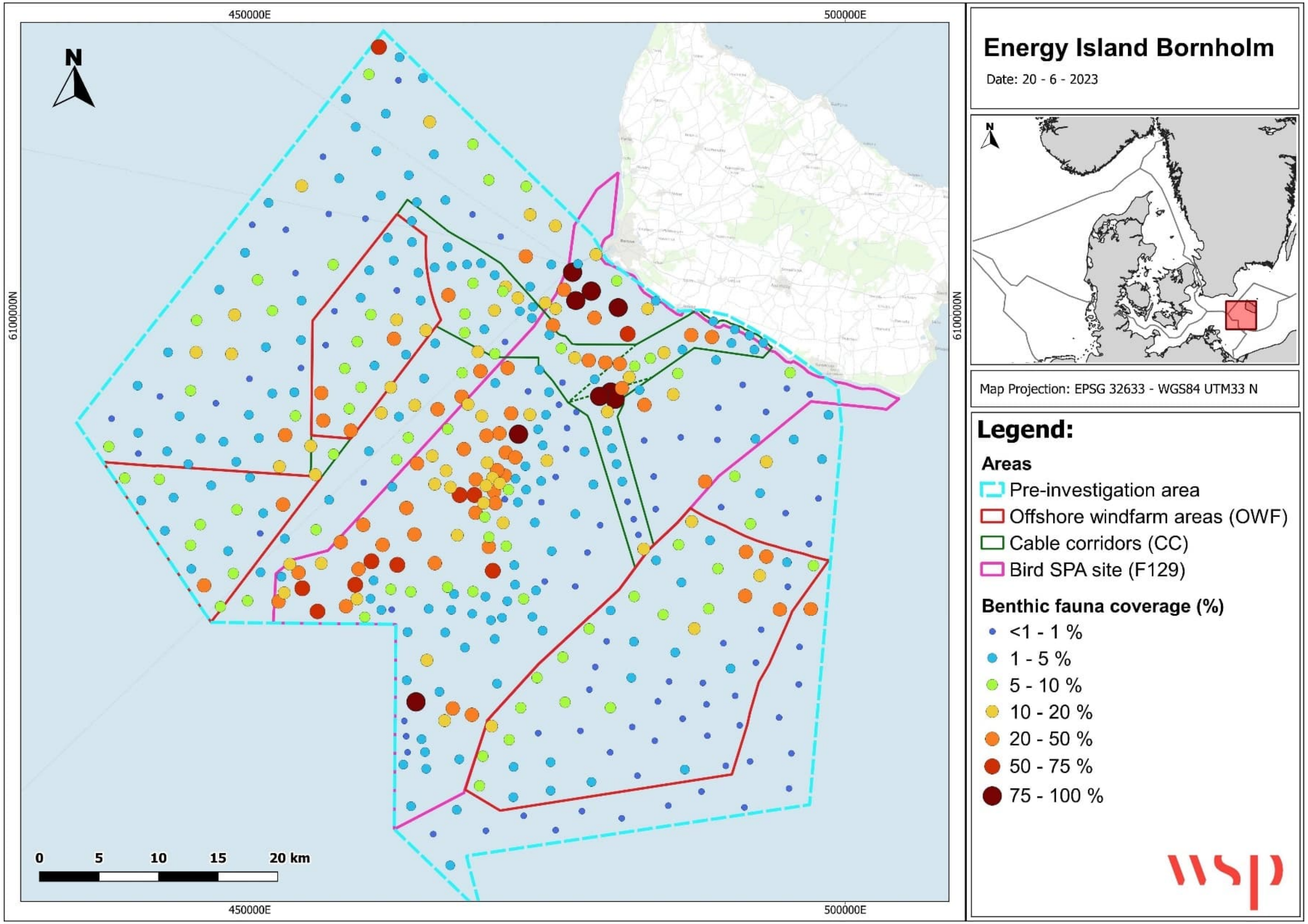


Figure 5-26. Overall area coverage percentage (%) of epifauna in the pre-investigation area. Overall coverage % is the coverage of the total video view of the seabed often given as a range in the logbooks in Appendix 3. The maximum coverage % in the range is shown in this figure. See Figure 5-28 for station number.

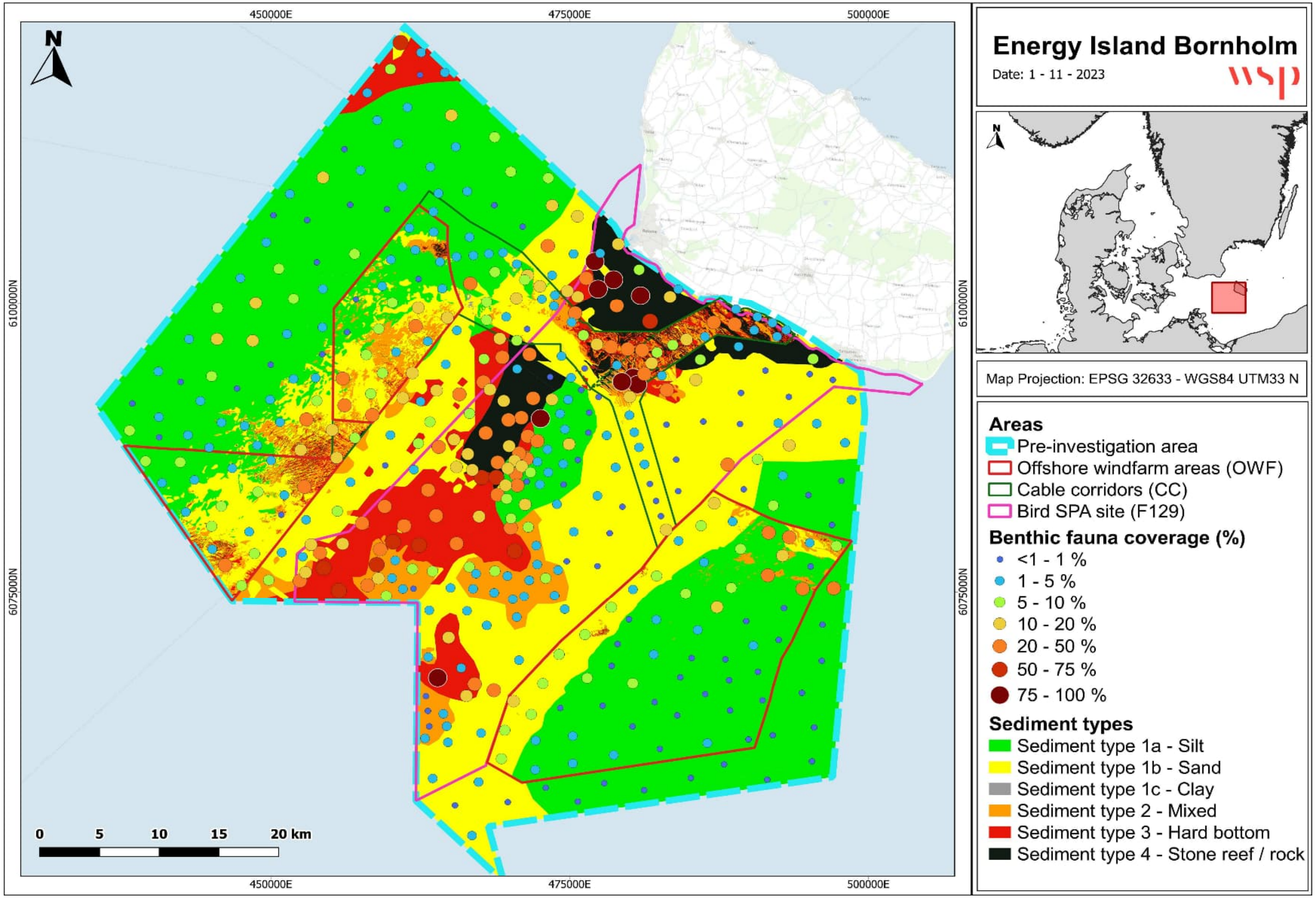


Figure 5-27. Sediment type and overall area coverage percentage (%) of epifauna in the pre-investigation area. Overall coverage % is the coverage of the total video view of the seabed on e.g. both sand and stones. Upper figure: Epifauna coverage % and sediment type map (adjusted, see section 5.2.1). Station numbers and color coding for subarea prefix (CC, CC1, CC2, OWF1, OWF2, SPA and INV) are given in Figure 5-28 below.

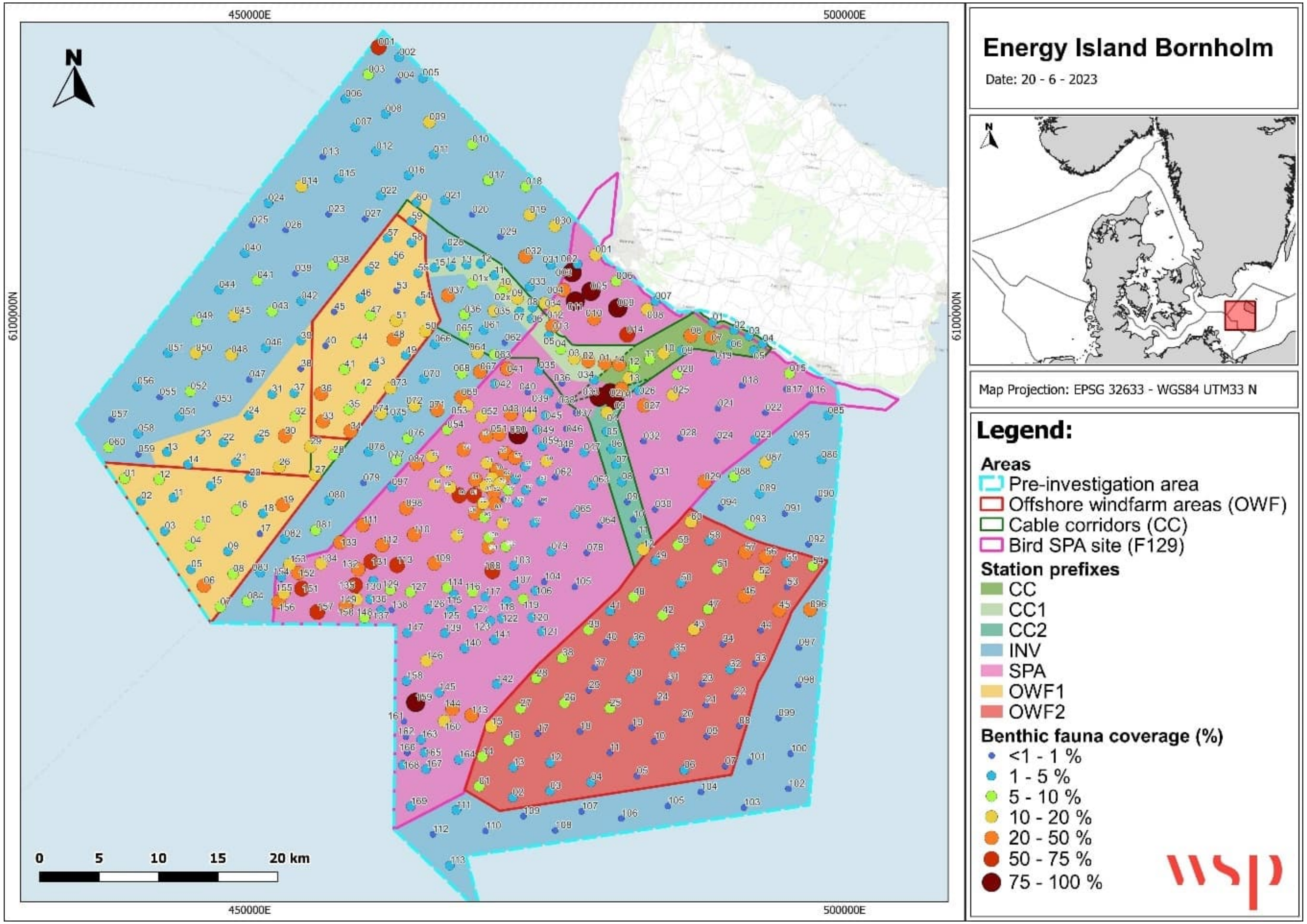


Figure 5-28. Station numbers for ROV stations within the pre-investigation area and color coding for the different subarea prefix (CC, CC1, CC2, OWF1, OWF2, SPA and INV). Stations numbers for zooms of the map can be found in Appendix 2.

Overall area coverage (%) of epifauna at ROV stations is presented in Figure 5-26 for the pre-investigation area. Highest epifauna coverage was generally found on the hard sediment types (sediment type 2, 3 and 4, see Figure 5-27) and was dominated by blue mussels (*Mytilus* spp.) (see section 5.5.1 – Blue mussels). Highest epifauna coverage was therefore found in the cable corridor - and SPA area with epifauna coverages of up to 100 % (Figure 5-27).

I general, epifauna coverages and species numbers decreased with depth (Figure 5-29), which may in part be caused by less optimal oxygen concentrations (se section 5.1.2) and finer sediments (sediment type 1a, Figure 5-27). Epifauna coverage increased from low (<10 %) to high (up to 100 %) around 10 meters of depth, where a change from macroalgae dominance at low depth (0-10 m) to blue mussel dominance at greater depths (>10m) was observed. Epifauna was found at all depths in the pre-investigation area.

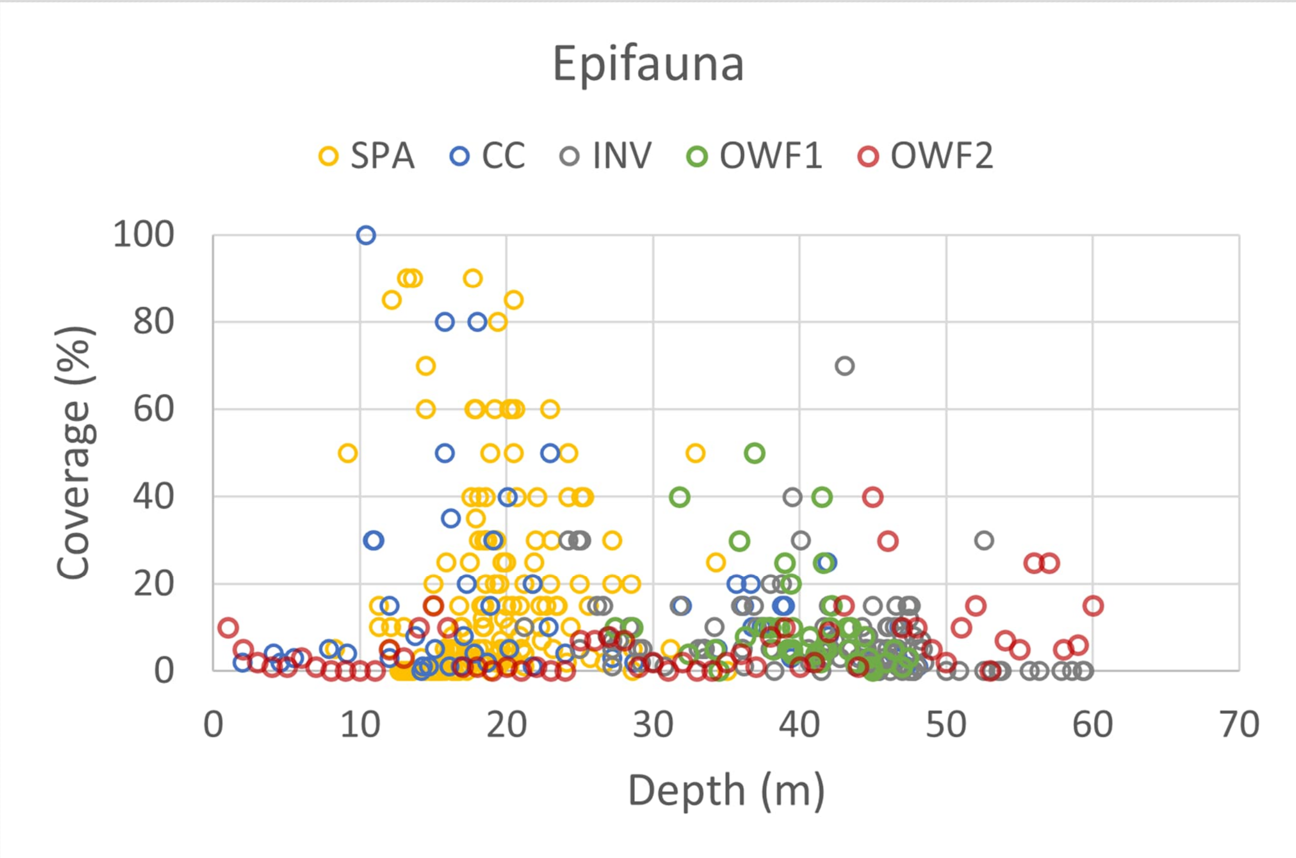


Figure 5-29. Epifauna overall coverage percentage (%) (coverage on total visible ROV video seabed area) at ROV stations in the CC-area (pooled stations within CC, CC1 and CC2), OWF1, OWF2, SPA and INV areas (see Figure 5-26, Figure 5-24 or Appendix 2). The maximum coverage in the observed overall epifauna coverage % range for each ROV station is used. Data with zero values are not included and lowest values displayed in the Figure is a coverage of 0.1 % = <1 % in logbooks see Appendix 3.

Comparing the different subareas (see Figure 5-28 for subareas) within the pre-investigation area shown in Figure 5-26, Table 5-10 (CC, OWF1, OWF2, SPA and INV) fewest species and lowest area coverages (<1-50 %) are found in the OWF areas (OWF1 and OWF2). The reason for this, is that the OWFs are located in areas with greater water depths and with lower coverage of hard sediment types and, thus, a less varied sediment compared to the other areas (CC, SPA and INV). Also, the number of stations is much larger for the INV and SPA increasing the chance of finding more species. Highest area coverages and species numbers were found in the shallower cable corridor and bird SPA area (<1-100 %) (Figure 5-26, Table 5-10).

Lugworm (*Arenicola marina*) had area coverages of 0-40 % highest in INV, CC and SPA and *Pygospio elegans* had area coverages of 0-70 %, highest in OWF1, OWF2 and INV (Figure 5-30). The bivalve ocean quahog (*Arctica islandica*) had area coverages of 0-30 % highest in INV and none in SPA (Figure 5-30 lower figure).

Bristle worms and bivalves are described in more detail in section 5.5.2 - Infauna.

WIND FARM AREAS

The wind farm areas (Bornholm I North and South and Bornholm II), generally, had the lowest epifauna coverages and species numbers compared with the other subareas (see Figure 5-26 and Figure 5-29). However, epifauna coverage in general was lowest at the deepest stations along the rims of the pre-investigation area (not accounting for subarea but looking at total pre-investigation area) (see Figure 5-26).

Both Bornholm I North and South and Bornholm II had comparable epifauna coverage ranging from approximately 0-50 % (Table 5-10) and were dominated by bristle worms and in general the species *Pygospio elegans*.

Comparing area coverage of epifauna Bornholm I South and North, epifauna coverages were within the same range (0-50 %) but the Bornholm I North area had a few more stations with the highest coverage of 20-50 % than Bornholm I South (Figure 5-26).

CABLE CORRIDORS

Since the cable corridor area was most varied according to sediment type and a larger area coverage of hard substrate such as stone and rock (Table 5-2), epifauna coverage (<1-100 %) was also highest here (Table 5-10, Figure 5-26 and Figure 5-29) and dominated by blue mussels Figure 5-31.

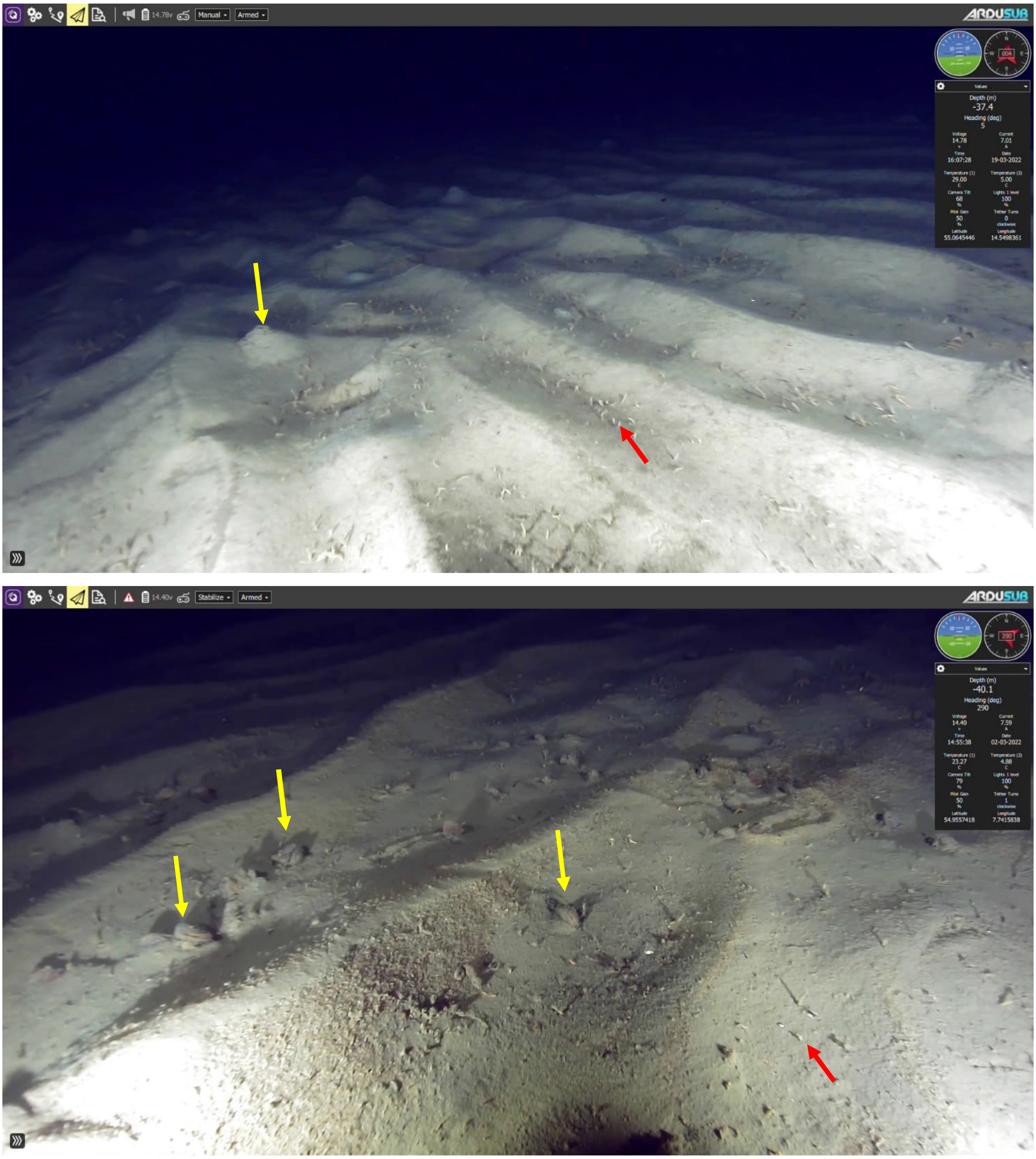


Figure 5-30. Dominant species on sand/soft bottom. Upper figure: Sand with dominance of lugworms (yellow arrow) and *Pygospio elegans* tubes (red arrow) (ROV station CC1_02x). Lower figure: Muddy sand with dominance of Ocean quahog (*Arctica islandica*) (yellow arrow) and *Pygospio elegans* tubes (red arrow) (ROV station OWF1_30).

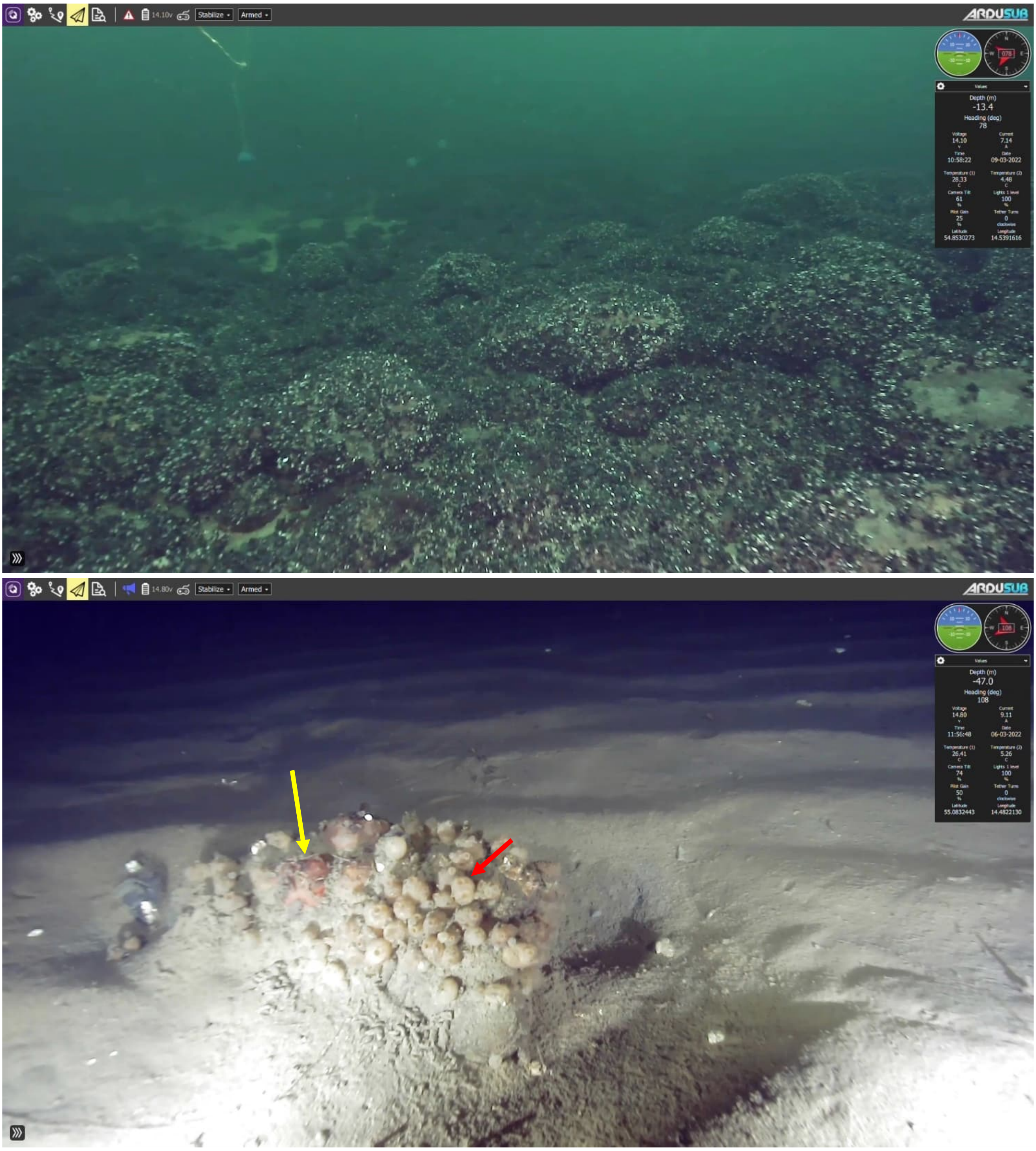


Figure 5-31. Dominating epifauna on rock. Upper figure: rocks (till, nature type 3) covered with blue mussels (*Mytilus* spp.) (ROV station SPA_108). Lower figure: Epifauna on rock (nature type 2 – Mixed bottom), including greyish tunicates (red arrow), hydroids, calcareous tube worms, barnacles and sea anemones with retracted tentacles (large reddish-grey bulbs, yellow arrow) (ROV station CC1_14).

BLUE MUSSELS

In the Baltic region the genus *Mytilus* is comprised by *M. edulis* and *M. trossulus* (or hybrids between the two). As these two species are difficult to distinguish morphologically, they are called *Mytilus* spp. in this report.

Blue mussels (*Mytilus* spp.) dominate on hard substrate (sediment type 2, 3 and 4) in the pre-investigation area (Figure 5-32 and Figure 5-33).

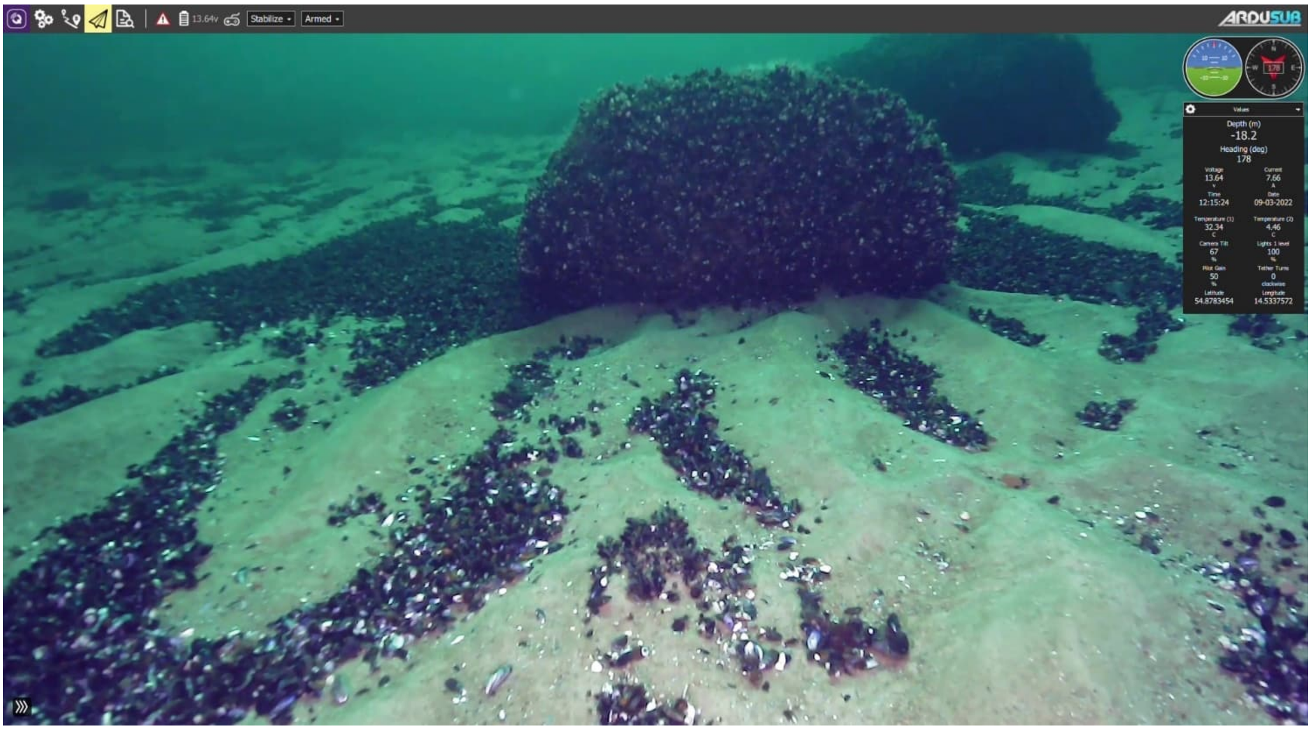


Figure 5-32. Blue mussels (*Mytilus* spp.) on large stones and on sand, gravel and smaller rocks in the seabed (ROV station SPA_100).

Blue mussels are found attached to boulders (Figure 5-32) and sedimentary rock (Figure 5-33, upper panel). On sand, blue mussels can be found in lower coverage (<1-15 %) as small ballistic, mobile balls/clusters consisting of blue mussel communities that are transported along the sandbed with the current (Figure 5-33, lower panel). These two life-forms of blue mussels were also found in connection with monitoring for North Stream 2 (Orbicon, 2019) and baseline mapping in Natura 2000-site N252/H261 “Adler Grund og Rønne Banke” (Miljøstyrelsen, 2021a) (see section 4.5.1 – Existing data/Epifauna).

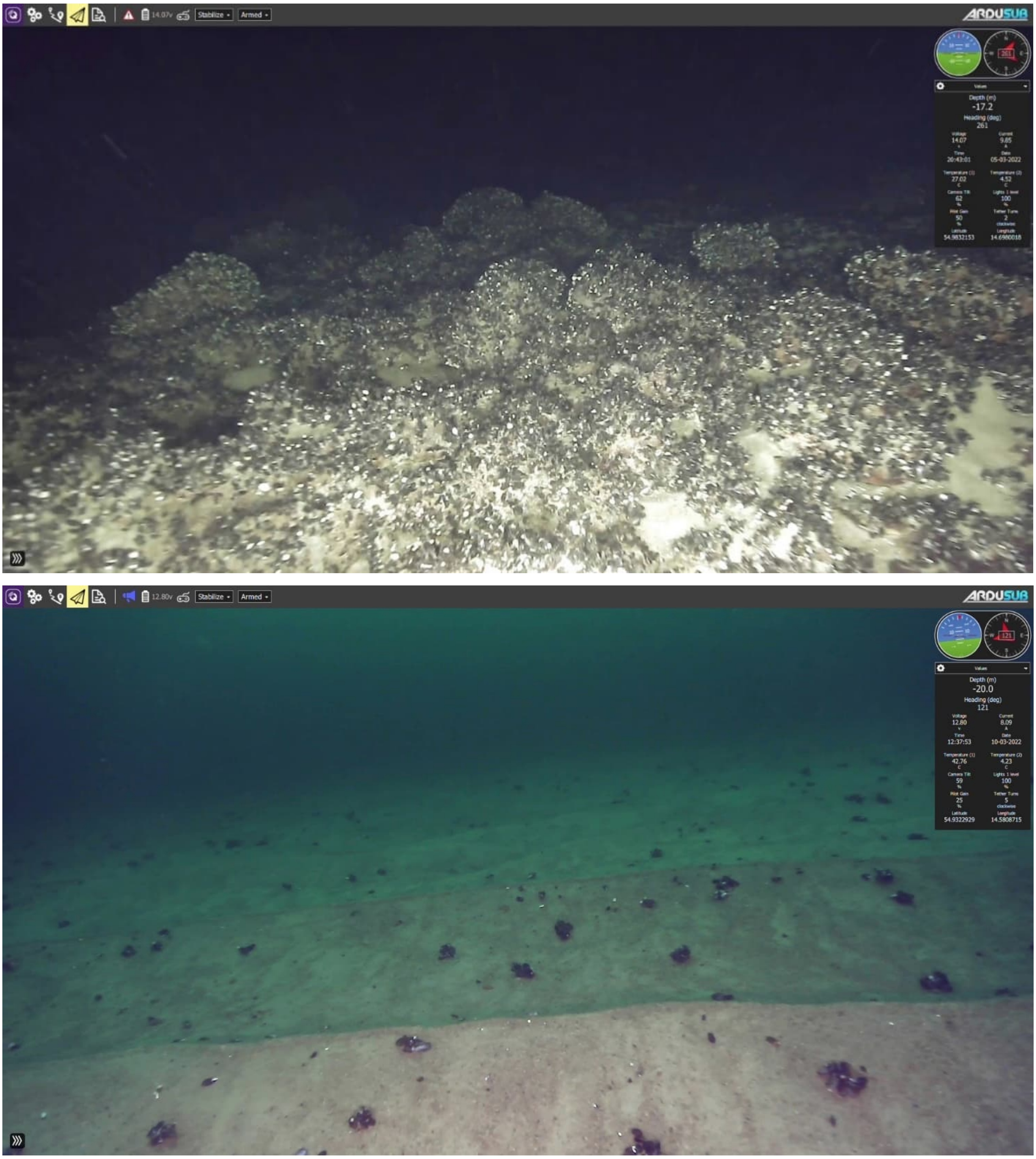


Figure 5-33. Different life-forms of blue mussel in the pre-investigation area. Upper panel: blue mussels on rocks and sedimentary rocks (ROV station CC2_03). Lower panel: On sand blue mussel clusters can be found as small, ballistic, mobile balls consisting of blue mussel communities that are transported along the sandbed with the current (ROV station SPA_058).

Blue mussel area coverage in the pre-investigation area as observed on the ROV stations with the sediment type map as background, are presented in Figure 5-34 and Figure 5-35 below. It is obvious that the highest blue mussel coverage is found on the hard sediment types (sediment type 3 and 4), which are predominantly found within and close to the Rønne Banke area, which is also the location of the Bird SPA area (see Figure 5-37).

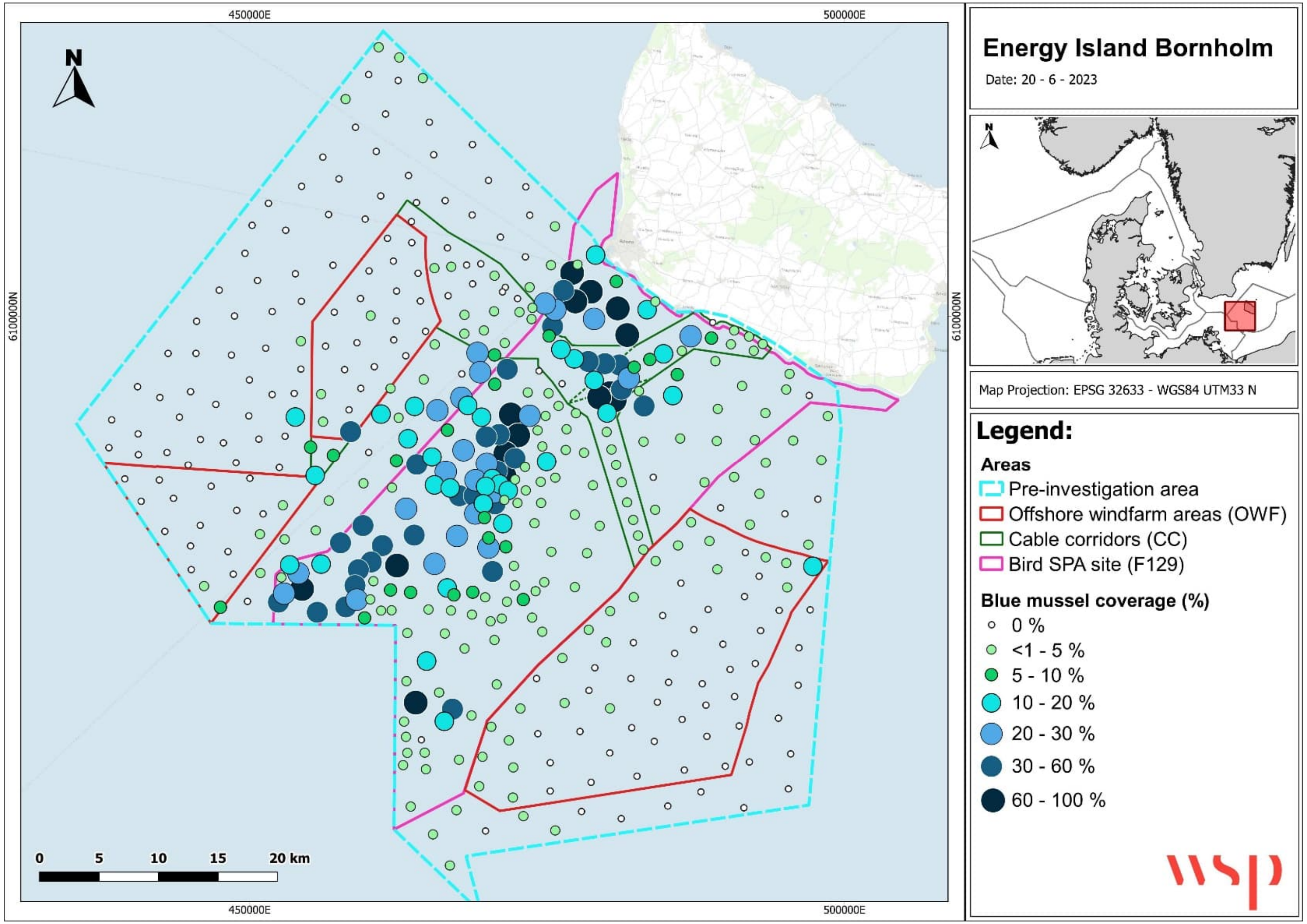


Figure 5-34. Blue mussel (*Mytilus* spp.) overall coverage in the pre-investigation area without station numbers (see next figure for station numbers). Overall coverage percentage (%) is the coverage of the total video view of the seabed often given as a range in the logbooks (Appendix 3). The maximum coverage % in the range is shown in this figure. See Figure 5-28 for station number and zooms in Appendix 2

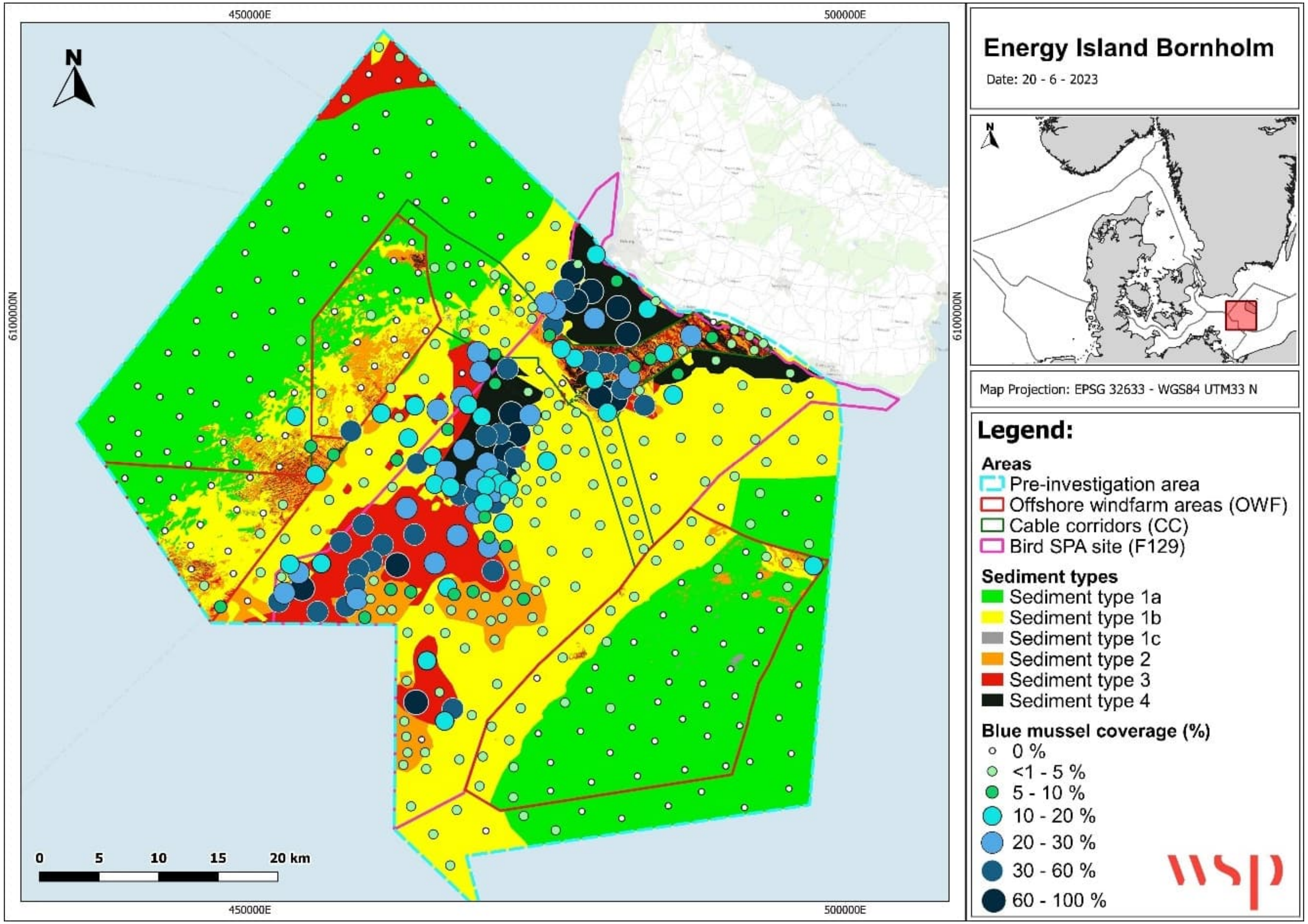


Figure 5-35. Blue mussel (*Mytilus* spp.) overall coverage in the pre-investigation area. See Figure 5-28 for indication of station numbers and prefix for the stations determined by the subareas e.g. cable corridor area (CC, CC1 and CC2), wind farm areas (OWF1 and OWF2), Bird SPA area (SPA) and the remaining pre-investigation area (INV) are given in Figure 5-28 and zooms in Appendix 2.

Blue mussel area coverage plotted as a function of depth shows that blue mussel coverage is highest at >10 meters of depth, where blue mussels outcompete macroalgae for attachment on the rocks (Figure 5-36). At lower depths (0-10 m) with more optimal light availability, macroalgae coverage dominate the hard sediment types with large stones (>10 cm) and rock.

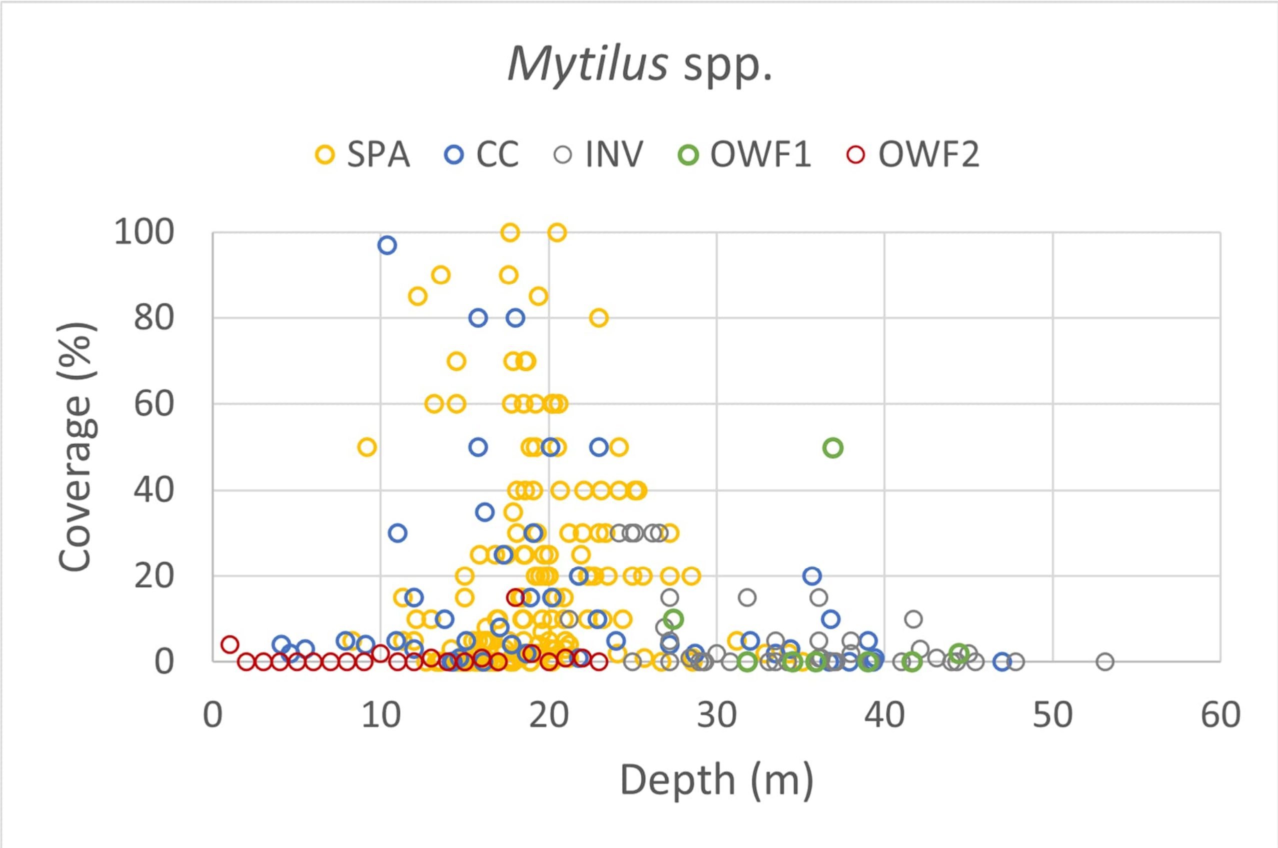


Figure 5-36. Overall blue mussel coverage percentage (%) (coverage on total visible ROV video seabed area) at ROV stations in the CC-area (pooled stations within CC, CC1 and CC2), OWF1, OWF2, SPA and INV areas (see Figure 5-33 or Appendix 2). The maximum overall blue mussel coverage % for each ROV station is used. Data with zero values are not included and lowest values displayed in the Figure is a coverage of 0.1 % = <1 % in logbooks (see Appendix 3).

Comparing blue mussel area coverage in the different subareas within the pre-investigation area shows highest coverage on hard substrate (sediment type 3 and 4), and thus, highest coverage in the bird SPA area, where hard sediment is most prevalent (see Figure 5-4).

This is illustrated in Figure 5-37 below, where blue mussel area coverage at ROV stations is combined with nature type 6 – blue mussel beds, based on sediment type 3 and 4. This figure gives a good indication of where blue mussels can be expected to be present in the pre-investigation area. Again, the map in Figure 5-37 shows that the main part of the blue mussels in the pre-investigation area is present in the SPA area.

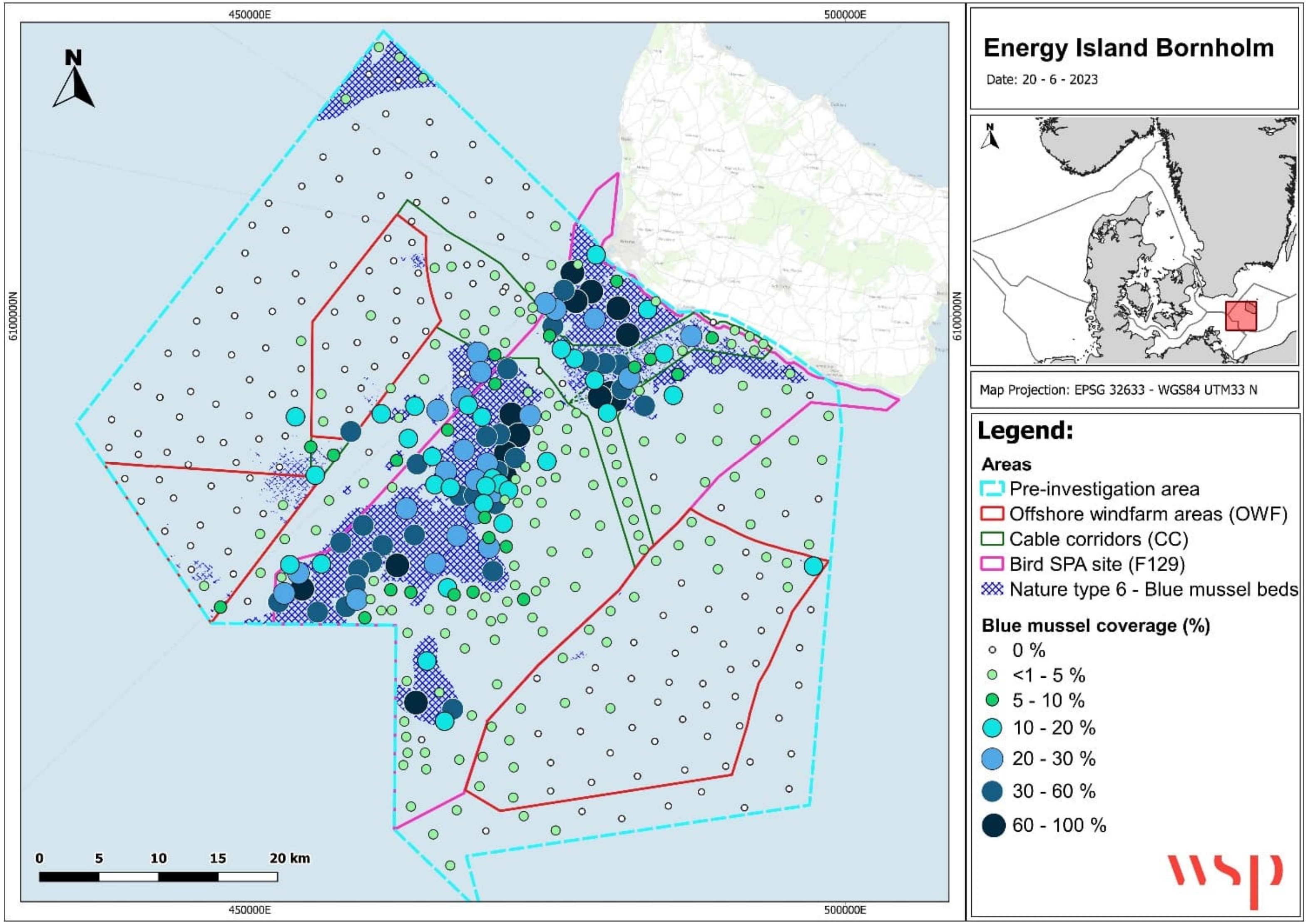


Figure 5-37. Blue mussel area coverage at ROV stations combined with nature type 6 – blue mussel beds (On sediment type 3 and 4). See Figure 5-28 for station number and zooms in Appendix 2.

WIND FARM AREAS

Blue mussel coverage is generally low (0-5 %) in the wind farm areas as hard substrate (stones and rock) is very limited in these areas (see Figure 5-37). Only, one station in each of the windfarm areas show coverages >5 %.

CABLE CORRIDORS

Since the cable corridor area has the largest area coverage of hard sediment types (Table 5-2), blue mussel coverage is highest in this area with up to 100 % coverage in the area closest to the coast with dominance of sediment type 3 and 4 (Figure 5-37).

5.5.2 INFAUNA

In total, 319 stations were sampled for infauna. Infauna species numbers, abundances and biomass are presented below, together with distribution of the different infauna classes in the different subareas within the pre-investigation area for Energy Island Bornholm. Note that in general, B1N and B1S areas are presented as one subarea called “OWF1” (excl. stations outside of B1N and B1S see Figure 3-2) as the sediment types and benthic communities are very similar in the two areas (see section 5.2.1 – Sediment types and Appendix 6 – Multivariate statistical analyses).

Table 5-11 provides an overview of per station averages for species numbers, abundances, and biomasses within the pre-investigation area. There was a wide range in abundance and biomass between stations in the subareas as evident from the high standard deviations. Overall, the CC area had the highest average abundance of infauna and INV the lowest. The average biomass was highest in OWF1 and CC, and lowest in OWF2. Species numbers, abundance, and biomass at the stations and within the subareas, are presented in more detail below.

Table 5-11. Overview of per station averages of infauna species numbers, abundance, and biomass (dry weight (DW) and wet weight (WW)) ± standard deviation (SD) in the different subareas within the pre-investigation area for Energy Island Bornholm.

Area	Number of species	Abundance (ind./m^2)	Biomass (gDW/m^2)	Biomass (gWW/m^2)
CC	4.5±2.5 (median 5, range 1-11)	2,736±7,081 (median 1,119, range 70-39,860)	36±84 (median 3, range 0.01-329)	65±159 (median 10, range 0.03-803)
Bornholm I (OWF1 = B1N+B1S)	4.1±2.4 (median 4, range 0-9)	740±552 (median 699, range 0-2,028)	48±105 (median 6, range of 0-574)	66±130 (median 17, range 0-715)
Bornholm II (OWF2)	3.1±1.9 (median 3, range 0-9)	873±1,152 (median 594, range 0-7,273)	6±12 (median 2, range 0-65)	14±23 (median 5, range 0-125)
INV	2.3±2.1 (median 1.5, range 0-9)	614±994 (median 140, range 0-4,196)	19±47 (median 2, range 0-289)	29±68 (median 6, range 0-409)
SPA	3.2±1.6 (median 3, range 0-7)	804±950 (median 559, range 0-5,315)	10±36 (median 1, range 0-334)	25±102 (median 3, range 0-970)

Species number, abundance and biomass found in the present study, are within the range found in other existing studies from the area, such as North Stream 2 and Baltic Pipe (see section 4.5.2, Table 4-10, Figure 4-14, Figure 4-15). The number of species present per station was lower in the present study than in the studies related to North Stream 2. However, it should be noted that the species number data from North Stream 2 (reported in Table 4-10 and Figure 4-15) consisted of the sum of three replicates, i.e. the sampled HAPS area "per station" was three times as high as in the present study. The average biomass found in the present study was lower than biomasses from North Stream 2 (baseline study), but higher than biomasses from the monitoring Natura 2000 site N252/H261 (NOVANA) (see Table 4-10).

NUMBER OF SPECIES

Overall, the number of infauna species found in the pre-investigation area ranged from 0-11 per station (Table 5-11). In general, species numbers were lowest in the INV area (2.3 species per station). In total, 28 stations had zero species present most of them (20 stations) located in the deepest part of the pre-investigation area (= INV area) (Figure 5-38). Stations in Bornholm I North, in general, had higher numbers of species per station (average of 5 species per station, range 1-9) than in Bornholm I South (average of 3.1 species per station, range 0-6) (note that data for B1N and B1S are not shown in Table 5-11). For Bornholm I (OWF1 area = B1N + B1S), the average number of species per station was 4.1, and in Bornholm II (OWF2), the average number of species per station was 3.1. Highest number of species was found in the CC area (range of 1-11 species per station) at a station close to Bornholm (st.CC_2), and the average was 4.5 species per station for the whole cable corridor (CC) area. In the bird SPA area, numbers of species ranged from 0-7, with an average of 3.2 species per station.

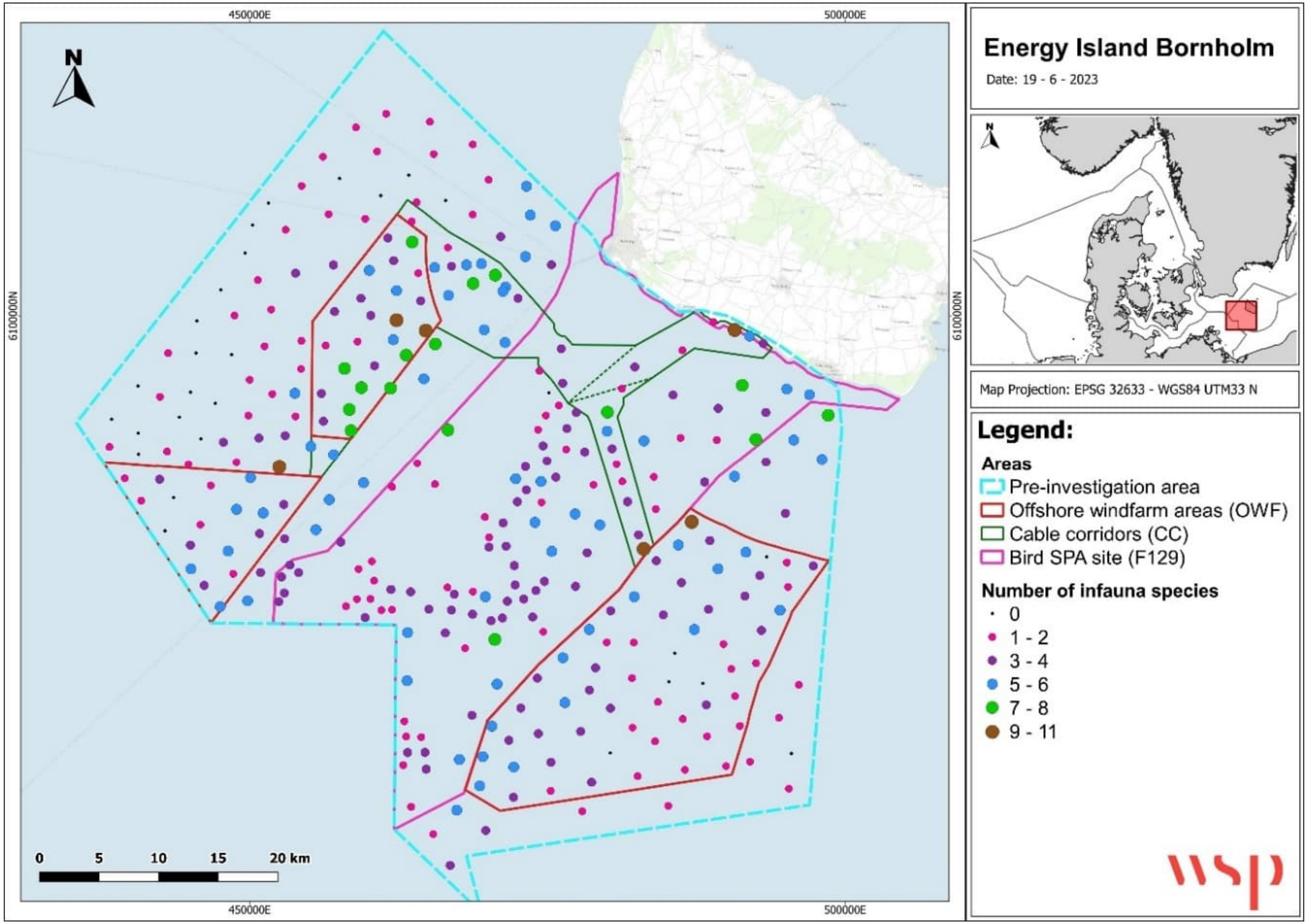


Figure 5-38. Infauna species numbers found at stations within the pre-investigation area. See Figure 5-39 for explanation of the different subareas (CC, CC1, CC2, OWF1, OWF2, SPA and INV) and station number and zooms of station number in Appendix 2.

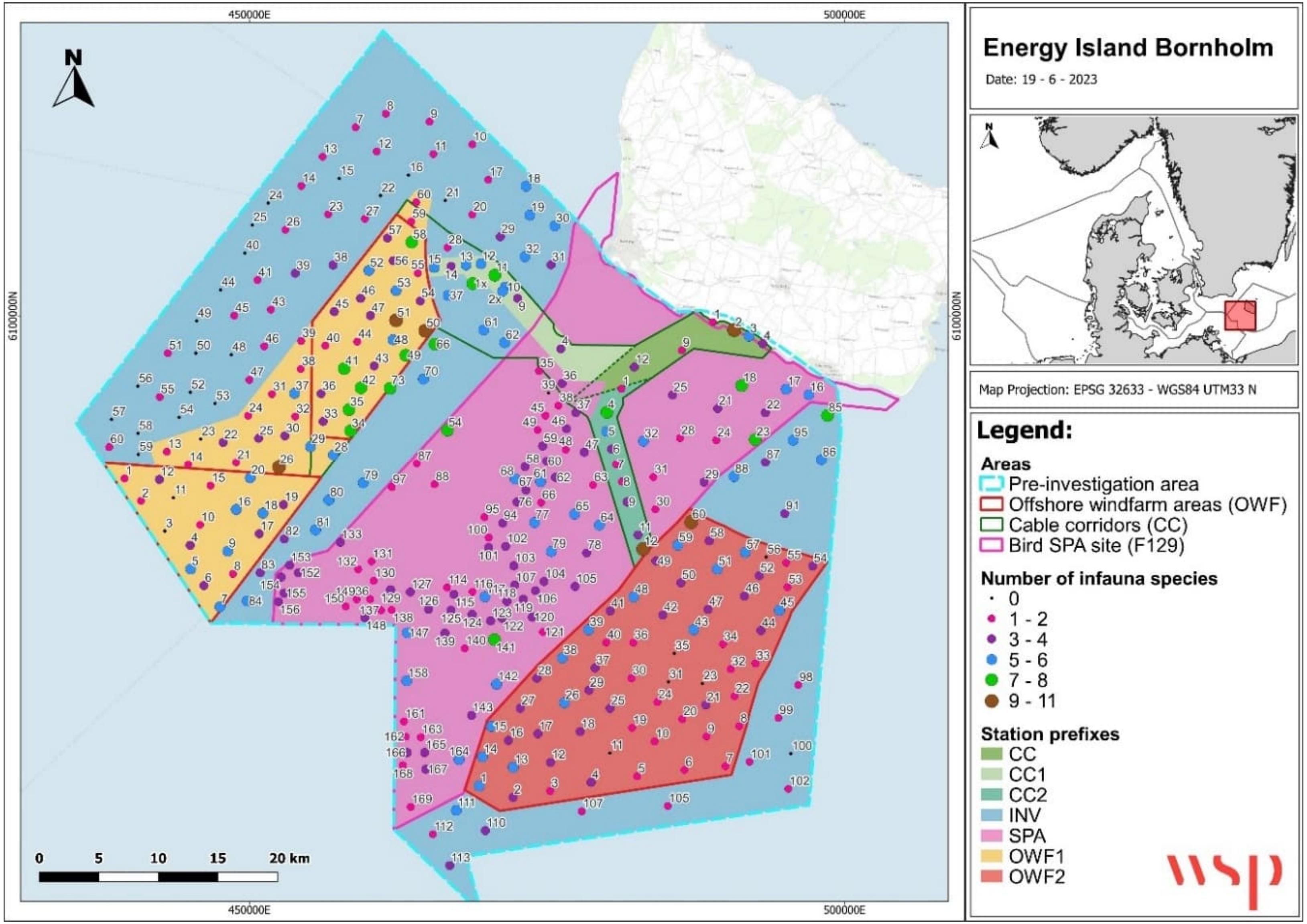


Figure 5-39. Station numbers and color coding for subareas (CC, CC1, CC2, OWF1, OWF2, SPA and INV) at infauna stations within the pre-investigation area.

In total, 47 species were found in the pre-investigation area, and highest number of species were found in the INV and OWF1 areas (30 species), followed by 29 species in the CC area, 20 in SPA and 16 in OWF2 (Table 5-12). Of the species found, the Malacostraca (crustacean) species *Pontoporeia femorata* is on HELCOMs Red List and is listed as of Least Concern (LC) (HELCOM, 2023b). *Pontoporeia femorata* was found in both the INV area (at 4 stations) and the OWF2 area (at 11 stations). This species was also found south of Rønne Banke, at a station on the border of OWF2 during the baseline study for North Stream 2 (station D_EEZ_22, Figure 4-15).

Table 5-12. Infauna species list found in the pre-investigation area for Energy Island Bornholm. See Figure 5-38 for species number per station in the total pre-investigation area and in CC, OWF1 and OWF2. Bornholm I = OWF1 and Bornholm II = OWF2. SPA = Special Protection Area.

Class	Species	CC	INV	OWF1	OWF2	SPA
Anthozoa	*Edwardsia* sp.	x	x	x		
Bivalvia	*Arctica islandica*		x			
Bivalvia	*Astarte sp.*	x	x	x		
Bivalvia	*Cerastoderma glaucum*					x
Bivalvia	*Limecola balthica* (previously *Macoma balthica)*	x	x	x	x	x
Bivalvia	*Mya arenaria*	x		x		x
Bivalvia	*Mytilus* spp.	x	x	x	x	x
Clitellata	*Oligochaeta* indet.	x	x	x	x	x
Clitellata	*Tubificoides benedii*	x	x	x		x
Gastropoda	*Hydrobia ulvae*	x		x		x
Gastropoda	*Pusillina sarsii*	x				
Gastropoda	*Theodoxus fluviatilis var. Balthica*	x				
Halicryptomorpha	*Halicryptus spinulosus*	x	x	x	x	x
Malacostraca	*Bathyporeia pilosa*	x	x			x
Malacostraca	*Corophium crassicorne*		x	x		
Malacostraca	*Crangon crangon*					x
Malacostraca	*Diastylis rathkei*	x	x	x	x	x
Malacostraca	*Gammarus* sp.	x			x	x
Malacostraca	*Idotea balthica*	x				
Malacostraca	*Jaera albifrons*	x				
Malacostraca	*Microdeutopus gryllotalpa*	x				
Malacostraca	*Phoxocephalus holbolli*	x		x		
Malacostraca	*Pontoporeia affinis*		x		x	x
Malacostraca	*Pontoporeia femorata*		x		x	
Nemertini	*Nemertini indet.*	x	x	x	x	
Polychaeta	*Ampharete baltica*		x	x	x	
Polychaeta	*Antinoella sarsi*		x	x	x	x
Polychaeta	*Arenicola marina*			x		
Polychaeta	*Aricidea suecica*	x	x	x	x	
Polychaeta	*Capitella capitata*		x	x		
Polychaeta	*Eteone longa*			x		
Polychaeta	*Hediste diversicolor*	x		x	x	x
Polychaeta	*Levinsenia gracilis*		x			

Class	Species	CC	INV	OWF1	OWF2	SPA
Polychaeta	*Marenzelleria viridis*	x	x	x	x	x
Polychaeta	*Neanthes succinea*		x			x
Polychaeta	*Neoamphitrite figulus*	x	x			
Polychaeta	*Nephtys caeca*	x	x	x		
Polychaeta	*Nephtys ciliata*		x			
Polychaeta	*Nephtys hombergii*	x	x	x		
Polychaeta	*Polydora quadrilobata*			x		
Polychaeta	*Pygospio elegans*	x	x	x	x	x
Polychaeta	*Scoloplos armiger*	x	x	x	x	x
Polychaeta	*Spio armata*		x	x		
Polychaeta	*Terebellides stroemii*	x	x	x		
Polychaeta	*Travisia forbesii*	x	x	x		x
Priapulimorpha	*Priapulus caudatus*			x		
Total number of species	46	29	30	30	16	20

ABUNDANCE

In general, highest infauna abundances (1000-5000 ind./m^2) (Figure 5-40) were observed on and along the slopes of Rønne Banke, where the sediment was dominated by mainly sediment type 1b - sand (Bornholm I) and sediment type 1a - Silt (Bornholm II) down to depths approximately 40 meters of depth (Figure 5-41). Lower abundances were observed in the deepest parts of the pre-investigation area (0-1000 ind./m^2) at depths more than approximately 40 meters of depth corresponding to the area within the pre-investigation area where oxygen deficiency was observed (see section 4.2.2).

Highest abundances were therefore found at lower depths <40 in the pre-investigation area including CC, SPA and Bornholm I (OWF1) and Bornholm II areas (OWF2) (Figure 5-40 and Figure 5-39 for station number and subarea prefix). Furthermore, highest abundances were observed in the CC area and in the part of the OWF areas closest to Rønne Banke.

Comparing the OWF areas, the two Bornholm I subareas had the same abundance ranges and distribution. The Bornholm II had single stations with high abundance (2,000-10,000 individuals/m^2) in the shallowest part close to Rønne Banke, however in the rest of the area abundances were generally lower than in the two Bornholm I subareas, again corresponding to the area where oxygen deficiency was observed in the Bornholm II area.

Average abundance per station in the five different areas within the pre-investigation area can be found in Table 5-11.

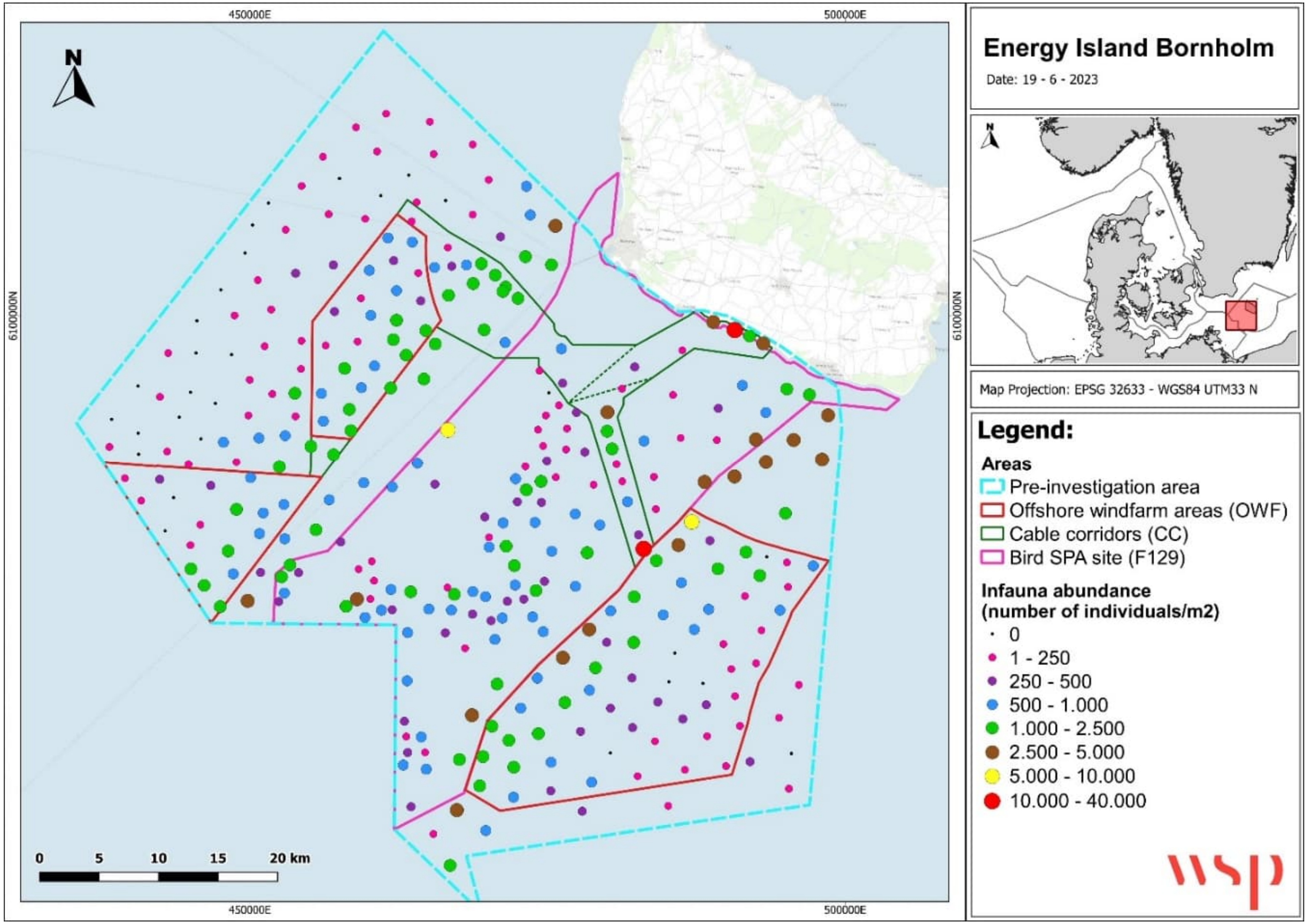


Figure 5-40. Infauna abundance (number of individuals/m^2) found at each station within the pre-investigation area. See Figure 5-39 for explanation of the different subareas (CC, CC1, CC2, OWF1, OWF2, SPA and INV) and station number and zooms of station numbers in Appendix 2. Figure 5-41 below shows sediment type map as background.

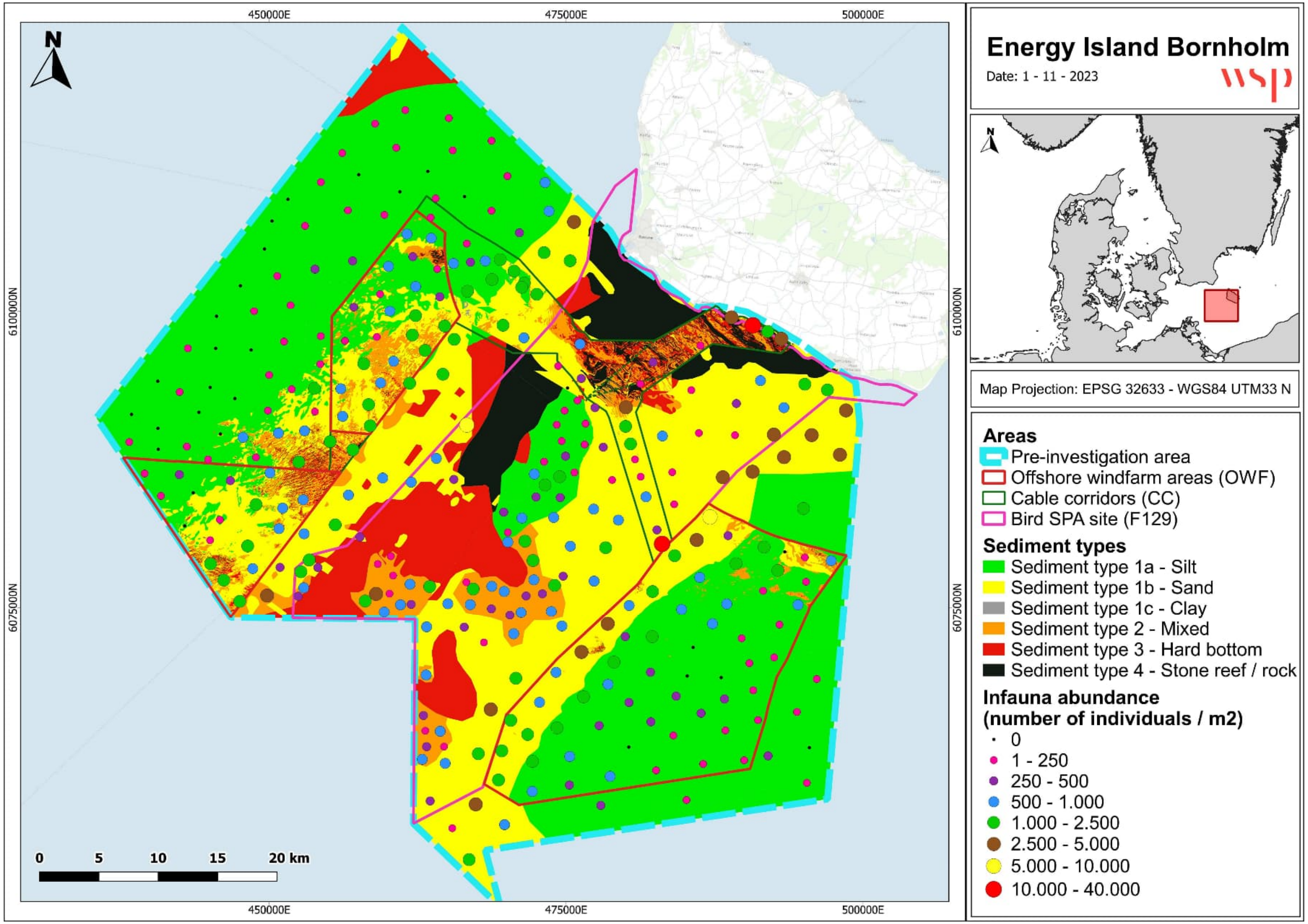
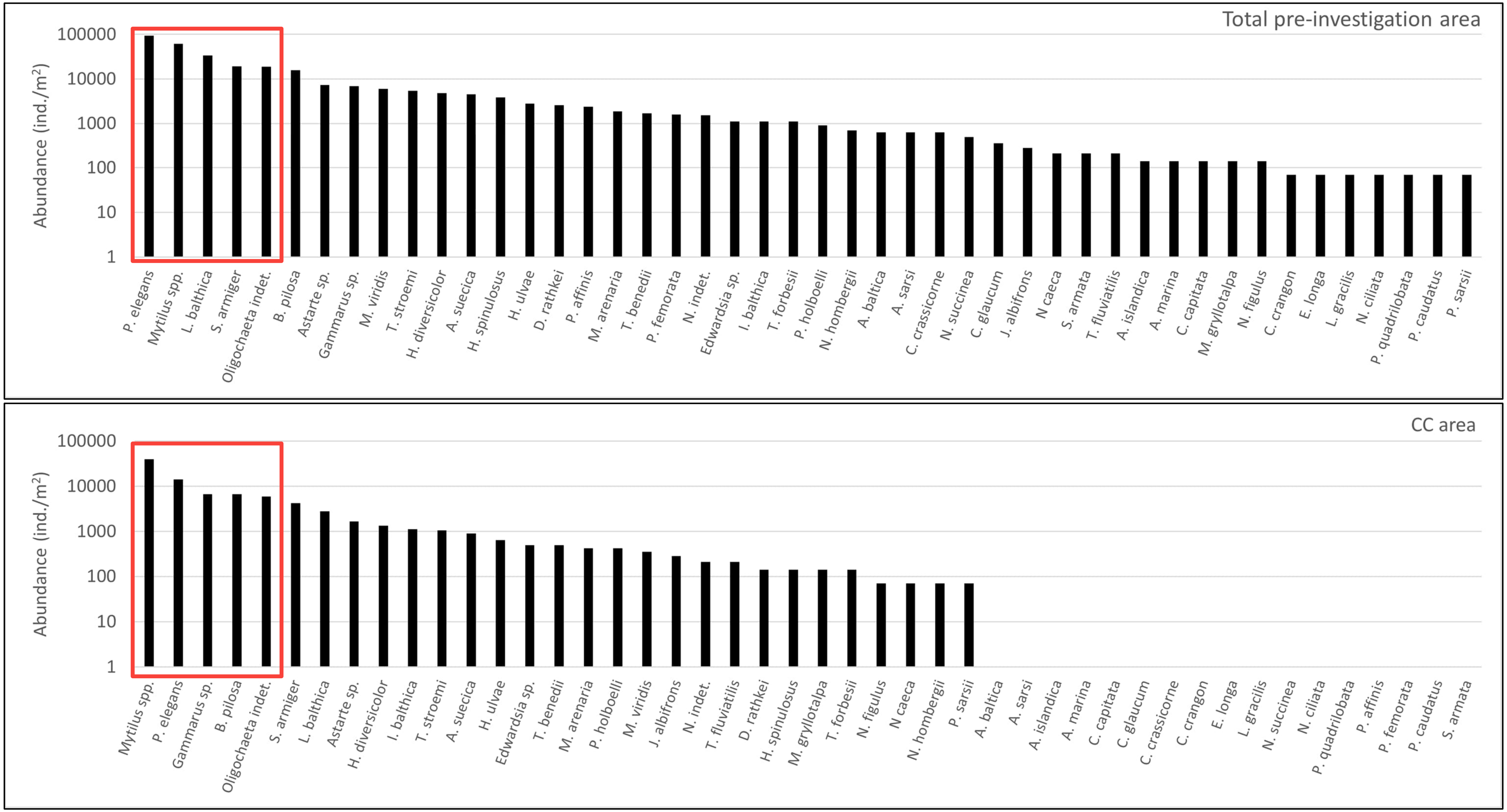


Figure 5-41. Infauna abundance (number of individuals/m^2) found at each station within the pre-investigation area with sediment type map as background. See Figure 5-39 for explanation of the different subareas (CC, CC1, CC2, OWF1, OWF2, SPA and INV) and station number and zooms of station numbers in Appendix 2.

The dominating species in the pre-investigation area based on abundances are presented in Figure 5-42 below. The dominating species were the bristle worm (polychaete) *Pygospio elegans*, and this species also dominated in the Bornholm II area (OWF2), whereas the bivalve *Mytilus* spp. and the bristle worm *Scoloplos armiger* dominated in CC and Bornholm I areas (OWF1), respectively (Figure 5-42). For the total pre-investigation area (OWF1, OWF2, CC, SPA, INV), the five most dominating species were *Pygospio elegans, Mytilus* spp., the bivalve species *Limecola balthica*, the bristle worm *Scoloplos armiger* and *Oligochaeta* worms (identified to subclass) (Figure 5-42). See also Table 5-12 for all species found in the present study.

The same infauna species were found to be abundant in the baseline study for North Stream 2 (Nord Stream 2, 2018b), where the most abundant infauna species in 2017 (for all stations) were blue mussel (*Mytilus edulis*), *Pygospio elegans*, *Scoloplos armiger*, Oligochaeta, mudsnail (*Hydrobia ulvae*), northern astarte (*Astarte borealis*), *Marenzelleria*, baltic macoma (*Limecola balthica*,), *Tubificoides benedii* and ragworm (*Hediste diversicolor*) (Nord Stream 2, 2018b) (see also section 4.5.2 – Existing data infauna).


Total pre-investigation area
Abundance (ind./m²)
100000
10000
1000
100
10
1
P. elegans
Mytilus spp.
L. balthica
S. armiger
Oligochaeta indet.
B. pilosa
Astarte sp.
Gammarus sp.
M. viridis
T. stroemi
H. diversicolor
A. suecica
H. spinulosus
H. ulvae
D. rathkei
P. affinis
M. arenaria
T. benedii
P. femorata
N. indet.
Edwardsia sp.
I. balthica
T. forbesii
P. holboelli
N. hombergii
A. baltica
A. sarsi
C. crassicorne
N. succinea
C. glaucum
J. albifrons
N caeca
S. armata
T. fluviatilis
A. islandica
A. marina
C. capitata
M. gryllotalpa
N. figulus
C. crangon
E. longa
L. gracilis
N. ciliata
P. quadrilobata
P. caudatus
P. sarsii
CC area
Abundance (ind./m²)
100000
10000
1000
100
10
1
Mytilus spp.
P. elegans
Gammarus sp.
B. pilosa
Oligochaeta indet.
S. armiger
L. balthica
Astarte sp.
H. diversicolor
I. balthica
T. stroemi
A. suecica
H. ulvae
Edwardsia sp.
T. benedii
M. arenaria
P. holboelli
M. viridis
J. albifrons
N. indet.
T. fluviatilis
D. rathkei
H. spinulosus
M. gryllotalpa
T. forbesii
N. figulus
N caeca
N. hombergii
P. sarsii
A. baltica
A. sarsi
A. islandica
A. marina
C. capitata
C. glaucum
C. crassicorne
C. crangon
E. longa
L. gracilis
N. succinea
N. ciliata
P. quadrilobata
P. affinis
P. femorata
P. caudatus
S. armata

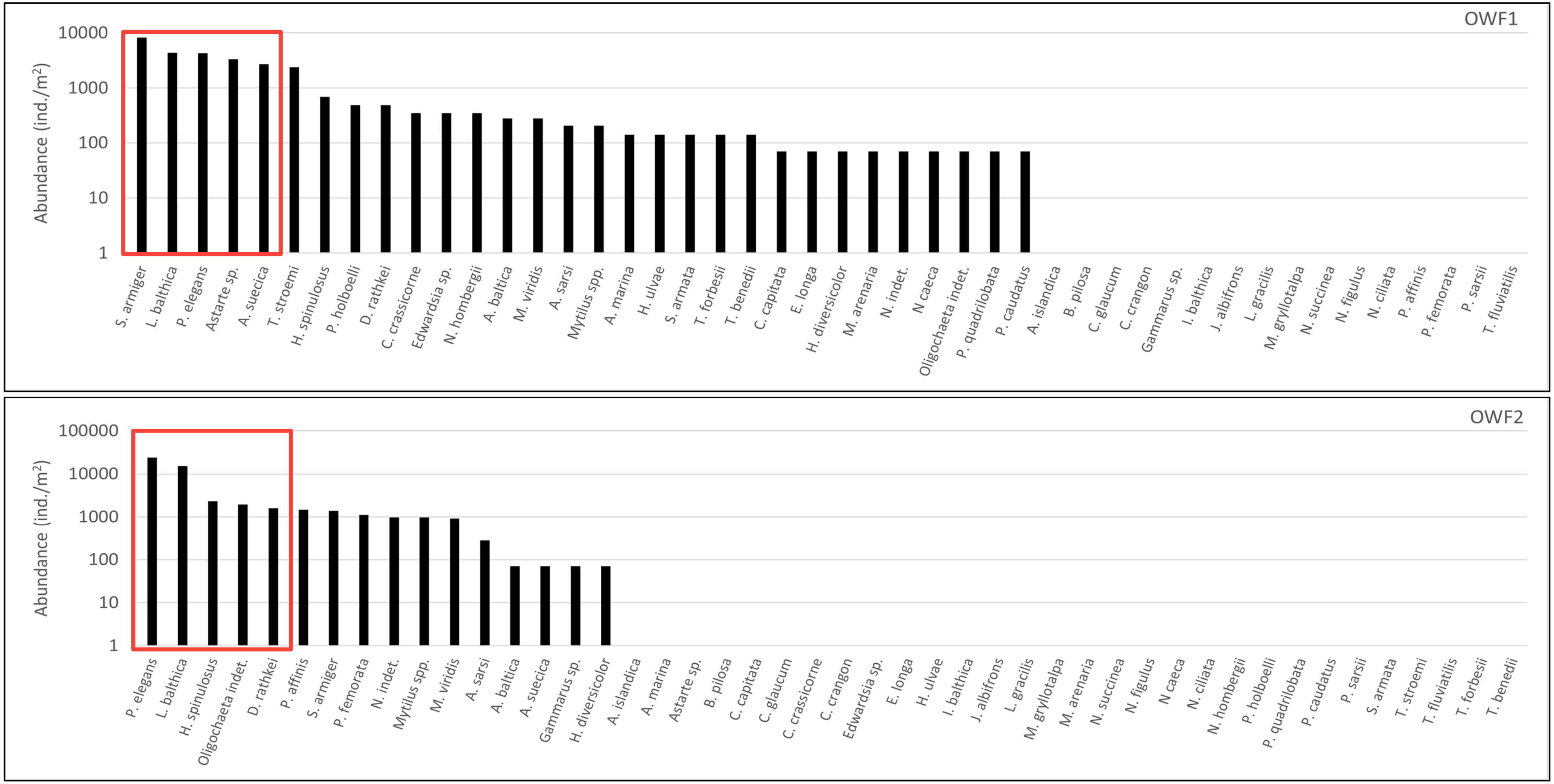


Figure 5-42. Dominating infauna species based on total abundance (individuals/m^2) of each infauna species found in the infauna samples in the total pre-investigation area and the subareas of CC, OWF1 (=B1S+B1N) and OWF2 areas (from upper to lower figure). Species without a visible bar were not present in the given area. Note logarithmic scale on the y-axis. Lowest abundances are 70 ind./m^2, corresponding to 1 individual caught per HAPS sample. For full species names see Table 5-12. Red squares mark the five most dominating species per area.

Some of the most abundant species found in the pre-investigation area are described in more detail in Table 5-13 below.

Table 5-13. Description of some of the dominating infauna species in the pre-investigation area. See also Figure 5-42.

Pygospio elegans is a species of tube-living bristle worm that can grow to a length of up to 15 mm. They live on sandy bottom both at shallow and deeper waters and lives along the coasts of all of Europe and can be found in abundances up to 600,000 individuals/m^2. The species is capable of both sexual and asexual reproduction, has a wide range of salinity tolerance and is both a suspension-, filtration- and deposit feeder. These characteristics make this species a very resilient generalist, which can recolonize quickly **(Thonig, 2018)**. The species is recognized on ROV video by its long brown to orange tubes, that gives the seabed a hairy appearance. This species is prey for fish and coastal birds as *P. elegans* often occur on relatively shallow depths **(Hiebert, 2014)**.
Limecola balthica (former *Macoma balthica)* is a bivalve species with a shell size up to 25 mm in length. The species is widely distributed from temperate to arctic coastal waters, both in the North Atlantic and North Pacific oceans. It has a depth range of 0-190 meters and lives a few centimeters below the surface in areas with sand, mud and muddy sand. *Limecola balthica* is an active suspension feeder and a surface deposit feeder. The species has a generation time of 1-2 years and a life span of 5-10 years **(Budd & Rayment, 2021)**.
Scoloplos armiger is a species of bristle worm (polychaete) that can become up to 12 cm in length and have up to 200 segments. The species live in a burrow system down to 15 cm depth in the sediment and do not usually appear at sediment surface. The species is present along the Danish and Northern European coasts and occurs on the low shore and shallow sublittoral in fine, muddy sand, often amongst seagrasses **(Ballerstedt, 2005)**.
***Mytilus* spp.** "Blue mussel" consists of both *Mytilus edulis* and *M. trossulus.* The blue mussel is a very common species found in Danish waters and lives in both salty and brackish waters (including the Baltic and inner fjords). Clusters of blue mussels are often found attached to hard substrate (e.g., rocks of varying size and other blue mussels). Blue mussels are filter feeders and an important food item for many species of fish and birds **(Newel R.I., 1989)**. Reproduction takes place during spring where eggs and sperm are released into the open water masses. The larvae will at one point attach to a suitable substrate **(Tyler-Walters, 2008)**.
Bathyporeia pilosa is a <1 cm amphipod which is common from the Baltic Sea to Iceland. They are found in areas with sand and muddy sand. The species often occurs in areas with dynamic bottom conditions and is tolerant of disturbed environments. Individuals have a short life span of one year but can produce multiple broods annually after 6 months of age, and the population can therefore reestablish rapidly **(Marlin.ac.uk, 2023)**. The species is food item for juvenile flounders and shorebirds among others **(Bengtson & Svensson, 1968; Mattila & Bonsdorff, 1998)**.
Astarte sp. is a bivalve species. Note that *Astarte* is not determined to species. Depending on species, they live in muddy sand mixed with gravel or mud from 10 meters of depth and deeper **(Køie & Kristansen, 2014)**.
Halicryptus spinulosus is a species of marine worms (priapulid worms) that can become up to 3 cm in length. The species lives in brackish waters down to 200 meters of depth and burrows in sediment down to 30 cm depth and is an important component of the zoobenthos in the northern Baltic Sea **(Saldarriaga & Storch, 1997)**. The species can live under hypoxic conditions and can withstand environment with hydrogen sulfide for prolonged periods **(Aarnio et al., 1998)**. They can feed on detritus and crustaceans, polychaetes among other infauna groups and are considered to be mainly carnivorous **(Ankar & Sigvaldadottir, 1981)**.
Aricidea suecica is a polychaete (bristle worm) that has a worldwide distribution. The species lives on soft bottoms (sand, mud, muddy sand, silty clay) and can grow up to 20 mm in length **(Pettibone, 1963)**.
Terebellides stroemii is a polychaete species (bristle worm) that can grow up to 7 cm in length and has a worldwide distribution, including from the North Sea to the Eastern Baltic **(Køie & Kristansen, 2014; Read**

& Fauchald, 2023). The species lives in mixed muddy sediments from 10 meters of depth and deeper, where they form thick, smooth clay tubes in which they live **(Køie & Kristansen, 2014)**.
Diastylis rathkei is a crustacean (Malacostraca) that live in both marine and brackish waters **(Sirenko, et al., 2023)**. Individuals can grow up to 1.5 cm in length and live in mixed sandy sediments from a few meters of depth **(Køie & Kristansen, 2014)**. It is an important food item for fish in the Baltic Sea **(Valentin & Anger, 1976)**.

BIOMASS

Total infauna biomass per station is here presented in both dry weight (gDW/m^2) and wet weight (gWW/m^2) (Figure 5-43 and Figure 5-44, respectively). The biomass distribution shown as wet weight and dry weight were similar.

Overall, infauna biomass data did not show the same distribution pattern as was seen for abundance, where e.g., some stations in the SPA and CC areas had relatively high abundance but did not have equivalent high biomass. However, some stations within the Bornholm I (OWF1) and Bornholm II (OWF2) subareas, where higher abundances were observed towards the SPA area, also had high biomass (Figure 5-43 and Figure 5-44).

In general, higher biomasses were observed in the area west of Rønne Banke and the SPA area (stations with up to 1000 gDW/m^2 and 1000 gWW/m^2) and lower biomasses at stations east of SPA (in general, stations with up to 50 gDW/m^2 and up to 100 gWW/m^2 with one station having up to 100 gDW/m^2 and 350 gWW/m^2, respectively). As was observed for abundances, biomass was generally lower in the deep areas of the pre-investigation area north of the Bornholm I sub areas and in most of the Bornholm II area and south of this.

The stations in the CC area close to Bornholm (CC_1 to 4), where abundances were high, did not have high biomasses, except for station CC_2, which was the station where the highest abundance was observed. In the SPA area, there was in general low to intermediate values of biomasses of infauna at the stations, with an average of 10.4 gDW/m^2 and 25.4 gWW/m^2, respectively. At at one station (SPA_54), the biomass was high (970 gWW/m^2 and 334 gDW/m^2, respectively), and at this station, *Mytilus* spp. constituted 99 % of the total biomass.

Comparing the wind farm areas biomass was highest in the two Bornholm I subareas and lowest in the Bornholm II subarea. The cable corridor area (CC) was intermediate between the two OWF areas.

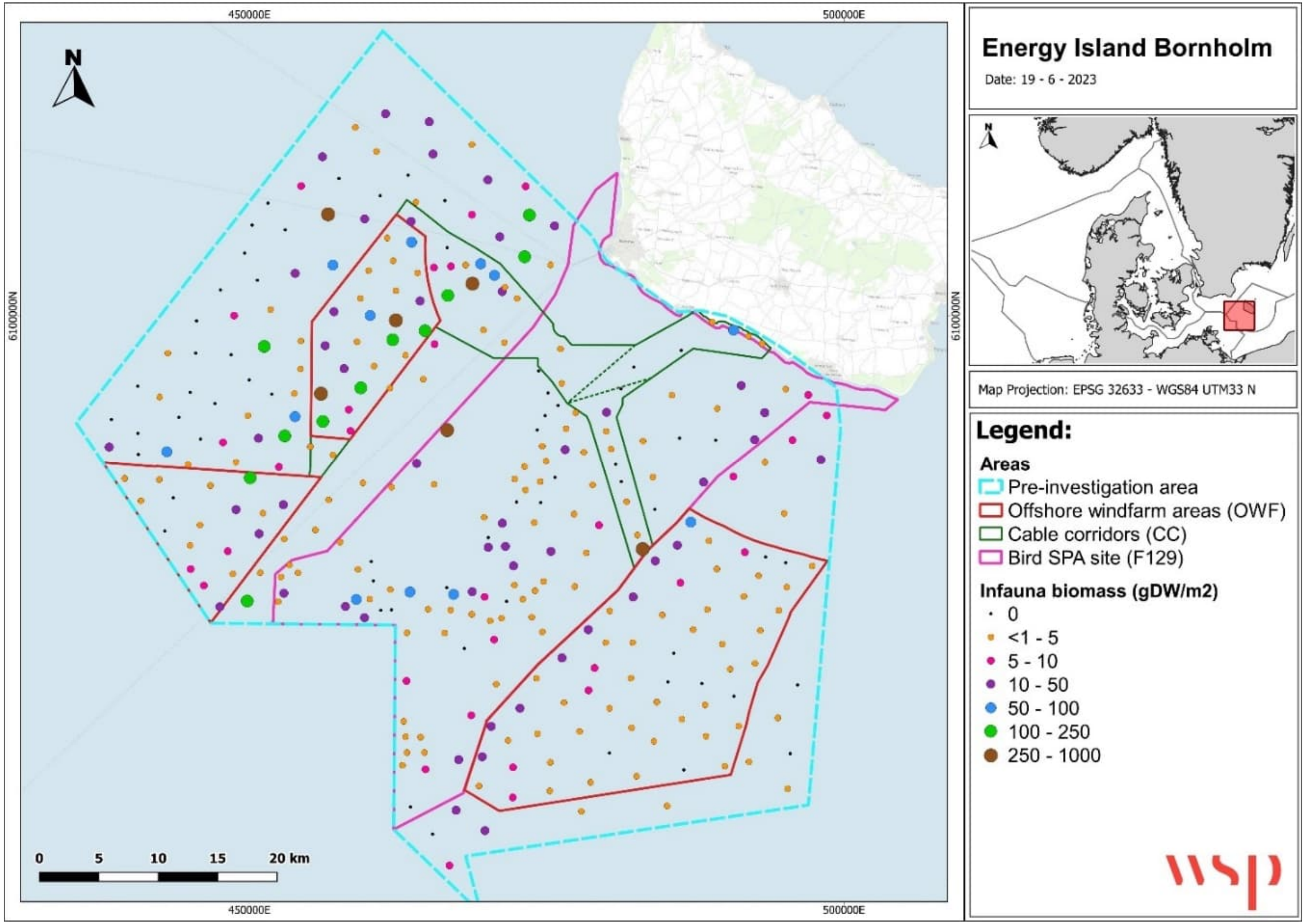


Figure 5-43. Infauna biomass at stations given as Dry weight (gDW/m²) found at each station in the pre-investigation area incl. See Figure 5-39 for explanation of the different subareas (CC, CC1, CC2, OWF1, OWF2, SPA and INV) and station number and zooms of station numbers in Appendix 2.

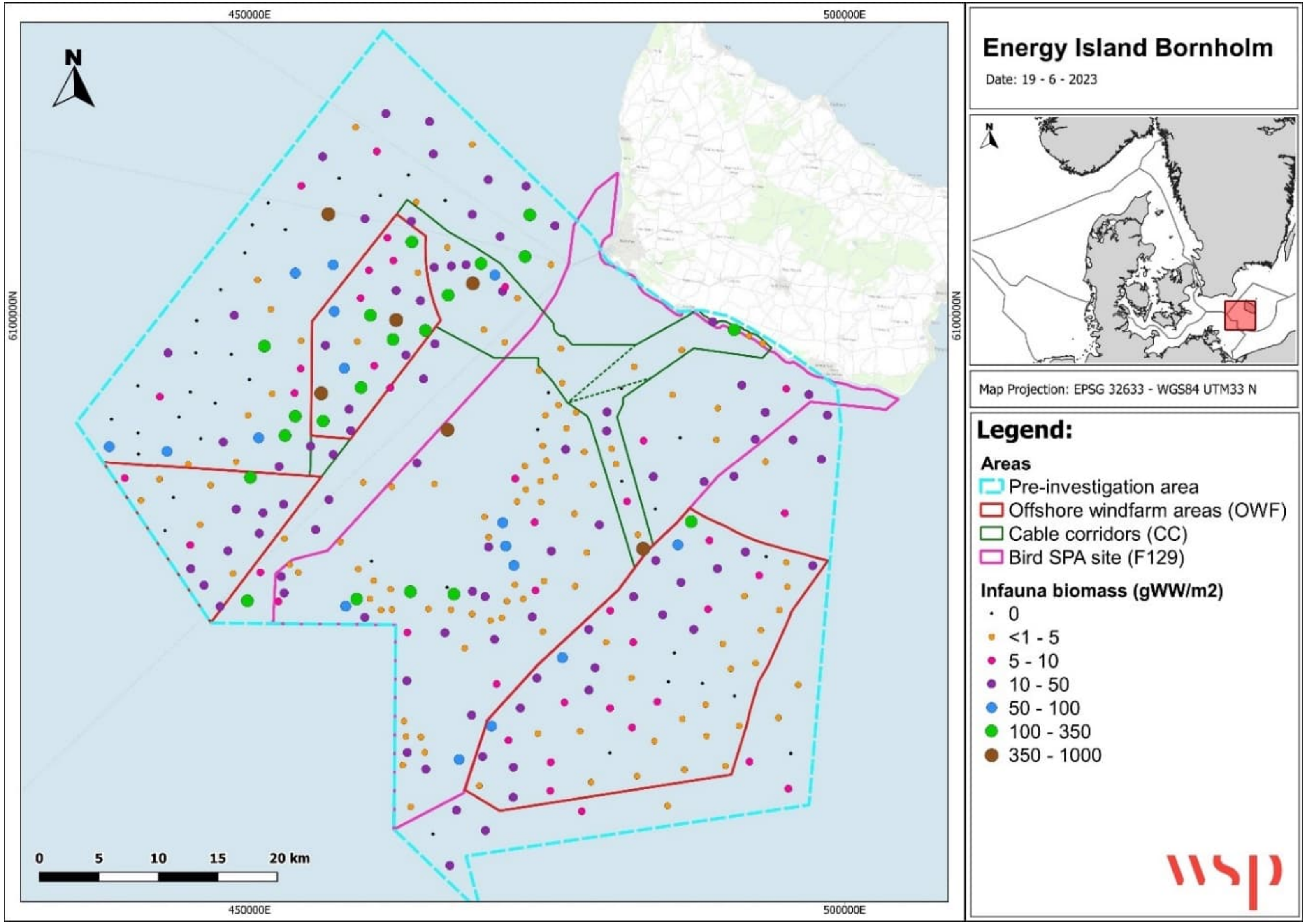


Figure 5-44. Infauna biomass at stations given as wet weight (gWW/m^2) found at each station in the pre-investigation area. See Figure 5-39 for explanation of the different subareas (CC, CC1, CC2, OWF1, OWF2, SPA and INV) and station number and zooms of station numbers in Appendix 2.

CLASS DISTRIBUTIONS

The abundance and biomass distributions (%) of infauna classes in the Bornholm I area (OWF1 = B1N+B1S) (also for the sub-area B1N and B1S), Bornholm II (OWF2), CC and SPA areas are shown in the pie charts below.

Figure 5-45 compares the distribution of infauna classes in the two Bornholm I sub-areas B1N and B1S that together form the OWF1 area, and as shown, the distribution of taxonomical classes is very similar between the two areas, where polychaetes dominate in terms of abundance and bivalves in terms of biomass. Thus, the two subareas were pooled into one large area in the following text “OWF1” (see Figure 5-46, and Appendix 6 – Multivariate statistical analyses).

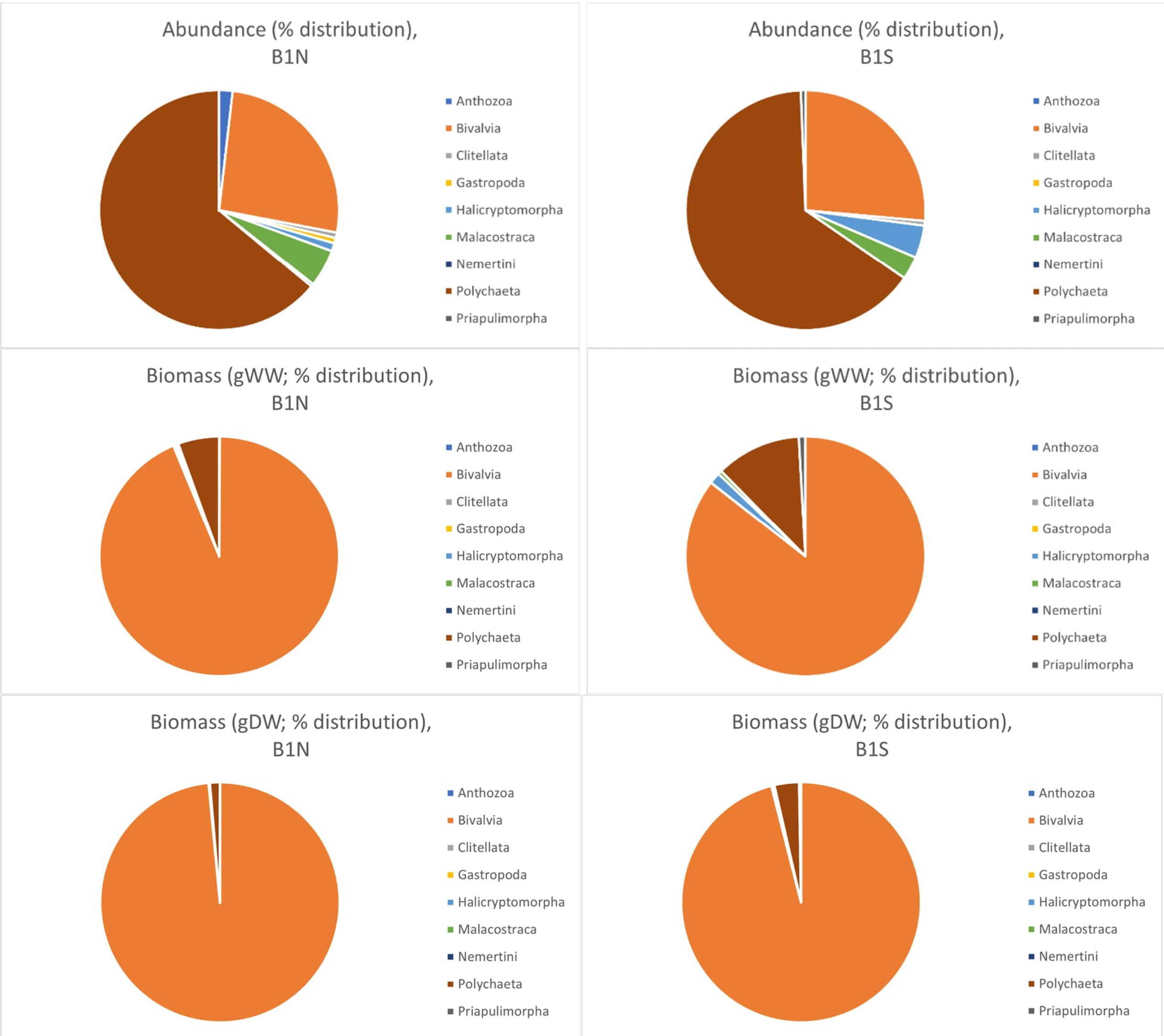


Figure 5-45. Pie charts of infauna classes in Bornholm I North (B1N) and South (B1S) areas (DW and WW). Distribution (%) of abundance (ind./m^2) and biomass (wet weight (WW) and dry weight (DW) per m^2) of different taxonomical infauna classes found in the B1N and B1S areas within the pre-investigation area of Energy Island Bornholm. See Figure 5-39 for explanation of the different subareas (CC, CC1, CC2, OWF1, OWF2, SPA and INV).

In Figure 5-46, abundance and biomass distribution of infauna classes in Bornholm I (OWF1) (B1N and B1S pooled) and Bornholm II (OWF2) are shown. In both areas, polychaetes dominated the abundance, constituting 64 % and 51 % in OWF1 and OWF2, respectively, followed by bivalves that constituted 26 % and 31 %, respectively.

Bivalves dominated biomass, constituting 98 % and 91 % (in terms of DW) in OWF1 and OWF2, respectively.

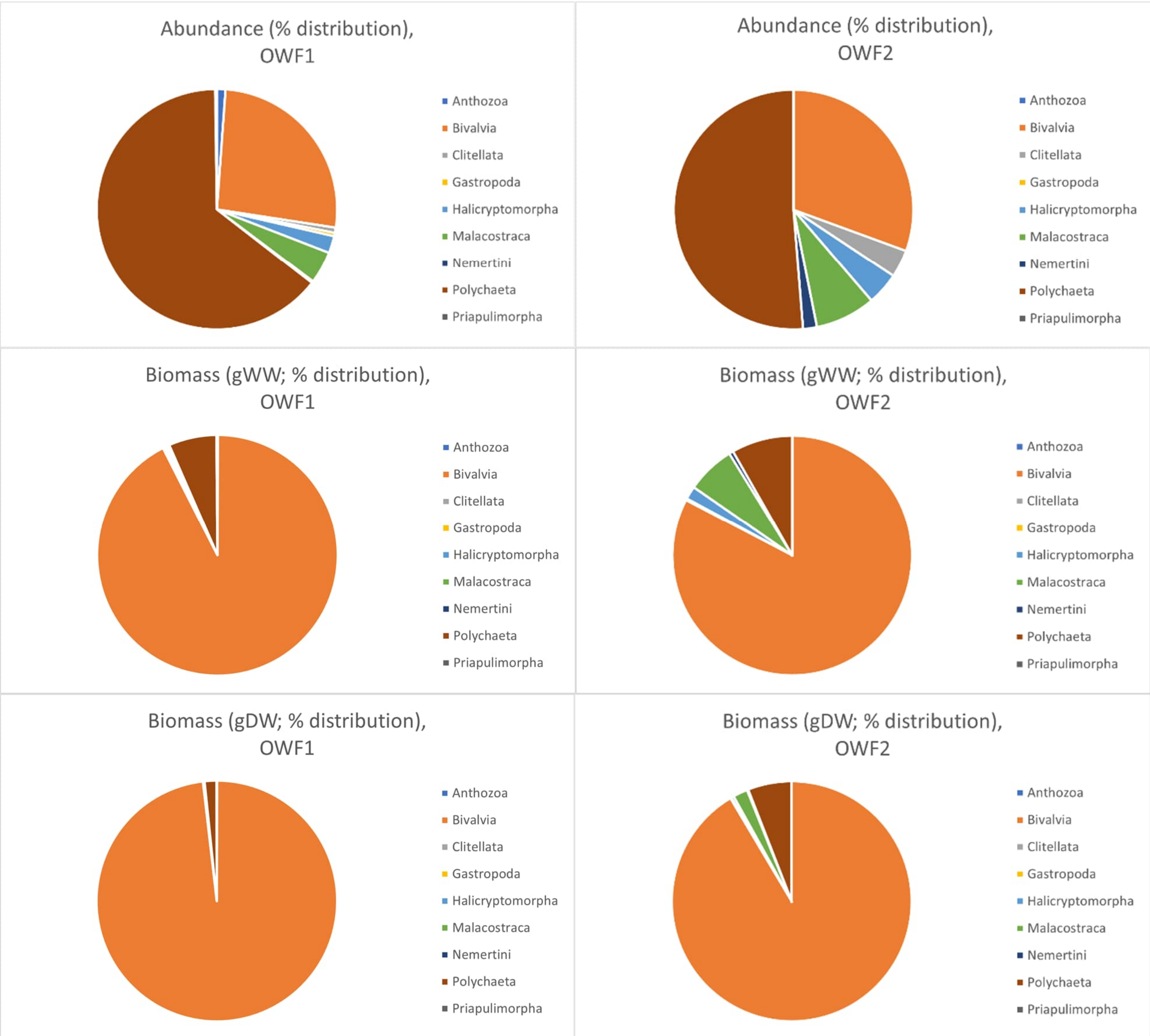


Figure 5-46. Pie charts of infauna classes in Bornholm I (B1N+B1S) and Bornholm II subareas (DW and WW). Distribution (%) of abundance (ind./m^2) and biomass (wet weight (WW) and dry weight (DW) per m^2) of different taxonomical infauna classes found in the OWF1 and OWF2 areas within the pre-investigation area of Energy Island Bornholm. See Figure 5-39 for explanation of the different subareas (CC, CC1, CC2, OWF1, OWF2, SPA and INV).

In the CC area (Figure 5-46), bivalves dominated both abundance (49 %) and biomass (97 %; DW), followed by polychaetes that made up 25 % and 2 % of the abundance and biomass (DW), respectively. In the SPA area, polychaetes dominated abundance (42 %) followed by bivalves (31 %), but bivalves dominated biomass (94 %; DW) and polychaetes only made up 5 %.

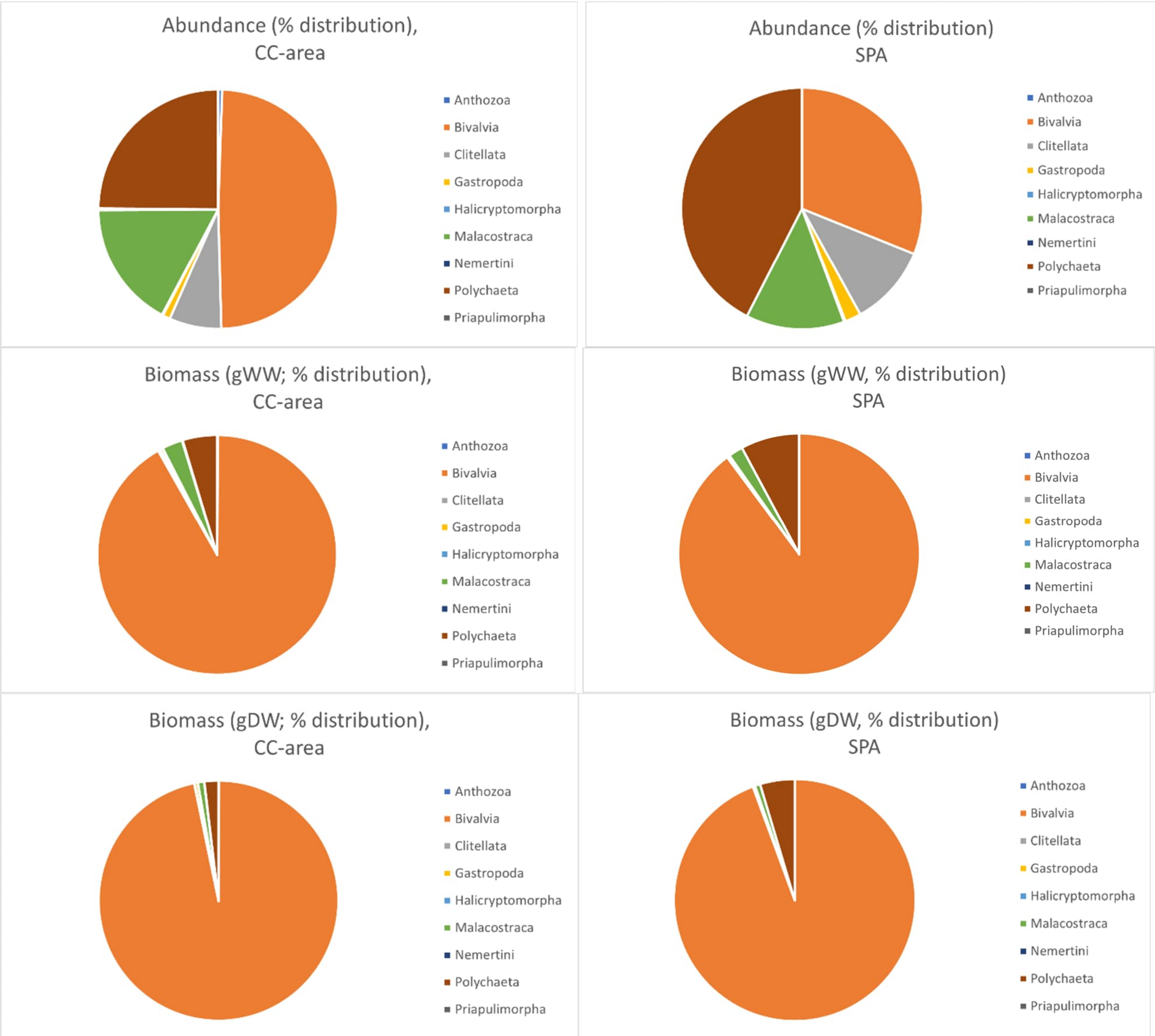


Figure 5-47. Pie charts of infauna classes in CC and SPA subareas (DW and WW). Distribution (%) of abundance (ind./m^2) and biomass (wet weight (WW) and dry weight (DW) per m^2) of different taxonomical infauna classes found in the CC and SPA areas within the pre-investigation area of Energy Island Bornholm. See Figure 5-39 for explanation of the different subareas (CC, CC1, CC2, OWF1, OWF2, SPA and INV).

STATISTICAL ANALYSES

The infauna data (analysed HAPS samples) collected in the pre-investigation areas were applied in varies quantitative- and multivariate statistical analyses described below. For more details on the statistical analyses and results see Appendix 6. Infauna data used for statistical analysis are presented in Appendix 5.

INDICES

The combination of the AMBI and Shannon Diversity indices can be used to describe and to index the state of the environmental condition and can assess whether the infauna community is negatively impacted by eutrophication and oxygen depletion events. A low value of AMBI and high value of H' indicates good environmental conditions and vice versa. Calculation and analysis of the AMBI and Shannon Diversity Index are described in detail in Appendix 6.

Shannon-Wiener diversity index

Species diversity in the pre-investigation area was investigated by the Shannon-Wiener diversity index (H'). The average H' for the whole pre-investigation area including all sampled stations was 0.78 ± 0.56 (Table 5-14). The highest species diversity was observed in the Bornholm I (OWF1 = B1N+B1S)) area (1.07 ± 0.59), followed by the CC area (1.00 ± 0.55), and was lowest in the INV area (0.49 ± 0.55).

Table 5-14. Results from Shannon-Wiener diversity index (H'). See Appendix 6 for methods and result details, including a table showing H' estimated for each station.

Area	H'
CC	1.00 ± 0.55 (0-1.74) Median 1.10
OWF1	1.07 ± 0.59 (0-2.00) Median 1.14
OWF2	0.76 ± 0.49 (0-1.57) Median 0.89
INV	0.49 ± 0.55 (0-1.89) Median 0.15
SPA	0.85 ± 0.49 (0-1.91) Median 0.89
Total area	**0.78 ± 0.56 (0-2.00)** **Median 0.85**

The species diversity in the pre-investigation area given by the Shannon-Wiener diversity index shows that the diversity is within the range found in Danish waters, though lower than the average (ranging between 0.2-3.1 with an average of 1.8 (Hansen & Høgslund, 2023)).

AMBI - condition of community/disturbance

The mean AMBI value for the pre-investigation area was 2.7, and the condition of the benthic community in all five subareas are classified as "unbalanced" and the locations as "slightly disturbed" according to (Borja et. al., 2000) (Table 5-15). In the latest NOVANA reporting for the Danish marine areas 2021, the AMBI index was found between 1.3-5.2 averaging at 2.9 for Danish waters (Hansen & Høgslund, 2023).

Table 5-15. Results from the AMBI-index analysis using (Borja et. al., 2000). The average AMBI and the distribution (%) of the ecological groups (I-V) are listed for the five subareas within the pre-investigation area for Energy Island Bornholm, together with the total pre-investigation area (data from all five areas pooled). The disturbance classification is listed for both the benthic community and the location.

Area	I(%)	II(%)	III(%)	IV(%)	V(%)	Average AMBI	Disturbance classification (community/location)
CC	19	4	70	0	7	2.58	Unbalanced/Slightly disturbed
OWF1 (B1N+B1S)	22.8	12.4	63.6	0.2	0.9	2.16	Unbalanced/Slightly disturbed
OWF2	5.7	1.9	88.7	0	3.7	2.91	Unbalanced/Slightly disturbed
INV	9.5	7.3	78.1	0	5.2	2.76	Unbalanced/Slightly disturbed
SPA	12.5	6.4	69.1	0	12	2.89	Unbalanced/Slightly disturbed
Total pre-investigation area	13.7	5.6	78.8	0	6.8	2.71	Unbalanced/Slightly disturbed

In all the subareas, the dominating ecological group was Group III (generalists tolerant to excess organic matter enrichment) (ranging from 69.1 % to 88.7 %, Table 5-16). The percentage distribution of the ecological fauna groups in the subareas reveal that more Group I species (sensitive to pollution) (22.8 %) are found in the Bornholm I areas (OWF1=B1N+B1S) compared to the other subareas, where only 5.7 % of Group I species were present in Bornholm II (OWF2), where the most widespread oxygen deficiency (<4 mgO_2/l) was also observed.

Table 5-16. Ecological group (AMBI – see Table 1 in Appendix 6) and total abundance (individuals/m^2) of the eight most abundant species in the pre-investigation area for Energy Island Bornholm. Ecological group (AMBI-index) for the species are found using (Borja et. al., 2000).

Taxonomic class	Species	Ecological fauna group (AMBI)	Pre-investigation area (individuals/m^2)
Polychaeta	*Pygospio elegans*	III	93,077
Bivalvia	*Mytilus* spp.	III	61,329
Bivalvia	*Macoma balthica*	III	33,497
Polychaeta	*Scoloplos armiger*	III	19,231
Clitellata	*Oligochaeta* indet.	V	18,951
Malacostraca	*Bathyporeia pilosa*	I	15,734
Bivalvia	*Astarte* sp.	I	7,273
Malacostraca	*Gammarus* sp.	I	6,923

Species belonging to the ecological fauna group I, are species that are very sensitive to organic enrichment and present under unpolluted conditions (initial state). Species in this group include the specialist carnivores and some deposit feeding tubicolous polychaetes. Species belonging to the ecological fauna group II are species that are 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. Species in the ecological fauna group III are generalists that are tolerant to excess organic matter enrichment. These species may occur under normal conditions, but their populations are stimulated by organic enrichment (slight unbalanced situations). These species are surface deposit-feeders, e.g. tubicolous spionids such as *Pygospio elegans,* which dominated the species abundance in the pre-investigation area (Table 5-16).

INDICES - SUMMARY OF RESULTS

The average H', as indication for species diversity, was below average for Danish waters for all subareas in the pre-investigation area for Energy Island Bornholm. The highest species diversity index (H') was observed in the Bornholm I (OWF1=B1N+B1S) area (1.07) and lowest in the INV area (0.49). 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. Here, we have samples from a large geographical area within each subarea, and we would therefore expect that physical and environmental parameters differ within each area. Thus, the results from the Shannon-Wiener diversity index are just an indication of the species diversity in the subareas and the total pre-investigation area, and results should therefore be interpreted with care.

The AMBI index classified the infauna community and location as "unbalanced" and "slightly disturbed", respectively in all areas within the pre-investigation area for Energy Island Bornholm. The average AMBI index found in the pre-investigation area using all data was 2.7, and comparable with the average AMBI index found in Danish waters (2.9). The dominating ecological fauna group was group III, which are defined as generalist species that are tolerant to excess organic matter enrichment.

MULTIVARIATE STATISTICAL ANALYSES

Multi-Dimensional Scaling (MDS; based on Bray-Curtis similarity index), Analysis of Similarity (ANOSIM) and SIMPER analysis were applied to analyze species composition, abundances and biomass, similarity and dissimilarity between stations in the different subareas (B1N, B1S, OWF1, OWF2, CC, SPA and INV) and at different depth intervals (divided into 10 meter depth intervals). Note that similarity is within each subarea and each depth interval, respectively (variance within the subarea or interval). Whereas the dissimilarity is the difference between the subareas and depth intervals (comparison of variance between subareas and depth intervals). Below, the main results are reported. MDS plots are shown from the analyses conducted with the abundance data, as the results conducted on the biomass data show similar results. Further details on methods and results can be seen in Appendix 6 – Statistical analyses of infauna.

Species composition and abundance/biomass in relation to area

The MDS plot shows some overlap of the infauna communities and abundances between the subareas especially B1N and B1S (Figure 5-48). However, an ANOSIM between the stations in the subareas showed that there was a significant difference between composition and abundance of the infauna communities when comparing all the subareas (p=0.001), though with a low strength (Global R) of the analysis (R=0.325). Furthermore, the ANOSIM revealed that there was a significant difference of composition and abundance of infauna communities between B1N and B1S (p=0.04), however with a weak R-value of 0.164, indicating a low degree of separation between the infauna communities in the two subareas, which both can indicate a high variation in the infauna communities between stations within each subarea and/or a high variation in infauna communities between the subareas.

A low degree of separation means that the separation is too small to be relevant. In relation to this, the SIMPER analysis (testing similarities within and dissimilarities between subareas, respectively), revealed that there was a similarity of 31.65 % between stations within B1N and 39.16 % between stations within the B1S area. The dissimilarity in the composition and abundance of the infauna communities between B1N and B1S was 72.48 %, and the SIMPER analysis lists seven species, that together explain 73.20 % of the dissimilarity between the two subareas. All seven species were present in both areas (e.g., *Scoloplos armiger, Limecola balthica* and *Astarte* sp.), which shows that the same species dominated the two subareas. The differences in abundances of the same species between the two subareas were, therefore, the reason for the high dissimilarity found.

Thus, the two subareas B1N and B1S have been pooled into one area OWF1 (Figure 5-49). The MDS plot for biomass data showed a similar grouping and can be found in Appendix 6, Figure 7.

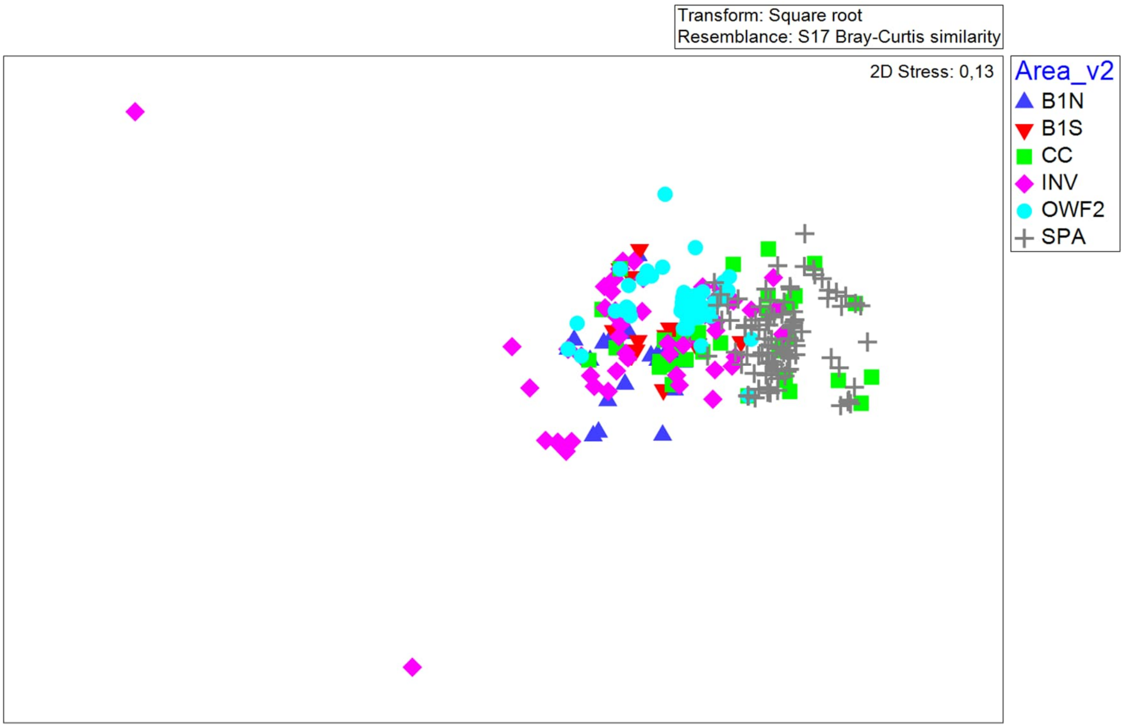


Figure 5-48. MDS plot of subareas excl. three outliers (see Appendix 6 for details). The MDS plot visually illustrates similarities and dissimilarities regarding infauna species composition and abundance within the pre-investigation area for Energy Island Bornholm (B1N, B1S, CC, INV, OWF2 and SPA). The Bray-Curtis Similarity Index displayed in the MDS plot is based on square-root transformed data from the species composition and abundance. If two stations (samples) are similar, they will be in the same position in the plot.

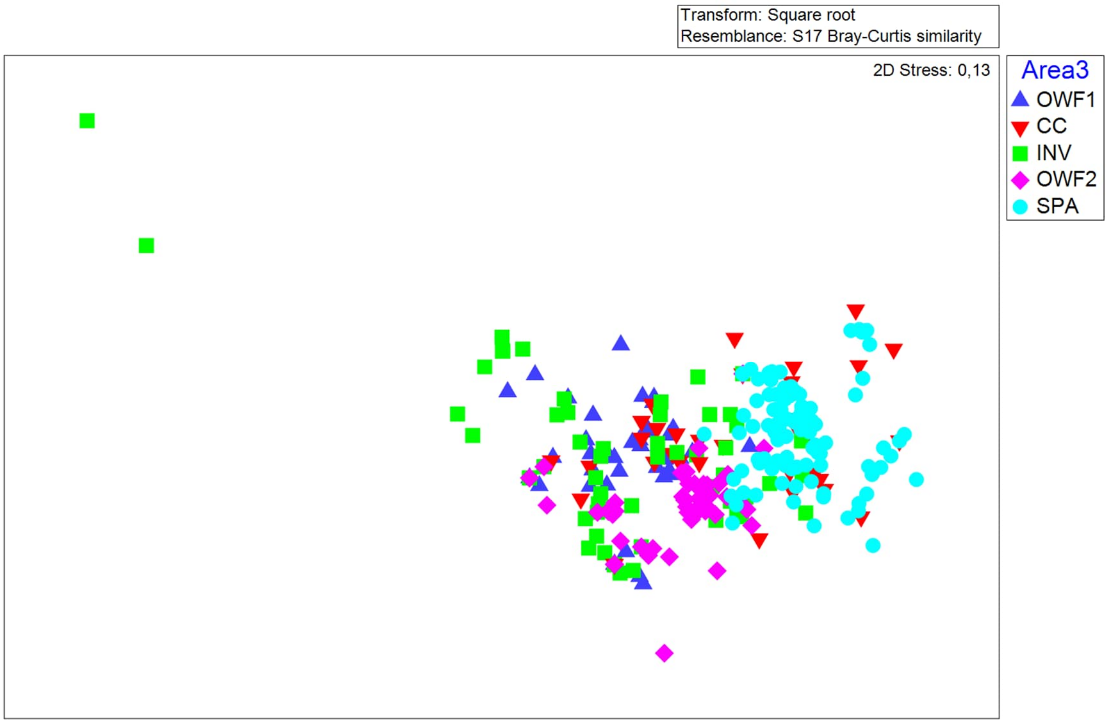


Figure 5-49. MDS plot of subareas incl. OWF1 (= merger of B1N and B1S). The MDS plot visually illustrates similarities and dissimilarities regarding infauna species composition and abundance within the pre-investigation area for Energy Island Bornholm (OWF1, CC, INV, OWF2 and SPA). The Bray-Curtis Similarity Index displayed in the MDS plot is based on square-root transformed data from the species composition and abundance. If two stations (samples) are similar, they will be in the same position in the plot.

The MDS plots (Figure 5-49 for abundance data; see Appendix 6) indicate that the infauna community abundance was different between the SPA/CC and OWF1/OWF2/INV area. This difference is caused by a higher area coverage of hard sediment types and, thus, blue mussels (=high biomass) in the SPA/CC subareas and the other subareas being dominated by soft sediment types and, thus, lower coverage of blue mussels (=lower biomass). The associated SIMPER analyses showed low similarities of infauna communities within each subarea and high dissimilarities between subareas. This was likely caused by sampling within a large, varied, geographical area, and thus, large variance in sediment type and depth within each subarea and between subareas.

In summary, the dissimilarities observed between subareas (B1N, B1S, OWF1, OWF2, CC, SPA and INV) were related to abundance and biomass differences between areas and not to species composition, as the species explaining the dissimilarities were generally the same in all the subareas.

Species composition and abundance/biomass in relation to depth intervals

It was evident that there were overlaps between composition and abundance/biomass of infauna communities in adjacent 10-meter depth intervals (Figure 5-50 in this report and Figure 8 in Appendix 6). The MDS plots furthermore indicate that there was a gradient of the grouping from lowest depths towards infauna communities at deeper depths (from right towards left in the plot).

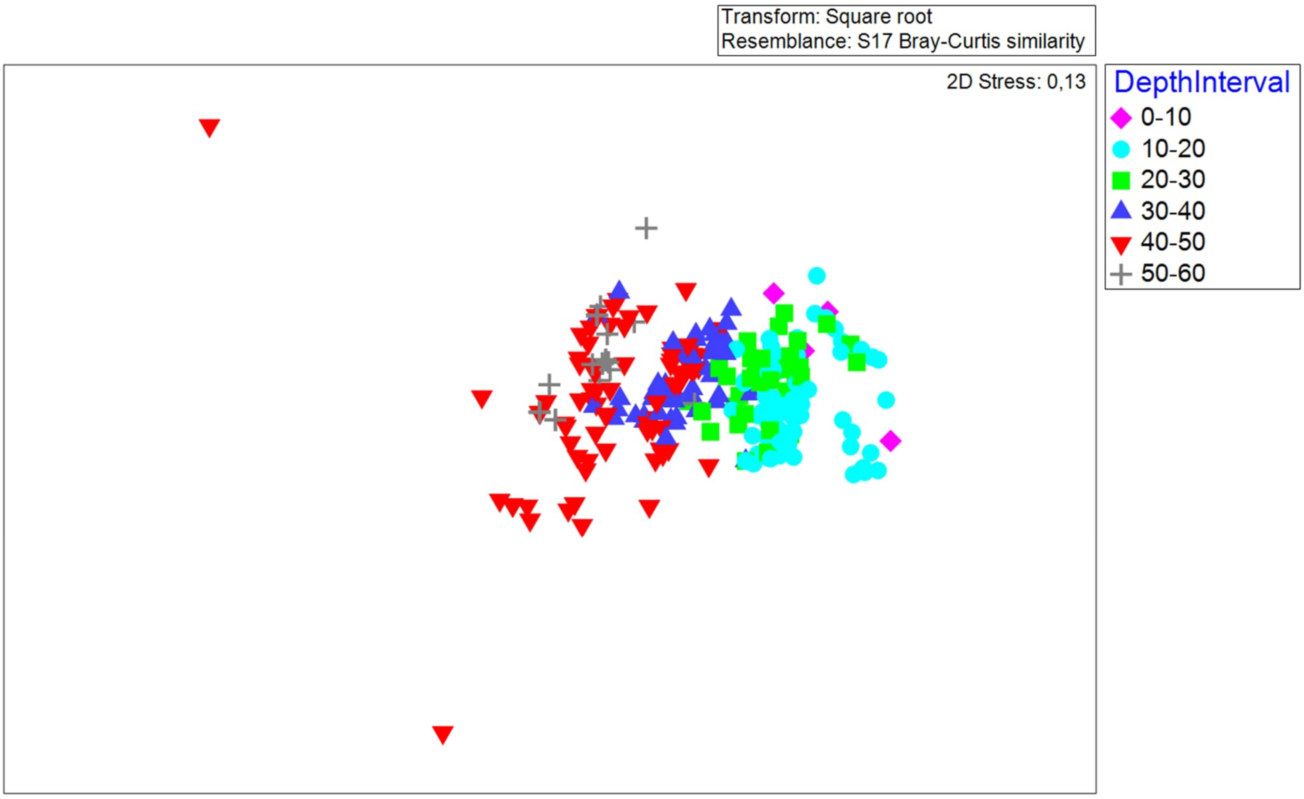


Figure 5-50. MDS plot for 10-m depth intervals based on abundance. The MDS plot visually illustrates similarities and dissimilarities regarding infauna species composition and abundance within the pre-investigation area for Energy Island Bornholm in relation to depth. The Bray-Curtis Similarity Index displayed in the MDS plot is based on square-root transformed data from the species composition and abundance at six different 10-m depth intervals. The three outlier stations are excluded. If two stations (samples) are similar, they will be in the same position in the plot.

A SIMPER analysis of similarities and dissimilarities between the 10-meter depth intervals between the subareas showed that the highest dissimilarity of the infauna community composition and abundance/biomass was observed between samples taken at the 0-10 meter and 50-60 meter-depth intervals. This high difference in infauna communities between the shallowest (0-10 m) and deepest samples (50-60 m) were likely caused by i) differences in sediment type (hard substrate><soft sediment), ii) TOC content, as TOC generally increases with depth and finally iii) more stations with moderate and significant oxygen deficiency at the deep soft sediment stations (sediment type 1a) (see section 5.1.2), which corresponds to very different living conditions for infauna between shallow and deep stations.

WIND FARM AREAS

The distribution of taxonomical classes was very similar between the two subareas of the Bornholm I wind farm area - B1N and B1S, where polychaetes dominate in terms of abundance and bivalves in terms of biomass (Figure 5-45), and due to similarities in infauna composition between these two subareas (see also Appendix 6 - Multivariate statistical analyses), data was pooled into one area "OWF1" (=B1N+B1S). Similarly, as in OWF1, polychaetes were the dominating infauna group in terms of abundance in OWF2, whereas bivalves dominated in terms of biomass (Figure 5-46). Species composition varied between the two OWF areas, though some species were present in both OWF1 and OWF2 (Figure 5-42). In OWF1, the five most dominating species in terms of abundance, were the bristle worm (polychaete) *Scoloplos armiger*, the bivalve *Limecola balthica*, the bristle worm *Pygospio elegans*, the bivalve *Astarte* sp. and the bristle worm *Aricidea suecica*. In OWF2, the five dominating species were the bristle worm *Pygospio elegans*, the bivalve *Limecola balthica,* the marine worm *Halicryptus spinulosus,* the worm *Oligochaeta* indet. (identified to subclass), and the crustacean *Diastylis rathkei* (Figure 5-42).

The total number of infauna species found in the OWF1 area was 30, with an average of 4.1 species per station, whereas the total species number in the OWF2 area was 16 with an average of 3.1 species per station.

Infauna average abundances were similar in the Bornholm I (OWF1) and Bornholm II (OWF2) areas, whereas average biomass (DW) was eight times higher in OWF1 compared to OWF2 (Table 5-11). Especially stations situated towards the Rønne Banke/SPA area, showed higher abundances both in OWF1 and OWF2 (Figure 5-40), where sediment primarily consists of sand or quaternary clay and silt and where good oxygen conditions are prevalent (Figure 5-41). The same pattern was observed for biomass for OWF1, whereas stations within the OWF2 area in general had lower biomasses than stations within OWF1 corresponding to more wide spread oxygen deficiency (<4 mgO_2/l) in the Bornholm II area (Figure 5-43 and Figure 5-44) (see section 5.1.2 – Salinity, temperature and oxygen concentration).

Species diversity (Shannon-Wiener diversity index, H') was highest in OWF1, compared to the other subareas, and lowest in OWF2 (Table 5-14). In both OWF areas, the AMBI index classified the infauna community and location as "unbalanced" and "slightly disturbed", and the dominating ecological group was group III (generalists tolerant to excess organic matter enrichment) (Table 5-15). OWF1 had the lowest AMBI value and the highest contribution of species in the ecological fauna group I, which are defined as species that are sensitive to disturbance/eutrophication, and present under unpolluted conditions. OWF2 had the highest AMBI values (i.e. worst condition of all subareas) and lowest contribution of ecological fauna group I and the highest contribution of ecological fauna group III, relative to the other areas. The lower species diversity and higher AMBI index in OWF2 are likely due to high TOC content in the sediment and most widely spread oxygen deficiency (<4 mgO_2/l) in OWF2 compared to the OWF1 and CC area.

CABLE CORRIDORS

In the CC area, bivalves dominated both abundance and biomass, followed by polychaetes (Figure 5-47). The five most dominating species in terms of abundance were the bivalve *Mytilus* spp. (blue mussels), the bristle worm *Pygospio elegans,* the amphipod crustacean *Gammarus* sp., the crustacean *Bathyporeia Pilosa* and the worm *Oligochaeta* indet. (identified to subclass) (Figure 5-47).

In total, 29 species was found in the CC area, with an average of 4.5 number of species per station.

There was a wide range in abundance between stations within the cable corridor area (CC), where one station had an abundance of 39,860 ind./m^2 (CC_2) and the average abundance for all stations was 2,736 ind./m^2 - the highest average abundance of all areas. The average biomass was similar to OWF1, where the highest average biomass for all stations was found (Table 5-11).

Species diversity (Shannon-Wiener diversity index, H') in the CC area (1.00) was on the same level as in OWF1, where the highest H' was found (Table 5-14). The AMBI index classified the infauna community and location in the CC area as "unbalanced" and "slightly disturbed", but with a lower AMBI index than the overall average for the whole pre-investigation area (Table 5-15). The dominating ecological group in the CC area was group III (generalists tolerant to excess organic matter enrichment), but there was also a relative high contribution of ecological fauna group I, which are defined as species that are sensitive to disturbance/eutrophication, and present under unpolluted conditions.

5.6 BIRD FOOD PROGRAM

5.6.1 BACKGROUND

This section gives an overview of the distribution of known food items for birds and especially long-tailed duck (*Clangula hyemalis*) in the pre-investigation area.

The Danish Environmental Agency has appointed a number of new Special Protection Areas for birds (SPAs) under the Habitats Directive (Miljøstyrelsen, 2023c).

Relevant for Energy Island Bornholm is a new Bird SPA (Rønne Banke F129/DK00FC373) in the Natura 2000 site no. 252/H261 "Adler Grund og Rønne Banke". The SPA site is placed on Rønne Banke in the middle of the pre-investigation area between the two wind farm areas (Figure 2-1). This SPA is designated to protect one bird species - long-tailed duck. The Natura 2000 impact assessment of the plan for Energy Island Bornholm, therefore, has to include an impact assessment for the Bird SPA F129 and long-tailed duck.

This technical report therefore includes maps that gives an overview of the distribution of bird food organisms in the pre-investigation area for long-tailed duck. The distribution maps are based on the comprehensive sampling program conducted in the pre-investigation area to map and describe benthic fauna - both epifauna (ROV stations) and infauna (Infauna stations) in this baseline study. The full sampling program conducted for this baseline study is described in section 3.1 – Sampling program. Furthermore, extra sampling (ROV and infauna station) was done to sufficiently map benthic fauna/bird food organisms in the SPA area (F129) and the pre-investigation area. The details of this program are given in section 3.1.3 – Sampling in different areas/ Bird food program (page 25).

The preferred food sources of long-tailed duck were investigated in a study from the period 2016 to 2018 by DCE – National Center for Environment and Energy (Aarhus University) in cooperation with the Danish Hunters Association and the Danish Environmental Agency (Petersen et al, 2019). This study by Petersen et al. (2019) concluded that long-tailed duck generally is rather opportunistic and feeds on different bivalves, snails, bristle worms (Category "Others" in Figure 5-51), crustaceans and small fish (Figure 5-51 and Table 5-17). Long-tailed duck can dive to a depth of 100 meters while foraging, thus all depths in the SPA site and the pre-investigation area are, therefore, possible foraging areas for the birds. Samples and stations have therefore been distributed at all depth intervals to describe bird food organisms in the pre-investigation area.

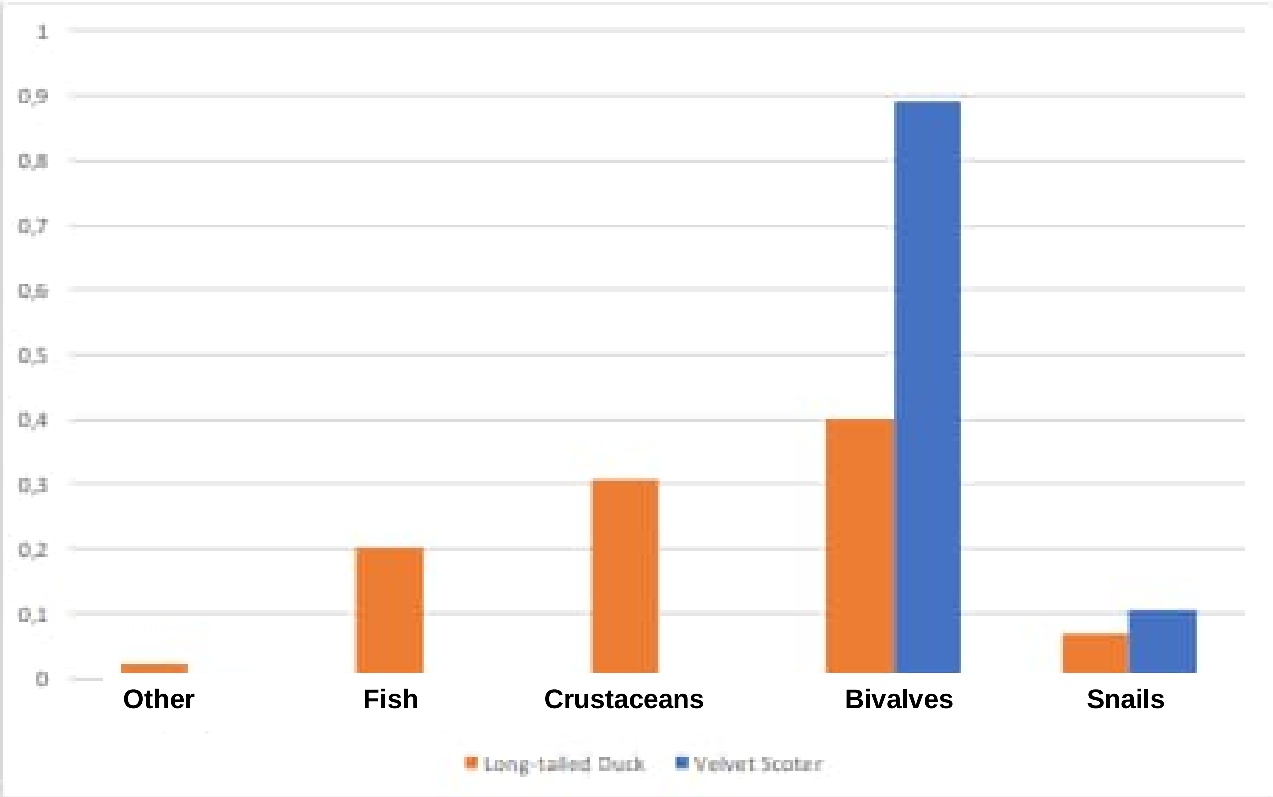


Figure 5-51. The frequency of individuals with specific food organisms listed by food organism group. Food organisms found in stomach of long-tailed duck and velvet scooter. Source: (Petersen et al, 2019).

Table 5-17. Ingested prey from 34 velvet scoter (*Melanitta fusca*) and 40 long-tailed duck (*Clangula hyemalis*). *Species found in the gizzard/esophagus of both species. Source: (Petersen et al, 2019).

Bird species/ Infauna food group (class)	*Clangula hyemalis* (Long-tailed duck)	*Melanitta fusca* (velvet scoter)
Crustacea (crustaceans)	*Crangon crangon* *Palaemon adspersus* *Balanidae sp.* *Idotea granulosa* *Carcinus maenas* *Gammarus* sp.	-
Bivalvia (bivalves)	*Chamelea striatula** *Cerastoderma edule* *Mytilus edulis* *Corbula gibba** *Modiolus modiolus* *Musculus subpictus* *Spisula* sp.	*Chamelea striatula** *Nucula nitidosa* *Venerupis corrogata* *Corbula gibba** *Arctica islandica*
Gastropoda (snails)	*Littorina littorea* *Nassarius reticulatus** *Rissoa parva*	*Turritella communis* *Nassarius reticulatus** *Polinices pulchellus*

Bird species/ Infauna food group (class)	*Clangula hyemalis* (Long-tailed duck)	*Melanitta fusca* (velvet scoter)
	Hyala vitrea *Ancylus fluviatilis* *Bittium reticulatum* *Hydrobia ulvae*	*Euspira catena* *Rissoa membranacea*
Asteroidea (Starfish)	*Asterias rubens*	-
Polychaeta (bristle worms)	*Bristle worms* spp. *Scoloplos armiger*	*Nereis* sp.
Chordata (fish)	*Syngnathus typhle* *Myoxocephalus Scorpius* *Pomatoschistus microps* *Gobiusculus flavescens*	-

We have therefore included maps of the main food groups from the survey area. This includes maps of the biomass of bivalves (excl. blue mussels), bristle worms, crustaceans and snails from the stations in the pre-investigation area (see Figure 5-52 and Figure 5-53). Furthermore, the distribution of blue mussel (*Mytilus* spp.) as area coverage (%) from ROV stations and the area coverage of nature type 6 - Blue mussel beds have also been included (high coverage 30-100 %) and sediment type 1b (medium coverage <1-15 %) (see Figure 5-52).

Fish are not represented in this report as this is reported under another work package (WP-I Fish and fish populations).

5.6.2 RESULTS

The bird food sources in the pre-investigation area were dominated by blue mussels, which had high coverages and standing biomass, especially in the hard sediment type areas (sediment type 2, 3 and 4), where blue mussel coverage on larger stones were up to 100 % (see Figure 5-52).

Highest **blue mussel** coverage/biomass was found from >10 meters of depth as macroalgae in general dominated the coverage of rocks at lower depths (0-10 m). However, blue mussels also observed under the macroalgae (where possible) at these depths, even if not visible on ROV video due to the dense coverage of the macroalgae. Furthermore, blue mussels are also found on dynamic sandbeds with relative low coverage (<1-15 %) as small ballistic, mobile balls/clusters consisting of blue mussel communities that are transported along the sandbed with the current (nature type 1b and sediment type 1b) (see Figure 5-33). This mobile blue mussel form is given as coverage % for ROV videos in Figure 5-52 but not as a nature type. This blue mussel life-form is mainly found in sediment type 1b and is included in Figure 5-52 below (see Figure 5-10).

The biomass of blue mussels could not be realistically quantified in HAPS samples, as these samples are collected on sand/soft sediment with low coverage of blue mussels. Highest coverage of blue mussels is on hard substrates such as boulders and sedimentary rock, which were not sampled for biomass. The distribution of blue mussels is therefore shown on the map in Figure 5-52 as:

- area coverage (%) observed on the seabed at ROV stations (circles),
- as the coverage of nature type 6 “Blue mussel beds with high mussel coverage of 30-100 %, based on the area coverage of the hard sediment types – sediment type 3 and 4.
- As coverage of nature type/sediment type 1b sand bottom community where the mobile blue mussel clusters were most prevalent and with generally low coverage of <15 %.

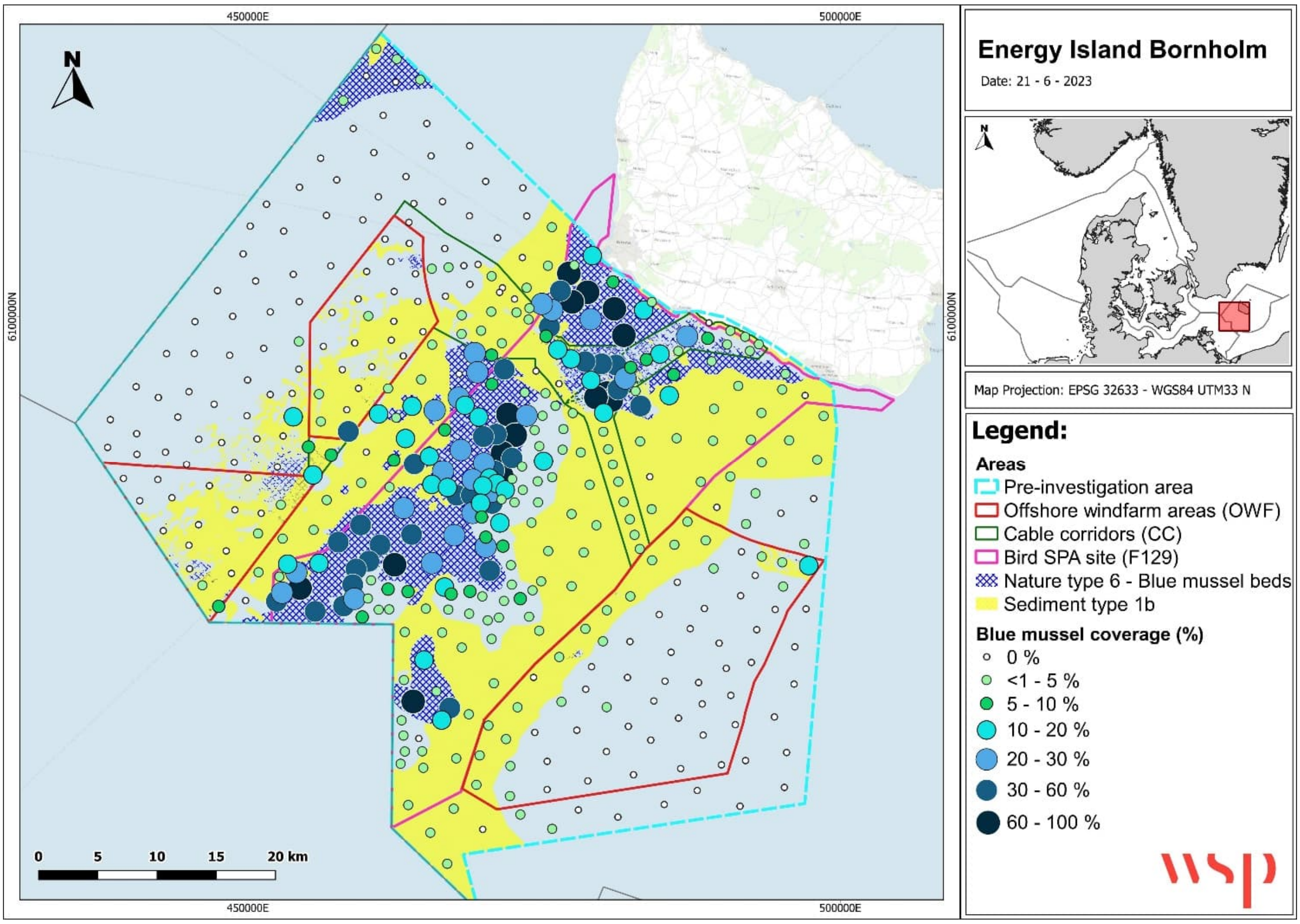


Figure 5-52. Map of blue mussel distribution in the pre-investigation area at ROV stations and as nature type 6 – Blue mussel beds, which are based on distribution of hard sediment types (Sediment type 3 and 4). Blue mussel (*Mytilus* spp.) overall coverage in the pre-investigation area without station numbers (see next figure for station numbers). Overall coverage % is the coverage of the total video view of the seabed often given as a range in the logbooks in Appendix 3. The maximum coverage % in the range is shown in this figure.

The map in Figure 5-52 illustrates that blue mussels are the most abundant, available food source in the pre-investigation area for birds and long-tailed duck, as blue mussels are present in highest numbers in the SPA area. This is also illustrated in the pie charts of the distribution of infauna classes in the subareas within the pre-investigation area (see Figure 5-54).

Other food sources for long-tailed duck in the pre-investigation area include other bivalves (excl. blue mussels in Figure 5-53), bristle worms, crustaceans and snails. The distribution of these fauna classes in the pre-investigation area is shown in maps in Figure 5-53 and as pie charts in Figure 5-54 below.

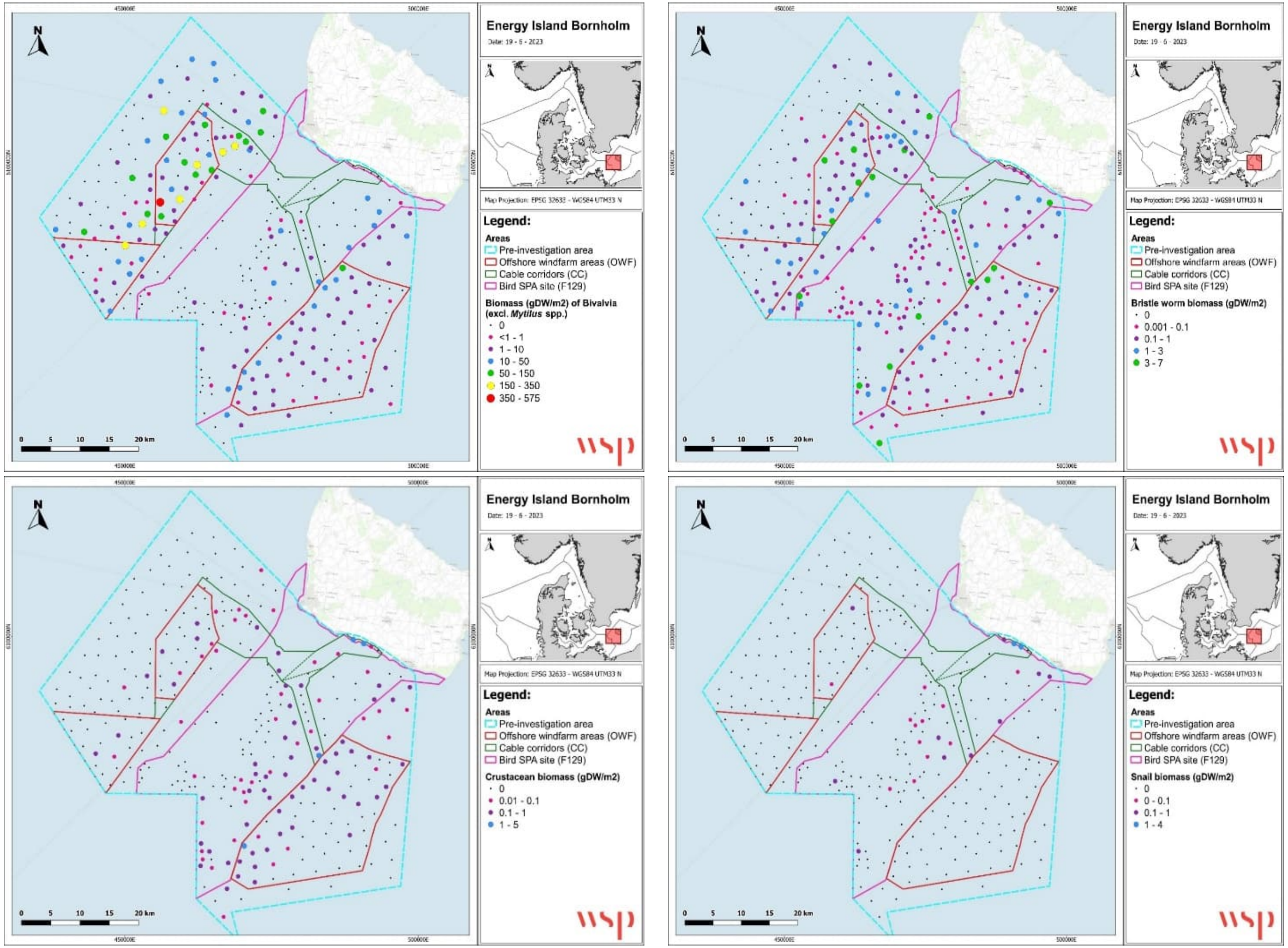


Figure 5-53. Biomass maps of bivalves (excl. blue mussels) (upper left), Bristle worms (upper right), Crustaceans (lower left) and Snails (lower right) (gDW/m^2). Data are shown for all stations in Appendix 5C – Bird food program. Station numbers are given in Appendix 2.

Bivalves (excl. blue mussels) have by far the highest biomass of these fauna classes (0-575 gDW/m^2) and has the highest biomasses in the western part of the pre-investigation area, where the two Bornholm I subareas are located. The dominating bivalves according to biomass were *Astarte* sp. followed by *Limecola balthica* (*Macoma balthica*), *Arctica islandica*, *Cerastoderma glaucum* and *Mya arenia* (see section 5.5.2 – Infauna). In the pie charts, the class bivalves (excl. blue mussels) dominate the biomass in all subareas except the SPA area, where blue mussels dominate (Figure 5-54). However, blue mussel abundance cannot be determined adequately from biomasses, as HAPS sampling does not quantify this species correctly (underestimates), which is due to this species being most dominant on hard sediment, which cannot be sampled by HAPS sediment core sampling.

All other food sources such as bristle worms, crustaceans and snails had low biomasses between 0-7 gDW/m^2 (see Figure 5-53 and Appendix 5C). See full species list in Appendix 5A.

Bristle worms dominated by the species *Pygospio elegans, Marenzellaria viridis, Scoloplos armiger and Hediste diversicolor* (in total 20 bristle worm species) were found in soft sediments (sediment type 1b and 1a) throughout the pre-investigation area, with lowest or no biomass at the deepest stations, where oxygen deficiency was also observed (see section 5.1.2 – Salinity, temperature and oxygen concentrations). This class did not dominate the biomass in any of the subareas.

Crustaceans dominated by *Gammarus* sp., *Bathyporeia Pilosa*, *Diastylis rathkei* and *Pontoporeia femorata* (in total 11 species) were found in the shallower part of the pre-investigation area and generally not deeper than the wind farm areas, as oxygen deficiency was observed at some deeper stations. This class did not dominate biomass in any of the subareas.

Snails were dominated by mudsnail (*Hydrobia ulvae*) followed by *Theodoxus fluviatilis var. Balthica* and very few *Pusillina sarsii* (all observed snail species) and were found mainly in the SPA area. Mudssnail was the most common species, however, this species is quite small (up to 6 mm, (Køie & Kristansen, 2014)) and their value as important food organisms for the birds is questionable. However, mudsnail has been found in larger numbers in the area in the baseline studies for NSP2 (see section 4.5.2 – Existing data/Infauna) and in the stomach of long-tailed duck (see Table 5-17). This class did not dominate biomass in any of the subareas.

Figure 5-54. Class distribution of infauna biomass in g dry weight (DW)/m^2, where the bivalve species blue mussels *(Mytilus* spp.*)* is separated from "Bivalvia" (orange color in pie charts) and included as its own group (dark blue color in pie charts). See Figure 5-39 for explanation of the different subareas (CC, CC1, CC2, OWF1, OWF2, SPA and INV).

In conclusion, the most abundant food source available for long-tailed duck in the pre-investigation area is, therefore, blue mussels and other bivalves, which are dominant and with highest biomasses in the SPA area and in the western part or the pre-investigation area, where the two Bornholm I areas (B1N and B1S) are located, respectively. Thus, the pre-investigation area provides a wide feeding area for long-tailed duck and other birds, with the main part of the food available for the birds consisting of dense coverages of blue mussels (up to 100 %) within the SPA area.

6 CONCLUSION

This report provides a comprehensive and detailed baseline study for seabed sediments, benthic flora and fauna in the pre-investigation area for Energy Island Bornholm.

The basis of this study is comprised by a large sampling program and data material exceeding those used in the existing baseline studies for the big pipeline projects in the area (Baltic Pipe and North Stream 2).

This study has been conducted in a large pre-investigation area for Energy Island Bornholm between the southern coast of Bornholm and the Swedish and German EEZ. The pre-investigation area includes two offshore wind farm areas e.g., Bornholm I and Bornholm II. Bornholm I has been subdivided into two separate windfarm areas i.e. Bornholm I North and Bornholm I South (see Figure 2-1).

The sediment types in the pre-investigation area are very varied and the content of organic matter (TOC) increases with depth. Sand (sediment type 1b) and sedimentary rock (sediment type 4 and 3) dominates in the cable corridors and bird SPA area, and at the deepest stations silt and muddy sediment dominate (sediment type 1a). Observed sediment types differed between the two windfarm areas Bornholm I (North and South) and Bornholm II. Bornholm II had higher area coverage of muddy sediments (sediment type 1a) and the Bornholm I areas had higher area coverage of rocky sediment types (sediment type 2, 3 and 4) and silt in the deepest half of the two subareas (B1N and B1S). The sediment types determine the distribution of benthic communities and, thus, hard bottom communities have higher area coverage in the cable corridors, bird SPA area and Bornholm I subareas, and soft bottom communities dominate the Bornholm II area.

Abiotic data showed mixing and full oxygenation of the water column over the shallow Rønne Banke area and stratification of the water column in the deeper parts (>30 m) along with moderate (2-4 mgO_2/l) and severe oxygen deficiency (<2 mgO_2/l) at some stations at depths deeper than 41 m. Severe oxygen deficiency that cause death of benthic flora and fauna was observed at one station in the Bornholm II area (OWF2_22) at 57.4 meters of depth. Moderate oxygen deficiency was observed in most of the Bornholm II area but was only observed at one station in the Bornholm I area. Oxygen deficiency was not observed in the cable corridor area. The more widespread oxygen deficiency observed in the Bornholm II area compared to the Bornholm I areas is likely coursed by depth differences, with the Bornholm II wind farm area being deeper with a larger part of the area with depths below 41 m and more silty sediment.

Chemical analyses of sediment samples from the pre-investigation area show that 11 pollutants (heavy metals (4), PAH-compounds (6) and organotin-compounds (1)) were found exceeding the applied threshold values in the pre-investigation area at 92% of the sampled stations (HAPS Chem stations). Most exceedances of pollutants were found at >34 meters of depth, in sediment type 1a containing silt, mud and clay as pollutants generally adsorb to fine-grained, organic-rich material and accumulate with depth (Strand & Larsen, 2013). This is likely also the reason for more observed exceedances of threshold values for pollutants in the Bornholm II wind farm area compared to the Bornholm I subareas (B1N+B1S) and the cable corridors.

Observed benthic flora and fauna species and communities are all common for the Sound and the Southwestern part of the Baltic Sea and observed with similar dominating species, benthic communities and area coverage as reported in the existing baseline studies (Baltic Pipe, North Stream 2), Natura 2000-baseline analyses and at NOVANA stations in the area.

The highest species numbers, area coverage (%) and biomass of both benthic flora (macroalgae) and benthic fauna (epifauna and infauna) were generally found where hard sediment types (sediment type 2,3 and 4; larger stones >10 cm and rock) were present corresponding to areas with the most varying sediment types and to the shallower parts of the pre-investigation area (Rønne Banke area). Data show similar epifauna and infauna species composition in the wind farm areas, only area coverage of the species varied. Very little macroalgae coverage (<1-1 %) was found in the Bornholm I wind farm subareas and none in the Bornholm II wind farm area.

Species diversity (H') based on infauna data in the pre-investigation area incl. all subareas was low compared to the average for Danish waters. According to the AMBI index (Borja et. al., 2000), the infauna community is classified as "unbalanced" and the locations as "slightly disturbed".

The dominating macroalgae, epifauna and infauna species in the pre-investigation area are generalists that are able to recolonize a disturbed area within a few years (<1-5 years). This is based on the observed macroalgae, e.g. red algae bushes and large brown algae in the area, which can recolonize boulders within one to a few years (Femern Sund og Bælt, 2013). Bristle worms in the pre-investigation area have a relatively short life cycle/generation time and is expected to recolonize after one or two growth seasons (Femern Sund og Bælt, 2013). The observed bivalve species live longer and recolonization to baseline coverage will take longer. Baltic macoma (*Limecola balthica* formerly known as *Macoma balthica*) and blue mussels (*Mytilus edulis*) have a generation time of approximately 2-4 years, while Sand gaper (*Mya arenaria*) and common cockle (*Cerastoderma edule*) have generation times of approximately 2-5 years (Femern Sund og Bælt, 2013). Barnacles (based on *Semibalanus balanoides*) have a generation time of approximately 1-2 years (MarLin, 2022).

None of the observed species of benthic flora and fauna in the pre-investigation area are considered threatened (Critically Endangered, Endangered or Vulnerable) according to the HELCOM red list (HELCOM, 2023a). The two brown algae species *Fucus serratus* and *Fucus vesiculosus* and the red algae species *Furcellaria lumbricalis* are, however, listed as Least Concern (LC). The infauna species *Pontoporeia femorata* is on HELCOMs Red List and is listed as of Least Concern (LC) (HELCOM, 2023b). *Pontoporeia femorata* was found in both the INV area (at 4 stations) and the OWF2 area (at 11 stations).

In relation to the Danish Water Framework Directive (WDF) no live eelgrass was observed in this baseline study. Depth limit of eelgrass is used to assess the ecological status of coastal waters under the WFD along with other quality elements. The objective of the WFD is to achieve good ecological status in surface and ground waters of the EU member states. The objectives of the WFD are implemented through the Danish water management plans and related legislative acts. For the current River Basin Management Plan (RBMP) covering the period 2021-2027, the depth limit of eelgrass is targeted at 7.5 meters in the River Basin Østersøen (Baltic Sea), Bornholm DKCOAST56, defining the threshold between moderate and good ecological status (Miljøministeriet, 2023).

A new Danish bird protection area (SPA site, F129) is placed in the middle of the pre-investigation area between the two wind farm areas. The SPA is designated to protect one bird species - long-tailed duck. The distribution of known food organisms for birds and especially long-tailed duck (*Clangula hyemalis*) was, therefore, investigated in the pre-investigation area. A comprehensive program was conducted mapping the distribution of bivalves, blue mussels, crustaceans, bristle worms and snails, which are preferred food organisms for long-tailed duck. The mapping showed that the most abundant food source available for long-tailed duck in the pre-investigation area is blue mussels and thereafter other bivalves (such as *Astarte* sp. followed by *Limecola balthica* (*Macoma balthica*), *Arctica islandica*, *Cerastoderma glaucum*), which are dominant in the SPA area and in the western part or the pre-investigation area, where the two Bornholm I areas are located. Other food sources such as bristle worms, crustaceans and snails occurred in low biomasses in the pre-investigation area.

Thus, the observed benthic communities of benthic flora and fauna in the pre-investigation area for Energy Island Bornholm are very common for the Southwestern Baltic, widely distributed, with generations times of <1-5 years and with a high recolonization potential from the surrounding similar populations.

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8 APPENDICES

See separate Appendices document.