Horns Rev Offshore Wind Farm

Environmental Impact Assessment
of
Sea Bottom and Marine Biology

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01.03.2000

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Summary

An Environmental Impact Assessment (EIA) of a planned 150 MW offshore wind farm at Horns Rev has been carried out for the marine biology and sea bottom in the area, and includes vegetation and benthic fauna. The study forms part of a total EIA of the planned offshore wind farm.

This EIA study has been drawn up in accordance with the guidelines laid down by the Ministry of Environment and Energy in the publication, "Guidelines for preparation of EIA-studies for offshore wind farms."

Horns Rev is situated off Blåvands Huk, which is Denmark's most westerly point. It is a shallow reef with water depths between 2 and 9 metres and is primarily composed of sand, gravel and pebbles. The area designated for the wind farm lies directly south of Horns Rev and is dominated by sand with a median particle size of 0.3 mm. Along the edges, towards areas of greater depth, the particle size increases. There are areas of fine sand in the deepest area, and in isolated pockets within the proposed wind farm site. The sediment is characterised by a very low (<1%) organic matter content.

Along the planned cable line, the sediment towards the shore and in deeper areas down to 25 metres consists of finer particles of silty sand and sandy clay-silt.

The wind farm and cable line areas are completely devoid of vegetation. No larger stones, which could serve as a suitable substrate for attached vegetation, have been found in either the wind farm area or the cable area.

The prevailing currents and the great degree of physical heterogeneity in the area result in the fauna being very heterogeneously distributed. No significant differences in species composition, numbers of individuals or total biomass have been registered in the faunal composition of the wind farm site and the reference area that extends 530 metres east and west of the area.

The fauna in the wind farm area has similarities to fauna recorded on other sandbanks in the North Sea and is best characterised as an *Ophelia borealis* community, so-named after one of the characteristic and important marine bristle worms in the area. Such sand banks are characterised by a lower number of species and individuals, and a lower biomass than adjoining areas where the bottom is less unstable and has a higher content of fine sand and organic matter.

The adjoining areas can be characterised as a true *Venus* and partial *Abra* community. The fauna here has a completely different composition than the fauna within the wind farm area and is characterised by the Venus-community bivalve *Chaemelea gallina*. In the deepest areas along the cable line, the fauna can be expected to be characteristic of the *Abra* community, which is related to finer sediment. There are also areas with finer sediments nearer the coast, where the fauna is characterised by a *Lanice conchilega* community, which is very common over large areas of the North Sea coast.

Bivalves, which are an important food source for marine birds, such as the common scoter, are far less common in the area around Horn's Rev than immediately south of here and in other areas of the North Sea. Similarly the thick trough shell, *Spisula solida,* was not recorded during this study, although it was from 1993 to 1995 the target of commercial fishing trials in this area.

The area of reclaimed sea bottom covered by establishing the wind farm, will be less than 0.1% of the total area of the site. It amounts to reclamation of an area with a potential biomass of benthic animals of approximately 600 kg.

During the production phase only local and minor impacts on current, wave conditions and sediment transport are expected in the immediate area of the individual foundations, and changes in the overall benthic fauna are therefore not envisaged.

An increased copper contamination of filter-feeding benthic animals can be expected as a result of the total annual discharge of 206 kg copper from the slip-rings in the wind turbines.

The wind turbine foundations and scour-protecting revetments can be considered as a kind of artificial reef, which will increase heterogeneity in the area and create a substrate for colonisation by fouling organisms. Artificial substrates at Horns Rev will potentially be colonised by many species that to-day are on the Red List of threatened or vulnerable species in the Wadden Sea area. Observations have meanwhile demonstrated that colonies of fouling organisms on Horns Rev may be vulnerable to extreme weather conditions.

Colonies of fouling organisms will probably produce a biomass that is many times greater than the present benthic community in the wind farm area on Horns Rev.

Erection of the wind turbines and burying of the cable connections during the construction phase will only marginally affect the existing benthic fauna, directly through physical disturbance or indirectly through spill products from the construction work. This applies both to the wind farm area and along the cable line, which runs to the coast through a protected area for birds.

The existing sampling design and baseline data for the benthic fauna are sufficient to be able to reveal any 50% changes in the biomass with a statistical certainty of 0.50 if future monitoring is undertaken.

On the basis of the expected impact from the establishment of the wind farm, it is not deemed necessary to carry out special programmes during the construction phase for monitoring of the environmental-biological conditions.

A monitoring and control programme is recommended during the production phase in order to follow the copper concentration in bivalves, or alternatively to initiate recovery or elimination of the copper-laden waste.

A control programme is recommended during the production phase in order to follow the establishment and succession of the fouling community on the wind turbine foundations and scour-protecting revetments.

Sammenfatning (in Danish)

Som led i en samlet VVM-redegørelse i forbindelse med en planlagt opførelse af en 150 MW havvindmøllepark ved Horns Rev er der udført en vurdering af det planlagte anlægs effekter på bundforhold og marinbiologiske forhold herunder vegetations- og bundfaunaforhold i området.

Udarbejdelsen af VVM-redegørelsen følger retningslinjerne i Miljø- og Energiministeriets "Retningslinjer for udarbejdelse af VVM-redegørelser for vindmølleparker på havet".

Horns Rev er beliggende ud for Blåvands Huk som er det vestligste punkt i Danmark. Horns Rev er et lavvandet rev med vanddybder mellem 2 og 9 m og udgøres fortrinsvis af sand, grus og småsten. Området ved mølleparken, der er beliggende umiddelbart syd for Horns Rev, er domineret af sand med en mediankornstørrelse på ca. 0,3 mm. Langs randområderne ud mod større dybder er sedimentet mere grovkornet. I det dybeste område og i enkelte mindre områder inden for parkområdet består bunden af finsand. Sedimentet er karakteriseret ved et meget lavt (<1%) indhold af organisk stof.

Langs det planlagte kabeltracé er sedimentet tættest mod land og i områder med større dybder ned til ca. 25 m mere finkornet og består af silt og lerblandet silt.

Området ved mølleparken samt området langs kabeltraceet mod land er uden forekomst af vegetation af nogen art. Der er ikke hverken i parkområdet eller langs kabeltraceet konstateret forekomst af større sten som egnet substrat for fasthæftet vegetation.

De fremherskende strømforhold og den store heterogenitet i området bevirker, at faunaen ligeledes er meget heterogent fordelt. Der er dog ikke konstateret forskelle i faunasammensætningen hverken med hensyn til arts- og individantal eller biomasse mellem selve parkområdet og et referenceområde henholdsvis 530 m øst og vest herfor.

Faunaen i parkområdet har lighed med faunaen registreret fra andre sandbanker i Nordsøen og kan bedst betegnes som et *Ophelia borealis*-samfund opkaldt efter en af de karakteristiske og betydende havbørsteorme i området. Sådanne sandbanker er karakteriseret ved et lavere arts- og individantal samt en lavere biomasse end i tilstødende områder hvor bundforholdene er mindre ustabile og har et højere indhold af finsand og organisk stof.

De tilstødende områder kan karakteriseres ved et egentligt *Venus*-, og til dels *Abra*-samfund. Faunaen her har en helt anden sammensætning end faunaen inden for parkområdet og er bl.a. kendetegnet ved forekomsten af venusmuslingen *Chaemelea gallina*. I de dybeste områder langs kabeltraceet formodes faunaen at være karakteristisk for *Abra*-samfundet, der er knyttet til mere finkornet sediment. Nærmere kysten er der ligeledes områder med mere finkornet sediment, hvor faunaen er karakteriseret ved et *Lanice conchilega*-samfund, der er udbredt i store områder langs nordsøkysterne.

Muslinger som udgør et vigtigt fødeemne for havfugle som bl.a. sortænder er langt mindre hyppige i det undersøgte område ved Horns Rev end umiddelbart syd herfor og i andre områder af Nordsøen og ligeledes er den tykskallede trugmusling *Spisula solida*, der har

været genstand for kommercielt forsøgsfiskeri i området fra 1993 til 1995, ikke registreret ved undersøgelsen.

Den fysiske beslaglæggelse af havbund som følge af etableringen af havmølleparken vil dække over et samlet areal på mindre end 0,1% af det samlede areal inden for parkområdet. Det svarer til en beslaglæggelse af et areal med en potentiel biomasse af bunddyr på ca. 660 kg.

I driftsfasen forventes der kun lokale og mindre effekter på strøm- bølgeforhold og sedimenttransport i umiddelbar nærhed af de enkelte fundamenter, hvorfor der ikke forventes ændringer i den generelle bundfaunasammensætning i området.

Som følge af udledningen af en samlet mængde på ca. 206 kg kobber årligt fra slæberinge i vindmøllerne kan der i driftsfasen forventes en øget kontaminering med kobber på filtrerende bunddyr.

Møllefundamenterne og erosionsbeskyttelsen i form af udlagte sten vil kunne opfattes som kunstige rev, hvilket vil øge heterogeniteten i området og skabe grundlag for etableringen af et begroningssamfund. Kunstige substrater ved Horns Rev vil potentielt kunne koloniseres af en lang række organismer der i dag er opført på rødlisten over truede eller sårbare arter i Vadehavs området. Observationer har imidlertid vist, at sådanne begroningssamfund på Horns Rev kan være sårbare over for påvirkninger som følge af ekstreme vejrsituationer.

Begroningssamfund på kunstige substrater vil sandsynligt kunne producere en biomasse der er mange gange større end det nuværende bunddyrsamfund i parkområdet ved Horns Rev.

I anlægsfasen vil etableringen af vindmøllefundamenter og nedspulingen af kabelforbindelser kun i ringe grad kunne påvirke den eksisterende bundfauna hverken i parkområdet eller langs kabeltracéet gennem fuglebeskyttelsesområdet mod land som følge af direkte fysiske påvirkninger eller indirekte gennem påvirkninger fra spild fra anlægsarbejderne.

Det eksisterende prøvetagningsdesign og baselinegrundlag for bundfauna er tilstrækkeligt til med en statistisk styrke på 0,50 at eftervise ændringer i biomassen på 50% ved eventuelt efterfølgende kontrolundersøgelser.

På baggrund af de forventede effekter som følge af etableringen af havmølleparken anses det ikke for nødvendigt at gennemføre særlige programmer for overvågning af de miljøbiologiske forhold under anlægsfasen.

I driftsfasen anbefales igangsat et overvågnings- og kontrolprogram for monitering af kobberindholdet i muslinger eller alternativt iværksætte opsamling eller eliminering af det kobberholdige affald.

For at følge etableringen og udviklingen af begroningssamfund på møllefundamenter og kunstige rev foreslås igangsat et overvågningsprogram i driftsfasen.

1. Introduction

The Ministry of Environment and Energy has requested ELSAM and ELTRA to establish an offshore wind farm with an output of 150 MW in the waters of Horns Rev, approximately 15 km off Blåvandshuk, which is the most westerly point of Denmark. An Environmental Impact Assessment (EIA) must be carried out in accordance with the guidelines prepared by the Danish Energy Agency in cooperation with the Danish Forest and Nature Agency (Ministry of Environment and Energy, 1999), before the final approval can be given for the establishment of the wind farm.

Developing an offshore wind farm at Horns Rev can have an impact on the sea bottom and the local marine biology during both the construction and production phases. In accordance with ELSAM's order no. 40 for studies in connection with the offshore wind farm for Horns Rev, the area of the designated wind farm and the line of the cable towards the shore have been mapped to analyse the impact of the construction of the wind farm. The mapping includes studies of the sea bottom and the marine biology, including vegetation and benthic fauna. Existing information on the vegetation and bottom fauna of the area has also been assembled, including material from Ribe County's regional monitoring programme.

These studies and this report are part of a total EIA for the construction and production phases of the wind farm at Horns Rev. In accordance with the requirements, the following subjects will be dealt with:

- Sediments
- Vegetation
- Benthic fauna

2. The research area

Horns Rev is an extension of Blåvands Huk, which is Denmark's most westerly point. The reef consists primarily of pebbles, gravel and sand. The water depth over the reef varies between 2 and 9 meters, and the width varies between 1 and 5 km. In geomorphological terms Horns Rev is a terminal moraine. Its formation is probably due to glacio-fluvial sediment that was deposited in front of the ice shelf during the Saale glaciation, being pushed up at some point when the ice advanced. The constituents of the reef are therefore not the typical mixed sediment of a moraine but rather well-sorted sediments in the form of gravel, grit and sand.

Horns Rev is considered to be a stable landform that has not changed position since it was formed (Danish Hydraulic Institute, 1999). Blåvands Huk forms the northern extremity of the European Wadden Sea area, which covers the area within the Wadden Sea islands from Den Helder in Holland to Blåvands Huk.

The wind farm area is located approximately 15 km off Blåvands Huk, (figures 1 and 2).

3. Methods

As part of the overall mapping work, studies have been made of the sediments and the marine biology. Specific details of the methodology are given in the literature (Bio/consult 1999a, Bio/consult 1999c).

The studies have been carried out in the wind farm site and in a reference area that extends both east and west of the wind farm (figure 1). The location of stations and the choice of reference areas were made with reference to the original design of the offshore wind farm with altogether 81 wind turbines in 9 rows. Studies within the wind farm area have included 40 stations for which analysis of the sedimentary characteristics and benthic faunal composition has been made. Sediment and benthic faunal analyses have been done on the basis of samples collected with a Haps core sampler covering an area of 0.0123 m^2. Biomass analyses were carried out as . Power calculations were made on the total biomass in the samples and on the basis of guidelines given in the literature (Cohen, 1977) and (Øresunds Konsortium, 1997).

The sea bottom and marine biology of the wind farm area, the reference areas and the area along the line of the cable have also been studied by divers (SCUBA diving), figure 2.

Aerial photography was also used to study the shallowest areas of the sea bottom for possible vegetation and bottom formations of rocky reef.

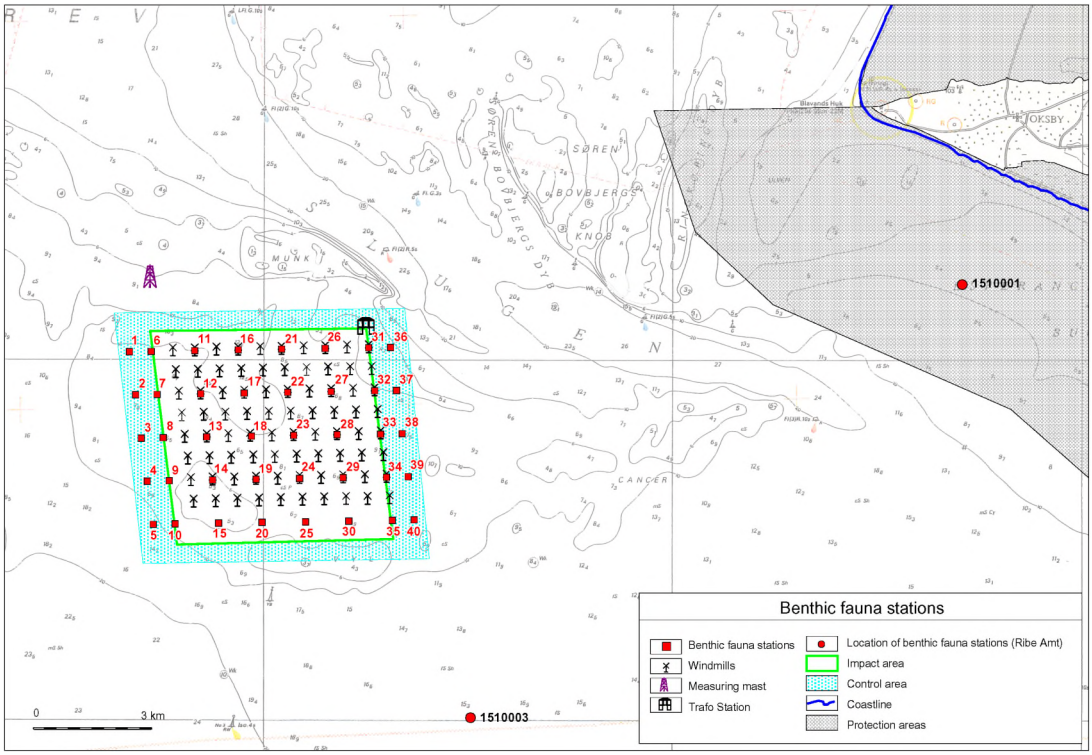

Figure 1. Location of stations for benthic fauna sampling.

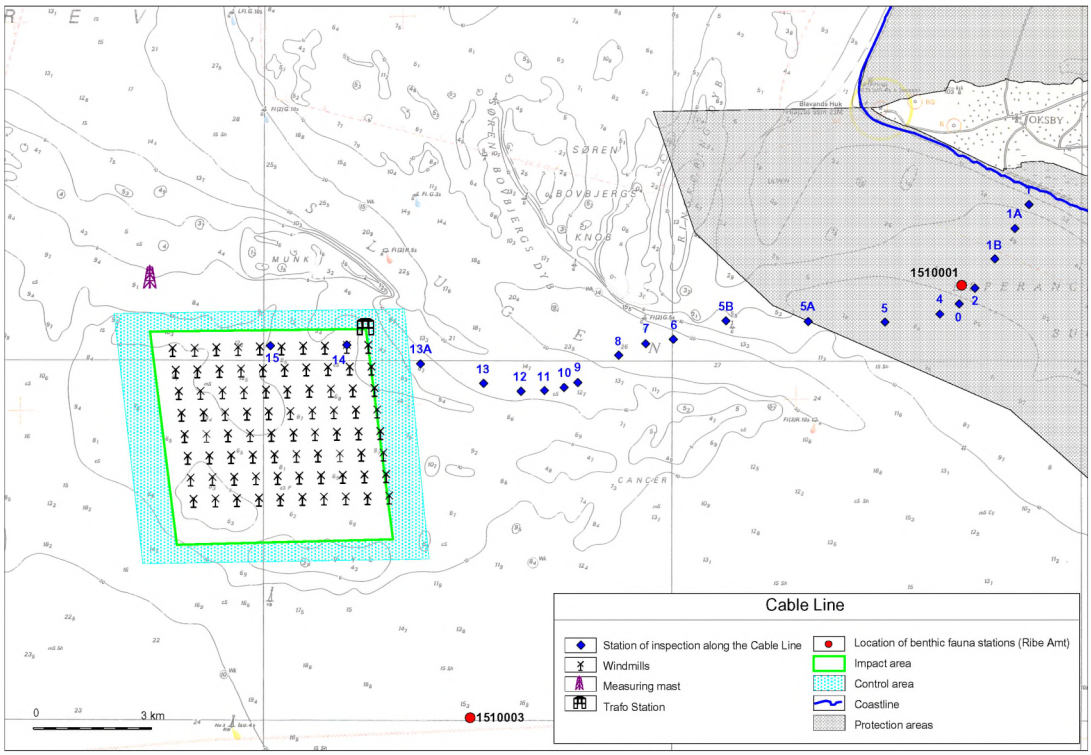

Figure 2. Location of stations along the cable line where video monitoring was done.

4. Existing situation

4.1. Sea bottom

The depth of the wind farm area varies from 5.8 m to 17.5 m. The shallowest depths of approximately 6 m are to be found at the sampling stations in the north-east corner, while the deepest stations lie in the south-east corner of the area. The planned cable line crosses a deeper channel, "Slugen", on its way to the shore where depths are down to 26 m.

The sediments in the wind farm area can generally be characterised as medium-fine sand (250 µm to 500 µm) with a median particle size of 370 µm. Particle sizes were found to be in the range 215 µm to 967 µm. Sediment from the station in the deepest area consisted of fine sand with a particle size of 215 µm, but apart from this there is no evident correlation between particle-size distribution and depth. There is an apparent tendency for the sediments to have a larger particle size towards the slopes facing towards greater depths. Sediments from depths of 12–14 m in both the south and north-westerly areas consist of rough sand/grit with particle sizes of 641 µm–961 µm. The general characteristic of the sediments in the wind farm area is pure sand with an ignition loss of less than 1%.

Along the planned cable line, the sediments closest to shore and in areas with depths down to approximately 25 m are finer and consist of silty sand and sandy clay-silt, (figure 3). While it is only in the shallower areas on the aerial photographs that the bottom can be discerned, it can be seen that there are active bottom formations in the shape of mega-ribbles.

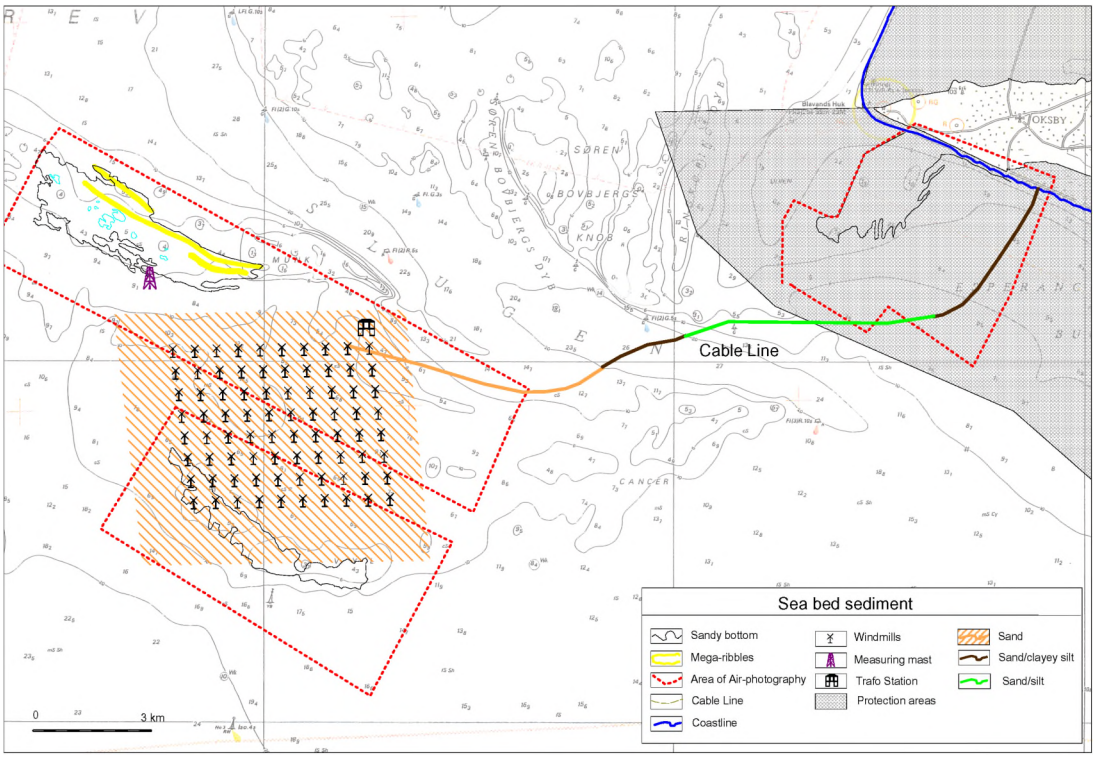

Figure 3. Sea bottom mapped by aerial photography and diving observation.

No large stones were found along the line of the proposed cable or in the wind farm area.

The geomorphology and sea bottom are further described in a report by the Danish Hydraulic Institute (Danish Hydraulic Institute, 1999), while the sediment studies and video observations are also reported separately (Bio/consult, 1999a; Bio/consult 1999b).

4.2. Vegetation

No vegetation was recorded in either the area of the wind farm or along the line of the planned cable. There are no available studies of possible vegetation in the adjoining shallow areas, but aerial photographs and other studies indicate that there is neither attached nor rooted vegetation in the area, nor are there any larger stones that could be a suitable substrate for attached vegetation.

There is some rooted vegetation in the form of eel-grass in the Danish part of the Wadden Sea (Ribe County, 1997). The vegetation consists primarily of dwarf eel-grass (*Zostera noltii*), which occurs widely-spread on the tidal flats, while the common eel-grass (*Zostera marina*) only occurs in a limited patch north of Langli in Ho Bugt. The eel-grass stock is much reduced in the Wadden Sea and is described as vulnerable (Ribe County, 1997; Wind et al. 1996).

Macroalgae in the shape of green algae are found in increasing amounts in the Wadden Sea while other macroalgae are generally fewer than previously (Ribe County, 1997; Nielsen et al., 1996). There are no records of observations of macroalgae in the area off Blåvands Huk.

4.3. Fauna

There are no previous studies of the fauna in the planned wind farm area on Horns Rev. Areas close to the wind farm have been studied by the Dana expeditions of 1932–55 (Ursin, 1960; Kirkegaard, 1969; Petersen, 1977). The studies concentrated primarily on the central part of the North Sea around the Dogger Bank, but sections along the west coast of Jutland in depths greater than 8–10 m were also included.

Ribe County has undertaken studies since 1989 at 6 stations east and south of the planned offshore wind farm, (figure 4). Station 1510001 is located on the shore side of the cable line and within EF-bird protection area 57 of the Wadden Sea, EU Habitat area 78 and Ramsar area 27.

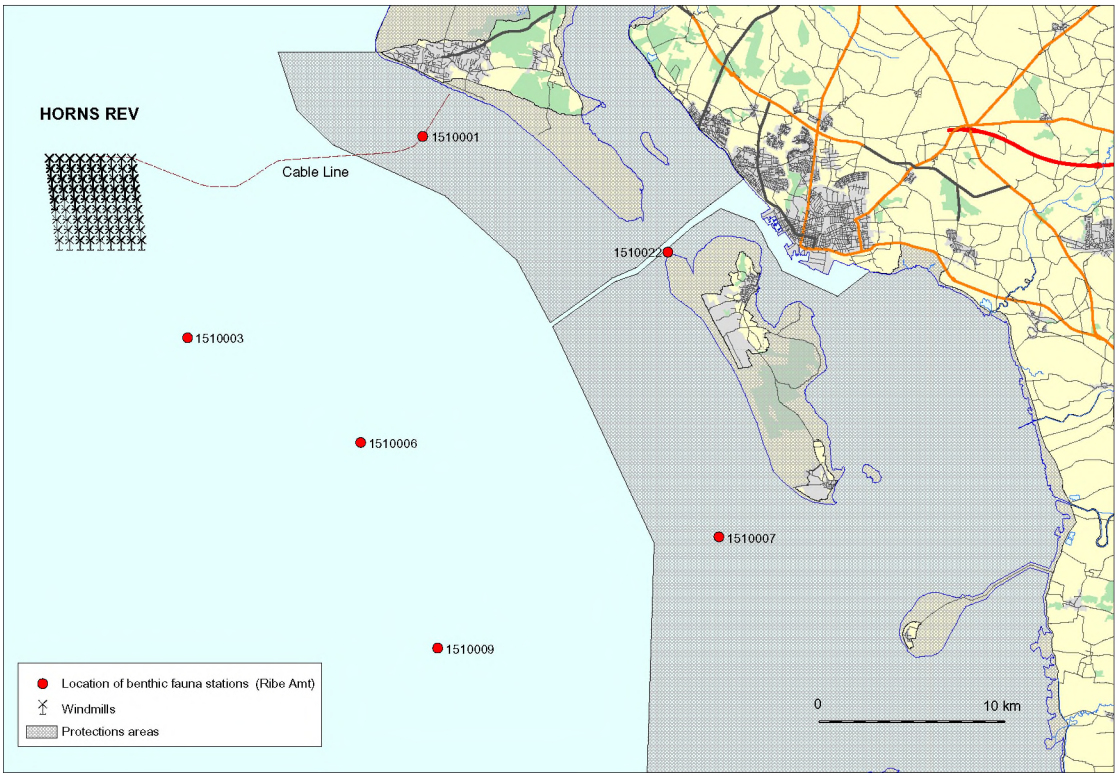

Figure 4. Location of Ribe County's fauna-sampling stations in the area south and east of the wind farm.

Studies carried out in connection with the present EIA have shown that the area of the wind farm site and the immediately adjoining reference area are very heterogeneous with regard to the faunal composition (Bio/consult, 1999c), and that the number of species, density of individuals and biomass of the benthic fauna vary greatly within the area, (figures 5–7).

The number of species recorded at the individual stations varies from 1 to 10 (figure 5) and the abundance of the biomass varies from 40–6,000 individuals/m^2(figure 6) and from 0.1–320 g wet weight/m^2 (figure 7), respectively.

The wind farm area is generally characterised by a relatively low species and individual density and thus also low biomass, which is characteristic of sand banks in the North Sea. The fauna must withstand very variable conditions determined by sand movement resulting from wave action (Heip et al., 1979; Degraer et al., 1999). The median particle size of 370µ shows that the currents in the area have a velocity greater than 0.5 m/s (Creutzberg et al., 1984) and even minor variations of 0.5 m in depth lead to variations in the sediment composition and thus the faunal composition.

The number of individuals and the biomass can be considerably greater in other areas along the west coast of Jutland. The average number of individuals and biomass recorded at stations offshore from Harboør Tange are 6,000 individuals/m^2 and 160 g wet weight/m^2 respectively (Ringkjøbing Municipality, 1995) against an average density of 730 individuals/m^2 and 46 g wet weight/m^2 in the wind farm area at Horns Rev. At Ribe County's

stations directly south of the wind farm densities have been recorded of 285–4,743 individuals/m^2 and biomass of 27–450 g wet weight/m^2.

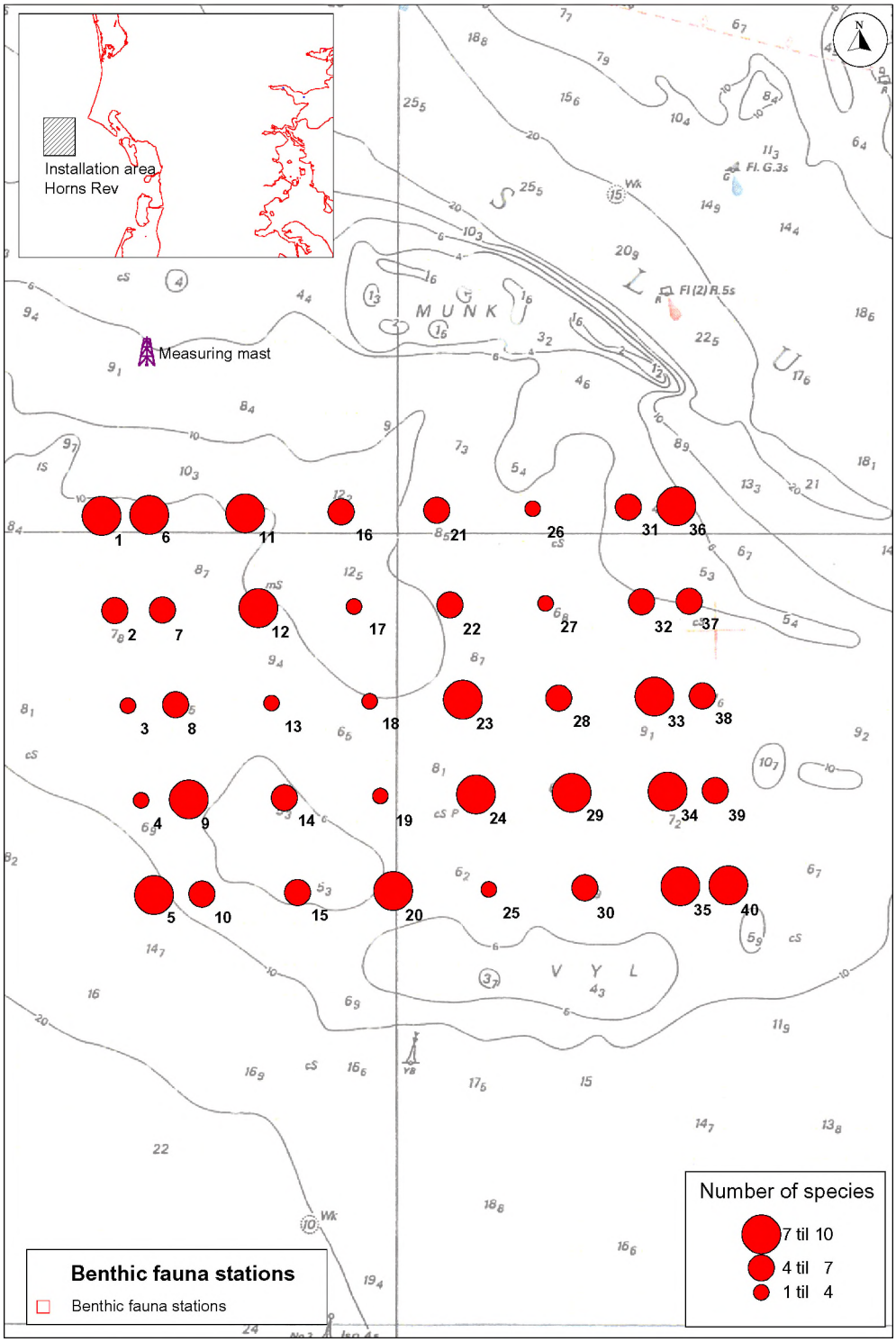

Figure 5. Species numbers at the stations on Horns Rev 1999.

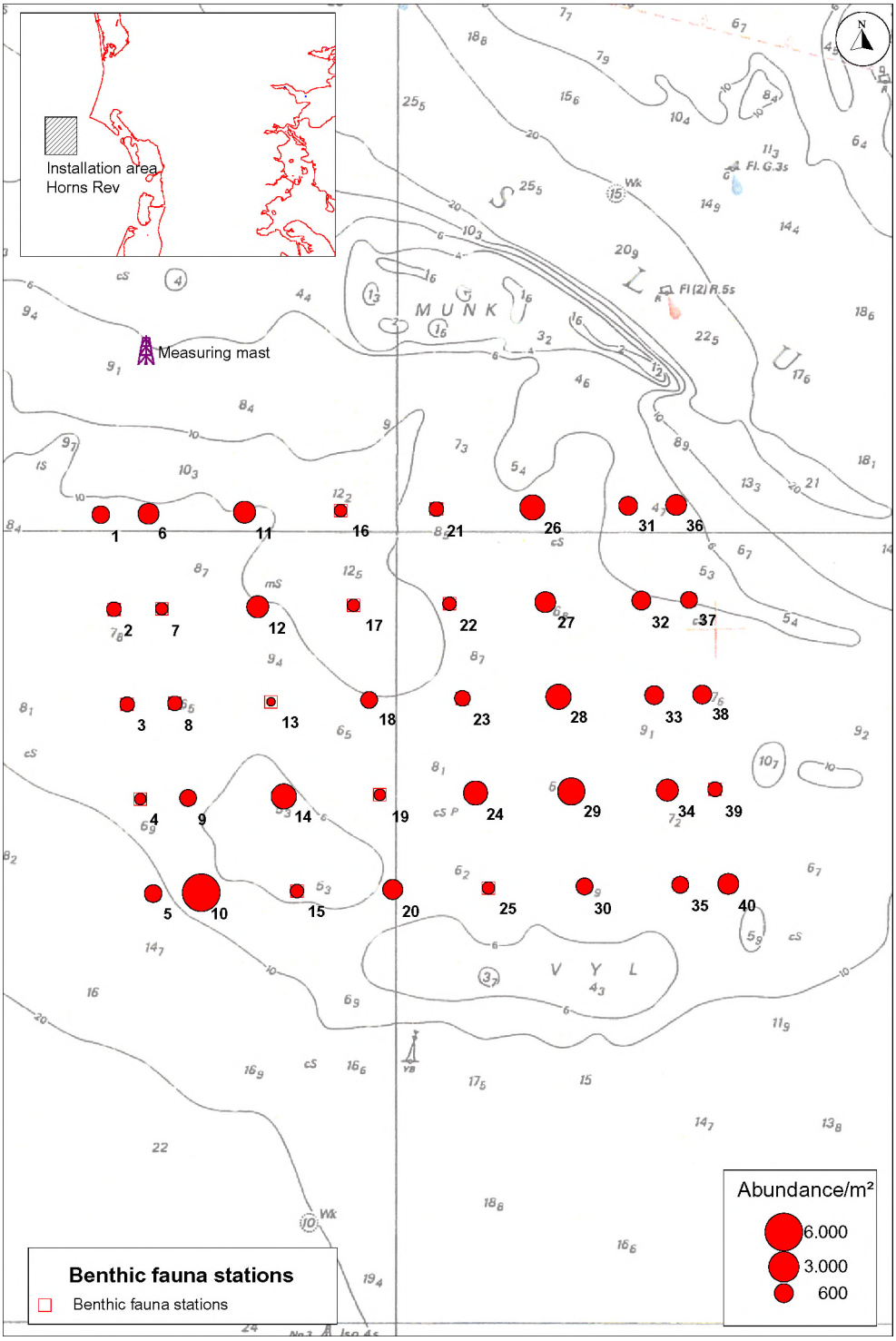

Figure 6. Abundance of benthos at the stations on Horns Rev 1999.

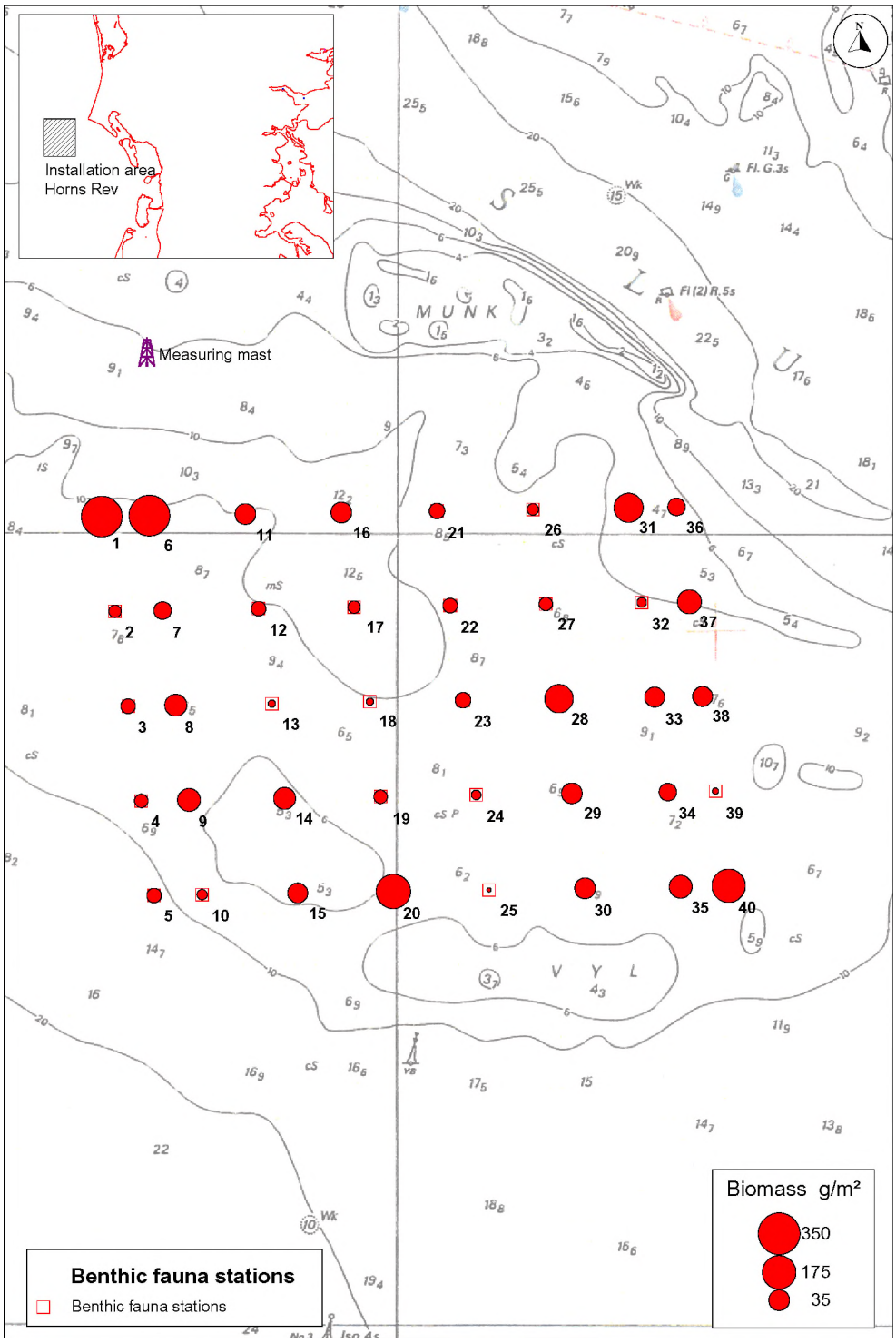

Figure 7. Biomass (wet weight) at the stations on Horns Rev 1999

There are few dominant species because most species are evenly distributed throughout the study area. The most frequently occurring species are the marine bristle worm *Pisione remota* and the bivalve *Goodallia triangularis*, which occur at densities of 175 individuals/m^2 and 166 individuals/m^2 respectively and comprise 24% and 23% of the total number of individuals. Other bristle worms such as *Goniadella bobretzkii* and *Protodorvillea kefersteini* are also relatively plentiful, comprising 15% and 9% of the total number of recorded individuals. The table below lists the most frequently occurring species.

Species	Group	Individuals/m^2	Relative frequency %
Pisione remota	Bristle worm	175	24
Goodallia triangularis	Bivalve	167	23
Goniadella bobretzkii	Bristle worm	107	15
Protodorvillea kefersteini	Bristle worm	68	9
Travisia forbesii	Bristle worm	38	5
Ophelia borealis	Bristle worm	36	5
Orbinia sertulata	Bristle worm	21	3
Haustorius arenarius	Crustacean	11	2
Pontocrates arenarius	Crustacean	11	2
Nephtys longosetosa	Bristle worm	11	2

Table 1. The most frequently occurring species at Horns Rev.

Goniadella bobretzkii is the most frequently occurring species, but *Pisione remota* and *Ophelia borealis* also occur relatively evenly distributed in the area, while *Goodallia triangularis* and especially *Protodorvillea kefersteini* have a more clumped distribution (Bio/consult, 1999c).

The most frequently occurring species (table 1), including the bivalve *Goodallia triangularis* are all small species, which each represent less than 1.3% of the biomass. The slightly larger but less frequently occurring marine bristle worms such as *Travisia forbesii, Ophelia borealis, Orbinia sertulata* and *Nephtys longosetosa* comprise between 4% and 20% of the total biomass of the area.

The relatively large bristle worm *Ophelia borealis*, which has recorded individuals of up to 0.9 g, and an age of 4 years (Kierkegaard, 1978) is thus one of the most important species in the area, with a biomass of 9 g wet weight/m^2 (table 2), whereas the most frequently occurring species *Pisione remota* with an average biomass of 0.1 g wet weight/m^2 only comprises 0.2% of the total biomass. Large species such as *Pagurus bernhardus* and other larger crustaceans like the shore crab *Carcinus maenas* and the common shrimp *Crangon crangon* comprise respectively 25%, 9% and 8%. This is a considerable percentage of the total biomass even though these species only occur in small numbers and are spread in the area. *Pagurus bernhardus* has an average biomass of 11 g wet weight/m^2 and only occurred at two stations, where it on the other hand is recorded with a biomass of 150–300 g wet weight/m^2. Small hermit crabs have frequently been recorded on a sandy bottom in groups of 4–10 individuals. The shore crab *Carcinus maenas* and the common shrimp *Crangon crangon* have only been recorded at a single station with a biomass of 150–170 g wet weight/m^2. The most important species are listed in the following table, (table 2).

Species	Group	Biomass g wet weight/m^2	Relative frequency %
Pagurus bernhardus	Crustacean	11	25
Ophelia borealis	Bristle worm	9	20
Nephtys hombergii	Bristle worm	5	10
Carcinus maenas	Crustacean	4	9
Crangon crangon	Crustacean	4	8
Nephtys longosetosa	Bristle worm	3	7
Spisula elliptica	Bivalve	2	5
Orbinia sertulata	Bristle worm	2	5
Travesia forbesii	Bristle worm	2	4
Haustorius arenarius	Crustacean	1	2

Table 2. The most important species in terms of biomass wet weight.

The large marine bristle worms like *Ophelia borealis* and *Nephtys longosetosa* exhibit a more even biomass distribution. There is though a tendency towards *Ophelia borealis* having a larger biomass in the northern and easterly areas, while *Nephtys longosetosa* makes the largest contribution to the biomass in the southern and westerly areas (Bio/consult, 1999c). The bristle worm *Nephtys hombergii* and the bivalve *Spisula elliptica* only occur, like the large crustaceans, at some stations and with a relatively large biomass of 170 g wet weight/m^2 and 70 g wet weight/m^2 respectively. They only have a density of 8 and 6 individuals/m^2 respectively and thus comprise only about 1% of the total number of individuals.

Other studies on sandbanks in the North Sea, which are comparable to the area studied at Horns Rev, have shown that the fauna on the sandbanks is both variable and heterogeneous. The fauna of these areas is difficult to compare with that on other sandbanks and adjoining deeper areas (Degraer et al., 1999).

The faunal composition of this area can best be characterised as an *Ophelia borealis* community. The *Ophelia* community is characteristic of areas with pure sand with relatively large particles (medium) (Dewarumez et al., 1992). It differs from the *Venus* community, which is the most prevalent in the North Sea, and the *Abra* community, which is characteristic of the coastal zones of the North Sea (Blegvad, 1922; Govare et al., 1980).

All of the dominant species are characteristic of areas with pure sand. Species like *Pisione remota* and *Protodorvillea kefersteini* have been recorded in other studies as being dominant in areas with coarse sand and grit, and are species that are either tolerant of hypoxia or able to recolonise areas hit by hypoxia (Westernhagen et al., 1986). In the studies at Horns Rev the species densities are greatest in the south-westerly corner of the area where the sediment is coarsest. The bristle worm *Travisia forbesii* is also primarily associated with coarser sand and the above species are characteristic of the so-called *Amphioxus* gravel (Kirkegaard, 1996), so named after the presence of the cephalochordate *Branchiostoma (Amphioxus) lanceolatum*, of which only a few examples were found at Horns Rev.

The cephalochordate *Branchiostoma (Amphioxus) lanceolatum* is also recorded as occurring in Grådyb the area that lies close to Søren Jessens Sand on Fanø, Ribe County's station 150022 (Ribe County, 2000) and the fauna here have the most similarity with the fauna in

the wind farm area in that *Ophelia borealis* is one of the most important species. *Ophelia borealis* has a relative frequency of 15% and represents 11% of the biomass (wet weight).

The results from Ribe County's stations, of which the three most westerly lie somewhat to the south and generally in deeper water (14 m) than the stations in the wind farm area, show a completely different species composition (Ribe County, 2000). It can be characterised as a *Venus* community with one of the characteristic species, the bivalve *Chaemelea gallina*. The fauna in these areas is characteristic of areas where the sand is generally finer and has a greater percentage of silt, but also here there are large variations depending on time and place. The fauna in this area has also greater similarity to the fauna in other areas along the west coast of Jutland (Ringkjøbing County 1995). The most frequent and important species in relation to the biomass are listed in the following tables 3 and 4.

Species	Group	1510003	1510006	1510009
Spiophaenes bombyx	Bristle worm	6	18	21
Fabulina fabula	Bivalve	13	14	12
Lanice conchilega	Bristle worm	14	4	7
Echinocardium cordatum	Echinoderm	4	5	15
Magelona mirabilis	Bristle worm	11	6	2
Ophiura texturata	Echinoderm	< 0.5	6	12

Table 3. The relative frequency (%) of the most frequently occurring species at Ribe County's stations 1510003, 1510006 and 1510009.

Species	Group	1510003	1510006	1510009
Echinocardium cordatum	Echinoderm	94	47	53
Chamelea gallina	Bivalve	1	14	10
Fabulina fabula	Bivalve	1	13	9
Nephtys hombergii	Bristle worm	1	5	4
Spisula subtruncata	Bivalve	< 0.1	3	4
Ophiura texturata	Echinoderm	< 0.5	6	0

Table 4. The relative biomass distribution (% wet weight) of the most important species at Ribe County's stations 1510003, 1510006 and 1510009.

Ribe County's sampling stations on the eastern side (5 m depth) give an approximation of the faunal composition along stretches of the cable line, when depths and sediment type are compared.

Video recordings of the bottom along the cable line show that the sediment in the deepest areas and in the inshore section has a finer composition and probably a greater degree of silt and organic material than the sediments west of Slugen and in the wind farm area. A large population consisting mostly of the brittle-star *Ophiura*, probably *Ophiura texturata*, which is one of the dominant species in samples from Ribe County's stations, was recorded in the area. The brittle-stars observed in the deep channel, Slugen, may belong to a different species *Ophiura albida*|, which is more common in the *Abra* community, which is widespread along parts of the west coast of Jutland (Blegvad, 1922). *Ophiura texturata* can occur in *Abra* communities. In contrast to *Ophiura albida,* it is generally most successful in areas with a greater proportion of pure sand.

Ophiura texturata, with a relative frequency of 2%, and a biomass share of 5%, is among the more common species recorded at Ribe County's station 1510001, which has a water depth of 5 m and is situated in the inshore section of the cable line. *Lanice conchilega* is recorded here as one of the dominant species. The area with shallower depths east of Slugen and towards the coast in the international protected area, can be characterised by the so-called *Lanice conchilega* community, which is widespread over large areas of the North Sea coasts (Govare, 1980).

The most frequently occurring and important species of the inshore section of the cable line, with regard to biomass, are listed in the following table, (table 5).

Species	Group	Relative frequency %	Relative biomass %
Magelona mirabilis	Bristle worm	26	1
Lanice conchilega	Bristle worm	12	< 1
Fabulina fabula	Bivalve	10	5
Bathyporeia guilliamsoniana	Crustacean	9	< 1
Scoloplos armiger	Bristle worm	5	< 1
Echinocardium cordatum	Echinoderm	2	49
Macoma balthica	Bivalve	2	20
Spisula subtruncata	Bivalve	1	7
Ophiura texturata	Echinoderm	2	5
Nephtys hombergii	Bristle worm	5	3

Table 5. The relative frequency and biomass distribution (% wet weight) for selected species at Ribe County's station 1510001.

As was seen with conditions in the wind farm, it is probable that the area along the cable line west of Slugen is not fully comparable to Ribe County's station 1510003, which has a depth of 14 m on a sandy bottom and lies directly south-east of the wind farm. Among other things is no record of brittle-stars. The area along the cable line west of Slugen compares therefore most closely with the area within the wind farm.

Spread populations were found of the common whelk *Buccinum undatum*, the razor shell *Ensis* sp., the shore crab *Carcinus maenas*, swimming crab *Liocarcinus holsatus* and the common shrimp *Crangon crangon*. The common starfish *Asterias rubens* occurs in the area with slightly greater frequency than the other species mentioned here. The hermit crab *Pagurus* sp. is common along the cable line. It is not recorded in the deepest areas, but is present at 10 of the remaining 13 stations along the cable line.

Hermit crabs are also relatively numerous in the reference area with a relative frequency of 30%, while they are apparently less numerous in the wind farm site where they have a relative frequency of 6%. This is supported by observations from the benthic fauna studies. Common starfish *Asteris rubens*, common shrimp *Crangon crangon*, shore crab *Carcinus maenas* and the European necklace shell *Polinices catena* are spread throughout the wind farm site and the reference area, but all occur significantly less frequently than the hermit crab.

The number of bivalves is low in the wind farm area, compared with the adjacent areas and other areas in the North Sea with their typical *Abra* and *Venus* communities. This is true of *Spisula elliptica, Angulus tenuis* and *Fabulina fabula*, which are important food items for

diving ducks such as the common scoter (Degraer et al., 1999). *Fabulina fabula* and the biomass of all bivalves have previously been recorded in areas adjoining Horns Rev. *Fabulina fabula* has a density of 50 individuals/m^2 and a biomass of 25 g wet weight/m^2 (Petersen, 1977) and is one of the most important species of the area directly south of the wind farm where it is recorded with a density of 377 individuals/m^2 and a biomass of 17 g wet weight/m^2, (Ribe County, 2000). Another important bivalve is *Spisula subtruncata*, which in other areas of the North Sea can be seen with 500 individuals/m^2 (Degraer et al., 1999). It is not recorded in the wind farm area at Horns Rev, but nevertheless occurs immediately south of it with a density of 127 individuals/m^2 and a biomass of 3 g wet weight/m^2 (Ribe County, 2000). The little bivalve *Goodallia triangularis*, which is not previously recorded in the Danish part of the North Sea (Jensen & Knudsen, 1995) occurs nonetheless in relatively large numbers in the wind farm area. This bivalve is very common in other areas of the North Sea, such as along the British coast (Tebble, 1966).

A bivalve of note that was not found in the wind farm area during this study is *Spisula solida*, which was the object a commercial trial-fishery in the study area from 1993-1995 (Thorbjørnsen, pers. com). It has previously been recorded along the west coast of Jutland (Petersen, 1977).

The bivalves *Spisula solida*, *Spisula subtruncata* and *Angulus tenuis* are included in the Red List of Wadden Sea species. In areas outside Denmark they are either sensitive or vulnerable (Petersen et al. 1996). There is no mention of the status in Denmark for these species.

5. Impacts

Two classes of environmental impacts are considered. Potential permanent changes connected with the construction and production phases, and potential temporary changes from the construction phase.

At the present time it is planned for the wind turbines to be established as mono-pile foundations with a diameter of 3.5 m. To this will be added a scour-protecting revetment of large boulders, to give a total foundation diameter of 7.5 m. The mono-pile will be sunk into the bottom during the construction phase. The reclamation area necessary to construct the foundations for the wind turbines covers a total area of 14,500 m^2 of sea bottom, together with its associated benthic fauna.

Work on the erection of the wind farm will also affect a narrow area along the approximately 19.5 km long cable line towards the land. The location of the cable line is not yet finalised.

5.1. Production phase

Potential direct or indirect impacts on the benthic fauna during the production phase are:

- Permanent reclamation of the present sea bed with its fauna.
- Permanent impact on current, sediment, water exchange and wave conditions of the area.
- Discharge of pollutants.
- Creation of new biotopes.
- Temporary impact due to oil spills, etc.

14,500 m^2 of sea bottom will be physically covered, equivalent to a benthic faunal biomass of approximately 600 kg. The reclaimed area represents less than 1% of the total area of the wind farm.

The water exchange and thus oxygen conditions in the area of Horns Rev will not be much affected by the construction of the wind farm (Danish Hydraulic Institute, 1999). Alteration of oxygen conditions in the area would have potential impact on the benthic fauna.

There will be minor local impact on current, wave conditions and sediment transport in the immediate area of the foundations (Danish Hydraulic Institute, 1999). This is not expected to have a significant effect on the benthic fauna. Construction of the wind farm will not affect the regional wave conditions, currents or sediment transport along the coast of Jutland at Blåvands Huk and Skallingen. Thus no impact is expected on the marine biology of the international protected areas.

An increased copper contamination of the filter-feeding benthic animals, such as bivalves, is expected to occur during the production phase. This is likely to be caused by discharge of copper and carbon dust from abrasion of the slip-rings of the wind turbines. There is also the potential for temporary inhibition of bottom-living microalgae, which are the food source for several benthic species. A total of 206 kg copper is expected to be discharged each year. The

effect is expected to be relatively minor because the temporary local increase in copper concentration will in the worst case be 1.4 µg/l (Danish Hydraulic Institute, 2000) compared to a background concentration of around 0.2 µg/l as recorded in the outer part of the German Bight (Schmidt 1996). Another possible result of the copper discharge can be increased local contamination of the sediment-ingesting organisms such as *Ophelia borealis* since the copper concentration in the pore water will in the worst case be increased by 0.5 µg/l (Danish Hydraulic Institute, 2000). The background level for copper concentration in the sediment in the outer part of the German Bight is by comparison 20–40 mg/kg (Rowlatt, S.M., 1996). Any possible impact will be local to the wind farm area, since the temporary increase in concentration for total copper in the water phase and dissolved copper in the pore water of the sediments outside the area, is calculated to be less than 1 µg/l and 0.35 µg/l respectively. The extent of the dispersion area, which primarily extends north of the wind farm area, has been documented (Danish Hydraulic Institute, 2000).

The degree of impact on the benthic fauna, from a possible oil spill from cable rupture or collision with a wind turbine or temporary spill from painting and maintenance work, has not been calculated

New biotopes
The wind turbine foundations and scour-protecting revetments will introduce a new biotope to the area, which today has no solid substrate, with the exception of small stones.

The wind turbine foundations can be regarded as an artificial reef for this area. Their presence will lead to colonisation by many epibenthic organisms, which have not been in the area previously because of the lack of suitable habitat. How life will develop around the wind turbine foundations is dependent on the surrounding environment, the interaction between the different species of the fouling community and the predation on the community of fouling organisms by star fish, birds and others. It is thus not possible to predict a qualitative or quantitative scenario.

Recruitment can primarily occur in two ways when a new foundation is set in place. By migration from the surrounding substrate or by settling of larvae or spat. The recruitment will be governed by the sea currents carrying the larvae and spat to the foundation, and by the location of the foundation in respect of depth, distance from shore, etc. It will also be dependent on the construction of the foundation, including materials, heterogeneity, etc. Recruitment will always be seasonal in Danish waters.

The first species to colonise the foundations will be algae and invertebrates. The colonisation will often have a characteristic succession, starting with diatoms and filamentous algae, followed by barnacles, and thereafter by a more diverse community. The qualitative and quantitative composition of the fouling community will further vary with the water depth. There will be differences in the composition of the fouling community at particular depths on the foundation and the scour protecting revetments.

Fouling by algae and invertebrates was recorded on a measuring mast at Horns Rev 5 months after it was erected (Bio/consult, 2000). The fouling consisted of a thick moss-like layer of diatoms, small filamentous algae, barnacles (*Balanus*), colonies of bryozoans (*Bryozoa*) sea anemones (*Urticina felina, Actinariidae*), sea-squirts (*Ascidiacea*), star fish (*Asterias*), the triangular-tube-dwelling polychaete (*Pomatoceros triqueter*) and some few common mussels

(*Mytilus edulis*) with lengths up to 4 cm. The visit to the mast also showed that the fouling is limited by the current and the near-bottom transport of sand. Sand scouring is so extreme in the area that the lowest areas of the foundation were devoid of fouling.

The impact of current, wave action and sand scouring can extend to the whole length of the foundation in connection with storms. This is confirmed by the findings of a later visit to the measuring mast following the storm of 3rd December 1999. The only signs left of fouling were the calcium traces from the previously-attached barnacles. It is therefore likely that the fouling communities on the foundations will be very variable and continually young in succession. It is uncertain how much this will also hold true for the fouling on the scour-protecting revetments.

It is however certain that the revetments will create increased heterogeneity in the area. This is of great importance for species diversity and density. The size, diversity and density of organisms on and in an artificial reef are conditional on the number and size of niches and not necessarily the presence of food. Structural complexity appears to be a condition for many productive and complex environments such as coral reefs, mangroves and sea grass meadows. These environments are productive, not only because they as a substrate have a great turnover, but also because they offer a high degree of substrate complexity and an extensive spectrum of niche sizes, which are advantageous for young and juvenile organisms. Growth of algae on the reef contributes to increased heterogeneity, as do the stones of the revetment. Increased algal growth can for example lead to colonisation by crustaceans. The artificial reef at Horns Rev will thus potentially be colonised by many different algae and associated fauna, some of which are included on the Red List for threatened or vulnerable Wadden Sea species (Nielsen et al. 1996; Petersen et al. 1996). The artificial reefs can further form substrate for a possible colonisation by the bristle worm *Sabellaria spinulosa*, another of the red-listed species in the Wadden Sea. *Sabellaria spinulosa* can form compact reef-like populations. After a heavy decline that started in the 1920s, it has again been seen in increasing numbers in parts of the Wadden Sea area (Nehring, 1999). *Sabellaria* reefs have not been recorded in the Danish part of the Wadden Sea (Nehring, 1999).

It is probable that the biomass produced on the artificial reef will be many times greater than the present biomass production by the benthic community on Horns Rev, especially in view of the presence of the common mussel. Changes in the biomass composition are not expected to have any notable consequences for the present stock of benthic fish or bottom-feeding birds, since the biomass of suitable food items, particularly small bivalves, is limited.

It is possible that the discharged copper can have temporary minor impacts on the fouling community and that the microalgal community may be inhibited.

5.2. Construction phase

Potential direct or indirect impacts on the benthic fauna during the construction phase are:

- Impact on the benthic fauna as a result of sedimentary spill.
- Complete or partial destruction of the benthic fauna due to foundation construction.
- Complete or partial destruction of the benthic fauna due to laying of marine cables within the wind farm and along the cable line.

The use of wind turbines of the mono-pile type of foundation will cause little or no spill. Spill simulations have been done for a worst-case scenario where the foundation is composed of a caisson with associated excavation (Danish Hydraulic Institute, 1999). The simulations show that it is improbable that there will be any impact from spill in the worst case scenario. In this there is a spill percentage of 5% comprising a total of 1.196 tons/day over a period of 8 days. The spill concentrations will exceed 10 mg/l during 50% of the excavation period within a very limited area of the wind farm. This figure lies within the natural variation of the area where concentrations of suspended material can vary from a background level of 2–10 mg/l to several hundred mg/l. This minor increase in the content of suspended material can even have a stimulating effect on the food uptake of bivalve and other filter-feeding organisms in the area, as has for example been demonstrated for the common mussel (Kiørboe et al., 1980).

There will similarly be no impact from sedimentation of spill, since the net sedimentation in the affected area will be less than 1 mm, which is equivalent to the natural conditions for an accretion area in the Skaggerak (SEMAC, 1999). In areas with very locally variable bottom conditions, such as Horns Rev, deposition of sediment that far exceeds sedimentation from possible spill material will frequently occur.

A total area of sea bed of 14,500 m^2 will be reclaimed to establish the wind farm. The total biomass of this area amounts to 600 kg, which is less than 1% of the total biomass in the area. During the construction phase, many of the mobile species like hermit crabs and other crustaceans (e.g. crabs and common shrimp) will be less affected than stationary species such as bivalves and bristle worms.

The impact on the marine biology of the area from water-jetting the cable to the wind farm, and cables between the individual wind turbines, into the sediment, will be local and temporary. Embedding the marine cable will affect an area of approximately 20,000 m^2 along the 19.5 km length of the cable line. The cable embedding phase will last 1–2 months. Spill calculations have not been made for work involved in laying the cable.

The impact on the benthic fauna from water-jetting the cable into the sediment is expected to be minimal. There will be a localised impact on the fauna directly in the path of the water jet that creates the ditch. It is expected that most of these animals will die during the process or because of subsequent predation. Recolonisation of the affected area will occur within a few weeks or months for most species and perhaps for some species up to a year or two after the construction is completed. The impact of sediment spill from the embedding process will as a result of the local sediment conditions be expected to be greater in the area within and east of Slugen compared to the area west of Slugen. The impact on this area within the bird

protection area will affect a very limited area with a benthic fauna that is very common along the west coast of Jutland. The impact on mobile species such as the hermit crab *Pagurus sp.*, the common shrimp *Crangon crangon*, crabs and others will be less than for sedentary species such as bivalves like *Fabulina fabula* and for most bristle-worms like *Lanice conchilega*. The precise line the cable will take, has still not finally been decided.

5.3. Proposed monitoring programme

The aim of a monitoring programme is to document and if possible to quantify the calculated expected impact, and even unforeseen impacts, during the construction and/or production phases. It must be stressed that the baseline data needs to be designed and organised to be able to register both the expected changes relative to the baseline situation (Green, 1979) and the criteria set by the controlling authorities. It is not sufficient to focus on data quantity and quality alone.

It is only possible to create a baseline for the benthic fauna, since the mapping studies of the area show that no forms of vegetation occur in the baseline condition.

Analyses show that there is no statistical difference between the faunal composition of the chosen reference area and the planned wind farm site (Bio/consult 1999c). This confirms that the areas chosen are suitable for a possible future monitoring programme.

Statistical calculations show that in these mapping studies of the benthic fauna, where 40 samples were taken in each of the sub-areas – the wind farm site and the reference area – a degree of certainty of 0.5 is necessary in order to prove a change of 50% in the biomass of the benthic fauna.. This means that a change in biomass of 50% must be demonstrated in half of the samples in repeated studies and with a statistical certainty of 95%. In benthic faunal studies a certainty factor of 0.8 is often preferable to demonstrate change in the biomass. To obtain a figure of 0.8 in a future baseline study will mean that a total of 90 sub-samples will need to be taken within the wind farm site and the reference area. This is based on the assumption that the criteria put forth in connection with the construction work are that the monitoring programme must be able to detect a 50% change in the biomass. It is worth noting, if a monitoring programme is to be initiated, that analysis has shown that sampling a greater number of stations is preferable to many replicates from each station, (Bio/consult 1999b).

5.3.1. Monitoring programme for the construction phase

The potential impacts from the construction phase are:

- The impact on the benthic fauna of sediment wastes.
- Complete or partial destruction of benthic animals due to the reclamation.
- Complete or partial destruction of benthic animals from water-jetting the marine cable into the sediment at the wind farm and along the cable line.

Special programmes for monitoring the environmental-biological conditions during the construction phase are not deemed to be necessary. This is based on three factors: the very limited and temporary spill impact associated with construction of the wind farm and the

cable line; the total reclaimed area being minor in relation to the total area; and the fact that in the affected area there are no species or habitat types that require special protection.

5.3.2. Monitoring programme during the production phase

Possible impacts during the production phase are:

- Permanent reclamation of the present sea bottom together with its benthic fauna.
- Permanent impacts on current, sediment, wave conditions and water exchange.
- Discharge of copper from the slip-rings of the wind turbines.
- Colonisation and succession of a fouling community on the revetments.
- Impacts resulting from oil spills in connection with accident or cable break.

No significant and general changes in the benthic community are expected to result from the construction of the wind farm, since the reclamation area covering the sea bottom and its associated benthic fauna affects less than 0.1% of the total area within the boundaries of the wind farm. There is also only localised impact on the water exchange, current, sediment and wave regime of the area.

It is not deemed necessary to initiate a special programme for monitoring and control of the benthic fauna. This is on account of the expected of only local and marginal changes and the fact that there are no species or habitats specially requiring protection,. It is worth noting that biomass changes (50%) can only be proved with a statistical certainty of 0.50 on the basis of the present existing baseline data. This can be relevant for design of control studies, or studies on subjects like temporary oil spills, or the food sources of fish and birds.

The discharge of copper from the slip-rings can cause a locally increased contamination of filter-feeding and sediment-eating organisms in the area. It is therefore recommended that a control and monitoring programme be initiated to follow the copper content in the bivalves during the production period. Or alternatively that the copper waste is avoided or collected.

It is suggested that a programme to monitor the establishment and succession of the fouling community on the artificial reef (revetment) and on the wind turbine foundation, be initiated for the production phase. The monitoring programme should undertake qualitative and quantitative studies of the course of succession, community stability, and sensitivity to extreme weather conditions. The results of the monitoring programme should be related to enhancement of the existing fish and bird fauna or that which is expected to develop.

Monitoring should be conducted on a representative sample of the wind turbine foundations and the reef and use a combination of quantitative sampling and video documentation.

The sampling area and the stations would be selected by a statistical sampling design, programmed to cover the depth range and the prevailing currents in the wind farm area.

6. Conclusion

Present situation
The wind farm area is characterised by bottom conditions that are relatively uniform with a sediment consisting of pure medium-grained sand with no organic matter. There is a tendency to more coarse-grained sediment along the edges of the study area, towards greater depths.

The wind farm and the area along the planned cable line are characterised by the fact that there is neither attached nor permanent vegetation of any kind.

The fauna in the study area is very heterogeneous. No significant differences are recorded between the wind farm site and the reference area, for faunal composition, density of individuals or biomass.

The fauna has similarities with that on sand banks in other areas of the North Sea, and can as such be characterised as an *Ophelia borealis* community after one of the typical and characteristic bristle worms.

The area is characterised by a lower number of species, a lower density of individuals and less biomass than in the immediately adjoining areas, which are characterised by *Venus* and *Abra* communities.

The inshore area, where the cable line passes through the international protection area, can be characterised as a *Lanice conchilega* community.

The rate of occurrence and biomass of the bivalves that are potential food sources for diving ducks is low compared to other areas of the North Sea.

Impacts
The wind farm turbines will occupy a benthic area of less than 0.1% of the total area of the offshore site.

No significant permanent or temporary changes in the benthic fauna are envisaged as a result of the construction work. It is therefore not deemed necessary to establish a general control and monitoring program for the benthic fauna.

The existing sampling design and baseline for benthic fauna is sufficient for any following control studies to be able to prove 50% changes in the biomass with a statistical certainty of 0.50.

A minor increase in copper contamination of filter-feeding benthic animals is expected to occur during the production phase. It results from the discharge of 206 kg copper annually from the slip-rings in the wind turbines. The discharge should either be avoided or a thorough control programme initiated for copper concentrations in filter-feeding organisms.

The establishment of wind-turbine foundations with associated scour-protecting revetments will introduce new biotopes to the park site. The artificial substrates have the potential to be colonised by new species for this area, including several red-listed species of the Wadden Sea area. It is recommended that a monitoring program be initiated to follow the fouling communities on the artificial substrates.

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Annexes

Annex 1
List of positions

Annex 2
Complete species list

Annex 3
Average densities of individuals and relative distribution of individual species

Annex 4
Biomass averages and relative distribution of individual species

Annex 5
Average densities of individuals in the sub-areas

Annex 6
Biomass averages in the sub-areas

Annex 1

Station positions, sediment and benthic fauna, Horns Rev, 25 April–12 May 1999

Station	UTM32_X	Y_UTM32	Lat_WGS84	Long_WGS84
1	422854	6151451	7°46,64'	55°30,07'
2	422991	6150336	7°46,79'	55°29,47'
3	423127	6149220	7°46,94'	55°28,87'
4	423264	6148116	7°47,09'	55°28,28'
5	423400	6147000	7°47,24'	55°27,68'
6	423414	6151452	7°47,18'	55°30,08'
7	423551	6150337	7°47,32'	55°29,48'
8	423687	6149221	7°47,47'	55°28,88'
9	423824	6148117	7°47,62'	55°28,28'
10	423960	6147001	7°47,77'	55°27,68'
11	424534	6151444	7°48,24'	55°30,08'
12	424671	6150340	7°48,39'	55°29,49'
13	424807	6149224	7°48,53'	55°28,89'
14	424944	6148109	7°48,68'	55°28,29'
15	425080	6147004	7°48,83'	55°27,70'
16	425654	6151447	7°49,30'	55°30,10'
17	425791	6150332	7°49,45'	55°29,50'
18	425957	6149227	7°49,63'	55°28,90'
19	426064	6148112	7°49,74'	55°28,30'
20	426200	6146997	7°49,89'	55°27,70'
21	426774	6151451	7°50,37'	55°30,11'
22	426911	6150335	7°50,51'	55°29,51'
23	427047	6149220	7°50,66'	55°28,91'
24	427184	6148116	7°50,81'	55°28,31'
25	427320	6147000	7°50,95'	55°27,71'
26	427894	6151443	7°51,43'	55°30,11'
27	428031	6150339	7°51,58'	55°29,52'
28	428167	6149224	7°51,72'	55°28,92'
29	428304	6148108	7°51,87'	55°28,32'
30	428440	6147004	7°52,02'	55°27,73'
31	429014	6151447	7°52,49'	55°30,13'
32	429151	6150332	7°52,64'	55°29,53'
33	429287	6149228	7°52,79'	55°28,93'
34	429424	6148112	7°52,93'	55°28,33'
35	429560	6146997	7°53,08'	55°27,73'
36	429574	6151449	7°53,03'	55°30,13'
37	429711	6150334	7°53,17'	55°29,53'
38	429847	6149219	7°53,32'	55°28,93'
39	429984	6148115	7°53,46'	55°28,34'
40	430120	6146999	7°53,61'	55°27,74'

Station positions, cable line positions, Horns Rev, 25 April–12 May 1999

Station	UTM32_X	Y_UTM32	Lat_WGS84	Long_WGS84
1	446058	6154900	8°08,64'	55°32,12'
1A	445688	6154292	8°08,30'	55°31,79'
1B	445167	6153519	8°07,81'	55°31,37'
2	444644	6152780	8°07,32'	55°30,97'
0	444240	6152374	8°06,94'	55°30,74'
4	443735	6152124	8°06,47'	55°30,61'
5	442321	6151920	8°05,13'	55°30,49'
5A	440347	6151968	8°03,25'	55°30,50'
5B	438611	6152004	8°01,60'	55°30,50'
6	436867	6151561	7°59,95'	55°30,25'
7	436160	6151460	7°59,28'	55°30,19'
8	435453	6151158	7°58,61'	55°30,02'
9	434393	6150484	7°57,62'	55°29,65'
10	434039	6150356	7°57,28'	55°29,58'
11	433534	6150286	7°56,80'	55°29,54'
12	432928	6150284	7°56,23'	55°29,53'
13	431969	6150510	7°55,31'	55°29,65'
13A	430352	6151025	7°53,77'	55°29,91'
14	428454	6151545	7°51,96'	55°30,17'
15	426494	6151544	7°50,10'	55°30,16'

Annex 2 Complete species list

Group	Species	Author
HYDROZOA,		
	Hydractinia echinata	Fleming
SCYPHOZOA,		
	Beroe cucumis	Fabricius
NEMERTINI,		
	Nemertini indet.	
NEMATOMORPHA,		
	Nematomorpha indet.	
NEMATODA,		
	Nematoda indet.	
POLYCHAETA,		
	Pholoe sp.	
	Pisione remota	(Southern)
	Eteone foliosa	Quatrefages
	Eulalia viridis	(L.)
	Nephtys caeca	(Fabricius)
	Nephtys hombergii	Savigny
	Nephtys longosetosa	Ørsted
	Nephtys sp.	
	Goniadella bobretzkii	(Annenkova)
	Protodorvillea kefersteini	(McIntosh)
	Orbinia sertulata	(Savigny)
	Spionidae indet.	
	Spio filicornis	(O.F. Müller)
	Aonides paucibranchiata	Southern
	Scolelepis bonnieri	Mesnil
	Magelona mirabilis	(Johnston)
	Travisia forbesii	Johnston
	Ophelia borealis	Quatrefages
	Terebellidae indet.	
COPEPODA,		
	Harpacticoida indet.	
	Harpacticus sp.	
TANAIDACEA,		
	Tanaidacea indet.	
DECAPODA,		
	Crangon crangon	L.
	Carcinus maenas	L.
	Pagurus bernhardus	L.
MYSIDACEA,		
	Praunus flexuosus	(O.F. Müller)
AMPHIPODA,		
	Haustorius arenarius	Slabber
	Eurysteus nitida	(Stimpson)
	Metopidae indet.	
	Oedicerotidae indet.	
	Pontocrates altamarinus	Bate & Westwood
	Pontocrates arenarius	Bate
	Westwoodilla caecula	Bate
GASTROPODA,		
	Hydrobia ulvae	Montagu
	Polinices polianus	(delle Chiaje)
BIVALVIA,		
	Goodallia triangularis	(Montagu
	Spisula elliptica	(Brown)
	Angulus tenuis	(Da Costa)
	Fabulina fabula	(Gmelin)
	Arctica islandica	(L.)
CORDATA,		
	Branchiostoma lanceolatum	(Pallas)

Annex 3
Average densities of individuals and relative distribution of individual species

Annex 4
Biomass g wet weight/m^2 averages and relative distribution of individual species

Annex 5
Average densities of individuals in the sub-areas

Annex 6
Biomass averages in the sub-areas