

# **Review report**

## The Danish offshore wind farm demonstration project

Environmental Impact Assessment and Monitoring

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<b>1</b>	<b>INTRODUCTION .....</b>	<b>4</b>
<b>2</b>	<b>POTENTIAL IMPACTS OF OFFSHORE WIND FARMS.....</b>	<b>5</b>
	2.1.1 <i>Destruction of bottom area .....</i>	5
	2.1.2 <i>Sediment spill and increased turbidity.....</i>	5
	2.1.3 <i>Noise and vibrations .....</i>	5
	2.1.4 <i>Electromagnetic fields .....</i>	6
	2.1.5 <i>Physical presence of the wind turbines.....</i>	6
	2.1.6 <i>Disturbances .....</i>	6
	2.1.7 <i>Introduction of hard substrate habitats .....</i>	6
<b>3</b>	<b>POTENTIALLY AFFECTED PARTS OF THE ENVIRONMENT .....</b>	<b>6</b>
3.1	HYDROGRAPHY / GEOMORPHOLOGY .....	6
3.2	MARINE BOTTOM FAUNA AND FLORA .....	7
3.3	FISH.....	7
3.4	MAMMALS.....	7
	3.4.1 <i>Seals.....</i>	8
	3.4.2 <i>Harbour porpoises.....</i>	8
3.5	BIRDS .....	8
3.6	VISUAL AND SOCIO-ECONOMIC IMPACT .....	9
3.7	REFERENCES.....	9
<b>4</b>	<b>DESCRIPTION OF THE OFFSHORE WIND FARM SITES.....</b>	<b>10</b>
<b>5</b>	<b>HORNS REV.....</b>	<b>10</b>
5.1	DESCRIPTION OF THE HORNS REV WIND FARM AREA.....	10
	5.1.1 <i>Cable connection to land .....</i>	11
5.2	DESIGNATED AREAS .....	11
5.3	SHIP TRAFFIC .....	11
5.4	ARCHAEOLOGICAL INTERESTS .....	12
5.5	HYDROGRAPHY / GEOMORPHOLOGY.....	12
	5.5.1 <i>Environmental Impact Assessment.....</i>	13
5.6	BENTHIC VEGETATION AND FAUNA .....	13
	5.6.1 <i>Benthic vegetation.....</i>	13
	5.6.2 <i>Benthic fauna .....</i>	13
	5.6.3 <i>Environmental Impact Assessment.....</i>	14
5.7	FISH.....	14
	5.7.1 <i>Fishery.....</i>	14
	5.7.2 <i>Environmental Impact Assessment.....</i>	15
5.8	MAMMALS.....	15
	5.8.1 <i>Seals.....</i>	15
	5.8.2 <i>Harbour porpoises.....</i>	15
	5.8.3 <i>Environmental Impact Assessment.....</i>	15
5.9	BIRDS .....	16
	5.9.1 <i>Environmental Impact Assessment.....</i>	17
5.10	VISUAL AND SOCIO-ECONOMIC IMPACT .....	17
5.11	REFERENCES.....	18
<b>6</b>	<b>RØDSAND.....</b>	<b>19</b>
6.1	DESCRIPTION OF THE RØDSAND NYSTED OFFSHORE WIND FARM .....	19
	6.1.1 <i>Cable connection to land .....</i>	19
6.2	DESIGNATED AREAS .....	20
6.3	RECREATIONAL INTERESTS .....	21
6.4	SHIP TRAFFIC .....	22
6.5	ARCHAEOLOGICAL INTERESTS .....	22
6.6	HYDROGRAPHY / GEOMORPHOLOGY.....	22
	6.6.1 <i>Environmental Impact Assessment.....</i>	23

6.7	BENTHIC VEGETATION AND FAUNA .....	24
6.7.1	<i>Benthic vegetation</i> .....	24
6.7.2	<i>Benthic fauna</i> .....	24
6.7.3	<i>Introduction of hard substrates</i> .....	27
6.7.4	<i>Environmental Impact Assessment</i> .....	27
6.8	FISH.....	28
6.8.1	<i>Environmental Impact Assessment</i> .....	28
6.9	MAMMALS.....	29
6.9.1	<i>Seals</i> .....	29
6.9.2	<i>Harbour porpoises</i> .....	30
6.9.3	<i>Environmental Impact Assessment</i> .....	30
6.10	BIRDS .....	31
6.10.1	<i>Environmental Impact Assessment</i> .....	32
6.11	VISUAL AND SOCIO-ECONOMIC IMPACT .....	33
6.12	REFERENCES.....	33
<b>7</b>	<b>APPENDIX I: LITERATURE ON THE DEMONSTRATION PROJECTS.....</b>	<b>36</b>
7.1	HORNS REV .....	36
7.1.1	<i>Hydrography / Geomorphology</i> .....	36
7.1.2	<i>Marine bottom fauna and vegetation</i> .....	36
7.1.3	<i>Fish and fishery</i> .....	36
7.1.4	<i>Mammals</i> .....	36
7.1.5	<i>Birds</i> .....	37
7.1.6	<i>Visualisation</i> .....	37
7.1.7	<i>General</i> .....	37
7.2	RØDSAND .....	38
7.2.1	<i>Hydrography / Geomorphology</i> .....	38
7.2.2	<i>Marine bottom fauna and vegetation</i> .....	38
7.2.3	<i>Fish and fishery</i> .....	39
7.2.4	<i>Marine mammals: seals and porpoises</i> .....	39
7.2.5	<i>Birds</i> .....	40
7.2.6	<i>Visualisation</i> .....	40
7.2.7	<i>General</i> .....	40
7.3	DEMONSTRATION PROJECTS GENERAL.....	41
<b>8</b>	<b>APPENDIX II: LITERATURE NOT RELATED TO THE DEMONSTRATION PROJECT.....</b>	<b>42</b>

## 1 Introduction

With the former Danish government's plan of action for energy, Energi 21, from 1996, it was decided to establish 5,500 MW of wind power in Denmark before 2030. Of this total, 4,000 MW was supposed to be established offshore in large wind farms.

In 1997 a plan of action was made and in this five areas were pointed out as usable for offshore wind farms. These are the area south of Læsø, Horns Rev (in the North Sea), Omø Stålgrunde (in the Great Belt south of Omø), Rødsand (in the Femeer Belt south of Lolland) and Gedser (in the Femeer Belt south of Falster). In Figure 1.1 the five areas are marked.

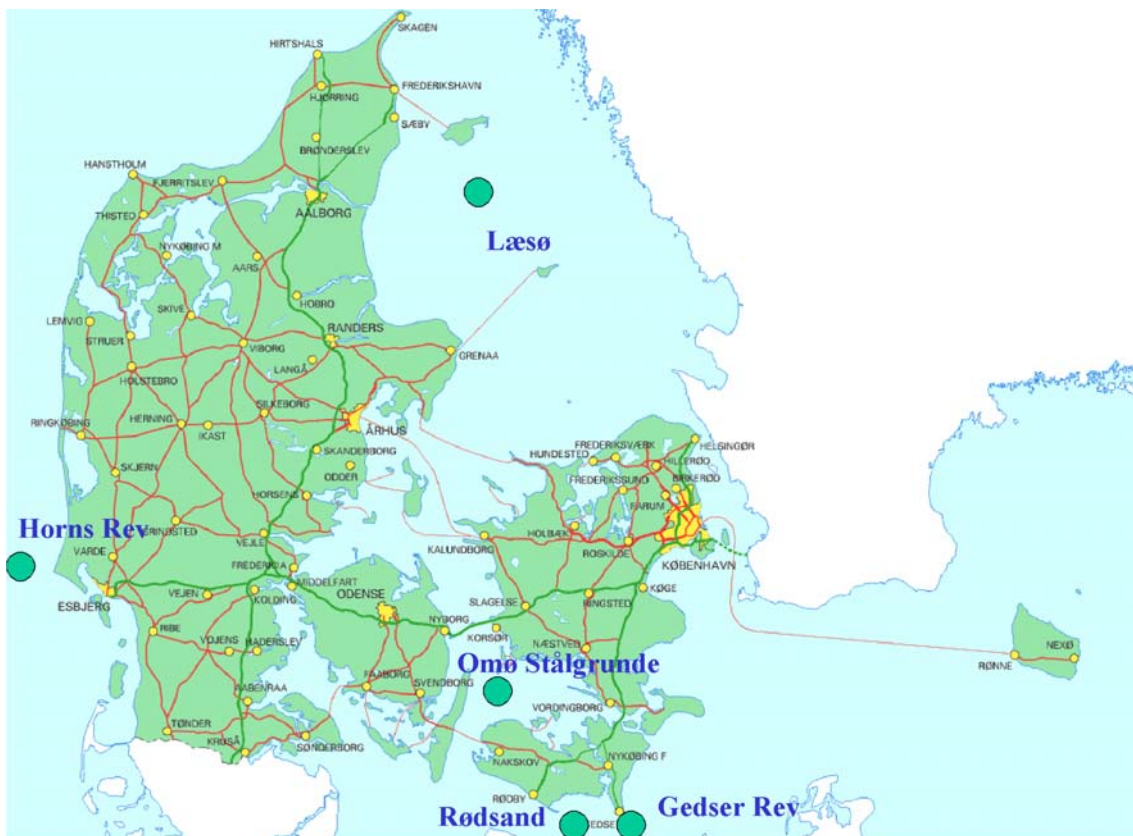


Figure 1.1. Map of the marine areas appointed for the construction of offshore wind farms in Denmark.

The five wind farm areas are going to form the basis for the 4000 MW established offshore. As a follow-up to Energi 21 in 1998 the Danish Environment and Energy Minister ordered the power producing companies to establish 750 MW<sup>1</sup> of offshore wind power as demonstration projects in Denmark.

The five proposed wind farms have been given the status of 'demonstration projects'. The objective of the demonstration projects is to shed light on the technical, financial and environmental circumstances with regard to the future electric power production in the Danish offshore environment.

The Danish Energy Agency has given an approval to make a pre-assessment for the five areas. In that approval it is stated that environmental monitoring programmes should shed light on the different environmental impacts of both the specific offshore wind farm and offshore wind farms in general. In each of the proposed wind farm areas, a series of studies on the environmental conditions and the possible impact of an offshore wind farm are undertaken.

<sup>1</sup> The Government that came into office late 2001 reversed that obligation only to include the two first wind farms at Horns Rev and Rødsand (equalling 318 MW).

The studies belong to two different categories, namely, studies which are important for the extension of the offshore wind farm at the specific sites, and studies which are important for the establishment of 4000 MW offshore wind farms in Denmark.

The present review report describes the two areas Horns Rev and Rødsand with regard to environmental characteristics and the results of the environmental studies carried out in connection with the Environmental Impact Assessment (EIA) and the baseline programmes at the two sites. Appendix I is a list of the literature published on the studies carried out at Horns Rev and Rødsand. Appendix II is a list of some of the literature relevant to the demonstration projects but not directly related to the projects.

## **2 Potential impacts of offshore wind farms**

In the following, the different types of potential impacts outlined in the Environmental Impact Assessments carried out in connection with the wind farms at Horns Rev and Rødsand are described.

The possible impact of an offshore wind farm can be divided into impacts during the construction of the wind farm and impacts during the operation of the wind farm.

### Potential impacts during construction

1. Destruction of bottom area
2. Sediment spill and increased turbidity
3. Noise
4. Disturbances due to construction activities

### Potential impacts during operation

1. Noise and vibrations from the turbines
2. Electromagnetic fields
3. The physical presence of the turbines
4. Disturbance due to maintenance operations
5. Introduction of hard substrate, due to scour protection around the foundations

The different types of impact listed above are described below. Some of the impacts can occur during both the construction and the operation phase and are thus described as one.

#### *2.1.1 Destruction of bottom area*

The establishing of the wind turbine and transformer platform foundations, and of the sea-cables interconnecting the wind turbines and connecting the wind farm to land, requires excavation of bottom area and possibly also sluicing of the bottom. In the areas affected it will cause an almost complete destruction of the bottom area.

#### *2.1.2 Sediment spill and increased turbidity*

Both excavation and sluicing activities during the construction phase will result in sediment spill and increased turbidity of the water. The extent of sediment spill will depend on the methods used, the steps taken to avoid sediment spill and the sediment type in the area and the hydrographic conditions in the area at the time of activities.

The increase of the turbidity will depend on the amount of sediment spill, the sediment grain size and the local hydrographic conditions at the time of the sediment spill. Sedimentation is slower for sediment with a small grain size and thus, the turbidity is increased more when the grain size of the sediment is small.

#### *2.1.3 Noise and vibrations*

Noise is coming from different sources during the construction phase and the operation phase.

The different construction activities will generate noise. The noise will come from shipping operations, excavation work, sluicing of cables etc. The noise generated by these sources, except mono-pile driving, will primarily be of low frequencies. If mono-piles are used as foundations for the turbines, pile driving will be used to construct them and this is likely to cause high noise levels.

When operating the wind turbines and the transformer will emit noise to the air and through the tower and foundation to the water. Measurements of noise from a wind turbine show that the airborne noise has a negligible contribution to the

underwater noise level. So, the noise measured underwater from the wind turbines is transmitted through the tower and the foundation of the wind turbine.

When operating the underwater noise from the offshore wind turbines is not higher than the ambient noise in the frequency range above approximately 1 kHz. In the frequency range below approximately 1 kHz, the underwater noise emitted from the offshore wind turbines is higher than the ambient noise (Ødegaard & Danneskiold-Samsøe, 2000).

When operating the turbines will give out vibrations to the surroundings and this might have an impact on the bottom fauna, fish and mammals in the vicinity of the foundations. So far, this type of impact has not been investigated thoroughly and the knowledge on the subject is very limited.

#### *2.1.4 Electromagnetic fields*

Around the cables interconnecting the wind turbines and the cable connecting the wind farm to land, electromagnetic fields are created when an electric current is running in the cables.

A direct current cable will contain a constant unidirectional current and induce a magnetic field with fixed poles. Alternating current cables do not generate the same constant magnetic field because of the alternating and pulsating current. Therefore, alternating current cables are not expected to influence the animals to the same degree as a direct current cable. The knowledge on the impact of electromagnetic fields on marine animals is limited.

#### *2.1.5 Physical presence of the wind turbines*

The wind turbines are large structures that will change the physical characteristics of the area markedly. This might have an impact on some animals, causing them to minimise their use of the area or completely abandon the area.

The physical structure of the foundations might also cause attraction of animals, which use them as resting-place or protection against predation.

#### *2.1.6 Disturbances*

Disturbances as a result of the wind farm might occur during both the construction and the operation phase.

During the construction phase, boats, machinery and people operating in the wind farm area, might disturb the animals living there.

During the operation phase, boats and people entering the wind farm area to carry out maintenance work, might disturb the animals living there.

#### *2.1.7 Introduction of hard substrate habitats*

As a secondary element of establishing offshore wind farms, the foundations and the rocks placed to prevent scour at their bases will introduce new hard substrate surfaces. The foundations and the scour protection may form a new type of sub-littoral habitat, which may be colonised by a variety of marine invertebrates.

The hard substrate may increase the opportunities for epifauna to settle and it may provide a substrate, which is more attractive to mobile fauna than the previous 'pre-wind farm seabed'. The establishment of epifauna and flora on the hard substrates will increase the food available to fish, which again will lead to an increase in the food available to marine mammals and birds.

The possible effects of introducing a hard substrate cannot be established until the foundations have been in place for some time.

### **3 Potentially affected parts of the environment**

The potential impacts of offshore wind farms described above are of various importance to the different parts of the environment in and around the offshore wind farms. In the following the possible impact of an offshore wind farm on the different parts of the environment is described in general.

#### **3.1 HYDROGRAPHY / GEOMORPHOLOGY**

The construction and operation of an offshore wind farm can potentially have an impact on the hydrography and the geomorphology in the wind farm area and in the areas surrounding the wind farm. The establishing of an offshore wind farm can change the water flow and thereby the transport of material and the sediment properties in the area.

The resistance from the foundations can influence the current and wave conditions in the wind farm area and this can influence the erosion and deposition of sediment in the area.

The potential impacts on local hydrography can also affect the coastal morphology in the area, due to changes in current conditions, erosion and deposition of material.

### 3.2 MARINE BOTTOM FAUNA AND FLORA

The excavation and sluicing activities during the construction phase will cause destruction and disturbance of the bottom fauna and flora.

Excavation activities will cause both increased sediment spills in an area around the activity and increased turbidity of the water. Increased turbidity can cause clogging and destruction of the feeding organs of the benthic organisms, enabling them to feed. Increased sedimentation of suspended material can cause shading of the benthic vegetation.

In the operational phase, changes in the pattern of erosion and depositing of sediment around the individual foundations might affect the benthic fauna. Changes in the sedimentary environment can make it less attractive to some species and perhaps more attractive to other species, and thereby change the species composition of the bottom fauna and flora.

Monitoring of the bottom fauna during the construction and operation of the wind farm is essential, not only to detect direct effects, but also because changes in the distribution of fish, birds and marine mammals around wind farms might result from local changes in abundance of their food.

### 3.3 FISH

Both the construction activities and the operation of the wind farm can affect the fish species using the wind farm area.

Noise and disturbances during the construction of an offshore wind farm can affect fish and cause them to abandon the area during construction. Noise from the operation of wind turbines can also affect the fish and perhaps cause them to avoid the wind farm area completely. However, it is also possible that the fish become habituated to the noise from the wind turbines.

Changes in the water quality and the food resources caused by the construction and/or operation of the wind farm can affect the fish population in the area.

Changes in the sedimentary environment can also affect the fish. Sandeels and Sprats are very dependent on the availability of suitable sediment, and are particularly sensitive to changes in the content of silt and fine sand.

The physical structure of the foundations and the scour protection might cause attraction of some fish species, e.g. because the physical structure provides protection against predation or because it provides protection against the prevalent current and thus saves the fish energy.

Monitoring of fish is essential, not only to detect direct impacts of the wind farm, but also because changes in bird and marine mammal distributions around wind farm might result from local changes in abundance of their food.

### 3.4 MAMMALS

The construction and operation of the offshore wind farm can potentially affect the marine mammals in the area, in a number of ways.

The marine mammals can be affected by the noise and disturbances caused by the construction work. The construction work might affect the food sources and thus, make the area less attractive to the marine mammals during the construction.

As a result of establishing an offshore wind farm, the habitat might change, making it less attractive to marine mammals which might abandon the area e.g. because it is no longer suitable as foraging or breeding area.

The electromagnetic fields generated around the cables interconnecting the wind turbines and connecting the wind farm to land, might affect and disturb the marine mammals and cause them to avoid the area.

### 3.4.1 Seals

The common seal (*Phoca vitulina*) and probably also the harbour seal (*Halichoerus grypus*) are breeding in Danish waters. Both species are included in Annex II of the EC-Habitat Directive, which aim is to maintain a favourable conservation status of natural habitat and species of wild fauna and flora of community interest.

The most significant impacts on seals are expected to come from the physical presence of the wind turbines, the noise from ships and construction work, as well as the temporary or permanent loss of habitats near offshore wind farms.

Seals use sound to communicate and perhaps for hunting both on the surface and under water. The seals ability to communicate can be affected by the noise generated by the construction work and the operation of the wind turbines, and cause them to leave the wind farm area.

### 3.4.2 Harbour porpoises

The harbour porpoise (*Phocena phocena*) is the only whale species that breeds and resides in all Danish waters. The species is also included in Annex II of the EC-Habitats Directives and listed as “vulnerable” in the “Red List of Globally Threatened Animals and Plants” by the International Union for the Conservation of Nature (IUCN). The areas designated for offshore wind farms in Denmark until now, are all known habitats for harbour porpoises.

The breeding period of harbour porpoises begins by late June and ends by late August. Ovulation and conception typically take place by late July and early August. The calves begin suckling immediately after birth and feed by their mother until March the following year and possibly longer (Sørensen & Kinze, 1994).

Harbour porpoises feed on school fishes such as herring and sprat. Porpoises are expected to follow the migrations of these species. The construction and/or operation of the wind farm might affect the distribution of food resources for the harbour porpoises.

Where pile driving is used for establishing the foundations there is a high risk of hearing damage to the harbour porpoises in the vicinity of pile driving. The animals will be able to hear the noise over a large area, both under and above the water, and will thus potentially be disturbed by the noise from the pile driving.

Since, the harbour porpoise is not by nature a stationary animal, but is believed to move around within a large sea area. It must be expected that harbour porpoises will leave areas in which construction activities are taking place.

Also the noise generated by the operation of the turbines can affect the harbour porpoises and this may cause the animals to abandon the wind farm area completely. Depending on the importance of the wind farm area as feeding or breeding area for the harbour porpoises, this can have an impact on the harbour porpoise population in the area.

## 3.5 BIRDS

Denmark is centrally placed on the East Atlantic flyway and is annually passed by large numbers of migrating birds. Furthermore, Danish waters hold very high concentrations of staging, moulting and wintering waterfowl. In total at least 5-7 million birds of more than 30 species of waterfowl winter in Danish waters and even more individuals stage for shorter or longer periods during migration.

As a consequence, Denmark has obligations under both the Ramsar and the Bonn Conventions, and the EU-Bird Directive, to protect and maintain these populations. For this reason, it is pointed out in the principal approval of the planned wind farms that the environmental impact assessment should give special attention to bird life.

The designation of EC Bird Protection Areas (SPA) and Ramsar Sites is based on a list of rare and vulnerable bird species included in Annex I of the EC-Bird Directive and the 1%-criteria for migrating birds. A Ramsar Site is e.g. a staging or wintering area for one or several bird species of which at least 1% of the population regularly stay at the locality. One percent of a population of birds connected to a certain breeding area, migration route and wintering area are found to be of international importance (Skov- og Naturstyrelsen, 1995).

With regard to birds, the potential impacts have been divided into two subjects of expected impact, namely disturbance-effects and collision-risk.

Disturbance-effects result in loss of habitat and physical changes of the habitat.

The noise and disturbances during the construction phase can affect the birds and cause them to abandon the area, resulting in a temporary loss of habitat area.

It is suggested that birds resting or foraging on or in the water will maintain a minimum distance from the wind farm, which will affect their ability to exploit the habitat for foraging and/or resting (NERI, 2000). The aspect of habitat loss is mainly relevant for the waterfowl species.

The physical changes of the area include loss of bottom area and provision of new underwater substrates being colonised by marine invertebrates. Foraging birds may exploit the food source resulting from the colonisation of the foundations and the scour protection. The physical structure of the turbine foundations may attract some bird species and serve as roost sites for them.

Collision-risk is the risk that birds will collide with the wind turbines. This can affect wintering and staging species, which over-flies the wind farm area every day in longer periods. Furthermore, it can affect a population of migrating birds, where a smaller or larger number of individuals over-fly the wind farm area once or twice a year. A rather limited knowledge exists on the risk of birds colliding with wind turbines.

### 3.6 VISUAL AND SOCIO-ECONOMIC IMPACT

The establishing of an offshore wind farm can potentially have a major impact on the landscape and the local community. An offshore wind farm with about 70 wind turbines will change the landscape considerably and this will affect both the local communities in the area and the people visiting the area.

The impact on tourism and on the local community can be either negative or positive. A negative impact will occur if the tourists stay away from the area, the rental of holiday cottages is reduced and the general use of the area for recreational activities such as yachting, angling, diving etc. is reduced due to the presence of the offshore wind farm. A positive impact will occur if the offshore wind farm becomes an attraction for tourists and the area becomes a resort area for the local citizen.

The noise emitted from the wind turbines during operation can potentially be a nuisance to the people on land. According to the modelling of the noise emitted by the offshore wind farm, the wind turbines will be heard at a distance of 1km at the most. The two offshore wind farms, Horns Rev and Rødsand, are both positioned at a longer distance from land and therefore, it will be impossible to hear them onshore.

### 3.7 REFERENCES

- NERI, 2000. Offshore wind farms. Proposals for criteria for acceptable impacts from bird populations. National Environmental Research Institute, Department of Coastal Zone Ecology.
- Skov- og Naturstyrelsen, 1995. EF-fuglebeskyttelsesområder og Ramsarområder. Kort og områdebeskrivelser.
- Sørensen, T. B. & Kinze, C. C., 1994. Reproduction and reproductive seasonality in Danish Harbour porpoise, *Phocoena phocoena*. *Ophelia* 39, 159-176.
- Ødegaard & Danneskiold-Samsøe A/S, 2000. Offshore wind turbines – EIA. Underwater noise measurements, analysis, and predictions. Report no. 00.792 rev 1. March 2000.



Monopiles will be used as foundations for the turbines and the transformer platform, and will be established by pile driving. The monopile foundation has a diameter of approximately 4m and will be driven in to a depth of approximately 25 metres.

The transformer platform (marked by a T on Figure 5.1) placed on three monopiles with a diameter of 1-2m will be built north of the most north-eastern wind turbine.

#### 5.1.1 Cable connection to land

The wind turbines are interconnected with a 36kV cable, which is connected to the transformer platform. The transformer platform is connected to land by a 150kV cable.

The cable will connect to land at Hvidbjerg Strand (see Figure 5.1). The length of the cable line is 19.5km. The cable will be embedded into the bottom by water-jetting. The cable trace passes through an international protection area.

Magnetic fields from cable trace, wind turbines, and the transformer station may be expected to reach geomagnetic field-strength levels only in the immediate vicinity of these structures, at distances no more than 1m (Eltra, 2000).

## 5.2 DESIGNATED AREAS

Relatively close to the projected wind farm area (5 nautical miles) are larger areas, which are designated for raw material extraction. The last few years have seen a decline in the extraction of raw materials, but the areas as such are not expected to be affected by the construction of the offshore wind farm (Rambøll, 1999).

North of the wind farm area is a military exercise area (Figure 5.4 )

Protected areas (Ramsar and EU bird and habitat areas) are situated in the vicinity of the planned offshore wind farm at Horns Rev (Figure 5.2). The Wadden Sea and neighbouring land areas constitute Ramsar area no. 27, and are also designated as Special Protection Areas under the EU Birds Directive (nos. 49, 50, 51, 52, 53, 55, 57, 60, 65 and 67) and as Special Areas for Conservation under the EU Habitats Directive (nos. 73, 78 and 90). Furthermore, the Wadden Sea also has the status of a Game Reserve (no. 48) with regulations concerning nature conservation and public access.

The offshore wind farm and the cable trace to land is included in the following international protections: EU-Bird Directive nos. 53, 55 and 57, EU-Habitat Directive area no. 78 and Ramsar area R 27 (Tech-wise, 2000).

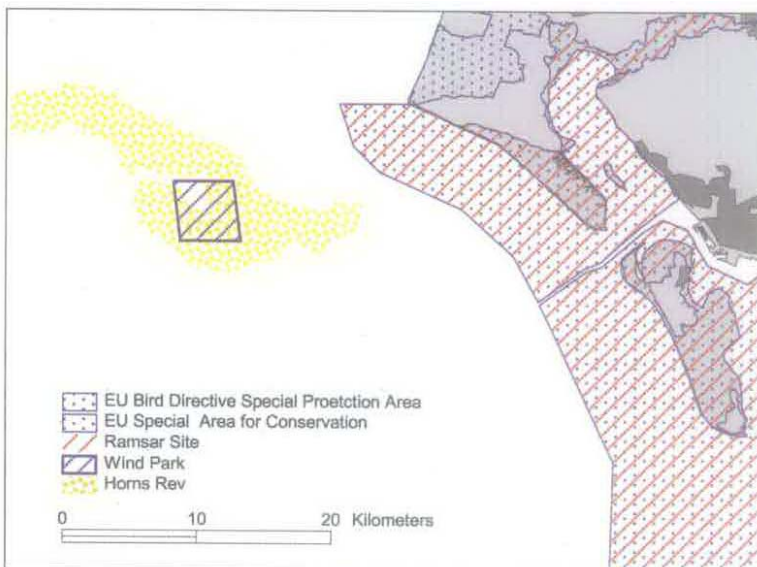


Figure 5.2. Protected area (Ramsar, EU Bird and Habitat areas) in the vicinity of the Horns Rev wind farm (from NERI, 2000)

## 5.3 SHIP TRAFFIC

From figure 5.3 it can be seen that there is considerable ship traffic in the area around Horns Rev. In the immediate vicinity of the wind farm area, including the wind farm area, mainly fishing vessels are sailing.

Besides fishing vessels there are some ship traffic in the area. However, the shipping routes lead around the areas of shallow water where the offshore wind farm will be established.

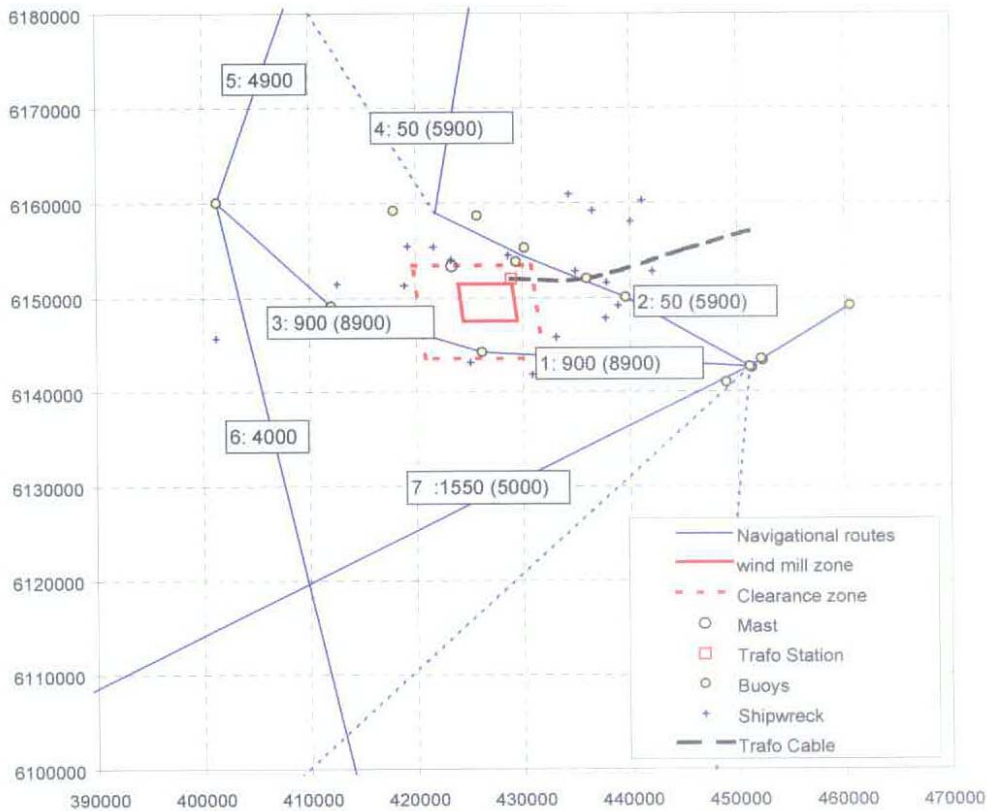


Figure 5.3. Definition of navigational routes in the vicinity of Horns Rev. The ship traffic in the vicinity of Horns Rev have been divided into a number of routes each characterised by a yearly number of movements and a size distribution (Rambøll, 2000).

#### 5.4 ARCHAEOLOGICAL INTERESTS

The area of the offshore wind farm has been surveyed to locate any wrecks or other items of archaeological interest. Neither wrecks nor items of archaeological interest have been found (Fiskeri- og Søfartsmuseet, 2000a; NMU, 1999)

#### 5.5 HYDROGRAPHY / GEOMORPHOLOGY

The Horns Rev forms the northern border of the area from Den Helder in Holland to Blåvands Huk; an area which is influenced by the tide. South of the Horns Rev is an area dominated by the tide, and a system of barrier-islands and lagoons behind the barrier-islands (The Wadden Sea). North of the Horns Rev, along the west coast of Jutland, the area is dominated by waves.

Horns Rev is an area of relatively shallow water. Within the wind farm area the water depth varies from 6.5m to 13.5m. The depth conditions in the area result in the waves breaking in the wind farm area. The average wave-height is about 1-1.5m and the tidal level is about 1.2m.

Morphologically the Horns Rev is stable and has not changed position since it was formed (DHI, 1999). The seabed at Horns Rev consists of relatively well sorted sediments of sand, gravel, pebble and boulders, with a few pockets of fine-grained material, and a low organic content (<1%) (Bio/consult, 1999a). In the area selected for the offshore wind farm, the sand layers on the seabed are 10-20m deep. Side-scan measurements indicate that there is considerable sand drifting along the sea floor (Bio/consult, 1999b). There has not been registered any occurrence of hard bottom in the wind farm area. This is explained by the very dynamic hydraulic conditions.

Along the planned cable line, the sediment towards the shore and in the deeper areas down to 25m consists of finer particles of silty sand and clay-silt (Bio/consult, 2000a).

The wind farm area is characterised by relatively high concentrations of inorganic nutrients, low transparency due to high amounts of re-suspended material in the water column, total mixing of the water column and generally good oxygen conditions (Bio/consult, 2000b).

The salinity in the area is 30-34psu and is determined by the inflow of freshwater from the German rivers to the German Bight and the inflow of relatively high-saline water from the North Sea. There is generally no thermocline in the area. Small differences in salinity of 1–1.5psu has infrequently been recorded between the surface and bottom layers, especially after long periods of strong south-easterly winds. The differences recorded between surface and bottom layers can better be characterised as a gradient than a discontinuity (Bio/consult, 2000b).

#### 5.5.1 Environmental Impact Assessment

Analyses of the hydrodynamic conditions have shown that the changes in sediment and current movements around the foundations will be very limited. Model calculations show that the total current velocity is reduced by 2% at the most before and after the establishment of the offshore wind farm (DHI, 1999).

The impact of the foundations on the water exchange in the area at Horns Rev is considered insignificant, because the prevailing turbulent conditions do not favour stratified conditions or oxygen depletion (DHI, 1999).

The offshore wind farm at Horns Rev is not expected to cause any appreciable change of the water quality in the area.

## 5.6 BENTHIC VEGETATION AND FAUNA

The seabed of the offshore wind farm area is characterised by sparse fauna and flora.

#### 5.6.1 Benthic vegetation

There has not been recorded any occurrence of benthic vegetation in the wind farm area. There is no registration of macro algae in the area west of Blåvands Huk.

#### 5.6.2 Benthic fauna

The faunal composition at Horns Rev is like the fauna typically recorded on other sand islets of the North Sea and is best described as a *Ophelia borealis*-community. *Ophelia borealis* is one of the most characteristic polychaetes in these areas.

The current conditions and heterogeneity of the hydrographic conditions in the area means that the fauna is distributed heterogeneously. Due to the turbulent conditions at the bottom and to the coarser sand and the limited organic material, the sandbanks are characterised by a lower number of species, a lower density and a lower biomass than in the adjacent areas where the bottom conditions are less unstable and where the sediment has a higher content of fine sand and organic material (Bio/consult, 1999a).

A total of 46 species of marine bottom fauna have been recorded. Of these, marine polychaetes constitute the largest group with 19 registered species/groups. Of crustaceans 7 species have been recorded and of bivalves 5 species have been recorded (Bio/consult, 2000a).

The most frequently occurring species at Horns Rev are all (including the bivalve *Goodallia triangularis*) small species, which constitute less than approximately 1.3% of the total biomass. The larger, but less frequently occurring polychaetes, such as *Travisia forbesii*, *Ophelia borealis*, *Orbinia sertulata* and *Nephtys longosetosa*, constitute between 4% and 20% of the overall biomass in the area.

It is expected that the fauna along the deeper parts of the cable trace is typical for the *Abra*-community, judged by the high number of brittle stars which are characteristic for this community. Closer to the coast at Hvidbjerg Strand, the sediment is finer, and it is expected that the fauna will be typical of a *Lanice conchilega* community, which is common along the North Sea coasts (Bio/consult, 1999a).

Bivalves, which are an important food source for seabirds (e.g. Common Scoter), are far less frequent in the areas studied, compared to other areas in the North Sea (Bio/consult, 2000a).

A high abundance of the brown shrimp (*Crangon crangon*) is observed east of the wind farm area. This species is an important prey species for both sea birds and fish (DIFRES, 2000).

Observations of the foundation of the established meteorological mast in the area have shown that new flora and fauna communities are established on the foundation. Observations further shows that sand stirred up in storms practically scrubs the foundation clean of animals and plants, where after colonisation starts all over. Thus, fouling on the foundations is not expected to develop much.

### 5.6.3 Environmental Impact Assessment

It is estimated that the total loss of habitat will affect less than 0.1% of the bottom fauna within the site. Furthermore, it is estimated that the loss of bottom fauna, caused by the presence of the wind turbine foundations, will be approximately 600 kg wet weight, which is less than 1% of the total biomass of the area (14.500 m<sup>2</sup>) (Bio/consult, 2000a).

During the construction phase many of the mobile species, e.g. crabs and crustaceans, will be less affected than stationary species such as bivalves and bristle worms (Bio/consult, 2000a).

Loss of bottom substrate comprises less than 0.3% of the wind farm area and is not expected to lead to measurable impacts. Furthermore, it is predicted that the benthic vegetation and fauna within the wind farm area will not change as a result of the establishing of the offshore wind farm (Bio/consult, 2000a).

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.

The turbine foundations and scour protection will provide substrate for the settlement of larvae of marine invertebrates. It is predicted that settlement will mainly involve barnacles (*Balanoides*) and possibly some bristle worms (*Polychaetes*), but is unlikely to include mussels due to impact from waves.

An examination of biofouling around a monitoring unit placed in the Horns Rev area, before and after a storm showed a sandblasting effect of the storm on the structure. Thus the hydrography in the area will prevent any permanent biofouling and a potential benefit from providing substrate for food-chain basis for fish are negligible (DIFRES, 2000).

The scour protection around each monopile will provide a high structural complexity. However, the lack of a firm seabed, the possibility of regular scour and/or burial events and severe storm conditions may reduce any food-chain base benefits of this type of structure in this locality (DIFRES, 2000). It is unlikely that the foundations will provide any measurable food chain basis for fish species in the area.

## 5.7 FISH

At Horns Rev the hydraulic conditions are so rough, that the occurrence of fish in the wind farm area is limited.

The most common species are dab (*Limanda limanda*), plaice (*Pleuronectes platessa*), hooknose (*Agonus cataphractus*), whiting (*Merlangius merlangus*), dragonet (*Callionymus lyra*) and grey gurnard (*Eutrigla gurnardus*) (DIFRES, 2000).

Numbers and distributions of fish in the wind farm area seem to be rather low, and the fish populations vary greatly from one year to the next (DIFRES, 2000).

Herring larvae drift from the spawning grounds across the North Sea and will be found as metamorphosing larvae and small juveniles in the Horns Rev area in March. During summer and autumn juvenile herring are found in schools, sometimes mixed with sprat, which are also abundant in the area.

### 5.7.1 Fishery

There are several types of fishery in the area around Horns Rev; the predominant type is trawling for sandeels (*Ammodytidae*) and sprat (*Sprattus sprattus*). There is also some net fishing for flatfish. Furthermore, there is trawling for brown shrimp (*Crangon crangon*). An important fishing ground for the Danish brown shrimp fishery is located in the shallow water areas between the proposed wind farm and the coast (DIFRES, 2000).

The wind farm does not overlap with the sandeel fishing grounds, but important fishing grounds are located north, north-east, and south of the wind farm (DIFRES, 2001).

The bivalve *Spisula solida*, which has been the object of commercial trial fishery in the area from 1993-1998, was not registered in the EIA-study (Bio/consult, 2000a)

The fishing activities will be affected, as trawling will not be allowed in the wind farm area and in the vicinity of the cable to the shore. The area, which will be rendered inaccessible for trawling, is, however, only a very limited part of Horns Rev, but in view of a long-term extension with more wind turbines in the area, it may be of increased importance. On the other hand, the attracting effect of the foundations may provide new possibilities for net fishing in the area.

### 5.7.2 *Environmental Impact Assessment*

It is likely that during the construction of both the wind turbines and the cable trace, many of the fish species will be disturbed. They will disappear from the relatively small area due to temporary increased turbidity of the water, underwater movements, noise and other activities on the sea bottom (DIFRES, 2000).

It is not expected that the physical presence of the cables buried in the seabed will cause any changes in the abundance of fish. Furthermore, the weak magnetic fields from the wind farm at Horns Rev are not expected to pose any serious problem for the fish species.

Because of the spatial extent of the low-frequency hydrodynamic/acoustic fields from the wind turbines, fish will perceive them to be very different compared to the low-frequency fields of other animals. Therefore, fish are not expected to be impaired in their ability to detect and interpret the fields from different sources (i.e. wind turbines or animals). The continuous character of the wind turbine noise is likely to promote habituation in the fish.

It is expected that the establishing of the wind turbine foundations will create an environment, which will increase the occurrence of fish in the area. The impact of fish will either be through increased productivity or simply through attraction. Considering the hydrography and material and design of the Horns Rev structures, there is no indication that the foundations will provide a significant food-chain basis. Codfish (Gadoids) and flatfish are attracted to underwater structures (DIFRES, 2000).

According to Executive Order no. 939 of 27 November 1992 on protection of sea cables, trawling is prohibited within 200m from a sea cable. Hence, trawling is prohibited in the wind farm area and along the cable trace. Since trawling is taking place both in the wind farm area and along the cable trace, the establishing of the wind farm might have a significant impact on the fishery in the area (Fiskeri- og Søfartsmuseet, 2000b).

## 5.8 MAMMALS

### 5.8.1 *Seals*

There are no haulout sites for seals in the vicinity of the wind farm, and not many seals have been observed in the area (DIFRES, 2000).

### 5.8.2 *Harbour porpoises*

Dense populations of harbour porpoises (*Phocena phocena*) are found north-east of the wind farm area, in the deep waters named "Slugen", whereas only few porpoises have been observed in the actual wind farm area.

At the western part of Horns Rev, approximately 15km from the wind farm area, harbour porpoises with calves have been observed during two summer registrations. Thus, this area might be a breeding area for harbour porpoises (Fiskeri- og Søfartsmuseet, 2000c).

In 2001 eight PODs (acoustic porpoise detectors) have been deployed in the Horns Rev area and the preliminary results suggest that there is a high number of harbour porpoises in the area. The study on the distribution of harbour porpoises at Horns Rev suggests that the distribution be connected to the hydrographic conditions in the area. In a period of intermediate salinity there was a higher density of harbour porpoises in the area, compared to a period of low salinity (NERI & Ornis Consult, 2001). The connection between hydrographic conditions and the distribution of harbour porpoises has not yet been properly investigated. One explanation for the observed pattern could be that the distribution of harbour porpoise food (fish) is influenced by the distribution of plankton (eaten by the fish), which again is influenced by the hydrographic conditions.

### 5.8.3 *Environmental Impact Assessment*

It is likely that during the construction period of both the wind turbines and the cable trace, the marine mammals will be disturbed. They will disappear from the relatively small area due to temporary increased turbidity of the water, underwater movements, noise and other activities on the sea bottom (DIFRES, 2000).

Due to the low abundance of seals in the area, it is evaluated that the establishing of an offshore wind farm at Horns Rev will not cause any significant effects on the seals in the area (Fiskeri- og Søfartsmuseet, 2000c).

It is not expected that the physical presence of the cables buried in the seabed will cause any changes in the abundance of marine mammals. The magnetic fields beyond a distance of 1 m from the cables, cable traces and underwater transformers are expected to be of the same magnitude as the geomagnetism (Eltra, 2000). It does not appear likely that the magnetic fields generated by the power transmission cable will have any detectable effects on the harbour porpoises and seals in the area (DIFRES, 2000).

In the construction phase, noise will be generated by the different construction operations (primarily the jack-up-rig ramming operations), by shipping operations (supply vessels coming and going as well as transportation within the area) and by helicopter traffic. The noise generated by these sources will primarily be of low frequencies with most energy probably below 1kHz. This is not expected to affect the echolocation abilities of the harbour porpoises (DIFRES, 2000).

In the production phase, noise will be generated by the wind turbines and by helicopter traffic. The wind turbines are expected to generate noise above ambient levels only in frequencies below 1-2 kHz (Ødegaard & Danneskiold-Samsøe, 2000). Below 500Hz, noise from the wind turbines could be considerably above ambient levels. It is not clear whether harbour porpoises use sounds with frequencies below 1 kHz. The noise generated in the production phase could potentially affect the communication of porpoises in the area, if they use these frequencies (DIFRES, 2000).

## 5.9 BIRDS

The preliminary counts from Horns Rev so far have shown relatively low numbers of all bird species in the wind farm area and its surroundings out to a distance of 2-3km. Figure 5.4 shows the area of the aerial counts of birds at Horns Rev (NERI, 2000).

Surveys made by plane and ship show that the birds are closer to the shore than to the offshore wind farm area. The tendency is that there are fewer birds at the planned offshore wind farm area than in the adjoining sea areas. For example, registrations made in the coastal area from November to March show quite a number of Common Scoters (*Melanitta nigra*) close to the coast.

The only species recorded offshore in significant number were fish-eaters: Divers, Gannets, Auks and Terns, plus large numbers of Gulls often concentrating around fishing vessels.

The waters around Horns Rev are known to hold large numbers of Red- and Black-throated Divers (*Gavia stellata* and *Gavia arctica*) during the winter season.

During the summer and winter large numbers of Common Scoter are in the area. The two bird species feeding on the bottom fauna (Eider and Common Scoter) were found almost exclusively along the coast (within the 6m depth contour), and only in a few cases more than 10km offshore. Very few individuals of either species have been observed within 2-4km of the projected wind farm area.

During late summer (and spring) Gannet (*Sula bassana*) occurs in large numbers, and terns (Common (*Sterna hirundo*), Arctic (*Sterna paradisaea*) and Sandwich (*Sterna sandvicensis*)) occurs in large numbers during their migration period spring and autumn.

All these species (except Common Scoter) are fish eating. The Divers take their prey by swimming, Gannet and Terns point out the prey while flying and take it by vertical dives.

The bird studies, which have been carried out at the Horns Rev, have therefore focused on the potential disturbance effect on divers and the other fish-eating species mentioned, and on Common Scoter.

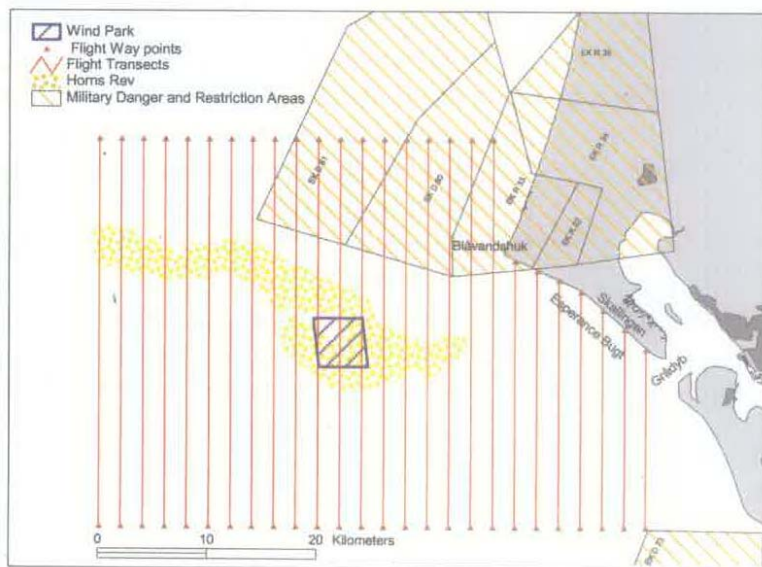


Figure 5.4. Study area (hatched) including transects (thin lines north-south) for aerial bird surveys. Military restriction areas are shown (e.g., EK R 33) (from NERI, 2000).

### 5.9.1 Environmental Impact Assessment

The results of the EIA study show that the area of the planned wind farm is of very limited significance for water- and seabirds judged by their overall distribution in the waters around Horns Rev. Impacts on birds resulting from the construction work are expected to be temporary and limited. The effect of laying the cable to land is also considered to be temporary and minimal.

On basis of the mapping of the distribution of birds and based on background knowledge of their behaviour, it is estimated that the largest risk for the birds will be to collide with turbine blades when chasing shoals of fish. This may refer to the different species of Terns, Arctic Skuas and Gannets, but would not, however, have any influence on the total population of these three groups of birds.

The bird species feeding on bottom fauna might be affected by the change in food items caused by the establishing of the foundations providing a new substrate for epifauna. However, settlement of fauna will mainly involve barnacles (*Balanidae*) and some bristle worm (Polychaetes) species that do not represent significant food items for birds, hence it is not expected that these modifications of the habitat will lead to any significant changes in numbers and distributions of birds in the area. The provision of platforms for sitting/perching may attract some gulls and possibly Cormorant to the wind farm area.

## 5.10 VISUAL AND SOCIO-ECONOMIC IMPACT

The offshore wind farm at Horns Rev is placed at such a large distance from land, that it will not have any significant impact on the coastal landscape (Birk Nielsens Tegnestue, 2000).

At a distance of about 45km from land, wind turbines of a height of 110m will not be visible from eye-height, due to the curvature of the Earth. Overall, it is evaluated that placing the offshore wind farm on Horns Rev, will not have any considerable visual consequences (Tech-wise, 2000).

It is uncertain to what extent the tourism will be affected and the effect can be both positive and negative. In connection with the construction of the offshore wind farm and the sea-cable to land, there will be a high level of activity in the area and this can potentially affect the recreational activities in the area. The effect will primarily be on the beach when the sea-cable is connected to land. However, this activity will be limited to a short time period (Tech-wise, 2000).

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## 6 Rødsand

### 6.1 DESCRIPTION OF THE RØDSAND NYSTED OFFSHORE WIND FARM

The planned offshore wind farm at Rødsand is placed 10 kilometres south of Nysted on Lolland, and 11-17 kilometres west of the town Gedser on the south tip of Falster.

Two barrier-islands, western Rødsand and eastern Rødsand, separate Rødsand Lagune from Femer Bælt and from the planned wind farm. Between the two barrier-islands, is the deep Østre Mærker, which is approximately 5.5km wide and on average 3.5m deep in the deepest parts. The distance from the barrier-islands to the nearest row of wind turbines will be about 2km (see Figure 6.1).

The wind farm is located on a gently sloping seabed consisting of glacier deposits covered by thin layers of sand. The water depth in the wind farm area is between 6m and 9.5m. The wind farm will cover an area of approximately 24km<sup>2</sup> (indicating the area between the four corner turbines) and a 200m wide exclusion zone will be established around the wind farm, resulting in an overall area of approximately 28km<sup>2</sup>.

The wind farm will consist of 72 turbines each of 2.2MW, with a hub height of 68.6m and 77.2m and a rotor diameter of 82.4m. The turbines are placed in 8 north-south orientated rows separated by a distance of 850m. Each row holds 9 turbines separated by a distance of 481m (see Figure 6.1). The wind turbines will have a discreet marine grey colour and be equipped with warning lights for the sake of sea and air traffic.

The turbine foundations will be gravity foundations in concrete or mono pile foundations in steel with special protection against ice. The expected erosion around the bottom plate of the foundations will be prevented by a stone protection. The foundations will take up an area of about 45.000m<sup>2</sup>, corresponding to 0.2% of the total area of the wind farm. The foundations will cause an increase of the overall surface area of up to 56.000m<sup>2</sup>.

In connection with the wind farm up to six meteorology masts will be erected. The masts will supply information for the operation of the farm and ensure the gathering of knowledge about the impact of the wind farm on the wind speed and turbulence inside and outside the wind farm.

#### 6.1.1 Cable connection to land

The turbines will be interconnected with a 30kV sea-cable, which will be sluiced or buried at a depth of 1 metre.

The sea-cable continues from the most northerly turbine, in the fourth row from east, to a 30/132kV transformer platform 200m north of the most northerly turbine. The total length of the 30kV sea-cable is about 48 kilometres. The transformer will be placed on a platform similar to the wind turbine foundations.

From the transformer platform to Vantore Strandhuse east of Nysted, a 132kV cable will be buried at a depth of 1 metre. The total length of the 132 kV cable connections to land is about 10km. Figure 3.1 shows the cable connection to land. The cables in the Rødsand wind farm are planned to be Alternating Current (AC) cables.

Along the cable trace the water depth decreases gradually from 6m to 3.5m in the outmost 4km of the cable trace. The bathymetry is complicated in the innermost 6km of the cable trace and the water depth is highly variable with shallower and deeper parts (Geoteknisk Institut, 1999a).

Geologically the cable trace area is generally characterised by the presence of moraine clay deposits with a variable cover of post-glacial sediments in the form of sand and/or mud (Geoteknisk Institut, 1999b).

In the outermost part of the cable trace the bottom consists predominantly of sand. In the innermost and more protected part of the Rødsand Lagune the sediment is muddier. Stones are abundant in the middle section of the cable trace (DHI, 2001a).

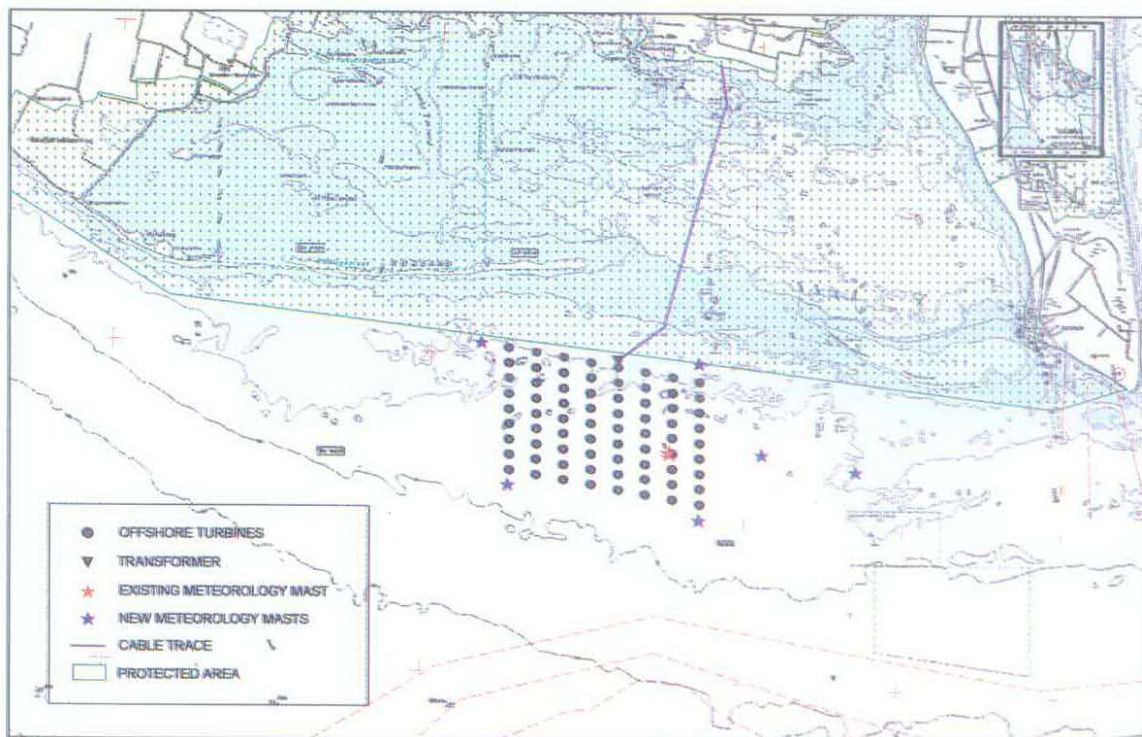


Figure 6.1. Map section with wind farm, transformer platform, cable trace and meteorology masts.

## 6.2 DESIGNATED AREAS

The offshore wind farm at Rødsand is located outside an area protected under the EC-Habitat Directive, the EC Bird Directive and the Ramsar Convention. The area from Gedser to Hyllekrog, including the Rødsand Lagune, Bøtø Nor and Guldborg Sund, is designated as Ramsar area no. 25, Special Bird Protection Area (EF83) and EC-habitat area no. 152 (Figure 6.2).

The area is designated as a EC Bird Protection Area (no. 83) and Ramsar Site (no. 25) due to breeding species like: March Harrier (*Circus aeruginosus*), Avocet (*Recurvirostra avosetta*), Arctic Tern (*Sterna paradisaea*) Common Tern (*Sterna hirundo*), Little Tern (*Sterna albifrons*) and Sandwich Tern (*Sterna sandvicensis*), and due to migrating birds like Mute Swan (*Cygnus olor*), Whooper Swan (*Cygnus cygnus*), Brent Goose (*Branta bernicla*), Bean Goose (*Anser fabalis*), Goldeneye (*Bucephala clangula*) and Coot (*Fulica atra*) (Skov- og Naturstyrelsen, 1995).

The EC Habitat Areas (SAC) are designated due to: Sandbanks which are slightly covered by sea water all the time; Mudflats and sand flats not covered by seawater at low tide; Large shallow inlets and bays; Perennial vegetation of stony banks; Salicornia and other annuals colonizing mud and sand; Atlantic salt meadows (*Glauco-Puccinellitalia maritimae*); Harbour porpoises (*Phocoena phocoena*); Grey seal (*Halichoerus grypus*); harbour seal (*Phoca vitulina*); Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes); Fixed dunes with herbaceous vegetation (grey dunes).

The 132 kV cable trace to land will pass through the protected area.

Around the western tip of the Rødsand sandbank (54°35'N, 11°49'E), east of the channel to Nysted, a seal sanctuary has been established to which access is prohibited between March 1 and September 30 (Ministry of the Environment and Energy 1993). The seal sanctuary was established in 1978. The area of the offshore wind farm lies right next to the seal sanctuary and the nearest turbine will be erected approximately 3km from the seal sanctuary (Figure 6.2).

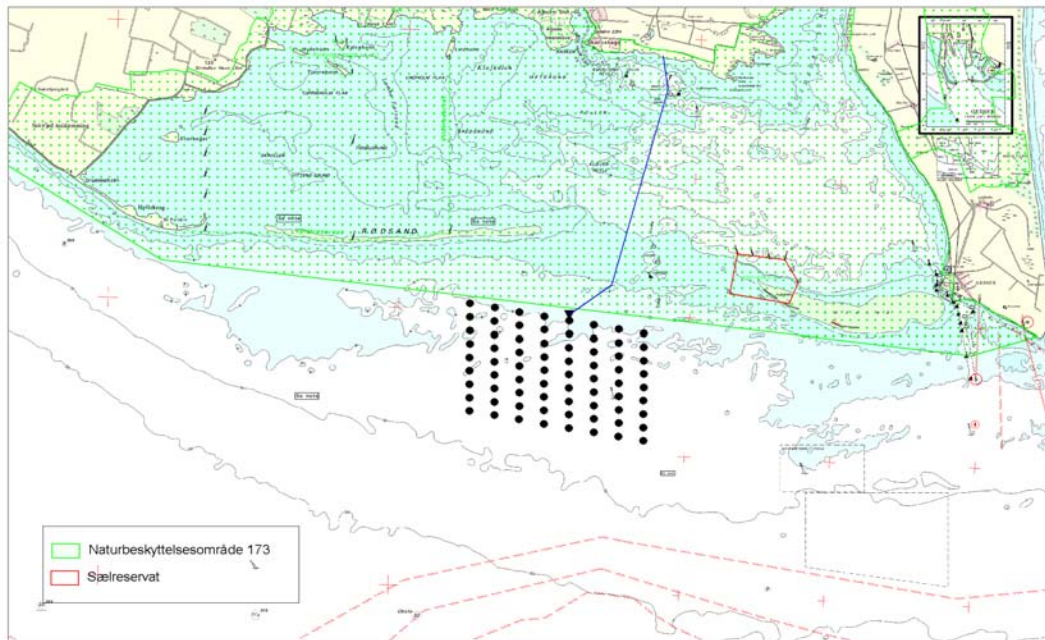


Figure 6.2. Designated areas north of the planned offshore wind farm at Rødsand.

It is important that the impact, which the wind farm may have on the surrounding area, does not extend into the protected area to any significant extent. Therefore, the possible effects of the offshore wind farm on the designated areas are given special attention and the environmental studies are targeted at catching up the possible effects on the designated areas.

According to an Executive Order on cables, raw material extraction is not allowed within 200m from a sea cable. Hence, raw material extraction will not be possible inside the wind farm or along the cable trace (Kabelbekendtgørelsen, 1986). Since the overall estimate suggests that the park area does not represent a potential sand reclamation area, establishing of the offshore wind farm will not affect the potential for raw material extraction (Geoteknisk Institut, 1999a).

### 6.3 RECREATIONAL INTERESTS

There is yachting of considerable magnitude in and around the area, and thus many sailors will experience impact from the offshore wind farm. Therefore, there is a potential risk of conflicts arising between the yachting and the establishing of the offshore wind farm (Water Consult, 2000).

Due to the long distances from land (Table 6.1), angling in the wind farm area is evaluated to be insignificant and is not expected to be affected by the offshore wind farm (Water Consult, 2000).

Harbour	Distance to wind farm area (kilometres)
Gedser	14
Nysted	17
Rødby	28
Warnemünde	47
Nakskov	82

Table 6.1. The distance from the wind farm area to the five harbours nearest to the wind farm area.

The use of the wind farm area for hunting is limited and it is evaluated that the impact on hunting from the establishing of the offshore wind farm is limited (Water Consult, 2000).

There has not been found significant non-professional diver interest in the area around Rødsand (Water Consult, 2000).

## 6.4 SHIP TRAFFIC

The municipality of Nysted estimates that approximately 8000 pleasure boats passes through Østre Mærker every year. In addition, a number of pleasure-boats pass through Østre Mærker, without calling at Nysted harbour. In the light of the present traffic at Rødsand, the increase in traffic of service boats must be characterised as small (Rambøll, 2001).

During the construction phase the wind farm area will be closed off, and this means that pleasure boats will have to sail round the area, resulting in a detour of 3km, at the most. Out of consideration for the yachting in the area, a shipping route is established diagonally (SE-NW) through the wind farm. The shipping route will be marked out for day-navigation when the wind farm is brought into operation.

A ship lane (the T route) for larger boats and ships is situated just south of the wind park area (Figure 6.3). The distance from the centre of the ship lane to the south of the wind farm area is approximately 8km. About 48000 ships pass through the T-route each year. The importance of the wind farm with regard to hindrance to the commercial traffic in the area is found to be minimal (Rambøll, 2001).

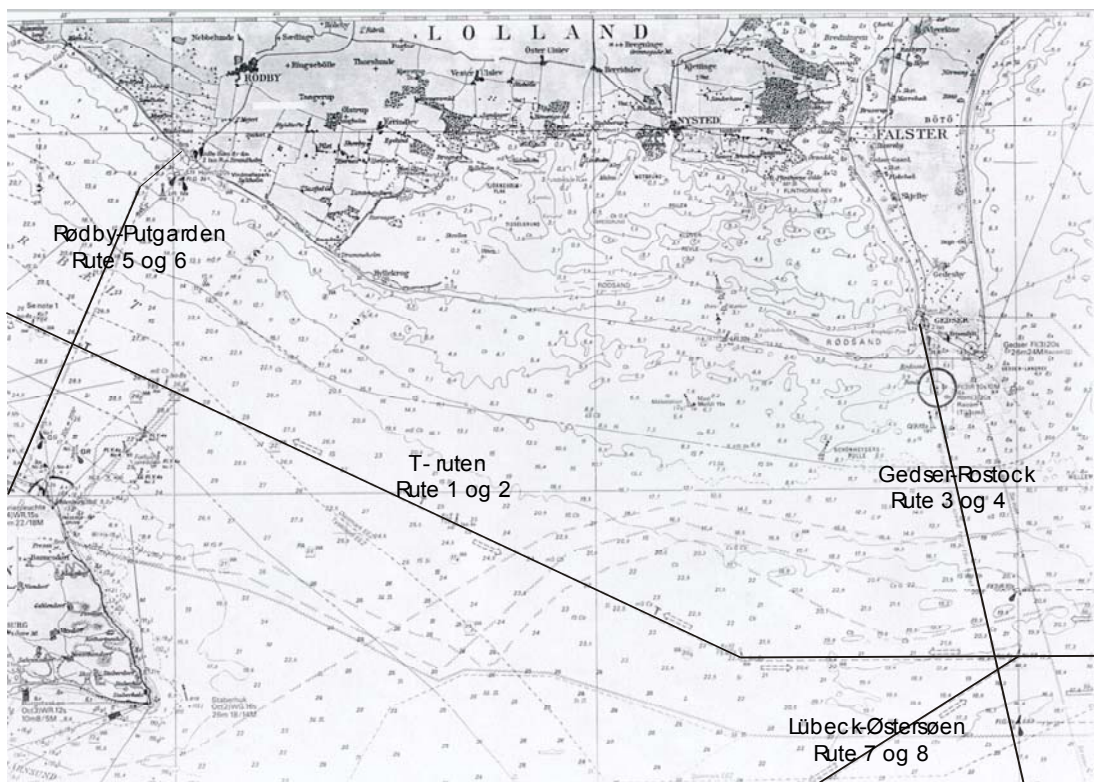


Figure 6.3. Sailing-routes around Rødsand.

## 6.5 ARCHAEOLOGICAL INTERESTS

There has not been found any signs of either Stone Age settlements or shipwrecks in the wind farm area or along the cable trace to land.

## 6.6 HYDROGRAPHY / GEOMORPHOLOGY

The hydrographic conditions in the Rødsand area are mainly influenced by the regional differences in the water-level between the Kattegat and the Baltic Sea, giving rise to the main current through the Femer Belt and Guldborg Sund.

Over the last 95 years the water depth has not changed substantially. The water depth in the offshore wind farm area is between 6m and 9.5m (Figure 6.4).

Due to the shallow water depth in the area and the mixing of the water masses caused by wind and currents, the water column will in most cases be completely mixed in and around the wind farm area. On the other hand, stratification typically occurs in the Femer Belt.

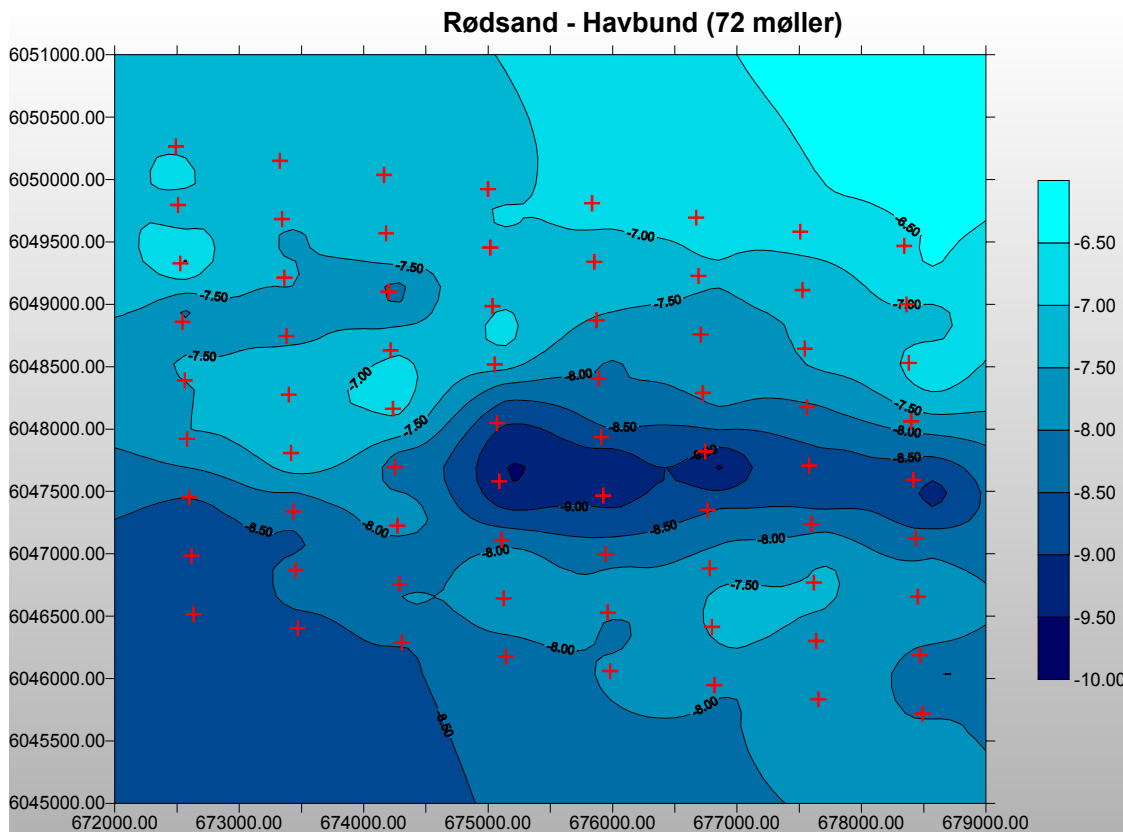


Figure 6.4. Water depths in the Rødsand offshore wind farm area.

Geologically the area is generally characterised by the presence of moraine clay deposits close to the bottom of the sea, which reflects repeated glacial and post-glacial erosion and sedimentation. The moraine clay deposits mainly consist of moraine clay (Geoteknisk Institut, 1999 a, b). Above the moraine deposits is a layer of sand with a medium grain size, a low loss on ignition and low silt/clay content.

The Rødsand formation consists of a series of long barrier-islands, stretching from Hyllekrog to Gedser, covering a distance of 25 kilometres. The barrier-islands form the southern demarcation of the shallow water area, towards the Femer Belt. Inside the Rødsand Lagune are islets and barrier-islands, which are drained during low tide. Along the coast are large areas of tidal meadow (Skov- og Naturstyrelsen, 1995).

The largest part of the area consists of sand bottom with larger and smaller ridges. In places there are pebbles, gravel or shells. Although there are outcrops of stones larger than 10cm, no reef-like aggregations have been recorded.

There are a great number of stones of varying sizes and the density is greatest in areas with moraine. Large stone concentrations covering 5-25% of the bottom are observed in the south-eastern part of the park (Geoteknisk Institut, 1999a).

In the period of measurements (May 1999 to September 1999) there were no incidents of oxygen-depletion and the concentration of inorganic nutrients was very low. Furthermore, the primary production was low, compared to Danish coastal areas in general (VKI, 1999b). It is estimated that the water quality, measured as nutritive salts, oxygen etc., in the area surrounding the wind farm area, will change by less than 1/1000 with the erection of the wind farm.

### 6.6.1 Environmental Impact Assessment

The changes in the current velocity and waves in the wind farm, in the operational phase, are small. There will, therefore, be only insignificant deposition/erosion (less than  $\pm 2$ cm) at distances greater than 10m from the foundations (DHI, 2000d). Analysis of the hydrodynamic conditions has shown that changes in the composition of the sediment and currents around the foundations are limited.

The resistance from the foundations will influence the current and wave conditions in the wind farm. The impact of the foundations on the water movements is estimated to be relatively limited. The changes to the flow rate will be less than 15% at a distance of 5 metres from the edge of the foundation and the wave height behind 9 wind turbines in a row will be reduced by a maximum of 4%. The flow rates within the wind farm will change by a maximum of 3-4%.

The model calculations on the movement of material show that the wind farm will delay the natural morphological development at Rødsand. With regard to the island-barriers, it is estimated that the barriers will move approximately 15m east every year without the wind turbines and approximately 12m every year with the wind turbines. This is due to the fact, that the wind farm will protect parts of the Rødsand area from the influence of waves and there by also affect the transport of materials. Overall, it is expected that the movement of Østre Mærke will be reduced from about 750m to about 500m over a period of 30 years after the wind farm has been erected.

It is thus evaluated that the wind farm at Rødsand will have no significant impact on the wind, the waves, the current, the residence time and the water exchange. The model calculations do indicate that water exchange between Femer Belt and Rødsand Lagune will be a few percent better over a 30-year period. Furthermore, the wind farm will not affect the water flow in the Femer Belt.

Model calculations on situations with and without the wind farm, have shown that there will be no impact ( $\ll 1\%$ ) on neither the oxygen concentration nor the nutrients or the chlorophyll, during a summer period with high temperature, low current velocity and calm winds, which is considered to be "worst case".

## 6.7 BENTHIC VEGETATION AND FAUNA

### 6.7.1 *Benthic vegetation*

In the wind farm area attached algae communities are rare and are dominated by brown algae. Single red algae attached to stones and common mussels have been observed but the overall degree of coverage is less than 5% (DHI, 2000).

At the beginning of May the brown algae community comprises mainly of annual filamentous algae presumably dominated by the species *Pilayella/Ectocarpus*. The algae are attached to pebbles and common mussels. The greatest density of algae is to be found in the southern part of the wind farm area. The distribution of the algae is identical with the areas, where the greatest concentration of stones and common mussels, which are a substrate for the algae, are observed (DHI, 2000). The algae community at Rødsand is only present for a short period of the year as the filamentous algae typically flower during May, culminate in June and decay in July/August (DHI, 2000).

There has not been registered any occurrence of eelgrass (*Zostera marina*) inside the wind farm area. Eelgrass is, however, found in Rødsand Lagune (VKI, 1999a).

Detached algae appear to be very scarce probably because the area is rather exposed to waves and currents and the conditions for accumulation of detached algae are not favourable (DHI, 2000 a, b).

### 6.7.2 *Benthic fauna*

In the wind farm area the benthic fauna consists of a shallow water *Macoma*-community (named after the Baltic Sea Mussel, *Macoma baltica*) dominating two thirds of the seabed, and a Common Mussel (*Mytilus edulis*) population dominating one third of the seabed in the wind farm area (Figure 6.5) (DHI, 2000).

Mussels are present over the entire wind farm area, but major communities of Common Mussels are found mainly in the southern part of the wind farm area and to a lesser degree in the north-western part of the wind farm area. In these areas the degree of coverage is more than 25% and locally Common Mussels covered more than 50% of the bottom. Mussels have a more limited distribution east of the wind farm area (DHI, 2000). The populations of Common Mussels are dominated by small individuals ( $< 10$  mm) at several stations in the wind farm area (DHI, 2000). It is difficult to assess the age composition of the mussel population because the mussels' growth may vary, but it is estimated that 0-3 year old individuals dominate the population (DHI, 2000).

The *Macoma*-community is dominated by typical low water species such as mud snails (*Hydrobia sp.*), polychaetes (*Pygospio elegans* and *Nereis diversicolor*) and bivalves (*Macoma baltica*, *Mya arenaria* and *Mytilus edulis*). The *Macoma*-community is highly homogenous in the entire area. A total of 43 species/groups of benthic animals have been registered (DHI, 2000b).

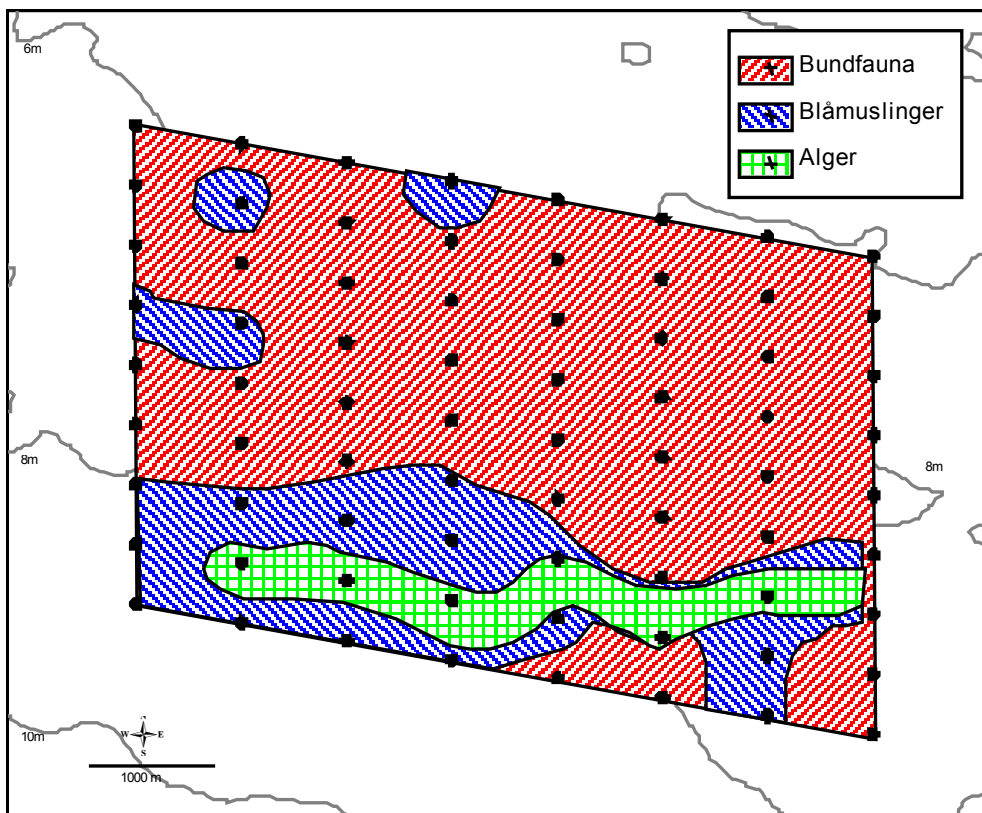


Figure 6.5. The distribution of benthic communities in the wind farm area. Based on photo sampling in May 1999.

The red areas are dominated by the *Macoma*-community, Common Mussels dominate the blue areas and the green area is the area covered by annual filamentous algae in 1999. The distribution of the algae coincided with the distribution of Common Mussels and the algae-covered area therefore became part of the area covered by Common Mussels (DHI, 2000a).

In most parts of the wind farm area the abundance of bottom fauna varies between 3000-5000/m<sup>2</sup> (DHI, 2000b). The bottom fauna richest in individuals with an abundance > 5000/m<sup>2</sup> is found primarily in the central and western parts of the wind farm area (DHI, 2000b). Figure 6.6 shows the abundance of the benthic fauna in the wind farm area.

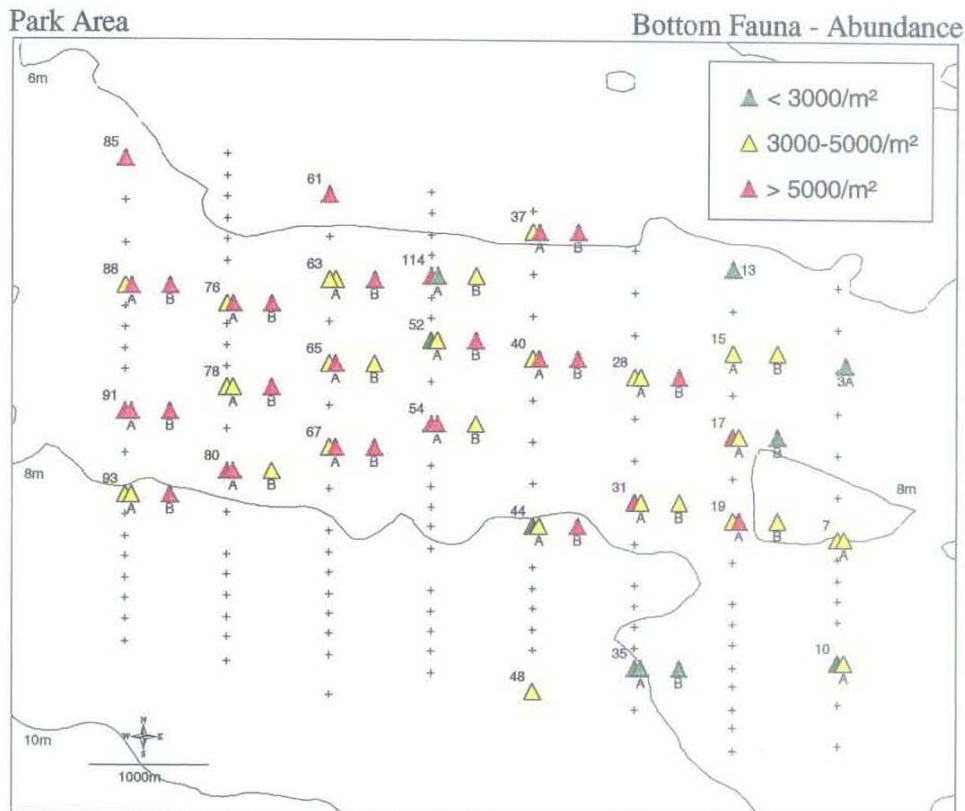


Figure 6.6. Map showing the abundance of the benthic fauna in the wind farm area (DHI, 2000b).

At most of the stations in the wind farm area the biomass is between  $10 \text{ gDW}/\text{m}^2$  and  $25 \text{ gDW}/\text{m}^2$ . Figure 6.7 shows the abundance of the benthic fauna in the wind farm area. There is no unique pattern to the bottom fauna's total biomass in the wind farm area, but there is a predominance of stations with a high biomass ( $> 25 \text{ gDW}/\text{m}^2$ ) in the western part of the wind farm area (DHI, 2000).

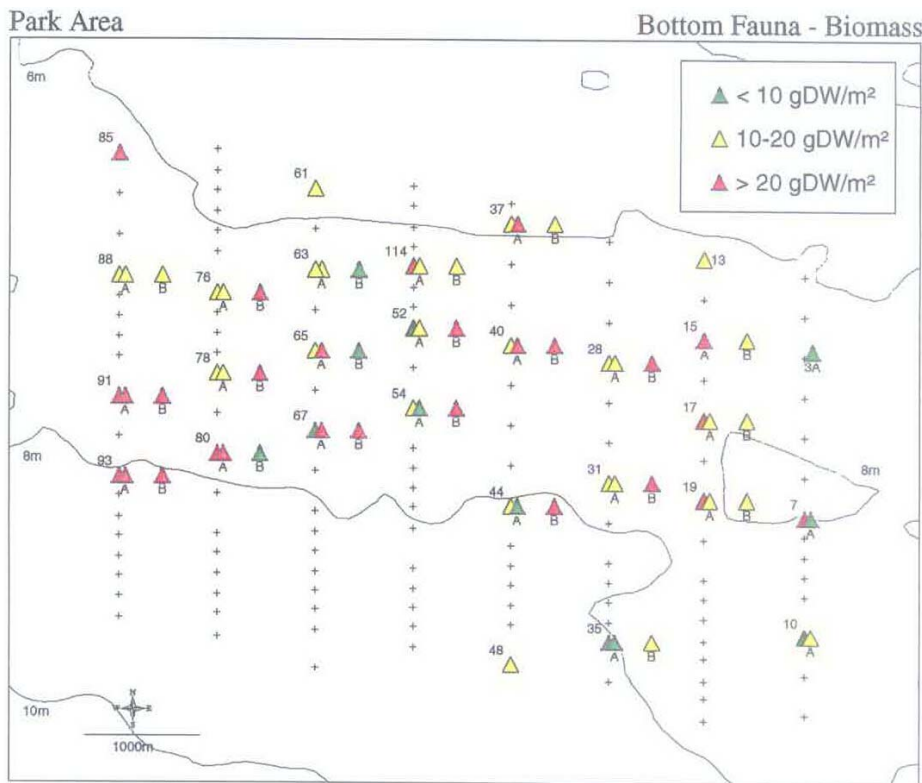


Figure 6.7. Map showing the biomass of the benthic fauna in the wind farm area (DHI, 2000b).

### 6.7.3 Introduction of hard substrates

In 1996 a monitoring mast was established in the planned wind farm area. The water depth at the position is approximately 7.6 metre.

The fouling community on the foundation of the monitoring mast was, after three years, completely dominated by Common Mussels. Mussels formed an approximately 5cm thick fouling layer around the entire foundation structure from the surface to the bottom. The abundance and size of the mussels on the foundation are higher compared to the mussels located on the bottom. This is due to better feeding conditions in the water column, which the mussels can utilise more effectively from the foundation. The biomass of other organisms including macro algae was insignificant, but many crustaceans, especially typical accompanying fauna such as sand-hoppers (*Gammarus sp.*), are found with the mussels (DHI, 2000).

Apart from a bloom of annual filamentous algae on mussels and pebbles in the spring, it is anticipated that a fouling of the perennial macro-algae will develop primarily on the stone protection around the foundations (DHI, 2000).

It is estimated that the biomass of a fouling community of Common Mussels is more than 10 times the biomass of common mussels, which is expected to be destroyed during the construction of the foundations (DHI, 2000b).

### 6.7.4 Environmental Impact Assessment

The increased turbidity will affect the vegetation by the shadow effect, but it is evaluated that the impact on the plant community, which has its main distribution in the southern part of the wind farm, will be transient and without any measurable effect. A shadow effect on the eelgrass and other vegetation in Rødsand Lagune caused by the excavation work will be of short duration and is not expected to cause any substantial effects on the shoot density, degree of coverage or biomass of the eelgrass (DHI, 2000b).

Only in the immediate vicinity of the construction work is the sediment spill expected to cause increased concentrations of suspended material, which will affect the feeding ability of the suspension-feeding benthic fauna. The impact will be of short duration and is not expected to cause any negative effects on the benthic community.

The settling of Common Mussels can take place throughout the summer, but the intensity is highest in the period from June to August. Excavation work in this period, in the southern part of the wind farm area where the Common Mussel has its main distribution, can have a negative impact on the settling success of the larvae. The natural mortality of new settled mussels is high, and a local and short duration effect of the excavation work is not expected to cause any measurable change in the recruitment or population size of Common Mussel in the wind farm area (DHI, 2000c).

Even at a distance of 5-10m from the foundations, only minor deposition/erosion will take place and, thus, only insignificant changes of the sediment will occur. Hence, no measurable change in the distribution of benthic fauna and Common Mussels are expected at a distance of 5-10m from the single foundations.

From a conservative estimate, the construction work in the wind farm is expected to give rise to the destruction of approximately 250 t common mussels and approximately 4 tonnes dry weight from benthic fauna. This is equal to 1.1% of the total biomass of common mussels and benthic fauna in the wind farm. Hence, it may be concluded that habitat loss caused by construction activities is negligible (DHI, 2000).

Based on a preliminary estimate the burial of the sea-cable between the wind farm and Nysted is expected to give rise to the destruction of the benthic fauna and vegetation in the order of 0.9 tonnes dry weight and 0.25 tonnes dry weight, respectively (DHI, 2000).

The resistance from the foundations will influence the current and wave conditions in the wind farm, but the diverted impact on erosion/deposition of the sediment is expected to be very small. Thus, this will not cause measurable changes in the distribution of benthic fauna and common mussels around the individual foundation or within the wind farm as a whole (DHI, 2000b).

## 6.8 FISH

The wind farm area is presumed to be part of a large foraging and breeding/spawning ground used by Atlantic Cod (*Gadus morhua*), Sprat (*Sprattus sprattus*), Haddock (*Melanogrammus aeglefinus*), Baltic herring (*Clupea harengus*) Small and Great Sandeel (*Ammodytes tobianus* and *Hyperoplus lanceolatus*), and possibly Flounder (*Platichthys flesus*) (Bio/consult, 2000a).

The foundations take up an area of approximately 0.2% of the total wind farm area and a proportional reduction in the amount of food is expected. It is expected that the reduction of the bottom area in the wind farm will only cause an insignificant reduction of the capacity of the area for benthic fish (such as plaice, dab and flounder) which forage in the area. Likewise species such as sand eels and gobies are expected to be affected only marginally by the reduction in the sand bottom area.

The possible impact of magnetic fields on fish is investigated along the cable trace at Rødsand.

### 6.8.1 Environmental Impact Assessment

It is expected that fish will be disturbed during the construction phase, due to an increase in the amount of suspended material caused by the excavation and spooling activities, underwater movements and other activities on the sea bottom, and thus disappear from the relatively small construction area (Bio/consult, 2000a).

Calculations of the magnetic field from sea-cables buried 1 metre below the seabed show that the magnetic field directly above the cable, will be less than the naturally geomagnetic field (30-50 mT). On this basis it is evaluated that the magnetic field will have no substantial impact on the behaviour of fish in the area.

Permanent effects on the fish fauna as a result of the location of the turbine foundations can be expected to include marginal limitation of food availability for those species that particularly feed on the benthic fauna of the *Macoma* community (Bio/consult, 2000a).

The foundations are expected to attract a variety of fish species typical of natural stone reefs. Lumpfish, Cod and Eelpout are characteristic stone reef fishes. Flatfishes such as Plaice, Flounder, Turbot, Brill and Smear Dab that, in fact, are bottom-living fish species will, to a certain degree, be able to find food around the foundations. The vegetation on the foundations may result in more spawning opportunities for e.g. Herring and Garfish (Bio/consult, 2000a).

The effect on pelagic eggs and fry from sediment during the construction work can be significant. This is especially true for turbot, which spawn during the period of the planned construction work (Bio/consult, 2001).

Flatfish fry that have recently settled on the bottom will probably be especially vulnerable to the large amount of suspended material, as they are not as mobile as adult fish (Bio/consult, 2001).

During the construction period, all types of fishing in the wind farm site will be excluded. The construction phase will therefore affect the gill net fishery for Cod, Turbot, Silver eel, Flounder, Plaice and Dab (Bio/consult, 2000b).

In the operation period there will be a ban on fishing with trawling equipment in the wind turbine area and in a zone of 200m around the submarine cable.

According Executive Order no. 939 of 27 November 1992 on protection of sea cables, trawling is prohibited within 200m from a sea cable. Hence, trawling is prohibited in the wind farm area and along the cable trace. Since, trawling is not taking place, neither in the wind farm area nor along the cable trace, the impact on the overall trawling fishery in the area is evaluated to be insignificant (Bio/consult, 2000b).

It is evaluated that the building of a wind farm at Rødsand will reduce the opportunities for commercial fishery in the area, partly due to the possible impact on the fish population and partly due to limitations of the fishery. The most important species for the commercial fishery are Sprat, Dab, Herring and Cod. Turbot is also important for the commercial fishery, due to the high price per kilo (Bio/consult 2000b).

For safety reasons, the construction area will be closed off and access is prohibited. This will prevent commercial fishery in the area during the construction phase. Trawling does not take place in the site itself and will probably be marginally affected during the construction phase (Bio/consult, 2000b).

## 6.9 MAMMALS

### 6.9.1 Seals

Since 1977 the harbour seal has been a fully protected species in Denmark (Bøgebjerg, 1986). The seal-locality at Rødsand is today and has historically been one of the most important seal-localities in Denmark. However, during the past 15 years, only a few hundred harbour seals (*Phoca vitulina*) and up to 16 grey seals (*Haliocerus grypus*) have been counted in the Rødsand area. Today, the Rødsand area holds a population of a few hundred seals. Apart from the seal sanctuary at Rødsand, the seals also use the Vitten/Skrollen stony reef in the westerly part of the Rødsand Lagoon (NERI, 2000c).

Seals go ashore on the most westerly point, from where they can rapidly enter deeper water. This is the most important haul-out and breeding site for harbour seals in the western Baltic Sea. Haul-out sites are important for the breeding, moulting and resting behaviour of the seal (NERI, 2001).

In 1967 a total ban on hunting grey seals was introduced (Søndergaard et al., 1976). The grey seal breeds in February-March, when disturbances can be fatal for the pups, which cannot survive entering the water until they are around two weeks old and have developed their final fur (NERI, 2000c). There is no evidence that the grey seal breeds regularly at Rødsand, but it is nonetheless recommended that extra care should be taken in February and March, which is the breeding season of the grey seal. The grey seal moults in June/July, when most of the population goes onto land.

There are two periods during which the harbour seals are especially sensitive to changes in the environment. The first is mid-June – mid-July, which is the breeding season for the harbour seal and it is therefore especially vulnerable in the seal sanctuary during this period. The second is in August where the harbour seals moult and therefore must spend most of the time on land.

The seals forage on Eel, Cod, Eelpout, Herring, Salmon Garfish and flatfish. The broad composition of the food items could indicate that the seals adapt to changes in the fish populations (NERI, 2000c). During the construction phase it is expected that the fish population of especially Cod and Herring to some extent will be reduced in the wind farm area and the adjacent areas. The reduction in the fish population is however, expected to be temporary and the fish population is expected to re-establish after the construction phase. Therefore, it is also expected that the seals will return to the wind farm area after construction.

Every year a number of exemptions to shoot harbour seals are granted to local fishermen, both commercial and sideline-fishermen. In 2001 exemptions were granted to shoot 15 harbour seals in the Rødsand area, but not in the vicinity of the seal-sanctuary. Of these 6 harbour seals were shot in 2001 (Falster Statsskovdistrikt, 2002).

Harbour seals have good hearing between 1 kHz and 50 kHz, where the threshold is below 85 dB (re 1  $\mu$ Pa). In the immediate vicinity of a wind turbine foundation the harbour seal will be able to hear the noise. However, at distances longer than 20m from the foundations it is unlikely that the seal will be able to hear the noise generated by the wind turbine. In “worst case” the seals will be able to hear the noise from the wind turbines in 0.4% of the overall area of the wind farm (NERI, 2000c).

### 6.9.2 Harbour porpoises

Harbour porpoises (*Phocena phocena*) use the Rødsand area throughout the year and it is evaluated to be highly likely that the area around the planned offshore wind farm serves as foraging ground for the harbour porpoises. Furthermore, it is likely that the harbour porpoises breed near the beaches north of Rødsand. Compared to other Danish breeding sites, the population density in the area is presumed to be low (Rambøll, 2000).

The EC-habitat area no. 152 (Smålandsfarvandet syd for Lolland, Guldborg Sund, Bøtø Nor and Hyllekrog-Rødsand) which border on the wind farm area, has been designated among other things because of the presence of harbour porpoises in the area.

The most important sources of stress on the species are disturbances from traffic of ships, construction work, noise and loss of habitats (Rambøll, 2000).

Only underwater noise is relevant in connection to harbour porpoises, as they spend all their lives in the sea and only occasionally emerge above the surface. During the operation of the wind farm the harbour porpoises will most likely not be able to hear the noise at distances longer than 20m from the wind turbines (Rambøll, 2000).

Harbour porpoises are especially sensitive to disturbances in May-June where they give birth, and in July-August where they mate. It cannot be ruled out that disturbances from the construction work will influence the reproduction of harbour porpoises in the area at Rødsand during the building year, but the impact is not expected to have any lasting effects on the population in general (Rambøll, 2000).

The harbour porpoise is not by nature a stationary animal, but is believed to move around within a large sea area. Therefore, it must be expected that harbour porpoises will leave areas in which construction takes place. In a worst case scenario, this will apply to the entire wind farm area and to the adjacent border areas, but the impact is expected to be important only where sediment spill or noise from construction activities significantly exceeds the natural background levels. As the impact is expected to be temporary, the harbour porpoises are expected to return to the wind farm area after constructions have been completed.

### 6.9.3 Environmental Impact Assessment

The most significant impacts on mammals are expected to be the physical presence and the noise from ships and construction work as well as temporary and even permanent loss of habitats near the wind farms.

It is concluded that no permanent reduction in the food sources of harbour porpoises is expected in the wind farm at Rødsand. If the foundations improve the habitat for, among others, Cod, Herring and Eelpout, the food base for harbour porpoises can be expected to improve, as well, in the area (Rambøll, 2000).

A pilot study on the use of PODs (acoustic porpoise detectors), as a tool to investigate potential effects on the harbour porpoises in the Rødsand wind farm area has been carried out in 2001 (NERI & Ornis Consult, 2001). The results showed that there is a medium activity of harbour porpoises at Rødsand.

Calculations of the magnetic field from sea-cables buried 1 metre below the seabed show that the magnetic field directly above the cable, will be less than the naturally geomagnetic field (30-50 my T) (Eltra, 2000). On this basis it is evaluated that the magnetic field will have no substantial impact on the behaviour of marine mammals in the area.

Based on measurements from existing offshore wind turbines, it has been estimated that the submarine noise will at most be audible to porpoises at a distance of a few metres and to seals maybe up to 20 metres from the foundations. When operating the turbines will give out noise and vibrations to the surroundings. Based on measurements on existing offshore turbines, it is estimated that the underwater noise will be audible to harbour porpoises within a few metres and for seals perhaps within 20 metres from the foundations (Rambøll, 2000).

## 6.10 BIRDS

The Rødsand wind farm area is geographically situated on a very important migration route for waterfowl and each autumn and spring very high numbers of bird pass through the area. Also migrating land-birds pass the area in high numbers especially during autumn.

At Rødsand the most frequently occurring species are Cormorant (*Phalacrocorax carbo*), Eider (*Somateria mollissima*), Mute Swan (*Cygnus olor*), Long-tailed Duck (*Clangula hyemalis*), Red-breasted Merganser (*Mergus serrator*), Common Scoter (*Melanitta nigra*), Mallard (*Anas platyrhynchos*) and Herring Gull (*Larus argentatus*).

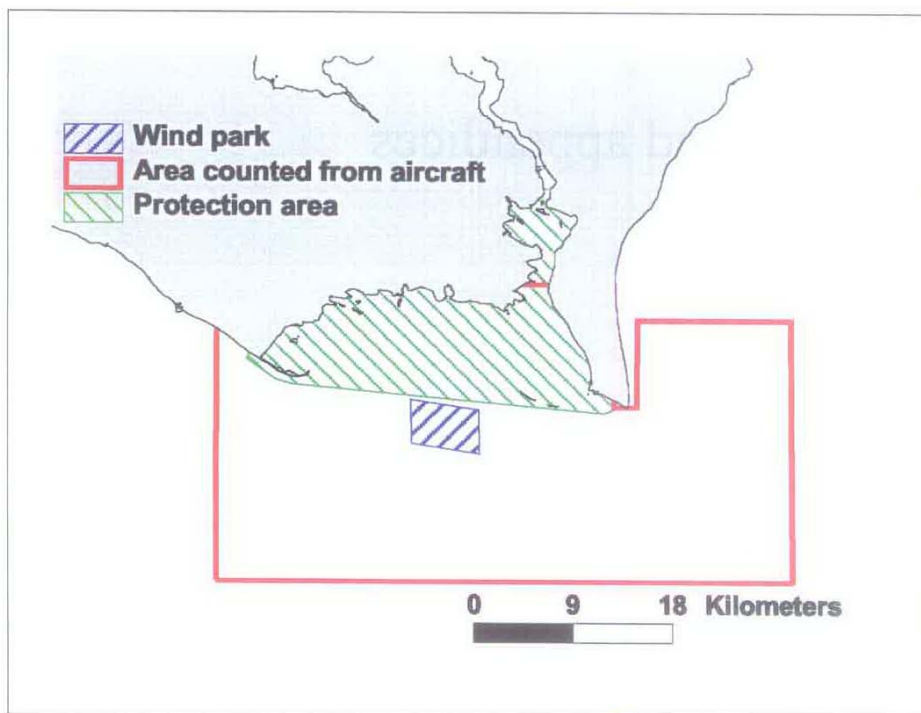


Figure 3.8. The study area at Gedser/Rødsand, the protection area (EU Special Protection Area no. 83, part of EU-habitat area no. 152 and the Ramsar Area no. 25), the area covered at the aerial surveys and the planned wind farm area (NERI, 2000a).

The area south of Rødsand is of international importance to Red-breasted Merganser, since 1.3% of the overall population of staging birds are registered here – of this about half is registered within or near the wind farm area.

The area between Hyllekrog and Gedser Odde is situated on one of the most important migration routes in Northern Europe. The area is passed by a minimum of 300.000 waterfowl, 15.000 raptors and 200.000 passerines during daytime in September-October. Spring migration peaks in April and May when daytime migratory Eiders (*Somateria mollissima*) and Brent Geese (*Branta bernicla*) occur in maximum numbers of 43.000 and 4.000 individuals, respectively (NERI, 2000a).

Especially sea ducks depend on benthic invertebrates as food.

It has been shown that more than 90% of the waterfowl migration at Rødsand consists of Eiders. In general, approximately 20% of the total waterfowl migration passed through the planned wind farm area (NERI, 2000a).



Figure 3.9. Radar registrations of 130 flocks determined as eiders migrating at Rødsand during autumn 2000. All flocks presented were migrating in a westerly direction (NERI, 2000b).

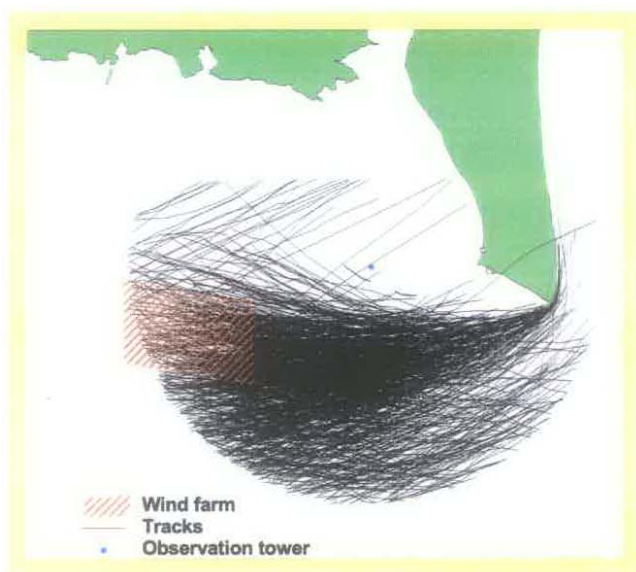


Figure 3.10. Radar registrations of 794 waterfowl flocks migrating at Rødsand during autumn 2000. Flocks that were not determined visually to species were classified as waterfowl on the basis of their migration speed exceeding 50 km/h. All flocks presented were migrating in a westerly direction (NERI, 2000b).

#### 6.10.1 Environmental Impact Assessment

Migratory birds might be at risk of colliding with the turbine blades. Measurements of the migratory height of the birds at Gedser Odde show that approximately 10% of Common Eiders, Cormorants and Seagulls passed the wind farm area at a height corresponding to the turbine blades (30-110m). During tailwind situations the percentage of Eiders migrating within the critical rotor height increased to 27%. For birds like Divers, Geese, Waders, Pigeons and Passerines it is assessed the percentage of individuals passing within the critical rotor height is even higher than for Eiders. However, it is not known whether these figures can be directly transferred to the wind farm (NERI, 2000a).

With up to 5000 Cormorants staging in the study area during autumn, it cannot be out ruled that the foundations of the turbines will be used as roost sites, which could increase the risk of collision (NERI, 2000a).

Only few bird species foraging on their wings (i.e. terns and skuas) occur in the wind park area. Normally, they forage between 0-20m above sea level. Thus, the risk of collision between these species groups and the wind turbines is assessed to be small (NERI, 2000a).

The number of collisions is expected to depend on the manoeuvrability of the birds, and therefore it is likely that number of collisions will increase in situations with low visibility (during night and in foggy weather). Foggy weather is rare at Rødsand and there is lower migration intensity in situations with foggy weather.

If the birds completely abandon the wind farm area due to disturbance, the total habitat loss will make up a maximum of 2% of the whole study area (Figure 3.8). In the “worst possible case” scenario (assuming that birds completely avoid the wind farm area up to a distance of 4km) it will affect 51% of Common Scoters, 46% of Red-breasted Mergansers and 27% of Long-tailed Ducks counted in the whole study area (Figure 3.8).

The calculations of sediment spill during the construction work show that only for very short periods and in that case only locally, will the concentration of suspended material be higher than 15mg/l. This is considered to be the limit to when birds are able to see under water and thereby search for food by the help of sight (NERI, 2000a).

Noise caused by the ramming of mono-pile foundations is assessed not to have a detectable impact on the breeding birds in the study area (Figure 3.8) (NERI, 2000a).

Habitat loss caused by the wind farm at Rødsand is likely to occur as a result of disturbance effects more than due to a reduction in the foraging area caused by the foundations (NERI, 2000a).

The bird species, due to which the EU Special Protection Area No. 83 was designated, show no particular preference for foraging in the wind park area, and it is thus assessed, that none of these species will be affected by the wind farm to any detectable degree (NERI, 2000a).

## 6.11 VISUAL AND SOCIO-ECONOMIC IMPACT

As a result of its size and its location relatively close to the coast, the wind farm will constitute a distinctive element in the coastal landscape between Germany and Denmark. Especially from the Danish coast and from Nysted, the wind turbines will be strikingly visible. The wind turbines area relatively close to the shore and the wind farm has its widest extent on the horizon seen from here (SEAS & Hasløv Kjærsgaard, 2000).

Due to the visual impact of the wind farm from land, mainly from Nysted, it is important that the wind turbines appear uniform with regard to design, colour and rotation-direction (SEAS, 2000).

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## 7 Appendix I: Literature on the demonstration projects

### 7.1 HORNS REV

#### 7.1.1 *Hydrography / Geomorphology*

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#### *7.1.7 General*

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### 7.2.2 *Marine bottom fauna and vegetation*

#### **English**

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