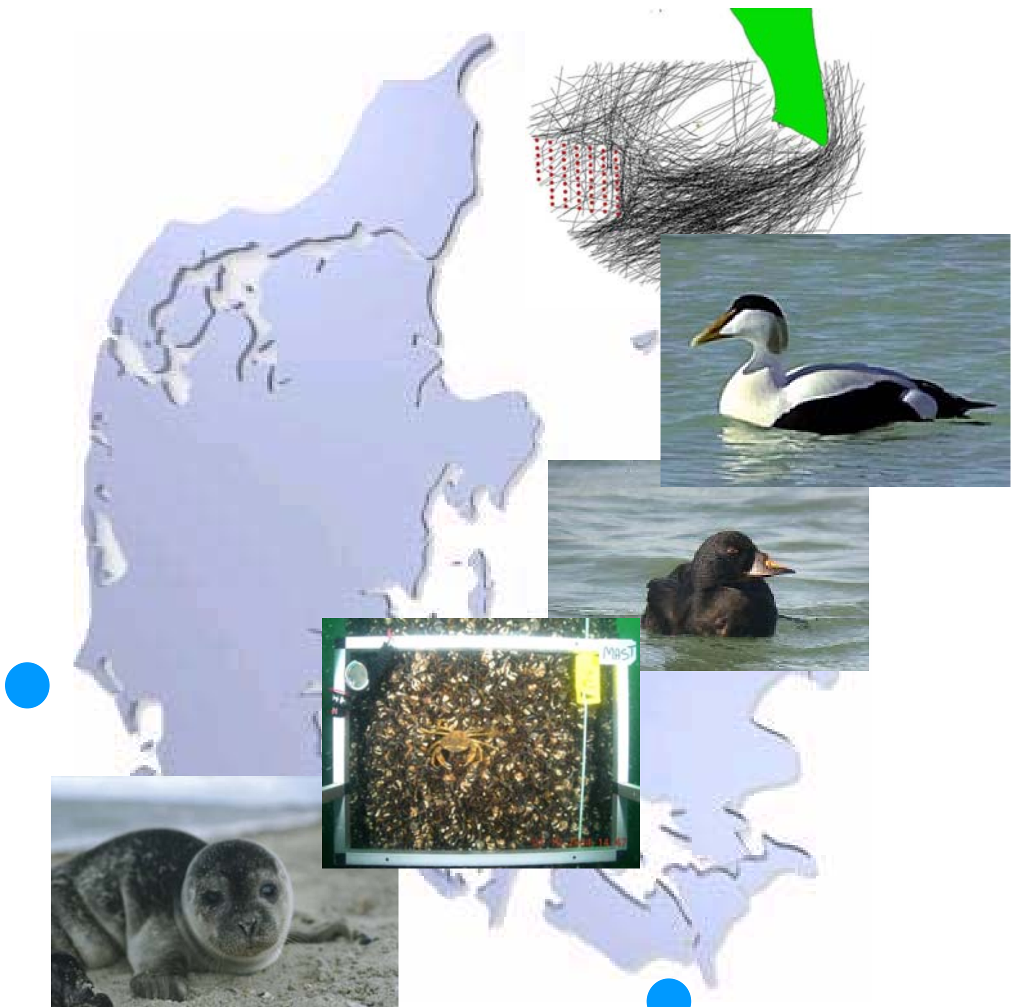
Review report 2005

The Danish Offshore Wind Farm Demonstration Project: Horns Rev and Nysted Offshore Wind Farms

Environmental impact assessment and monitoring



Prepared for The Environmental Group
by DONG Energy and Vattenfall

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The Danish Offshore Wind Farm Demonstration Project: Horns Rev and Nysted Offshore Wind Farm Environmental impact assessment and monitoring

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Report prepared for:
The Environmental Group of the Danish Offshore Wind Farm Demonstration Projects

1 Introduction

In 1995 the Danish Government formed a committee to define the main areas in Danish waters suitable for establishing offshore wind farms. In total an area of approximately 1,000 square kilometres has been identified, corresponding to 7,000-8,000 megawatt (MW). Most of the areas are located at a distance from the coast of 15-30 kilometres, and at a water depth of 4-10 meters.

The possibilities for utilizing shallow waters for offshore turbines in Denmark were evaluated in collaboration between the Danish Utilities and the Danish Energy Authority. An action plan was proposed in which two of the main recommendations were to concentrate offshore development within a few areas and to carry out a large-scale demonstration programme. In 1998, an agreement was reached between the Government and the production companies to establish a large-scale demonstration programme. The objective of the program was to investigate economic, technical and environmental issues, to hasten offshore development and to open up the selected areas for future wind farms.

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

In the Danish action plan for offshore wind farms from 1997, five areas (figure 1.1) were identified as suitable for future offshore wind farms. The selection was based on experiences from the first two small demonstration farms (Vindeby and Tunø) and the recommendations from the work of the Governmental Committee in 1995, which included both a mapping of water depth, all interests in the Danish waters and visual impact assessments of the coastal landscapes. Development of Horns Rev Wind Farm and Nysted Offshore Wind Farm (Rødsand) is a result of the action plan.

Due to the special status of the demonstration programme a comprehensive environmental measurement and monitoring programme was initiated to investigate the effects on the environment before, during and after the completion of the wind farms. The purpose is to ensure that offshore wind power does not have damaging effects on the natural ecosystems and to provide a solid basis for decisions about further development of offshore wind power. In addition the economic and technical aspects are to be evaluated as part of the demonstration programme. A series of studies were initially undertaken in the two wind farm areas. They focussed on the environmental conditions and the possible impact of an offshore wind farm. The studies are important for both the extension of the offshore wind farm at the specific sites, and for the establishment of additional large scale offshore wind farms in Denmark.

The present review report presents the two wind farms Horns Rev and Nysted 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 and monitoring programmes at the two sites. The descriptions of the programmes are based on extracts from the individual annual reports. Detailed information on method, programmes and conclusions can be found in these reports (see Appendix 1).

This review report is divided into two parts. The first part contains a description of the potential environmental impacts of offshore wind farms and the potentially affected part of the environment. The second part includes a description of Horns Rev and Nysted Offshore Wind Farm and the environmental studies carried out here until the end of 2005. Appendix I is a list of the literature published on the studies carried out at Horns Rev and Nysted Offshore Wind Farm. Appendix II is a list of some of the literature relevant to the demonstration projects but not directly related to the projects.

The offshore wind farm situated in the Rødsand area is officially denoted Nysted Offshore Wind Farm, and in the present report the denotation "Nysted" will be used as well when referring to Nysted Offshore Wind Farm. The denotation Rødsand will be used when referring to the actual area Rødsand.

2 Potential impacts of offshore wind farms

The possible impact of an offshore wind farm can be divided into impacts during the construction and impacts during the operation of the wind farm. In the following, the different types of potential impacts outlined in the Environmental Impact Assessments for the Horns Rev and Nysted offshore wind farms are described.

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 foundations and scour protection

The different types of impact are described below.

2.1 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.

2.2 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 in 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.

2.3 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.

Under operation, 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. The noise measured underwater from the wind turbines is transmitted through the tower and the foundation of the wind turbine.

Under operation, 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; Betke 2006).

Under operation, the turbines will emit 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 knowledge on the subject is very limited.

2.4 Electromagnetic fields

Electromagnetic fields are created when an electric current is running in the cables. This includes the cables interconnecting the wind turbines and the cable connecting the wind farm to land.

A direct current cable contains a constant unidirectional current and induces 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 animals to the same degree as a direct current cable. The knowledge on the impact of electromagnetic fields on marine animals is, however limited.

2.5 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 or completely abandon the area. The physical structure of the foundations might also attract animals, which may use them as a resting place or as protection from predation.

2.6 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.

2.7 Introduction of hard substrate habitats

As a secondary aspect of establishing offshore wind farms, foundations and the rocks placed to prevent scour at foundation 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 elements of the environment

The potential impacts of offshore wind farms described above are of varying importance to the different elements of the environment in and around the offshore wind farms. The possible impacts of an offshore wind farm on these different elements are outlined bellow.

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 establishment 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, making them unable 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 deposition 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, thereby changing 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 living in 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 also affect the fish population in the area.

Changes in the sedimentary environment can affect the fish. Sand eels and Sprats are very dependent on the availability of suitable sediment, and are particular sensitive to changes in the content of silt and fine sand. The physical structure of the foundations and the scour protection might be attractive to some fish species, eg 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 the wind farm might result from local changes in abundance of their food.

3.4 Mammals

Construction and operation of the offshore wind farm can potentially affect marine mammals in the area in following 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 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 because it is no longer suitable as foraging or breeding area. Finally 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.

3.5 Seals

The Harbour seal (*Phoca vitulina*) and probably also the Grey seal (*Halichoerus grypus*) breed in Danish waters. Both species are included in Annex II of the EC-Habitat Directive, with the aim of maintaining 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 underwater. The seals' ability to communicate can be affected by the noise generated by the construction work and the operation of the wind turbines, and may cause them to leave the wind farm area.

3.6 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 in 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 of fish 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.

The noise generated by the operation of the turbines can also 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 areas for the harbour porpoises, this can have an impact on the harbour porpoise population in the area.

3.7 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 the Ramsar and 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 includes 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 relates to three different factors, namely disturbance , physical changes to the habitat and collision risk.

Disturbance effects are a result of a behavioural response of the birds to the wind turbines and associated activities.. 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.

Physical changes in the area include loss of bottom area and the addition of new underwater substrates colonised by marine invertebrates. Foraging birds may exploit the food source resulting from the colonisation of the foundations and the scour protection areas. 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 fly over the wind farm area on a daily basis. Furthermore, it can affect a population of migrating birds, where a smaller or larger number of individuals fly over the wind farm area once or twice a year. There is rather limited knowledge to date on the risk of birds colliding with wind turbines.

3.8 Visual and socio-economic impact

The establishment of an offshore wind farm can 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 inhabitants.

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 1 km at most. The two offshore wind farms, Horns Rev and Nysted, are both positioned at a longer distance from land and therefore, it will be impossible to hear them onshore.

3.9 Order of priority for the environmental monitoring programme

To ensure optimal use of the allocated resources, the following order of priority with respect to the subjects to be investigated was applied, with number one representing the highest priority:

1. risk of substantial negative effects
2. ecological vulnerability of the specific sites
3. suitability of the specific sites for demonstrating specific effects
4. relevance of the effects for a decision about the extension of the specific areas
5. relevance of the effects for a decision about the overall extension of the offshore wind farms
6. importance of the effects in relation to the required of effort

Three different types of environmental studies are undertaken at each of the two sites:

Basic condition studies are carried out to evaluate the basic environmental and biological conditions on the sites.

Monitoring studies are carried out to monitor the possible effects on the environment, which have been pointed out in the EIA study on each of the sites.

Research programmes are carried out to evaluate the impacts of the offshore wind farm on the development of affected species, habitats or environmental conditions, and to study the previously unknown impacts of the wind farm on specific species and habitats.

The possible impacts from the offshore wind farms have been divided into a series of subjects, concerning birds, mammals, fish etc. The table below shows which subjects will be investigated at the two offshore wind farm areas and with which type of study.

Subject	Baseline	Monitoring	Research project
Bird	HR & Nysted		
• Disturbance/Habitat loss			HR & Nysted
• Risk of collision		HR & Nysted	Nysted
Mammals:	HR & Nysted		
• Seal		HR	Nysted
• Porpoise		HR & Nysted	
Fish	HR & Nysted	HR	Nysted
Benthic invertebrates & plants	HR & Nysted	HR & Nysted	
Hydrology / Geomorphology	HR & Nysted	Nysted	
Electric & magnetic fields			Nysted
Noise/Vibration	HR & Nysted		(HR & Nysted)
Theme project:			
• Introduction of hard bottom habitat			HR & Nysted
• Visual and socioeconomic impact of wind farm			HR & Nysted

3.10 Presentation of wind farms and monitoring programme results

In the following two sections (4 and 5), each of the offshore wind farm sites, Horns Rev and Nysted, is described with regard to their characteristics and the assessed and investigated impacts at successive stages in the course of the monitoring programme, including the assessments made in the Environmental Impact Assessments. The monitoring programme addressed the following topics: hydrography, benthic vegetation and fauna, fish, marine mammals, birds, and visual and socio-economic considerations.

The two wind farm areas differ greatly in geographic, hydrographic, ecological and biological conditions, and these differences ultimately affected which environmental studies were undertaken at the two sites.

4 Horns Rev Offshore Wind Farm

4.1 Wind farm characteristics

The Horns Rev Offshore Wind Farm is situated approximately 15 km west-southwest of Blåvands Huk, Denmark's most westerly point. The main challenge with operating an offshore wind farm at Horns Rev, is the distance to the coast and the harsh weather conditions prevailling in the North Sea, which makes access difficult during longer periods the year. The wave climate in the North Sea is rough both during summer and winter.

The fact that ice cover is only observed at rare occasions around Horns Rev makes it an ideal location for an offshore wind farm.

The offshore wind farm at Horns Rev consists of 80 wind turbines of 2MW (Vestas V80), and covers an area of 24 km² including the 200 m exclusion zone around the wind farm (Figure 5.1). The distance between both adjacent wind turbines and rows of turbines is 560 m. The turbine foundations including the scour protection cover approximately 50,000 m² of the seabed, which is less than 0.2% of the total area of the wind farm.

Figure 5.1. The offshore wind farm at Horns Rev and the cable trace to land at Hvidbjerg Strand. T marks the transformer platform.

The total height of the turbine is 110 m, with a hub height of 70 m and the rotor diameter 80 m. The minimum free height from sea level to lower wing tip will be 27 m.

The foundations for both the turbines and the transformer platform are monopiles, and will be established by pile driving. The monopile foundations have a diameter of approximately 4 m and were driven in to a depth of approximately 25 metres. The transformer platform, placed on three monopiles with a diameter of 1-2 m, was positioned north of the north-eastern-most wind turbine (marked by a T on Figure 5.1).

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

Magnetic fields from the cable, 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 1 m (Eltra, 2000).

4.1.2 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.

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). After construction, a new SPA were designated south of the wind farm area under the EU Birds Directive (area no. 113). Furthermore, the Wadden Sea also has the status of a Game Reserve (no. 48) with regulations concerning nature conservation and public access.

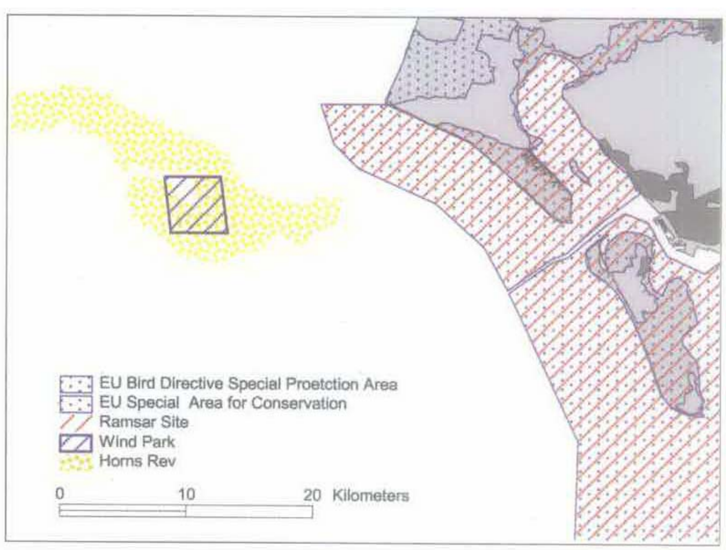

Figure 5.2. Protected areas (Ramsar, EU Bird and Habitat areas) in the vicinity of the Horns Rev wind farm, at the time of construction (from NERI, 2000)

The cable trace route 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 (Techwise, 2000).

4.1.3 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 pass around the areas of shallow water where the offshore wind farm will be established.

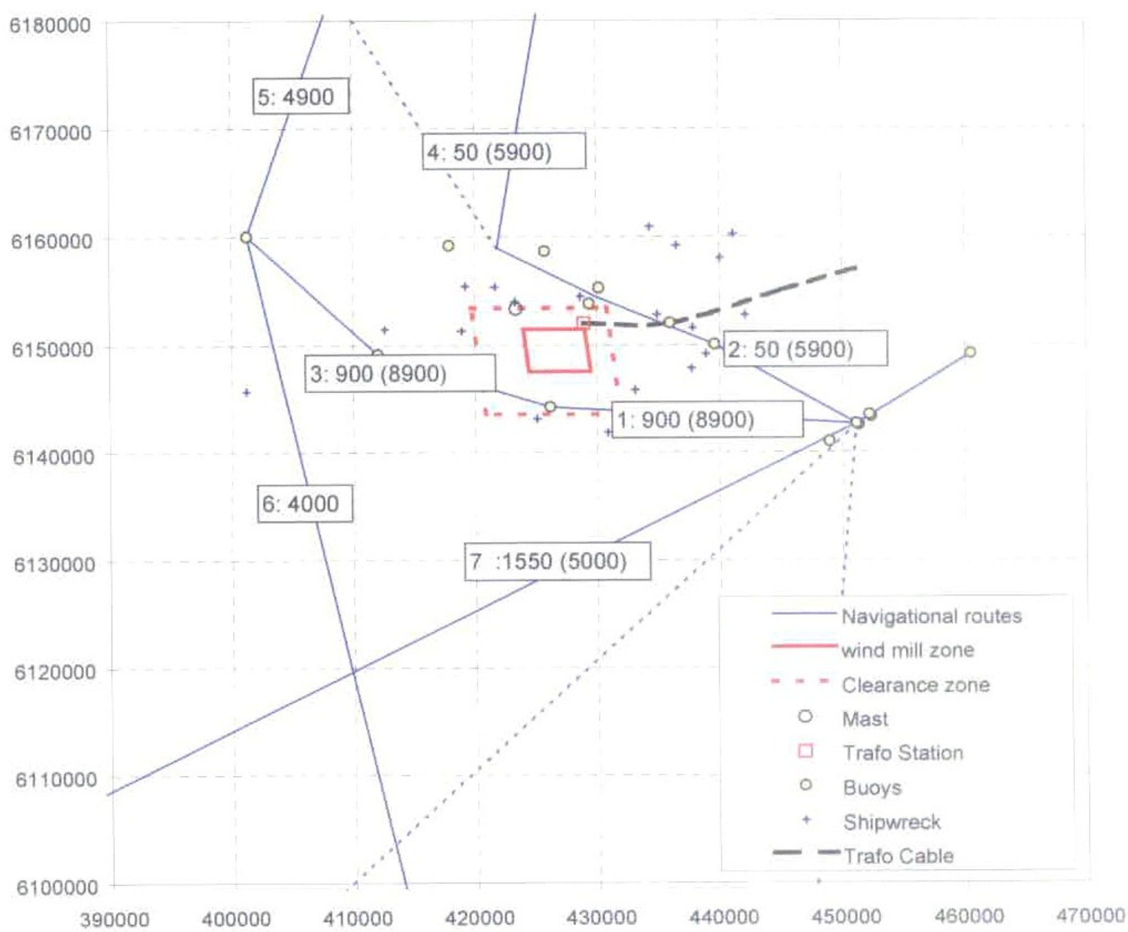

Figure 5.3. Definition of navigational routes in the vicinity of Horns Rev. The ship traffic in the vicinity of Horns Rev have been divided into a number of routes each characterised by a yearly number of movements and a size distribution (Rambøll, 2000).

4.1.4 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)

4.2 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 6.5 m to 13.5 m. The depth conditions in the area result in the waves breaking in the wind farm area. The average wave-height is about 1-1.5 m and the tidal level is about 1.2 m.

4.2.1 Environmental Impact Assessment

Analyses of the hydrodynamic conditions showed that the changes in sediment and current movements around the foundations will be very limited. Model calculations showed that the total current velocity is reduced by 2% at the most 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 was considered insignificant, because the prevailing turbulent conditions do not favour stratified conditions or oxygen depletion (DHI, 1999).

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

To demonstrate the hypothesis that there will be only very limited changes in the sediment, it has been decided to monitor the influence on sandeels, as they are very sensitive towards changes in the seabed and only live in very specific kind of sediments, see 5.9 for more information about the sandeels.

4.2.2 Baseline 2001

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 10-20 m 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 substrate in the wind farm area.

Along the 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 have 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).

4.3 Benthic vegetation and fauna

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

4.3.1 Environmental Impact Assessment

It was estimated that the total loss of habitat would affect less than 0.1% of the bottom fauna within the site. Furthermore, it was 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^2) (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 0.2% 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.

The effects of introducing a new hard substrate habitat (the foundations and scour protection) to the Horns Rev area are monitored, see further in chapter 5.8.

4.3.2 Baseline 2001

Benthic vegetation

No benthic vegetation, including makro algee, was recorded in the wind farm area.

Benthic fauna

The faunal composition at Horns Rev is similar to the fauna typically recorded on sand islets in 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, 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 were recorded. Of these, marine polychaetes constitute the largest group with 19 registered species/groups. Of crustaceans 7 species were recorded and of bivalves 5 species were recorded (Bio/consult, 2000a).

The most frequently occurring species at Horns Rev was all small (including the bivalve *Goodallia triangularis*), 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 was expected that the fauna along the deeper parts of the cable trace was typical for the *Abra*-community, judged by the high number of brittle stars which were characteristic for this community. Closer to the coast at Hvidbjerg Strand, the sediment was finer, and it was expected that the fauna will be typical of a *Lanice conchilega* community, which was common along the North Sea coasts (Bio/consult, 1999a).

Bivalves, which is an important food source for seaducks (e.g. Common Scoter), were 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*) was 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 meteorological mast in the area have shown that new flora and fauna communities are established on the foundation. Observations further showed that sand stirred up in storms practically scrubs the foundation clean of animals and plants, whereafter colonisation starts all over again. Thus, fouling on the foundations was not expected to develop much.

4.3.3 Monitoring 2002

No monitoring was carried out in 2002, as the construction was ongoing.

4.3.4 Monitoring 2003

Sediment samples showed an increase in the particle size from a range of 228 - 426 µm in 2001 to a range of 404 - 699 µm in September 2003 in the wind farm area. The particle size in the reference areas in 2001 and in 2003 could not be compared, because different sampling positions were used in 2001 and 2003.

The sampling stations in 1999 and 2003 was the same and could therefore be directly compared. The mean particle size increased from 370 µm in 1999 to 515 µm in September 2003 in the wind farm area and similarly from 347 µm to 498 µm in the reference area verifying the very shifting current regimes and shifting sediment transport conditions in the Horns Rev area.

Horns Rev is characterised by an extremely energetic hydrodynamic regime with frequent resuspension events and migrating bottom topography. Therefore, it is difficult to make any conclusions based on only two years of data, but since the increase in median grain size occurred both inside and outside the wind park area, the variation is probably a matter of natural variation more than an effect of the establishment of the wind farm.

The change in community structure as well as changes in sediment structure before and after establishing the wind farm, occurred both inside and outside the wind farm indicating that it was a matter of natural variation and not an effect of the establishment of the wind farm.

A statistical analysis using both abundance and biomass of each species at the 18 stations in the wind farm and at the six stations in the reference area showed no significant difference. These results indicate that the naturally occurring level of variance was higher than a possible effect from the establishment of the wind farm.

There was no significant difference in the benthic community structure related to the distance from the scour protection.

The main difference between the survey in 2001 and in 2003 was the decline of the *Pisione remota* and *Spisula solida* populations and the increase of the *Goodallia triangularis* population.

In 2003 new species were introduced compared to previous records from infaunal surveys in the wind farm area.

4.3.5 Monitoring 2004

The wind farm area and the reference areas are characterised by bottom conditions that are relatively uniform with sediments consisting of pure medium-fine sand with no organic matter. From September 2003 to September 2004, the mean sediment grain size shifted from 515 µm and 498 µm in the wind farm area and reference areas, respectively, to 503 µm in both areas indicating only a minor change compared to previous years.

There was no significant difference in benthos community structure related to the distance from the wind turbine foundations in either 2003 or 2004.

The main difference between the survey in 2001 and 2004 was the decline of the *Pisione remota* and *Goniadella bobretzkii* populations and the massive increase of the *Goodallia triangularis* population.

New species were introduced in 2003 and 2004. The occurrence of some of these might be a result of changes in sediment characteristics. Others may be a result of the introduction of hard bottom habitats in the wind farm area.

The statistical analysis indicated a trend toward a positive effect from the wind farm on the community, because the abundance of the eleven most common species was higher in the wind farm area compared to the reference area, despite the observations of increasing fish populations in the wind farm area.

In general, the abundance of the most abundant bivalves and bristle worms was higher in the wind farm area indicating that the potential predation pressure from birds could contribute to increasing differences between the densities of their favoured prey because they mainly feed outside the wind farm area.

In general, the abundance of the most common species increased in the wind farm area between 2003 and 2004, whereas the reference area remained unchanged from 2003 to 2004.

4.3.6 Monitoring 2005

The sediment sampling carried out in spring 2005, showed an average median grain size of 494 µm and 509 µm in the wind farm and reference areas, respectively, which was almost identical to the two previous years.

In general, a considerable increase in abundance of benthic fauna in spring was found during the monitoring period from the screening and baseline surveys up to the 2005 survey. A similar increase in spring abundance was found in the reference area.

In the spring 2005 survey, the bivalve *Thracia phaseolina* and the bristle worm *Travisia forbesii* made a considerable contribution to the overall local biomasses. A change in spring biomass was observed from 2001 to 2005, mainly due to declines in biomasses of the bivalve S*pisula solida* .

No statistically significant differences were found in the abundance and biomass of the most dominant and character species (*Pisione remota*, *Goodallia triangularis* and *Ophelia borealis)* between the spring surveys from 1999 to 2005.

In 2005 an extended reference area was surveyed. A rather heterogeneous spatial distribution pattern was displayed for more of the most dominant and character species in the wind farm, reference and extended reference area. Most notably for the American razor shell (*Ensis americanus*), which was most abundant in the northwestern part of the extended reference area, resulting in a conspicuously larger biomass in the extended reference area compared to the wind farm area and – to a lesser extent - the reference area, where this mussel was also found. The small mussel (*Goodallia triangularis* was most common in the wind farm area, whereas *Thracia phaseolina* seemed to be more homogeneously distributed even though the biomass of *Goodallia triangularis* was higher in the wind farm area

No statistically significant differences were found in the community structure in the reference and wind farm areas between 1999 and 2005 or in the wind farm area between 2001 and 2005. In 2005, the benthic community in the extended reference area was comparable with the benthic communities in both the wind farm area and in the reference area, although considerable differences in abundance were found for most of the dominant species.

4.4 Introduction of hard bottom substrate

As part of the monitoring programme concerning the environmental impact of the introduct-ion of hard substrate related to the Horns Rev Wind Farm the first surveys on the fouling communities were performed in March 2003 and September 2003.

In the EIA it was expected that suspended sand and severe storms would prevent large scale fouling on the scour protection and the turbine towers. Observations from the baseline partly backed this expectation. Nevertheless, the 2003 studies revealed a marked increase in individual numbers and biomass after the introduction of hard bottom substrate. This might in part be due to the absence of severe storms since December 1999.

4.4.1 Monitoring 2003

In March 2003 observations on specific faunal assemblages revealed the existence of the giant midge *Telmatogeton japonicus* new to Denmark inhabiting and feeding on the dense mats of filamentous green algae growth in the splash/wash zone at the turbine towers.

A total of 16 taxa of seaweeds were registered on the turbine towers and scour protections showing a distinct variation in spatial and temporal distribution. The vegetation was more frequently found on the turbine foundations compared to the scour protections. Only a few species were found on stones at the scour protections and almost exclusively at turbine sites in the shallowest areas. Typical vertical zonations were found on the turbine foundations, *Enteromorpha Ectocarpus* and *Pilayella littoralis* being the most abundant.

A total of 65 taxa of invertebrates were registered. Of these, nine, mainly very mobile species, were exclusively observed during the transect surveys. Great variations in spatial and temporal distribution between species and communities were found. In general community structures between sites and sample locations were statistical different. Differences in abundances of the dominant species, the amphipods *Jassa marmorata* and *Caprella linearis,* were the main factor to the found vertical and spatial differences. The cosmopolitan *Jassa marmorata*, not previously recorded in Denmark, was most frequently found on the turbine towers in abundances as high as 380,000 no/m^2.

Distinct vertical zonations in the faunal assemblages on the turbine towers were observed. Dense aggregations of either spat or larger individuals of the common mussel *Mytilus edulis* were found in the sub-littoral zone just beneath the sea surface at the turbine foundation. Typically the vertical and spatial distribution of *Mytilus edulis* was controlled by the starfish *Asterias rubens,* the keystone predator, found in numbers on both the turbine foundations as well as the scour protections.

Towards the sea bottom more mobile species like the edible crab *Cancer pagurus* were found. Juveniles of the edible crab were found in numbers and registration of both juveniles and egg masses of other species shows that the hard substrate structures are used as hatchery or nursery grounds for more species.

A weakly significant evidence of impact of different hydraulic regimes caused by the turbine towers on the fauna community on the scour protection was shown, whereas no impact on faunal assemblages due to different exposure on each side of the turbine towers was shown.

Mosaics of faunal assemblages resulting in great variability between sites are often found in initial epifaunal communities. Greater similarities between some of the turbine sites were shown in September compared to March, which might be a result of the succession approaching stability in the fouling communities on the artificial substrates although stable communities cannot be expected within 5 - 6 years.

4.4.2 Monitoring 2004

At the turbine sites in the offshore wind farm area at Horns Rev, the indigenous benthic community characterised by infauna species belonging to the *Goniadella-Spisula* community has been changed to an epifouling community associated with hard bottom habitats since the introduction of hard bottom structures in 2002. The small crustacean *Jassa marmorata* is found to be the most abundant species on the hard bottom substrates.

Introduction of epifouling communities have increased the general biodiversity in the wind farm area and progress succession in the benthic community, and biodiversity has been observed compared to the surveys in 2003.

Evidence that the hard bottom substrates provide habitat as nursery grounds for larger and more mobile species was shown for the edible crab *Cancer pagurus*.

Significant differences between sampling in 2003 and 2004, annual variations and variations in the epifouling communities at the hard bottom substrates have been registered, and the faunal assemblages at all turbine sites at Horns Rev have also shown to be different. Differences in community structures between monopiles and scour protections were shown, mainly due to differences in abundance and biomass of a few epifouling dominants.

A significant vertical zonation was found in epifouling communities at the monopiles. The splash zone at the monopiles was entirely dominated by the "giant" midge *Telmatogeton japonicus* with a pronounced increase in abundance since 2003. The upper investigated zones of the monopiles were characterised by high numbers and high biomass of the common mussel *Mytilus edulis* and by a vegetation cover of green and brown algae. No clear distribution pattern was found in the lower zones or near the bottom apart from a general lower abundance of the dominant species.

Considerable changes in vegetation cover at the monopiles between 2003 and 2004 were found, which might be a result of succession.

The starfish *Asterias rubens* was found to be a keystone predator mainly controlling the distribution of the common mussel and the barnacles at the hard bottom substrates in the wind farm area.

Succession in community structure was demonstrated and some primary colonisers were less abundant in 2004, which might be a result of predation and competition for space. It is anticipated that stability in fouling communities will not be attained within the next 5-6 years. Heavy storms and severe winters may even prolong this process.

Some species observed on hard bottom structures at Horns Rev are characteristic for slightly scoured circalittoral rock habitats.

Loss of infauna habitats has been replaced by hard bottom habitats providing an estimated 60 times increase in the availability of food for fish and other organisms in the wind farm area compared to the native infauna biomass.

Special attention should be directed towards the recording of two new species introduced to the Horns Rev area; the bristle worm *Sabellaria*, presumably the ross worm *S. spinulosa*, and the white weed *Sertularia cupressina*, which are both regarded as threatened or red listed in the Wadden Sea area.

There is no evidence that other regulatory factors other than natural succession in communities, predation, recruitment and the presence of hard bottom substrates have caused the observed changes in species diversity and community structure.

4.4.3 Monitoring 2005

Considerable changes in the vegetation community have occurred since 2003, especially in the splash zone and at the upper part of the monopiles. The initial vegetation cover of filamentous algae was replaced by more or less permanent vegetation consisting of different species of green algae (*Ulva*). In 2005 the red algae *Polysiphonia fibrillosa*, the purple laver *Porphyra umbilicalis* and the green algae *Chaetomorpha linum* were observed for the first time.

The total number of epifauna species associated with the hard bottom structures at Horns Rev has increased gradually from the first surveys in 2003 to the surveys in 2005.

At the scour protection a considerable increase in abundance was found from 2003 to 2005. This was most obvious for the autumn surveys and was largely a consequence of an increase in the abundance of *Jassa marmorata*. Also a drastic increase in biomass was found in the autumn sampling from 2003 to 2005.

The number of edible juvenile crabs (*Cancer pagurus*) has increased significantly since 2003 with local densities being found up to 700 ind./m^2 in 2005. During the transect surveys, mature edible crabs with carapace width up to 18-20 cm could frequently be observed in crevices and holes between the stones on the scour protections.

Sertularia cupressina has become more common in 2005. Records of low numbers of the ross worm (*Sabellaria spinulosa*) were made on the scour protection in 2005.

At the monopiles, a considerable increase in abundance was found for the autumn surveys from 2003 to 2005, whereas the abundance found in March 2005 was lower compared to the abundance found in previous years. This was mainly a consequence of the variation in abundance of *Jassa marmorata*, which locally could be found in densities up to 994.775 ind./m^2 in the autumn 2005.

A drastic increase in biomass was also found in the autumn sampling from 2003 to 2005. The common mussel (*Mytilus edulis*) showed an increase in the average body weight from 4.6 mg(dw) in spring 2003 to 550 mg(dw) in autumn 2005, as well as an increase in the biomass in the autumn samples from 2003 to 2005. Lengths in the population of Common mussels increased from a maximum of 10 mm in March 2003 to a maximum of 75 mm in September 2005.

In general statistical analysis found no significant differences between the sampling at the two sides of the monopiles, i.e. NNE and SSW, concerning current regimes, except for 2005 where a significant difference in the community structure at the bottom between each side of the monopile was found.

In 2005, successful establishment of Common mussels was found at more turbine sites than previously. Clear discrepancies in the distribution and abundance between the Common mussel, the barnacle *Balanus crenatus* and the predator *Asterias rubens* indicated that the starfish was the main keystone predator controlling the vertical and horizontal distribution of its prey species.

From 2003 to 2005, a considerable increase in total biomass was found for *Cancer pagurus*, which was a result of increasing abundance and an increase in average individual body weight from 1.52 mg(dw) in September 2003 to 44.16 mg(dw) in September 2005.

In the material of *Caprella linearis,* some of the specimens were identified as *Caprella mutica* in 2005, which is an alien species introduced from the Japanese Sea.

Succession in the epifaunal community was demonstrated but the community will continuously undergo changes due to ecological succession enabling a climax community to be formed. A climax community is not expected within 5-6 years after hard substrate deployment. Occasional disruption of community succession due to effects from storm events and hard winters may even prolong this process until a stable community is attained.

4.5 Fish

At Horns Rev the hydrogrhaphic conditions are so rough, that the occurrence of fish in the wind farm area is expected to be limited in such a degree, that it is difficult to predict any eventually changes with statistic significance.

4.5.1 Environmental Impact Assessment

It is likely that during the establishment of both the wind turbine foundations and the cable, 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 (ie 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).

There are several types of fishery in the area around Horns Rev; the predominant type is trawling for sand eels (*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).

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).

The wind farm does not overlap with the sand eel 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 it will not be allowed to fish 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.

4.5.2 Baseline 2001

The most common species found were 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 seemed 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.

4.5.3 Monitoring 2002

Sandeel pre-construction monitoring
Sandeels are a good indicator for changes in the sediment in the sea bottom, and an important food source for marine mammals, fish and sea birds. For these reasons the international expert panel, IAPEME, has recommended that the occurrence of sand eels be investigated.

The monitoring of sandeels will take place before and after the construction of the wind farm. The monitoring in 2002 took place in February and March i.e. before the wind farm was established and therefore gives a baseline.

In total 9 positions in the wind farm area (impact area) and 3 positions in an area northwest of the wind farm (control area) were chosen and at these positions a dredge was hauled to collect samples of sand eels.

At the same positions samples of the sediment were collected for analysis for its composition.

The result of the baseline investigation is that sandeels were found in all sample locations in small densities, approx 0,010 m^{-2}. Similar densities are found in the impact and control area. These densities are much smaller than densities measured in many other areas of sand eel habitat in the North Sea.

The area of the wind farm seems to constitute a small part of an area of sand eel habitat in the Horns Rev area. Areas north and south of the wind farm seem to contain higher densities of sandeels.

4.5.4 Monitoring 2003

Observations made in relation the monitoring of the hard bottom substrate
No separate monitoring programme concerning fish was performed in 2003 but observations were made in conjunction with the monitoring on the hard bottom substrate in March and September 2003. Thus, the results mentioned below are not collected after the same procedure used in the previous fish monitoring programmes.

The observations showed a marked succession in the number of fish species between the survey in March and September respectively. Only three species were observed in March; the Rock Gunnel being the most numerous whereas a total of 14 species were observed in September most of these species in numbers. Shoals of Bib, Cod and Whiting were often observed around the wind turbines and at the edge of the scour protections probably feeding on the inhabitants of the hard substrate structures.

Estimation of epifauna biomass revealed an increase in food availability of eight times compared to that of the normal soft seabed fauna in the wind farm area. Therefore an increase of fish production related to the presence of the hard substrate is considered possible.

4.5.5 Monitoring 2004

Observations made in relation to the monitoring of the hard bottom substrate
In 2004 the food availability on the foundations and scour-protection had increased further so the estimated increase in biomass compared to the surrounding soft seabed is approximately 60 times higher. This will increase the food availability for fish and could in turn attract fish to the wind farm area.

Seasonal variations in fish fauna diversity were found with bib and shoals of cod often observed at the scour protections as well as individuals of benthic fish species. Comparison with the fish fauna on shipwrecks in other parts of the North Sea showed that there was no indication that noise and vibrations from the turbine generators had any impact on the fish community at Horns Rev. Compared to 2003, a few more fish species seem to have established populations around the turbine sites in 2004.

Acoustic fish survey
In 2004 a hydroacoustic fish-monitoring programme was launched to investigate if the foundations/scour-protection has an attracting effect on the fish community and if the wind farm area in general serves as a refugee for fish.

With the use of the hydroacoustic method, comprehensive and continuous data sets of abundance, biomass and size frequencies together with behavioural observations were made available.

Four transects were surveyed within the wind farm as close to the turbine foundations as possible, and they were extended to a distance beyond 500m outside the wind farm which was defined as the reference area.

On the background of the analysed data and numerical results obtained by this study, the following conclusions are derived:

- A large diurnal variation of fish densities was encountered in the entire study area, with markedly higher fish activity at night.

- The result indicates that the offshore wind farm attracts fish beyond a distance of 500 metres, and it is thus recommended to select reference areas further away than this.

- A significantly higher density of fish near turbine foundations (hard bottom substrates) was only found in one out of the four transects surveyed.

- Large fish were predominantly found in areas of coarse sand and gravel south of the wind farm.

Sandeel post-construction monitoring
A post-construction monitoring programme was finalised in February 2004 in order to evaluate potential changes of the sandeel abundance and distribution compared to pre-construction conditions (see section 5.9.3 above).

At all locations fished during both years, a marked increase in density of sandeels (all species combined) was observed in the impact area from 2002 to 2004. This increase coincides with a small decrease in densities in the control area (away from the wind farm/impact area). Average densities of sandeels in the impact area increased about 300% from 2002 to 2004, whereas densities decreased about 20% in the control area. It is therefore concluded that the construction of the wind farm has had no negative impact on sandeels in this area.

Furthermore, there is no indication that the construction of the wind farm has had a marked effect on the sediment composition in the wind farm area. There was no indication of an increase in the content of silt/clay and very fine sand in the impact area from 2002 to 2004. Sandeels are very sensitive to changes in the content of these sediment sizes and will completely abandon the area if the weight fraction of the silt/clay content raises above 6%.

4.5.6 Monitoring 2005

Observations made in relation to the monitoring of the hard bottom substrate
In 2005 the food availability on the foundations and scour-protection had increased further so the estimated increase in biomass compared to the surrounding soft seabed is approximately 150 times higher. This will increase the food availability for fish and could in turn attract fish to the wind farm area.

A total of 22 species have been registered during the surveys on the hard bottom substrate since the erection of the wind turbines in 2002. In the test fishing, more cod and bib were caught in 2005 compared to 2003 and 2004.

Acoustic fish survey
The 2005 monitoring data have not been analysed separately, thus the results presented below represents the combined outcome of the 2004 – 2005 monitoring.

No general and unambiguous regional effects on the fish community were demonstrated by the presence of the wind farm by the hydroacoustic surveys. No distinct temporal or geographic patterns in densities, biomass or length distribution could be found in sampling periods, diurnal variations, or transects inside and outside of the wind farm area.

Different species composition might be responsible for the variances found in the fish communities. Abiotic factors, like the area with coarse sand south of the wind farm, aggregated fish to a much higher extent than the presence of the wind farm itself.

Fish density was expected to be higher inside the wind farm and especially higher in the vicinity of the turbine foundations because of a potential attraction effect on reef fish. However, no statistical evidence was found confirming that densities of pelagic and semipelagic fish near the vicinity of the turbines were different from between the turbines.

In conclusion, the programme found no significant effect on fish communities either at the wind farm scale or at a local scale around the foundations. There was a pronounced variability in biotic and abiotic factors influencing the fish communities in the general area. It proved very difficult or impossible to achieve statistically useful representative replicates and geographical representative reference areas due to the high variability in the spatial and temporal distribution of both pelagic and semi pelagic fish populations.

4.6 Mammals

4.6.1 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). During the driving of the monopiles the marine mammals was scared with pingers and a seal scrammer. This measure was taken to make sure that the marine mammals were at a distance where the high noise level would not harm the animals.

In the production phase, noise will be generated by the wind turbines and by boat and 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).

4.6.2 Baseline 2001

Seals

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

Harbour porpoises

Dense populations of harbour porpoises (*Phocena phocena*) were found north-east of the wind farm area, in the deep waters named "Slugen", whereas only few porpoises were 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 were 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 was a high number of harbour porpoises in the area. The study on the distribution of harbour porpoises at Horns Rev suggests that the distribution was 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.

4.6.3 Monitoring 2002

Seals
The monitoring programme has been set up with the purpose of:

- Mapping the Harbour seal's use of the area of Horns Rev
- Surveying the seals' foraging strategies accordingly

Figure 5.4. A total of 10 Harbour seals were caught and equipped with satellite transmitters on three separate occasions.

The most significant result of the present survey in relation to Horn's Reef is probably that the previous view of the seal's use of the reef should be revised. The reef seems to be a central corridor for movements between foraging areas and haul out banks and of lesser importance as foraging area, compared to previous expectations. The seals spent less than 0.1% of their time in the farm area compared to the area they visited in the entire North Sea. The limited extent of the present wind farm, compared to the entire reef makes it unlikely that it will be a barrier to movement.

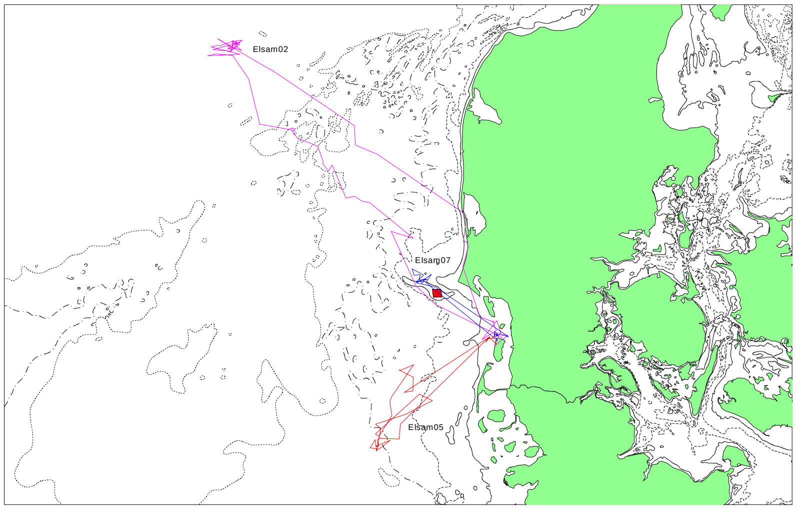

Figure 5.5. Selected examples of foraging trips. Purple: Seal on an 18-day trip to the deeper parts of the North Sea. Note the visit to Holmsland Klit and Vejers on return journey. Red: Seal on a 15-day trip to the German Bight. Blue: Seal on a 10-day trip

In the environmental impact assessment on the Horns Rev wind farm it was anticipated that seals would leave the area during construction and return again following completion of the wind farm. No firm conclusions can be reached on this issue from the present data. The animals in general spent little time in or immediately around the farm area, both before and during the construction phase. Considerable traffic across the reef by most of the seals was recorded however, both before and during construction. Some animals also spent shorter or longer periods in the reef area, presumably foraging, both before and during construction. There is thus no reason to believe that construction - most notably the noisy pile driving of monopiles into the seabed - had any large-scale effect on the seals in the area. As accurate tracking of the animals with high temporal resolution was not possible with the type of transmitter available, it is not possible to evaluate whether the mitigations employed in order to reduce the risk of hearing damage in seals and harbour porpoises were effective.

Harbour porpoises

The programme has been designed in relation to the following hypotheses:

a. During the construction phase, a major impact on harbour porpoises is expected in the wind farm area. The ratio of density and acoustic activity of harbour porpoises in the impact area to the reference areas will presumably decrease.

b. During the operational phase following construction of the wind turbines, harbour porpoises will return to the wind farm area. Compared to the baseline, the change in the ratio of density and acoustic activity of harbour porpoises in the impact area to the reference areas will not exceed 25 %.

During the pile driving, a ramp-up procedures and pingers/seal scaring devices was applied as mitigations for reducing the risk of inflicting permanent hearing damage to marine mammals. It was found that the behaviours were significantly different from periods without pile driving.

The impact of pile driving activity seemed to have a short-lived effect on harbour porpoise acoustic activity in the Horns Reef area in general, as the activity returned to normal levels approximately 3-4 hours after pile driving activity had ceased. The pile driving activity had an effect on positions within both impact area and control areas.

The statistics on daily intensities indicated a significant negative effect over the entire period, indicating that the resumed level of activity in the wind farm area was lower during the construction period compared to the baseline. This would be expected, due to the potential disturbance from the large number of service vessels continuously present in the area.

4.6.4 Monitoring 2003

Seals

Based on the experiences from the previous studies and on recommendations from IAPEME more accurate transmitters were required in order to provide a precise location of the seals. It was therefore decided to conduct a test before the production of four transmitters intended for deployment on wild seals in the Wadden Sea and at Nysted. The test was carried out under controlled conditions on a seal in captivity at the Sealarium, Fisheries and Maritime Museum in Esbjerg, Denmark.

Within a few days it became clear that the transmitter was not functioning properly as SMS-messages from the GSM-subunit were not received. As none of the measures to establish contact were successful, the test was terminated. The transmitter was removed and handed over to the producer for inspection and faultfinding.

Because the accuracy of the baseline data is quite low (in the range from a few hundred metres to several kilometres) a comparison with post-constructional data would be difficult, even if these were to be generated.

In combination with the technical difficulties, the seal monitoring programme was suspended based on the results from the previous studies, indicating that the wind farm area is only of minor importance to the entire area visited by the seals.

Harbour porpoises

The 2003 field campaign has been concerned with the assessment of effects of wind farm operation on harbour porpoises. As monitoring continues through 2004, conclusions are preliminary and await a complete and more thorough analysis of the entire data set after completion of the 2004 season.

Occurrence and distribution of harbour porpoises (*Phocoena phocoena*) were monitored using both data from acoustic dataloggers (T-PODs) and visual surveys conducted from ships confirmed the presence of harbour porpoises inside the wind farm area.

Comparison with baseline data from 1999-2001 and with control areas outside the wind farm did not show a statistical significant decline in sighting rates inside the wind farm area in the first year of turbine operation.

Porpoises were present inside the wind farm on 10 out of the 12 surveys preformed in 2003, with the exception of the surveys in February and July. Very few animals were sighted on the February survey whereas porpoises appeared to have a more westerly distribution on the July survey, concentrated around the shallows "Tuxen" and "Vovvov" (app. 10-20 km WNW of the wind farm). T-POD data showed porpoise activity inside the wind farm throughout all periods with T-PODs deployed.

An analysis of the survey data did not show significant changes in porpoise abundance inside the wind farm (impact) area relative to control areas from baseline to post-construction. The power of this analysis is low, however, as only data from one year of post-construction is available.

Echolocation activity in the impact area relative to the control area almost returned to baseline levels after the end of the construction period. Of the effects tested, only encounter duration was significantly affected from baseline to post-construction period, with lower levels in the post-constructional phase. Survey data also showed a return to baseline levels in the post-constructional phase. The lower encounter durations seen in 2003 compared to baseline years indicate a relatively lower porpoise activity in the park. Whether this reflects a true permanent effect of the wind farm on the porpoises or just that return to baseline levels occurs over a longer period will hopefully be resolved when data from 2004 are analysed.

4.6.5 Monitoring 2004

Seals

In 2004 a cooperation between the University of Kiel and the Fisheries and Maritime Museum in Esbjerg, Denmark has been established. The combined effort of the two institutes in 2004-05 will lead to a detailed description of the exploitation of the Wadden Sea area by the seal population.

The programme was launched to provide information about the distribution, occurrence and behaviour of the animals after the erection of the turbines. The gathered data will also be able to determine if seals use the wind farm area, and if so, for what. Finally, the data will be compared with the baseline data to see if any significant changes will emerge.

In late 2004 a total of ten seals were tagged. The transmitters have returned positions from both the Danish, German and Dutch Wadden Sea, as well as from the North Sea, Rømø and the Horns Rev area. The transmitters will stay on the animals until the mould in July/August 2005.

Since the loggers were only deployed in late 2004, no compilation of data has been reported in the 2004 annual report. Thus, data from the current programme will be reported in the final report in 2006.

Harbour Porpoises

The surveys planned for autumn 2004 was postponed due to the extensive boat traffic in the area linked to the work with dismantling and resituating all the turbines in this period. The extraordinary activity in the autumn did not represent the conditions that are associated with a normal operational phase, thus only data from spring/summer 2004 were collected.

Three 2-day surveys with line transect observations of porpoises were conducted in 2004 and data from acoustic dataloggers (T-PODs) were collected from January through July. Porpoises were seen on all three surveys, with lowest density in February and highest in August. Porpoises were observed inside the wind farm in February and August, but not in April. Observations were distributed over the entire surveyed area without any obvious focus of activity.

The analyses performed on the 2004 data have added only little to conclusions from previous years' reports. The 2004 analyses have however brought us closer to understanding the complexity and dynamics of the Horns Reef area and the factors, which may govern the fine-scale distribution of harbour porpoises in the area.

As the situation stands at this point the conclusions that can be drawn on general effects of the operating wind farm are very weak. The conclusion from 2002 on specific effects of the construction (especially pile drivings) is strong and unchanged. The analyses of T-POD data and survey data from the construction period as a whole and the following operational period points to a weak or absent negative effect, but it should be stressed that this conclusion is very weak and could well change after final analysis of the entire dataset in 2006.

4.6.6 Monitoring 2005

Seals

With the completement of the 2005 monitoring programme a total of 36 harbour seals had been caught and equipped with satellite transmitters (21) and/or dataloggers (21) since 2002 – eight of these in 2005. Seven of the deployed dataloggers have been retrieved to date.

The data from the 2005 monitoring was combined with the previous post-construction data from 2003 – 2004 to strengthen the comparison with the baseline and construction period data.

The data document that Horns Reef and thus also the wind farm is located in the centre of the foraging area of the seals from Rømø and the area is thus of importance to the seals. Nothing seems to indicate however, that the reef or the wind farm area is of greater importance than the surrounding areas.

The accuracy of the positions retrieved from satellite transmitters and dataloggers turned out to be insufficient to conclude with certainty on the degree to which construction of the wind farm has affected the seals. However, it is close to certain that one or more of the tagged seals were inside the wind farm area during the period the transmitters were active. Visual observations from ship surveys, conducted as part of the monitoring program on harbour porpoises, supports this, as seals were observed inside the wind farm area in numbers not readily different from the surrounding waters. An exception from this was the construction period in spring and summer 2002, where very few seals were observed inside and in the immediate surroundings of the wind farm.

Underwater noise from the turbines appears to be the only potential negative source of impact of practical relevance. The scale of this impact is considered to be marginal, based on measurements of the emitted noise from the turbines and compared to the other sources of underwater noise in the area, caused by e.g. ship traffic. It is believed that the artificial reef formed on the foundations and scour protection potentially will benefit the seals in the area through an increase in food availability.

Harbour Porpoises

Five 2(3)-day ship surveys with line transect observations of porpoises were conducted in 2005 plus two in spring 2006. Data from acoustic dataloggers (T-PODs) were collected throughout 2005. As the wind turbines was operating normally during this period, these data were used as representative of the operation period, and used for comparison with data obtained during baseline (1999-2001), construction (March – August 2002), and semi-operation periods (December 2002 – October 2004).

Acoustic recordings (with T-PODs) did not show any significant change in abundance in the wind farm area as a whole during construction (see figure below). However, there was a significant difference between semi-operation (when intensive maintenance work too place) and operation, measured on the indicator porpoise-positive-minutes (PPM). PPM reached the lowest mean value in the entire monitoring period during semi-operation. Porpoise acoustic activity was higher in the operation phase than during baseline, but this was the case both in the wind farm and in the surrounding reference areas.

Conclusions from the ship surveys point in the same direction as the acoustic data, i.e. a weak negative and local effect of the wind farm during construction but otherwise no significant changes. Also ship survey data indicate more porpoises in the area as a whole during the operational period than for any other of the periods, baseline included.

Although the design of the monitoring program was only aimed at detecting general effects of the construction and operation of the wind farm on porpoise abundance, it was nevertheless possible to document specific effects of a single activity: pile drivings. The T-POD data indicate that porpoises left the entire Horns Reef area in response to the loud impulse sound generated by the pile driving operation. After a period of 6-8 hours, activity returned to levels normal for the construction period as a whole.

In conclusion, no effects were observed from the operating wind farm, but the dataset indicates a weak negative general effect from the construction and semi-operation on porpoises, with more specific effects linked to pile driving activities.

German studies initiated in 2005, and scheduled to continue in 2006, on acoustic behaviour of harbour porpoises within and in close proximity of the wind farm, have found first indications that the presence of porpoise were higher inside than outside the wind farm (Blew *et al.* 2006). However, the results are preliminary and solid conclusions cannot be made at this point.

4.7 Birds

4.7.1 Environmental Impact Assessment

The results of the EIA study showed 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.

4.7.2 Baseline 2001

The baseline 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 2-3 km. Figure 5.6 shows the area of the aerial counts of birds at Horns Rev (NERI, 2000).

Surveys made by plane and ship show that the birds were closer to the shore than to the offshore wind farm area. The tendency was that there were 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 showed quite a number of Common Scoters (*Melanitta nigra*) close to the coast.

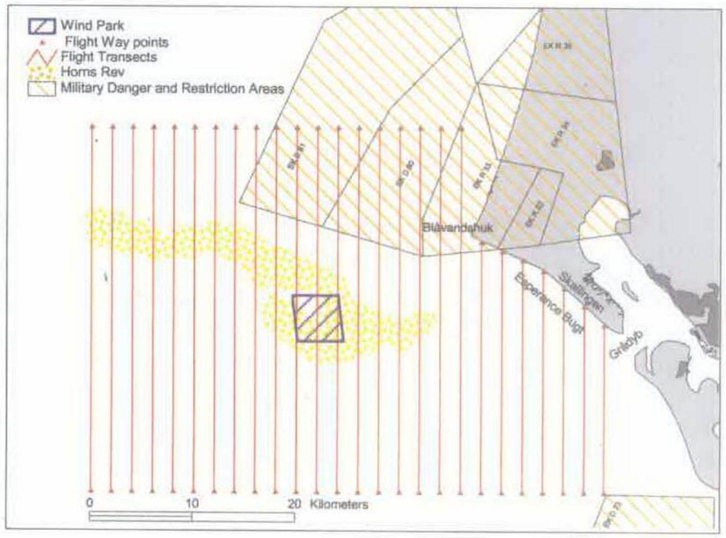

Figure 5.6. Study area (hatched) including transects (thin lines north-south) for aerial bird surveys. Military restriction areas are shown (e.g., EK R 33) (from NERI, 2000).

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 were observed within 2-4km of the projected wind farm area.

During late summer (and spring) Gannet (*Sula bassana*) occured 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.

4.7.3 Monitoring 2002

The objectives of the counts in 2002 were to obtain data for the construction period, compare to the baseline and determine whether there was any impact from the construction.

The main purposes of the counts were:

- to map the numbers and distributions of birds in the area throughout the year
- to assess the relative densities and numbers of different species present

The number of birds recorded in the surveys conducted from 1999 to 2002 is shown below. The first two years cover the baseline and the last year covers the construction phase.

Species	Period	Total	WF	WF +2km	WF +4km
Divers	Baseline 1999/00	773	11	32	48
	Baseline 2000/01	504	10	32	45
	Construction 2001/02	322	1	2	12
Gannet	Baseline 1999/00	306	0	6	40
	Baseline 2000/01	136	0	1	5
	Construction 2001/02	12	0	0	0
Arctic/Common Tern	Baseline 1999/00	1,343	9	33	94
	Baseline 2000/01	217	0	3	7
	Construction 2001/02	5	0	0	0
Sandwich Tern	Baseline 1999/00	73	0	5	6
	Baseline 2000/01	298	0	2	2
	Construction 2001/02	54	0	0	1
Alcids	Baseline 1999/00	608	3	15	53
	Baseline 2000/01	334	7	11	33
	Construction 2001/02	207	0	0	0
Eider	Baseline 1999/00	3,331	1	1	1
	Baseline 2000/01	8,441	0	0	0
	Construction 2001/02	1,349	0	0	0
Common Scoter	Baseline 1999/00	41,158	4	9	55
	Baseline 2000/01	52,165	513	3,089	10,369
	Construction 2001/02	49,823	378	1,629	2,546
Common Gull	Baseline 1999/00	191	1	2	10
	Baseline 2000/01	70	1	1	6
	Construction 2001/02	21	1	1	1
Black-headed Gull	Baseline 1999/00	37	0	1	1
	Baseline 2000/01	421	0	0	0
	Construction 2001/02	15	0	0	0
Herring Gull	Baseline 1999/00	10,509	2	38	136
	Baseline 2000/01	4,905	4	11	80
	Construction 2001/02	4,131	23	254	625
Great Black-backed Gull	Baseline 1999/00	229	0	1	9
	Baseline 2000/01	145	0	2	3
	Construction 2001/02	108	0	3	11
Kittiwake	Baseline 1999/00	1,161	11	35	83
	Baseline 2000/01	783	5	27	66
	Construction 2001/02	700	3	4	16
Little Gull	Baseline 1999/00	13	0	0	1
	Baseline 2000/01	37	0	1	2
	Construction 2001/02	286	0	3	11

Table 5.1. The total number of birds recorded within the total survey area and within the wind farm (WF), in the wind farm area +2 km zone (WF +2 km) and in the wind farm + 4 km zone (WF +4 km) during the base-line years and during the period of construction. Birds recorded during August 2001 are not included.

The results indicate that divers and alcids avoided the wind farm area during the construction, while the herring gull was attracted to the wind farm area during the construction phase.

The low and variable number of birds recorded within the wind farm area and the adjacent reference areas makes assessments of potential disturbance effect very tentative as accidental occurence of even a few individual birds may change the test results.

4.7.4 Monitoring 2003

In 2003 a total of six aerial surveys were performed in the Horns Rev study area. Thus a total of 27 aerial surveys have been carried out since the spring of 1999.

Table 5.2 and 5.3 shows the combined numbers for the 16 pre-construction surveys, and similarly for the 6 available post-construction surveys. The preference of the most numerously occurring species was calculated using Jacobs's selectivity index. Jacobs selectivity index (D) varies between –1 (all birds present outside the area of interest) and +1 (all birds inside the area of interest).

Species	MA	D for MA+0	P	MA+2	D for MA+2	P	MA+4	D for MA+4	P	N
Diver sp.	1.58	0.00	n.s.	4.81	-0.01	n.s.	7.66	-0.13	**	1,331
Gannet	0.00	-1.00	**	1.94	-0.45	***	9.51	-0.02	n.s.	515
Cormorant	0.00	-1.00	n.s.	0.00	-1.00	**	0.60	-0.90	***	168
Eider	0.01	-0.99	***	0.01	-1.00	***	0.02	-1.00	***	12,600
Common Scoter	0.40	-0.60	***	2.44	-0.35	***	8.59	-0.07	***	128,786
Herring Gull	0.06	-0.93	***	0.38	-0.86	***	1.47	-0.76	***	18,005
Great Black-backed Gull	0.18	-0.80	**	1.44	-0.56	***	4.14	-0.43	***	556
Little Gull	0.79	-0.34	n.s.	3.15	-0.23	n.s.	7.87	-0.12	n.s.	127
Kittiwake	0.79	-0.34	***	2.70	-0.30	***	6.51	-0.22	***	2,520
Arctic/Common Tern	1.00	-0.23	*	2.13	-0.41	***	5.75	-0.28	***	2,400
Guillemot/Razorbill	0.91	-0.28	n.s.	2.63	-0.32	***	7.79	-0.13	*	1,104
% of total survey coverage	1.59			4.93			9.81			

*Table 5.2. Percentage of birds (number of individuals) encountered in the wind farm area (MA) based on 16 pre-construction aerial surveys, as compared to the entire survey area, and in wind farm area plus zones of 2 and 4 km radius from the wind farm site (MA+2 and MA+4). Also shown are the total numbers of birds for each species/species group recorded throughout the surveys from the total study area from the pre-construction period (N). For each species and area, the Jacobs Index value (D) is given which varies between -1 (complete avoidance) and 1 (complete selection). The last column for each species category and area is the probability that these encounter rates differ from those of the entire area, based on one sample χ^2-tests. Values (P) are probabilities using standard statistical notation, n.s. represents P > 0.05, * P<0.05, ** P<0.01, *** P<0.001.*

By far the most numerous bird species recorded in the study area in 2003 was Common Scoter, with close to 600,000 recorded individuals. The second most numerous species was Herring Gull, with more than 11,000 observed individuals.

The number of Divers, Common Scoters and Little Gulls has increased in the general study area in 2003, as compared to the previous years of surveys.

Species	MA	D for MA+0	P	MA+2	D for MA+2	P	MA+4	D for MA+4	P	N
Diver sp.	0.00	-1.00	***	0.10	-0.96	***	0.77	-0.87	***	1,036
Gannet	0.00	-1.00	n.s.	0.67	-0.77	*	2.01	-0.68	***	149
Cormorant	0.00	-1.00	n.s.	1.37	-0.57	n.s.	1.37	-0.77	*	73
Eider	0.00	-1.00	***	0.04	-0.98	***	0.20	-0.96	***	5,018
Common Scoter	0.00	-1.00	***	0.00	-1.00	***	0.74	-0.87	***	574,988
Herring Gull	0.34	-0.65	***	1.36	-0.57	***	3.24	-0.53	***	11,064
Great Black-backed Gull	6.32	0.62	***	11.58	0.44	**	22.11	0.45	***	95
Little Gull	4.14	0.46	***	10.58	0.40	***	19.10	0.37	***	822
Kittiwake	7.08	0.65	***	7.08	0.20	n.s.	9.73	0.00	n.s.	113
Arctic/Common Tern	0.00	-1.00	*	9.26	0.33	***	14.29	0.21	***	378
Guillemot/Razorbill	0.00	-1.00	*	1.45	-0.55	***	4.10	-0.44	***	415
% of total survey coverage	1.58			4.86			9.81			

*Table 5.3. Percentage of birds (number of individuals) encountered in the wind farm area (MA) based on 6 post-construction aerial surveys, as compared to the entire survey area, and in wind farm area plus zones of 2 and 4 km radius from the wind farm site (MA+2 and MA+4). Also shown are the total numbers of birds for each species/species group recorded throughout the surveys from the total study area from the post-construction period (N). For each species and area, the Jacobs Index value (D) is given which varies between -1 (complete avoidance) and 1 (complete selection). The last column for each species category and area is the probability that these encounter rates differ from those of the entire area, based on one sample χ^2-tests. Values (P) are probabilities using standard statistical notation, n.s. represents P > 0.05, * P<0.05, ** P<0.01, *** P<0.001.*

Divers, Gannets, Common Scoters and Guillemots/Razorbills showed an increased avoidance of the wind farm area after the erection of the wind turbines, including also zones of 2 and 4 km around the wind farm. In contrast Herring Gulls showed a decreased avoidance of the wind farm area, while Great Black-backed Gulls, Little Gulls and Arctic/Common Terns showed a general shift from pre-construction avoidance to post-construction preference of the wind farm area.

Common Scoters showed a change in distribution within the study area in 2003 as compared to previous years. An area southeast of the wind farm, previously used by Common Scoters and particularly in February through April, has become less attractive to the birds. Simultaneously areas west and north of the wind farm, with previously very few Common Scoters, have supported greater numbers of this species.

The reason for the change in avoidance of the wind farm area for Divers, Gannets, Common Scoters and Guillemots/Razorbills is unknown. Disturbance effect from the wind turbines is one possible reason. Disturbance from increased human activity associated with maintenance of the wind turbines could be another. But changes in the distribution of food resources in the study area could potentially play a role too.

The change in Gull and Tern preference of the wind farm area is likely to have been caused by the presence of the wind turbines and the associated boat activity in the area.

Visual and radar observations of birds in relation to collision risk

The international expert panel stated that high priority should be given to the quantification of potential bird collision rates at the offshore demonstration wind farms. Thus, in 2003 after the erection of the Horns Rev wind farm a programme was launched to assess the risk of birds colliding with the wings of the turbines.

Observations were made both visually and by radar. The visual observations were made to map the species and give estimates of flying altitudes and traveling speed. For obvious reasons the visual surveys were only possible in daylight and on days with good visibility. On the other hand, the radar observation should quantify the behavior of the birds at night and in poor visibility, when the wind farm is less visible from the distance. Knowledge of the traveling speed of the individual species can be used to provide an estimate of the bird species approaching the wind farm at night and in poor visibility.

Although a substantial proportion of bird radar tracks, which approached the wind farm for unknown reasons, disappeared before entering the wind farm (48.8% and 55.2% from North and East respectively), the majority of the longest bird tracks showed a lateral deflection in orientation, resulting in birds flying around the wind farm. Consequently only a few bird echoes (7.1% of a total of 1.088 tracks) were recorded entering the wind farm. This low number was in all probably somewhat affected by reduced detectability of radar tracks within the wind farm related to a shadow effect from every single turbine hampering recordings of bird echoes within the wind farm. However, consistent visual observations of lateral deflections around the wind farm in several species indicate that avoidance of the wind farm was a frequent behavioral response shown by most of the bird species occurring at Horns Rev.

Given one year of study, the aim was to describe a series of variables that is considered the most important parameters to contribute to a final risk assessment for bird species occurring at Horns Rev.

Based on the results obtained through the 2003 study, no final conclusions about the risk of collision can be made. It seems, however, reasonable to cautiously conclude, that since most species react to the presence of the turbines at relatively long distances, many avoid entering the wind farm, or do so flying in the corridors between turbine rows, the risk of collision seems to be lower than if birds did not modify their migration behavior when approaching the wind farm. Likewise, the turbines were not found to act as a platform for loafing that potentially would attract a high number of perching bird species as Gulls, Terns and Cormorants, that potentially would collide with the turbines.

Based on the recorded patterns of deflection in the orientation of migrating birds approaching the wind farm, it may be possible that birds that migrate at night may experience an increased risk of collision. At night, adjustment in migration orientation in birds that fly in close to the wind farm was less accurate in relation to passing the wind farm through the free areas between turbine rows, than in birds migrating during daytime. This probably results in a higher frequency of passing one or more rows of turbines, and hence increases the risk of collision.

As expected, no observations were made of actual collisions during the eight periods of observation performed at the wind farm site in the post-constructional phase.

4.7.5 Monitoring 2004

A total of nine surveys from 2003 and 2004, the operational phase of the wind farm, are available. Because of the extensive work done in the wind farm with the dismantling, overhaul and replacement of all the turbines in the wind farm in fall 2004 the bird monitoring programme planned for fall 2004 was postponed, since the situation in the wind farm did not describe the conditions expected during a normal operational phase. Thus, in order to achieve maximum comparison between the pre- and post-construction data set, the 2004 analyses have been carried out on the basis of seven pre-construction surveys and six post-construction surveys, all performed between February and May.

The importance of the wind farm area and of the adjacent 2 and 4 km zones to birds occurring at Horns Rev was assessed from the preference of the birds for these areas using the Jacobs selectivity index. The index indicates whether a species occurred in an area in a higher or lower proportion than expected from a geographically even distribution.

Table 5.4 and 5.5 shows the combined numbers for the seven pre-construction springtime surveys, and similarly for the six available post-construction springtime surveys.

Species	MA	D for MA+0	P	MA+2	D for MA+2	P	MA+4	D for MA+4	P	N
Diver sp.	1.54	-0.01	n.s.	4.97	0.02	n.s.	7.05	-0.16	**	1106
Gannet	0.00	-1.00	n.s.	0.00	-1.00	n.s.	1.35	-0.77	*	74
Eider	0.01	-0.99	***	0.01	-1.00	***	0.03	-0.99	***	9168
Common scooter	0.71	-0.38	***	4.31	-0.06	***	15.17	0.26	***	71978
Herring gull	0.05	-0.94	***	0.31	-0.88	***	1.12	-0.81	***	13027
Little gull	0.00	-1.00	n.s.	0.00	-1.00	n.s.	5.41	-0.30	n.s.	37
Kittiwake	0.35	-0.63	n.s.	2.83	-0.27	n.s.	7.77	-0.11	n.s.	283
Arctic/Common tern	1.02	-0.21	n.s.	2.39	-0.35	*	5.29	-0.31	***	586
Auk/Guillemot	1.37	-0.07	n.s.	4.11	-0.08	n.s.	5.02	-0.33	*	219
% of total survey coverage	1.56			4.79			9.52			

*Table 4.4 Percentage of birds (number of individuals) encountered in the wind farm area (MA) based on seven pre-construction aerial surveys, as compared to the entire survey area, and in the wind farm area plus zones of 2 and 4 km radius from the wind farm site (MA+2 and MA+4). Also shown is the total number of birds for each species/species group recorded throughout the surveys from the total study area in the pre-construction period (N). For each species and area, the Jacobs index value (D) is given. This value varies between -1 (complete avoidance) and 1 (complete selection). The column (P) for each species category and area is the probability that these encounter rates differ from those of the entire area, based on one sample χ^2-tests. Values (P) are probabilities using standard statistical notation, n.s. (not significant) represents P > 0.05, * P<0.05, ** P<0.01, *** P<0.001*

Species	MA	D for MA+0	P	MA+2	D for MA+2	P	MA+4	D for MA+4	P	N
Diver sp.	0.00	-1.00	***	0.12	-0.95	***	0.99	-0.81	***	1611
Gannet	0.00	-1.00	*	0.00	-1.00	***	0.67	-0.87	***	450
Eider	0.00	-1.00	***	0.11	-0.96	***	0.27	-0.94	***	4730
Common Scooter	0.05	-0.93	***	1.29	-0.56	***	2.50	-0.58	***	578233
Herring Gull	0.22	-0.74	***	1.11	-0.61	***	2.45	-0.59	***	13298
Little Gull	0.24	-0.71	**	7.02	0.24	***	14.29	0.27	***	826
Kittiwake	0.00	-1.00	*	4.92	0.06	n.s.	5.46	-0.25	*	366
Arctic/Common Tern	0.00	-1.00	**	5.74	0.14	n.s.	11.83	0.16	*	575
Auk/Guillemot	0.00	-1.00	n.s.	0.97	-0.65	**	1.94	-0.66	***	309
% of total survey coverage	1.42			4.41			8.81			

*Table 4.5 Percentage of birds (number of individuals) encountered in the wind farm area (MA) based on six post-construction aerial surveys, as compared to the entire survey area, and in the wind farm area plus zones of 2 and 4 km radius from the wind farm site (MA+2 and MA+4). Also shown is the total number of birds for each species/species group recorded throughout the surveys from the total study area in the post-construction period (N). For each species and area, the Jacobs index value (D) is given. This value varies between -1 (complete avoidance) and 1 (complete selection). The column (P) for each species category and area is the probability that these encounter rates differ from those of the entire area, based on one sample χ^2-tests. Values (P) are probabilities using standard statistical notation, n.s. (not significant) represents $P > 0.05$, * $P<0.05$, ** $P<0.01$, *** $P<0.001$*

During the three aerial spring surveys of birds in the Horns Rev study area, common scoter and herring gull were the most numerous species.

Divers, gannet, common scoter and guillemot/razorbill showed an increased avoidance of the wind farm area after the erection of the wind turbines, including also zones of 2 and 4 km around the wind farm. In contrast herring gull, little gull and arctic/common tern showed an increased preference for the wind farm area.

Changes in general distribution of common scoter compared to previous years was observed. The species was found in shallow, offshore parts of the study area. This general shift in distribution was not believed to be caused by the presence of the wind turbines. There are, on the other hand, clear indications that the common scoter responded negatively to the presence of the wind farm. An area southeast of the wind farm, previously used by common scoter, particularly in February through April, was used less by this species. Simultaneously, areas west and north of the wind farm with previously very few common scoter supported larger numbers of the species in 2003 and 2004.

The reason for the change in avoidance of the wind farm area for divers, gannet, common scoter and guillemot/razorbill is unknown. Disturbance effect from the wind turbines is one possible reason. Disturbance from increased human activity associated with maintenance of the wind turbines could be another. However, changes in the distribution of food resources in the study area could potentially play a role too.

The change in gull and tern preference for the wind farm area is likely to have been caused by the presence of the wind turbines and the associated boat activity in the area.

Visual and radar observations of birds in relation to collision risk

As for the aerial counts, the collision risk studies planned for the fall 2004 was also postponed due to the extraordinary ship activity that took place in the area in late 2004 when all the nacelles where moved to and from Esbjerg harbour.

Studies were however performed in spring/summer 2004 and as expected, no actual collisions were observed during the three periods of observation performed at the wind farm site during spring 2004.

Generally, very few birds were recorded inside the wind farm. Gulls and terns were the most frequently occurring species recorded in between turbines, but mainly observed at the edge of the wind farm and far less in the central parts of the wind farm. During April and May thousands of common scoters were present in the area close to the wind farm, and flocks of this species were occasionally seen flying inside the wind farm. The low number of seabirds and waterfowl recorded inside the wind farm and the general tendency of deflection around the wind farm by migrating birds recorded by radar, indicate that most bird species generally exhibit an avoidance reaction to the wind turbines, which reduces the probability of collision.

As recorded during autumn 2003, most birds that actually entered the wind farm seemed to adjust flight orientation to pass through the wind farm in parallel with turbine rows and not to cross several rows. Even though more data on both occurrence and behaviour still needs to be sampled during periods of poor visibility, a less accurate adjustment of flight orientation was recorded during nighttime, suggesting that a higher risk of collision may be associated with migration during periods of darkness and therefore also of low visibility.

4.7.6 Monitoring 2005

Numbers and distribution

A total of six aerial surveys were conducted in 2005, bringing the total number of post-construction surveys up to 15. No separate analysis of the 2005 data were carried out, rather they were pooled with the previous post-construction data to make an overall comparison with pre-construction data (represented by 16 aerial surveys).

The big scale wind farm at Horns Rev had an effect on the distribution of a number of bird species utilising the area for staging and/or wintering. The effects were found to be highly species-specific, ranging from avoidance of the wind farm area and adjacent zones to indications of increased utilisation of the wind farm area as a result of attraction to the structures.

Red-throated/Black-throated Divers in the Horns Rev study area showed significant avoidance response to the wind farm when comparing pre-construction data with corresponding post-construction data. This avoidance effect was found out to a distance of 2 km from the wind farm.

The analysis of a potential effect on the distribution of Common Scoters at Horns Rev was made difficult by the fact that the species showed major changes in distribution across the study area during the study period, since post-construction distribution involved the utilisation of the Horns Rev area to a much higher extent than previously, and the BACI-design analysis therefore was no option. The distribution of Common Scoters at Horns Rev clearly indicated that the birds responded to the presence of the wind farm by general avoidance of the actual wind farm area, but with concentrations of birds in its near vicinity of few hundred meters.

Analyses of food preference of Common Scoter at Horns Rev in March 2005 showed that American Razor Clam *(Ensis americanus)* was the sole prey species at this site (Petersen et al. in prep, Freudendahl and Jensen 2006). Razor Clams of 6 to 9 cm were most abundant in the intestines of the birds.

During the post-construction phase no significant difference between pre- and post-construction selectivity for the wind farm areas was found for gulls. No firm conclusions can be made on the effect of the wind farm on Little Gull. It was indicated that the species is attracted to the wind farm, with higher preference for the wind farm site and the surrounding zones after the establishment of the turbines. The change was only significantly different for the 2 km zone around the wind farm.

Arctic/common Tern showed no significant response to the establishment of the Horns Rev wind farm. Selectivity indices indicate an avoidance response in the wind farm area, but an increased utilisation of the 2 km zone around the park.

Results from selectivity index calculations for Guillemot/Razorbill at Horns Rev indicate that these species avoid the wind farm area and the 2 and 4 km zones around it after the erection of the turbines. The results were not statistically significant when analysed on a subset of the data, mainly due to large confidence intervals in the data set.

Generally, the patterns in density of birds gathered over the surface of the open sea reflect two dominant features of the environment, namely their food availability and safety from predation. There are abundant studies that show that human disturbance, including that caused by man-made objects, represent a quasi-predatory stimulus that initiates avoidance. Hence, the avoidance of the immediate vicinity of the turbines shown by some species could be ascribed to this hypothesis. However, it cannot entirely be ruled out that the alternative explanation, namely changes in food supply, have been responsible for the observed changes in distributions in the wind farm area.

Visual and radar observations of birds in relation to collision risk

Combined visual and radar observations of migratory birds were performed in spring and autumn of 2003-2005, with a total of 19 visits to the area - eight of these in 2005.

The combined results from radar studies showed that birds generally demonstrate avoidance behaviour, although the responses were highly species specific. Radar tracks of birds show adjustments in their northward and southward flight tracks around the periphery of the wind farm which create a circular avoidance pattern out to 5 km. These data also show that between 71 and 86% of all bird flock radar trajectories heading for the wind farm at 1.5-2 km distance ultimately avoided entering into the wind farm between the turbine rows.

Minor adjustments in flight orientation were observed at 1-2 km range and major reorientation at 200-500 m range, typically to fly between the turbine rows perpendicular with the end of the wind farm or to follow the outer edge of the wind farm and avoid entry altogether.

Changes in flight direction occurred closer to the wind farm at night, and because it is more difficult for migrating birds to detect the wind farm at night, the proportion of birds crossing the wind farm will be greater at night than by day. The lateral deflection tended to occur closer to the wind farm at night (0.5 km) than by day (1.5 km or more).

Major conclusions cannot be drawn about the effect of poor visibility (e.g. as a result of fog or precipitation) on the avoidance response, because too few observations of intense migration traffic occurred during periods of poor visibility to enable such an assessment.

Some species were almost never witnessed flying between the turbines despite their abundance outside (e.g. divers and Gannets), others rarely do so (e.g. Common Scoters) or generally avoid flying a long way into the wind farm (e.g. terns), whilst others (e.g. gulls, especially Greater Black-backed and Herring Gulls) showed no sign of avoidance at all.

Given the general avoidance of the wind farm by most bird species and the lack of observed collisions, the present study found no indications that bird collisions with the wind turbines could substantially increase the annual mortality of any of the bird populations utilizing or migrating through the area.

German studies initiated in 2005, and scheduled to continue in 2006, on migration intensity and altitude in the immediate vicinity of the wind farm indicate – in accordance with the Danish studies – a marked avoidance response during daytime and an apparent reduced ability of migrating birds to avoid the wind farm at night. Further investigations are required, however, before conclusions can be drawn (Blew *et al.* 2006).

4.8 Visual and socio-economic impact

4.8.1 Environmental Impact assessment

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 45 km from land, wind turbines of a height of 110 m 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 (Techwise, 2000).

It was on a recommendation from the Green Group and IAPEME decided to initiate a project concerning the socio and environmental economic aspects of the two offshore wind farms. The project is a joint project for Nysted and Horns Rev offshore wind farms and was started in spring 2003.

4.8.2 Monitoring 2003

To assess the beliefs and opinions of people and how they act in reality as a consequence of the erection of the wind farm, a questionnaire has been prepared in 2003 to provide data for a quantitative analysis of the environmental-economic effects. The sociological effects have been subjected to a qualitative analysis of the opinions in the local area around the wind farm.

Sociological effects

14 interviews have been made at Horns Rev wind farm. The selection of informants seeks to give a variation in how the informants have been involved in the local process. This means interviews with: local politicians; local and regional officers; members of NGO's; people with a business interest in the wind farm (i.e. tourism and fishing) and citizens that have participated in the public debate.

In 2003 two of three studies were carried out and the third study starts in September 2004. Due to this fact, the results are only provisional.

Between the 14 people involved there was widespread consensus on the positive aspects of wind energy, accepting that a dilemma exists between nature (preservation of landscape) and environment (CO_2 reductions). At the same time there was a widespread criticism of wind turbines in the landscape and thus, a preference towards offshore wind farms. According to the interviewed group, the offshore wind farms should be placed at a distance from the coast, which makes the farm invisible to leave the impression that nature is unaffected by human enterprise.

At Horns Rev the public debate was limited and initiated relatively late (1999-2000) and this was in conflict with the local expectations of involvement in the process in advance of the decision. It left the impression that the decision was made in advance. In general, lack of information was criticized - the interviewed people felt that the state had an obligation inform about the plans and its consequences.

Among the interviewed people at Horns Rev, there was a fear of the economic effects that the wind farm potentially could have on tourism, house prices etc.

Environmental economic effects
In 2003 a questionnaire has been developed and testing of this questionnaire is expected to take place in the spring 2004. Subsequent launching of the questionnaire will take place after the final approval of the questionnaire.

4.8.3 Monitoring 2004

Sociological effects
The sociological project is a qualitative study. There are two reasons for that: First, identification of attitudes earlier in the process requires the use of written sources. This is primarily local and regional newspapers but also documents from the central, regional and local authorities. In the local and regional newspapers it is possible to identify themes and the extent of the local debate, participants and the attitudes they promote. Secondly, identification of attitudes in this case is best done through qualitative interviews that are better suited for investigating contexts and changes. It is important to note however, that qualitative interviews hinder representative results, as the number of interviews is limited.

The interview investigations in both the Horns Rev and Nysted communities and the analyses of the statements in the local newspapers have in both cases pointed out some similarities and differences leading to some overall findings:

The process
From the beginning, scepticism regarding the plan existed in both communities. The interviewees who had been involved in the decision making process at both sites have stated that they were ignored and it was perceived that the decision of wind farm erection was made in advance by the central authorities. At Horns Rev the scepticism changed into actual opposition when the locals felt ignored by the central authorities. The scepticism did not turn into opposition at Nysted but the experience from this, first process is claimed to cause aversion to the plans for a new wind farm.

Regardless of the size of the opposition, an important point of the analysis is the fact that the opposition was much more widespread than the governmental authorities apparently noticed. Furthermore, this indicates that in future projects it may be appropriate to establish an early dialogue.

The coverage in the regional newspaper
In both cases the decision process for the wind farms has been covered by the regional newspaper. The timing and extent have varied as well as activity from the readers in respect to debating points. In advance it was assumed that the newspaper could influence the attitude towards the wind farm. In both cases the newspaper has expressed negative attitudes towards the plans and wind energy in general. The last years (2003 and 2004) both papers have changed the attitudes as wind turbines have increasingly been related to national and regional occupational interests and export. The analyses of the interviews have pointed to the fact that the papers have not changed the attitudes of readers who were already interested in the matter and being pro or con. Other readers have apparently not taken interest in the matter and presumably not taken notice of the coverage. Unless it has

been framed in a way that has a broad interest, i.e. higher prices on electricity due to wind power. This might have created a negative cultural resonance for negative opinions towards the wind farm.

The study at Nysted has pointed out that information about the results of the investigations of the impact on nature is important. It contributes to overcome some of the negative attitudes towards the farm based on fear of negative impacts on nature.

The analysis indicates that it is important to pay attention to the local debate in a regional paper in future projects and to use the paper to inform the local community.

Similarities in positive attitudes towards the wind farms.
At both sites the supporters stress the environmental argument for being pro the wind farm. Many are concerned about the CO_2-emission and argue that Denmark has an obligation to reduce the emission. Others are more concerned about other kinds of emission and doubt the assumption about green house effect. Some of the supporters have participated in the local debate in the regional paper defending the plans for the wind farm. The occupational effect of production of wind turbines in Denmark is another important argument in favour of the wind farms.

Differences in negative attitudes towards the wind farm.
The interviewees at both sites were concerned about whether the presence of the wind turbines and their visibility would alter the scenery negatively and at both sites, the regional and local authorities have made attempts to erect the wind farm further off the coast. The analysis have demonstrated the apparent existence of different arguments for the opposition in the two communities; at Horns Rev the opposition was based on substantial business interests in tourism; in Nysted the interviewed opponents wished to preserve nature unspoilt by human hands.

The fact that the view on aesthetics and landscape is based on different concerns at the two sites can explain the extent of changes in attitudes in the two local communities.

Changes in attitudes
One of the main purposes of the entire investigation is to detect the scope and direction of the change of attitudes:

- In both cases it can be concluded that time and adaptation to a situation can change the attitudes towards offshore wind farms. At both sites interviewees have stated that it was difficult to imagine how 110 meters high turbines will look out in the water (10 km at Nysted and 14 km at Horns Rev) and this caused some concern.

- In both cases the general local attitude is reported to have changed to acceptance by the interviewees. One year after the erection the wind farms are no longer a matter of debate in the local communities.

- The opposition seem to have been louder at Horns Rev than at Nysted. But it also seems as if the attitudes were more easily changed when it turned out that the tourist did not disappear because of the visual change of the landscape.

- It seems as if the aesthetic argument is more solid at Nysted and hence the opponents have maintained their negative opinion.

Environmental economic effects

The study is a quantitative study based on a mail survey including 700 households in a national sample and 350 households in each of the two sub sample areas near Horns Rev and Nysted.

Of the 1400 randomly selected households in the three samples close to 50% returned the questionnaires. Only 3% were discarded because of lack of information, leaving 48% or 672 respondents in the three samples. The number of respondents was 362 for the national sample and 140 and 170 for the Horns Rev and Nysted sample respectively.

The socio-economic costs associated with visual externalities from off-shore wind farms were estimated using the choice experiment valuation method. The applied choice experiment was designed to estimate the visual externalities as a function of the size of wind farms, number of wind farms and their distance from the coast. Furthermore, the project investigated whether the preferences for the visual externalities vary between the Danish population in general and the population living in the vicinity to the two existing off-shore wind farms at Horns Rev (HR) and Nysted (NY).

In the choice experiment four alternative off-shore wind farm distances from the coast were used namely: 8, 12, 18 and 50 km. Based on the respondents choices between alternative off-shore wind farm locations their preferences/willingness to pay for increasing the distance were elicited. The main results are presented in Figure 5.7 where it can be seen that the annual willingness to pay (WTP)/household for moving the wind farms from:
8 to 12 km is between 261-666 DKK
8 to 18 km is between 643-743 DKK
8 to 50 km is between 591-1,223 DKK

Across the three samples the respondents in Nysted had the highest WTP for all three distances. The Horns Rev sample is atypical in the sense that WTP does not increase for extending the distance from 18 to 50 km.

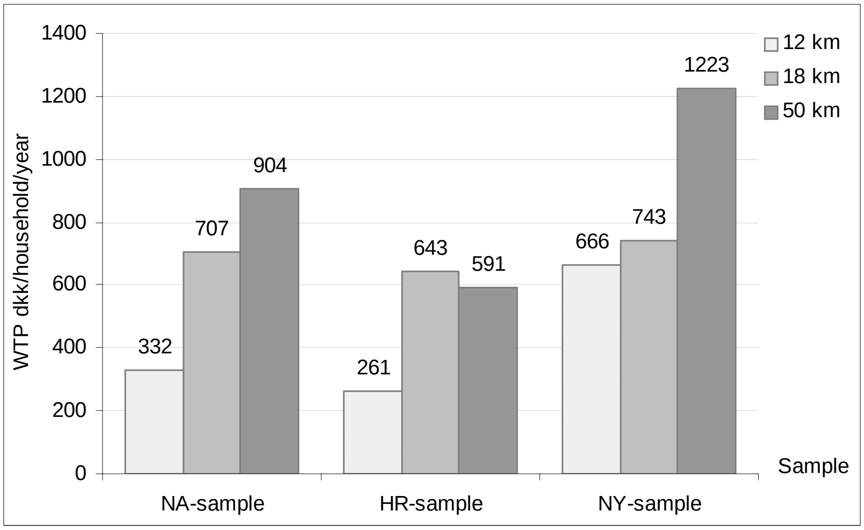

Figure 5.7 Willingness to pay for locating future off-shore wind farms at the specified distances from the shore – relative to an 8 km baseline. DKK/household/year. NA: National, HR: Horns Rev, NY: Nysted.

Attitudes Towards Wind Power and Energy Policy in General

In the survey the respondents were asked to indicate their attitudes towards wind power and other types of alternative energy on a five point scale ranging from very positive to very negative and a "do not know option".

Land based wind turbines

Across the three samples less than 15 % of the respondents indicated a negative attitude towards existing land based wind turbines, see Figure 5.8. In the two local samples, though, the attitudes were a bit more negative than in the national sample. It is possible that this difference in attitude can be explained by the relatively high density of wind turbines in the local sample areas compared to the national density level. However, it is the general conclusion that there is a high level of public support for this part of the Danish energy policy.

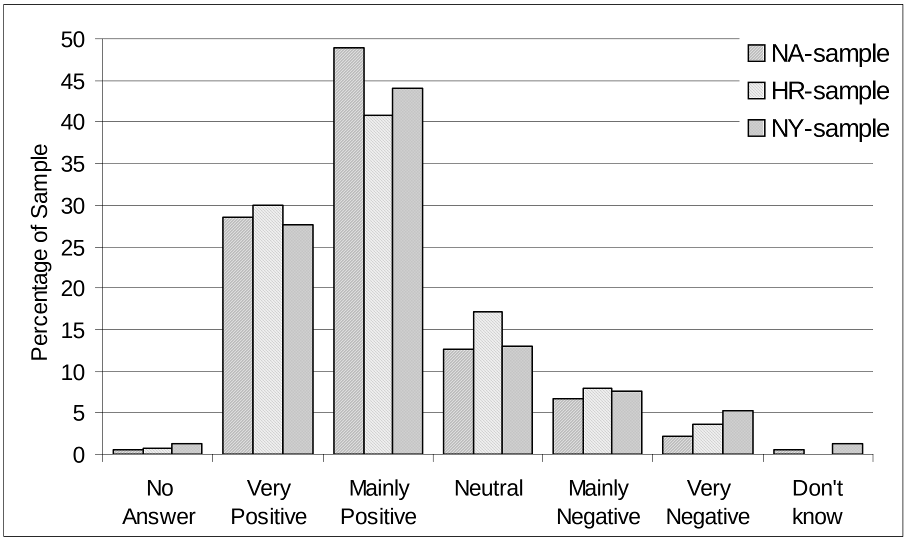

Figure 4.8 Attitudes toward existing land based wind turbines

The attitude towards the erection of *more* land based wind turbines is also quite positive, but the number of respondents with a negative attitude has almost doubled, see Figure 5.9. Between one fifth and one fourth of the respondents have a negative attitude towards more land based wind turbines. The respondents in the NY-sample are the most negative. More than 25 % of the respondents here indicate a negative attitude towards more land based turbines. A negative attitude towards land based wind power is highly correlated with the attitude that wind turbines have a negative impact on landscape amenities.

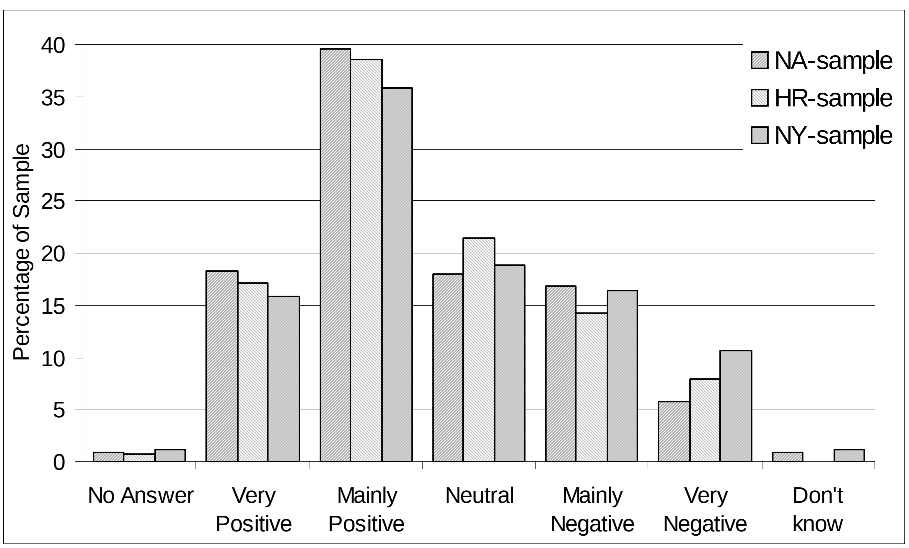

Figure 4.9 Attitudes towards an increase in land based wind turbines.

Off-shore wind turbines

The figures below (Figure 5.10 and Figure 5.11) showing the attitudes towards existing as well as more off-shore wind farms are almost identical. The figures reveals that the respondents attitude towards offshore wind energy is even more positive than it was towards land based turbines. Less than 10 % of the respondents across the three samples have a negative attitude towards existing off-shore wind farms. The same goes for an expansion of off-shore wind power generation. The respondents in the HR-sample have the most positive attitude among the three samples. The Horns Rev off-shore wind farm is located 14-20 km from the coast. The NY-sample is the most negative. Here the wind farm is located relatively close to the coast, i.e. 10-14 km. Nevertheless, it is the general conclusion that there is a high level of public support for further wind power development in Denmark – also in the two areas where large wind farms have already been established.

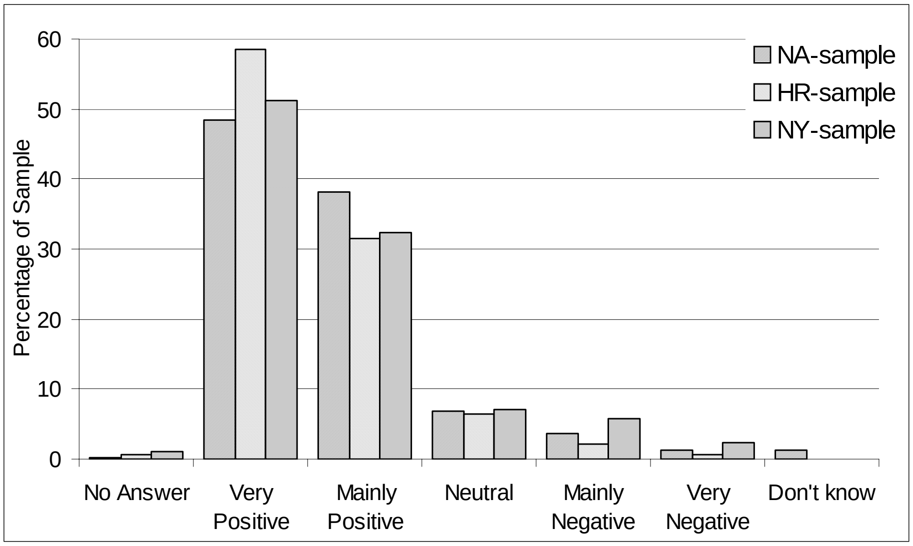

Figure 4.10 Attitudes towards existing off-shore wind farms

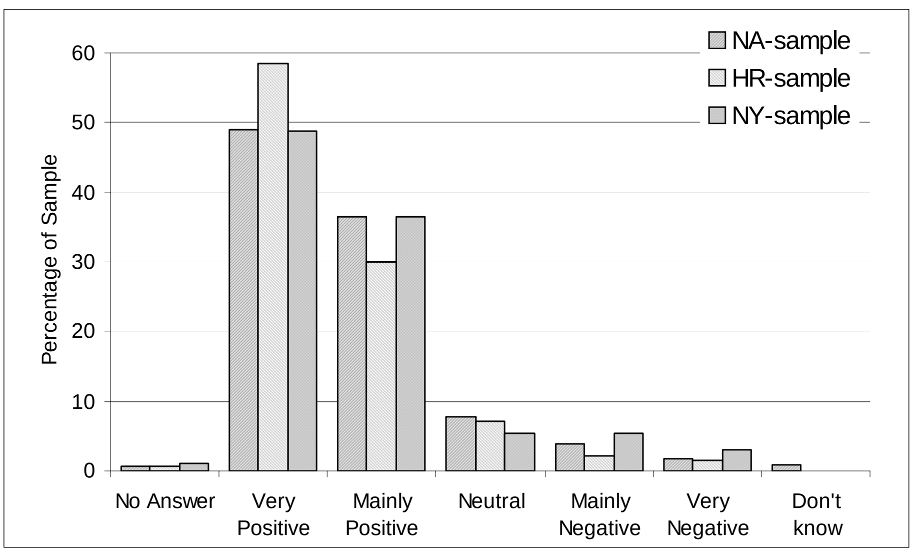

Figure 4.11 Attitudes towards establishment of new off-shore wind farms

5 Nysted offshore wind farm

5.1 Wind farm characteristics

Nysted Offshore Wind Farm is located 10 kilometers (km) south of Nysted on Lolland, and 11-17 km west of the town Gedser on the south tip of Falster. Two barrier-islands, western Rødsand and eastern Rødsand, separate Rødsand Lagune from Femer Belt and from the wind farm. Between the two barrier islands the deep Østre Mærker is approximately 5.5 km wide and on average 3.5 metres (m) deep in the deepest parts. The distance from the barrier-islands to the nearest row of wind turbines is about 2 km (see figure 6.1).

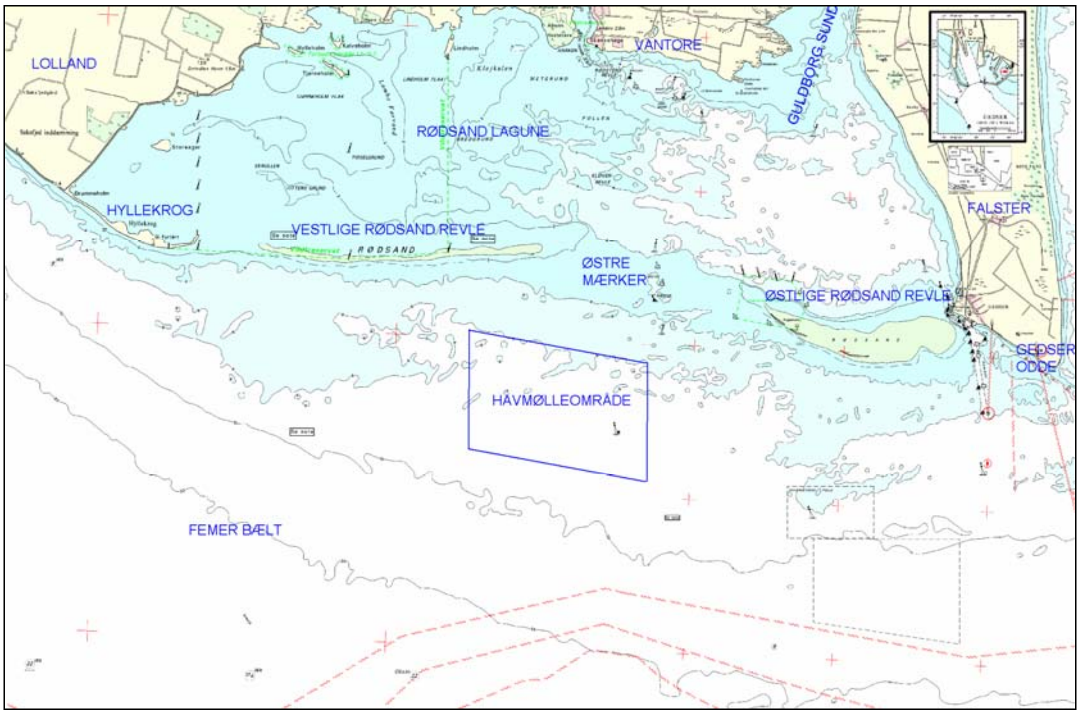

Figure 6.1. Map of the area south of the island Lolland showing the position of Nysted Offshore Wind Farm (blue square).

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

The wind farm (see figure 6.2) consists of 72 turbines each of 2.3 megawatts (MW), with a hub height of 68.6 m and 77.2 m and a rotor diameter of 82.4 m. The turbines are placed in 8 north-south oriented rows separated by a distance of 850 m. Each row holds 9 turbines separated by a distance of 480 m. The wind turbines have a discreet marine grey color and are equipped with warning lights for avoidance by sea and air traffic.

The turbine foundations are gravity foundations (figure 6.3) of concrete with specially designed protection against ice. The expected erosion around the bottom plate of the foundations will be prevented by a stone protection. The foundations take up an area of about 45,000 m², corresponding to 0.2 % of the total area of the wind farm. The foundations cause an increase of the overall surface area of up to 56,000 m².

In connection with the wind farm, four meteorology masts (figure 6.2) were erected. The masts will supply information necessary for the operation of the farm and facilitate information about the impact of the wind farm on the wind speed and turbulence inside and outside the wind farm.

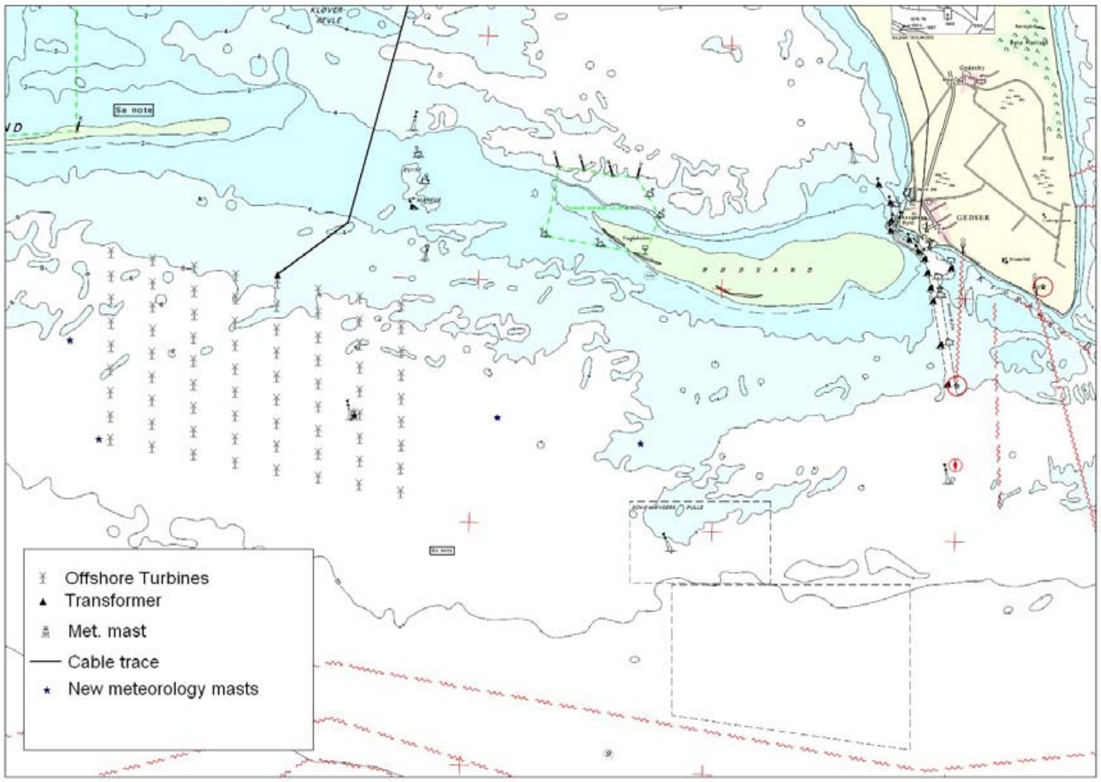

Figure 6.2. Map of the wind farm area, showing the position of the 72 wind turbines, the transformer station, the meteorology masts and the 132 kV cable to land.

Construction of the Nysted Offshore Wind Farm was launched in June 2002 with the excavation for the foundations. In mid August 2002 the excavation of the 132 kV cable trench from the transformer station to the shore began and the excavation of the 33 kV cable trench was initiated in February 2003. The laying and covering of the 132 kV cable was completed in January 2003. The optical fiber along the 132 cable was laid subsequently in May to June 2003 due to a damage on the original optical fiber. The mounting of the wind turbines began in May 2003 and was completed within approx. three months, with the last turbine in place on July 27th 2003. The operation phase of the Nysted Offshore Wind Farm officially started December 1st 2003, which is accepted as the dividing date between the construction and operation phase. The wind farm has been in stable operation since December 1st 2003.

Figure 6.3. Picture of one of the turbine foundations put in position in the wind farm area.

5.1.1 Cable connection

The turbines are interconnected with a 33 kilovolt (kV) sea-cable, which is sluiced or buried at a depth of 1 m. The sea-cable continues from the most northerly turbines to a 33/132 kV transformer platform 200 m north of the most northerly turbine. The total length of the 33 kV sea cable (figure 6.4) is about 48 km. The transformer is placed on a platform similar to the wind turbine foundations.

From the transformer platform to Vantore Strandhuse east of Nysted, a 132 kV cable is sluiced or buried at a depth of 1 m. The total length of the 132 kV cable connections to land is about 10 km. Figure 3 shows the cable connection to land. The cables in the Nysted Offshore Wind Farm are Alternating Current (AC) cables.

Along the cable connection (also called cable trace) the water depth decreases gradually from 6 m to 3.5 m in the outermost 4 km of the cable trace. The bathymetry is complicated in the innermost 6 km 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 characterized 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 section 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).

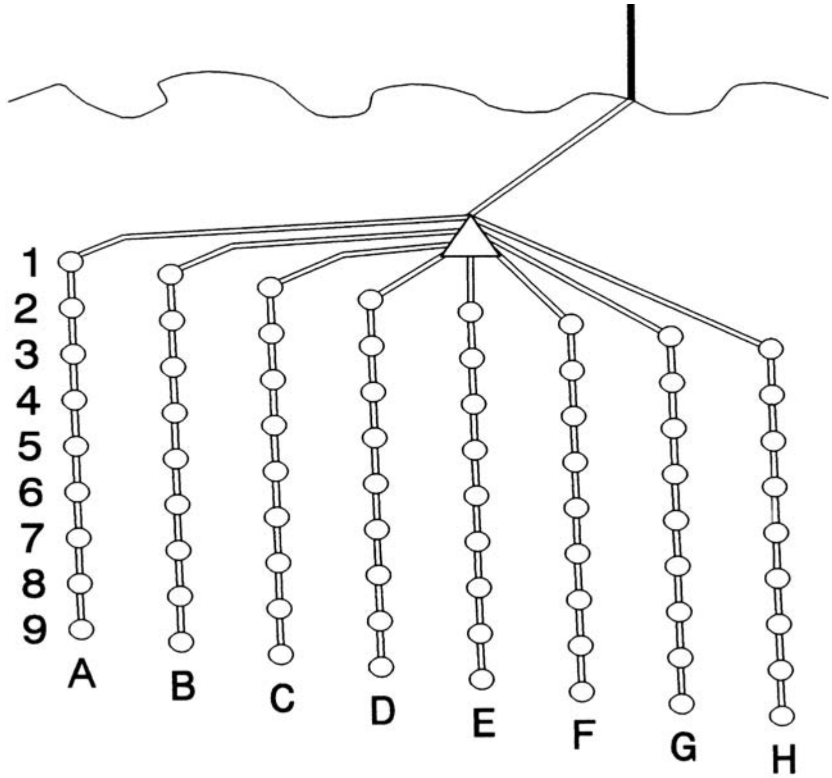

Figure 6.4. Cable connection between the wind turbines in the wind farm.

5.1.2 Designated areas

The offshore wind farm at Nysted borders 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 6.5). The 132 kV cable trace to land passes through the designated area.

The above-mentioned 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 the 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 general 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 *Ammnphila arenaria* (white dunes); Fixed dunes with herbaceous vegetation (grey dunes).

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 1st and September 30th (Danish Ministry of the Environment and Energy 1993). The seal sanctuary was established in 1978. The area of the offshore wind farm is adjacent to the seal sanctuary and the nearest turbine will be erected approximately 3 km from the seal sanctuary (figure 6.5).

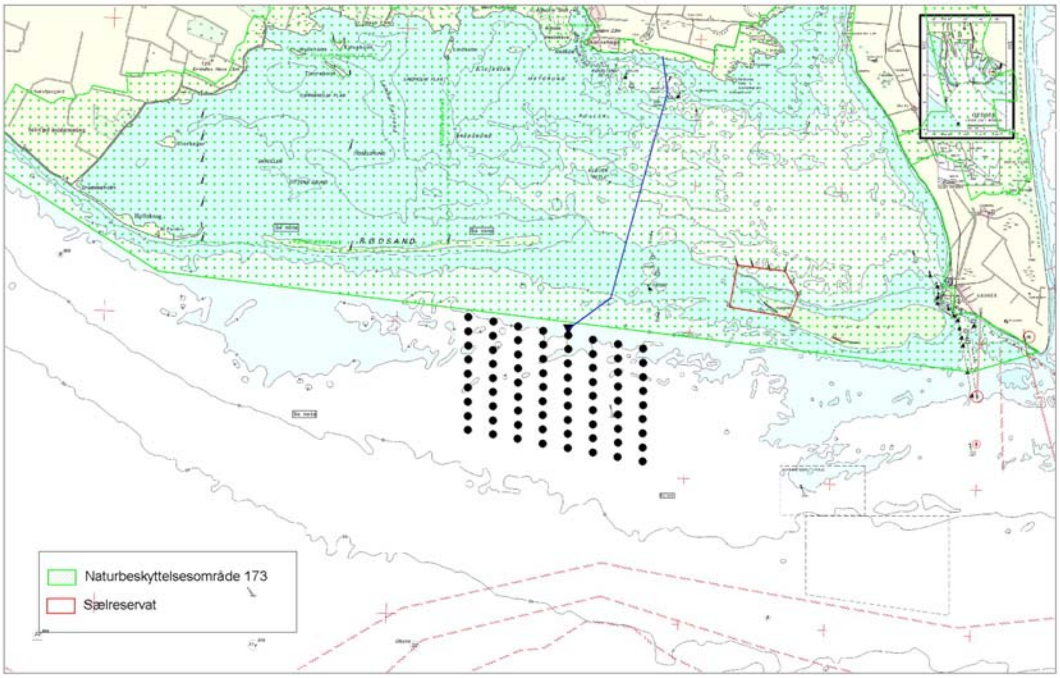

Figure 6.5. Map showing the designated areas (Naturbeskyttelsesområde 173) north of Nysted Offshore Wind Farm. The red square marks the seal sanctuary.

It is important that the wind farm's effect on the surrounding area, do not extend into the protected area to any significant degree. Therefore, possible effects on the designated areas are given special attention and the environmental studies focus on the identification of these effects.

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 assessment suggests that the park area does not represent a potential sand reclamation area, establishment of the offshore wind farm will not affect the potential for raw material extraction (Geoteknisk Institut, 1999a).

5.1.3 Recreational interests

There is a considerable amount of recreational boating in and around the area, and therefore many boaters will be affected by the offshore wind farm. This may lead to conflicts between recreational boating and the establishment of the offshore wind farm (Water Consult, 2000).

Due to the long distances from land (Table 6.1), fishing in the wind farm area is insignificant and not likely 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. Distances from the wind farm area to the five nearest Harbours

Similarly, use of the wind farm area for hunting is limited and the impact on hunting from the offshore wind farm is also evaluated as limited in significance (Water Consult, 2000). Non-professional diver interest in the area around Nysted is also of limited significance (Water Consult, 2000).

5.1.4 Ship traffic

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

During the construction phase the wind farm area has been closed off. This has caused pleasure boats to sail around the area, resulting in a maximum detour of 3 km. Out of consideration for the boating in the area, a shipping route is established diagonally (SE-NW) through the wind farm. The shipping route will be marked for day navigation when the wind farm is in operation.

A shipping lane (T route) for larger boats and ships is situated just south of the wind park area. The distance from the centre of the ship lane to the wind farm area is approximately 8 km. About 48,000 ships pass through the T route each year. The wind farm has been found to cause minimal hindrance to the commercial traffic in the area (Rambøll, 2001).

5.1.5 Archaeological interests

No signs of either Stone Age settlements or shipwrecks have been found in the wind farm area or along the cable trace to land, prior to construction of the wind farm.

One two occasions during construction remains of shipwrecks were found in the wind farm area, and one of the remains was identified as the anchor of the ship "Sct. George" which went down in the area in the year 1811. The other remains of a shipwreck have not yet been identified by the authorities.

5.2 Hydrography / geomorphology

The hydrographic conditions in the wind farm 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 6 m and 9.5 m. Due to the relatively 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. Stratification typically occurs in the Femer Belt.

Geologically, the wind farm 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.

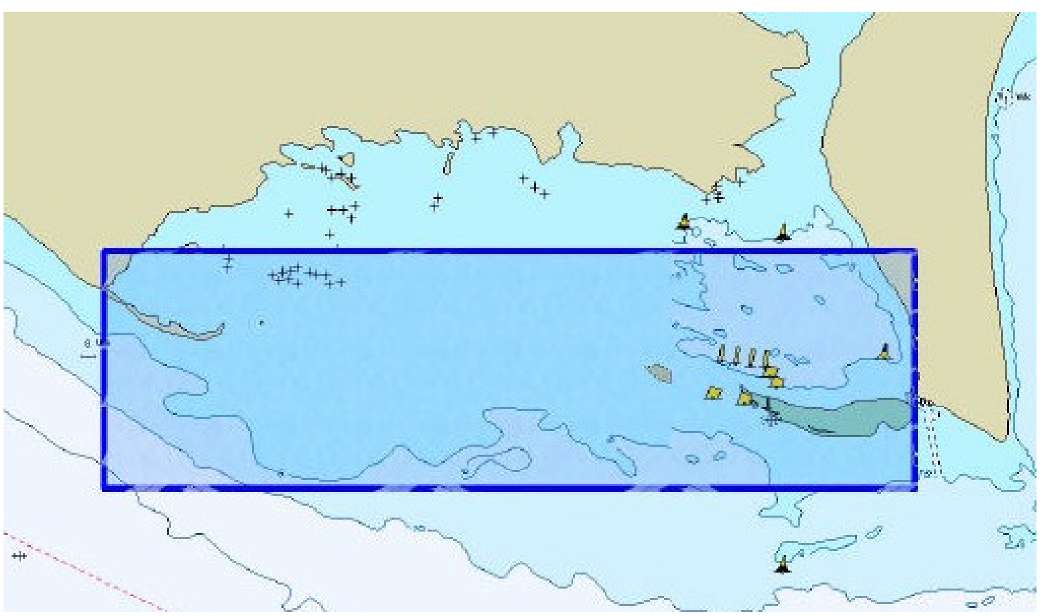

Figure 6.6. Area for the Morphological survey. The barrier islands are left and right in the blue square.

Figure 6.7. Aerial photo of the eastern part of the Rødsand formation. Gedser Harbour can be observed in the bottom to the right of the photo.

The Rødsand formation (figure 6.6 and 6.7) consists of a series of long barrier islands, stretching from Hyllekrog to Gedser, covering a distance of 25 km. The barrier islands mark the southern boundary of the shallow water area, towards the Femer Belt. Inside the Rødsand Lagune are islets and barrier islands, which are drained during low tide. Large areas of tidal meadow are found along the coast (Skov- og Naturstyrelsen, 1995).

The largest portion of the area consists of sandy bottom with larger and smaller ridges. In places there are pebbles, gravel or shells. 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 southeastern part of the park (Geoteknisk Institut, 1999a). Although there are outcrops of stones larger than 10 cm, no reef-like aggregations have been recorded.

In the measurement period between May 1999 and 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, will change by less than 1/1000 with the construction of the wind farm.

5.2.1 Environmental Impact Assessment

During the operational phase, changes in the current velocity and waves in the wind farm are expected to be small. There will, therefore, only be insignificant deposition/erosion (less than ± 2 cm) at distances greater than 10 m 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 expected to be limited. The changes to the flow rate will be less than 15% at a distance of 5 m 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. It was concluded that the barrier reefs will move approximately 15 m eastward each year before erection of the offshore wind turbines as opposed to approximately 12 m per year after the erection of the offshore 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 thereby also affect the transport of materials. Overall, it is expected that the movement of Østre Mærke will be reduced from about 750 m to about 500 m over a period of 30 years after the wind farm has been erected.

It is thus concluded that the wind farm at Nysted will have no significant impact on wind, waves, current, residence time and water exchange in the project area. The model calculations indicate that water exchange between Femer Belt and Rødsand Lagune will be a few percentage points greater over a 30-year period. The wind farm will not, however, affect water flow in the Femer Belt.

Model calculations on situations with and without the wind farm, have shown that there will be no impact (<< 1‰) on either the oxygen concentration, nutrients or chlorophyll, during a summer period which is considered to be "worst case", with high temperature, low current velocity and calm winds (DHI, 2000d).

5.2.2 Baseline 2002

In order to obtain an accurate and unambiguous baseline reference for subsequent morphological surveys in the Rødsand area, a morphological survey campaign was conducted during 2002 (DHI 2003a). The survey area comprised the area along the Rødsand barrier reefs and islands (figure 6.6).

The morphological survey was divided in to four different surveys:

- **The static GPS campaign**
  The purpose of this survey was to facilitate an accurate geographical reference for the bathymetric- and the photogrammetric surveys.

- **The bathymetric survey campaign**
  The bathymetric campaign was conducted to facilitate a geographic reference for the subsequent photogrammatic surveys.

- **The temperature and salinity measurement campaign**
  Temperature and salinity measurements were undertaken in order to determine the air to water refraction angle to be used in order to compensate for aerial photography.

- **The photogrammetric survey campaign**
  The purpose of the photogrammetric campaign was to establish a digital terrain model (DTM) for the area around Rødsand. The DTM was controlled against the bathymetric survey, resulting in an overall accuracy of the morphological campaign of 0,3 m, which is considered acceptable.

The morphological survey has resulted in photo prints, digital orthophoto, digital terrain models and contour curves. The survey will serve as a reference for the future coastal monitoring programme.

5.2.3 Monitoring 2003

The Coastal Morphology Program implemented during 2003 had the long-term aim of analyzing the development of the Rødsand barrier, and the short–term aim of analyzing the impact from single storm events, as well as impacts from Nysted Wind Farm. In 2003, aerial photo surveys were replaced by satellite photos.

A storm scenario from June 2003 was selected from the hydrographical and meteorological data collected at the offshore farm site during the construction period. Work on the project was temporarily discontinued in December 2003, by decision of the Danish Energy Authority. Until then, the following tasks had been completed:

- Satellite based evaluation of the long-term morphological development of the Rødsand barrier.
- Analysing of Guldborgsund for the current regime at the Rødsand barrier, through hydrographical modeling.
- Analysis of the development in the coastline of the Rødsand barrier before and after the June 2003 storm event (figure 6.8). This was utilized to set up a model for the natural development of the Rødsand barrier, thereby facilitating a long term prediction of the barrier development.

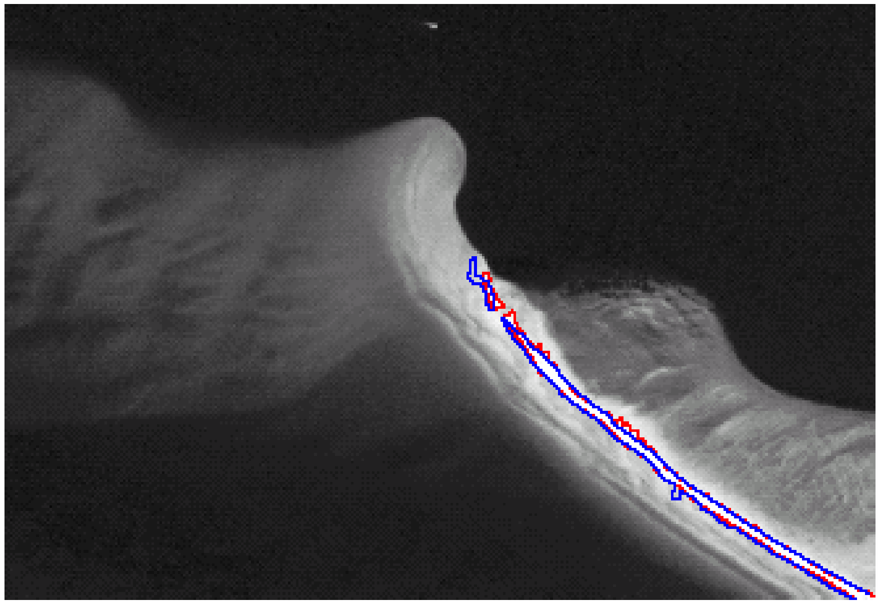

Figure 6.8. Satellite based evaluation of the east Rødsand barriers before and after the June 2003 storm event. Blue line indicates the waterline before the storm and the red indicates the waterline after the storm.

5.2.4 Monitoring 2004

The work continued in 2004 (DHI 2004a), and a numerical model study of short-term nearshore morphology of the barrier island system close to Nysted Offshore Wind Farm was conducted. The study was based on two significant storm events in June 2003, two different model approaches were used; one providing transport patterns and one providing morphological evolution. In the first case, a study of the effect of the offshore wind farm on the wave, current and sediment transport was performed. In the second case, a morphological model was run for the a-priori most exposed areas (with respect to offshore wind farm disturbances).

The model study has been based on a unique set-up of nested model areas: a large scale nested model set-up (900 m – 300 m – 100 m grid) from where boundary conditions to a local nested model (100 m – 33 m – 11 m grid) were transferred. Only the innermost (finest resolved) model areas were considered for the sediment transport calculations and for the morphological runs.

It was found that the applied numerical models for waves, hydrodynamics and sediment transport are capable of simulating the impact of an offshore wind farm on the nearshore conditions.

Furthermore the applied numerical model for morphological nearshore evaluation is capable of reproducing the morphological development in the nearshore area. The morphological modelling complex can therefore be used to model the morphological impact of offshore wind farms on the nearshore morphology.

Satellite images are sufficiently accurate to be used for analysis of nearshore morphological changes following significant morphological events.

5.3 Benthic vegetation and fauna

5.3.1 Benthic vegetation

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

In 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 (substrate for the algae) are observed (DHI, 2000). The algae community in the wind farm area is only present for a short period in the year as the filamentous algae typically flower during May, culminate in June and decay in July/August (DHI, 2000).

Eelgrass (*Zostera marina*) has been registered inside the wind farm area. Eelgrass is, however, found in Rødsand Lagoon where the 132 kV cable trace pass through (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 therefore not favourable (DHI, 2000 a, b).

5.3.2 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 population dominating the remaining third of the seabed (Figure 6.9) (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 northwestern 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 population of Common Mussels is 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).

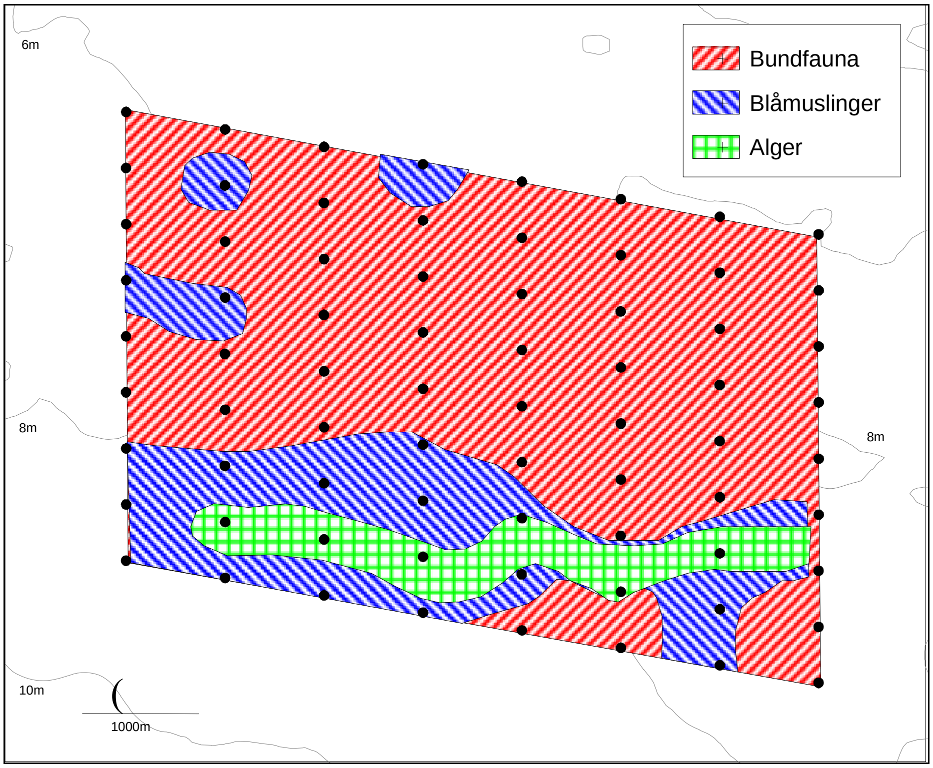

Figure 6.9. Distribution of benthic communities in the wind farm area. Based on photo sampling in May 1999 Red areas are dominated by benthic Macona community. Blue area dominated by Common Mussels. Green area is dominated by algae.

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 (figure 6.9). 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^2 (DHI, 2000b). The bottom fauna richest in individuals with an abundance > 5000/m^2 is found primarily in the central and western parts of the wind farm area (DHI, 2000b). Figure 6.10 shows the abundance of the benthic fauna in the wind farm area.

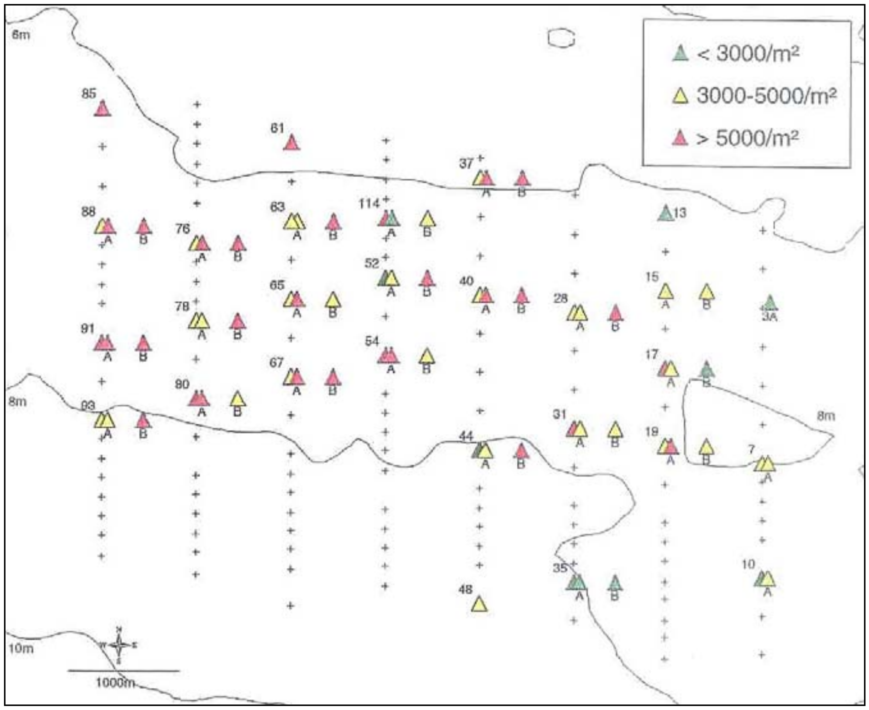

Figure 6.10. Map showing the abundance of the benthic fauna in the wind farm area (DHI, 2000b)

At most of the stations in the wind farm area the biomass is between 10 gDW/m^2 and 25 gDW/m^2. 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 gDW/m^2) in the western part of the wind farm area (DHI, 2000).

5.3.3 Environmental Impact Assessment

Increased turbidity caused by sedimentation from the construction work may have a negative impact on vegetation. Sediment settling on vegetation can block its exposure to sunlight. 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).

Sediment spill only in the immediate vicinity of the construction work is 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 lasting 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 5-10 m 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 5-10 m from the single foundations.

At a conservative estimate, the construction work in the wind farm is expected to give rise to the destruction of approximately 250 tonnes (t) Common Mussels and approximately 4 t 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. It may therefore 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 benthic fauna and vegetation in the order of 0.9 t dry weight and 0.25 t dry weight, respectively (DHI, 2000).

The resistance from the foundations will influence the current and wave conditions in the wind farm, but the impact on erosion/deposition of the sediment is expected to be very small. 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).

5.3.4 Baseline 2001

The surveys in the wind farm area and along the cable connection (figure 6.11) between the wind farm and Lolland, included photo sampling carried out in May 2001 and collection of quantitative samples of benthic flora and fauna in August 2001. In addition to these surveys, the benthic communities were mapped at four sites in August 2001, where pound nets were established.

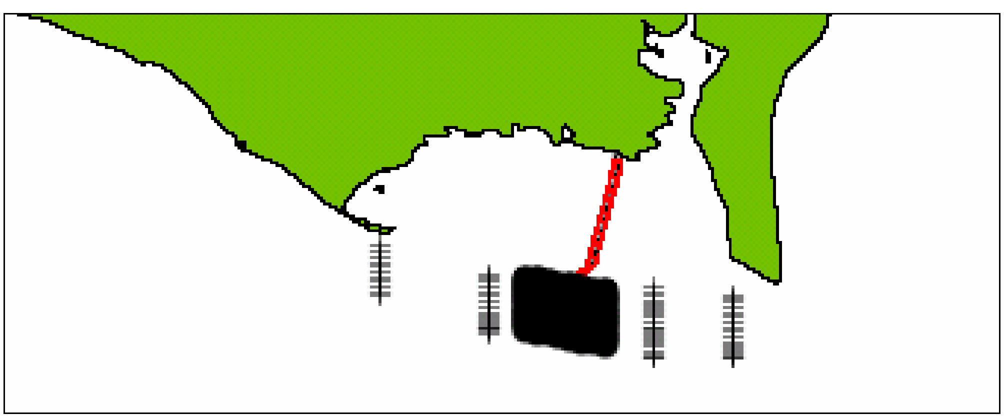

Figure 6.11. Study area showing the location of the planned wind farm, the reference transects and the cable connection between the wind farm and Lolland surveyed in May 2001.

There have been no surveys on the benthic vegetation and fauna in the wind farm area in 2002 and 2003. It is planned to follow up on the baseline survey carried out in 1999 and 2001, by conducting a similar survey after the construction has been completed.

Survey in the wind farm area

The photo sampling in May 2001 provided data on the distribution and abundance of vegetation and fauna in the wind farm area (DHI 2001a). In addition, samples of the bottom fauna, vegetation and surface sediment were collected in the wind farm and along the reference transect in August 2001 (DHI 2002b). Quantitative samples of Common Mussels were collected on the seabed and on the foundation of the monitoring mast at the wind farm (DHI 2002b).

The surface sediment consists mostly of pure sand with scattered stones. The median grain size of the sediment has remained unaltered since 1999 but the frequency of stations with a higher content of silt/clay has increased in the wind farm. Regarding the bottom fauna, the number of species and the species composition has changed little between 1999 and 2001, but the average abundance and biomass of the bottom fauna has declined both in the wind farm and along reference transects. This decline is regarded as due to natural fluctuations.

Epibenthic communities of Common Mussels and brown filamentous algae attached to the mussels developed in the southern part of the wind farm. The overall spatial distribution of Common Mussels and attached blown algae in the wind farm area was similar in 1999 and 2001 (figure 6.12). Changes in coverage of mussels at individual stations from 1999 to 2001 are due to a patchy distribution of the mussels. The occurrence of detached algae and attached red algae appears to be very scarce in the wind farm area both in 1999 and in 2001. In contrast to 1999, Eelgrass was recorded at one station in 2001.

The average biomass of mussels has declined about 30% since 1999, as a result of a lower density in 2001. Though, the size of the mussels was bigger in 2001 than in 1999.

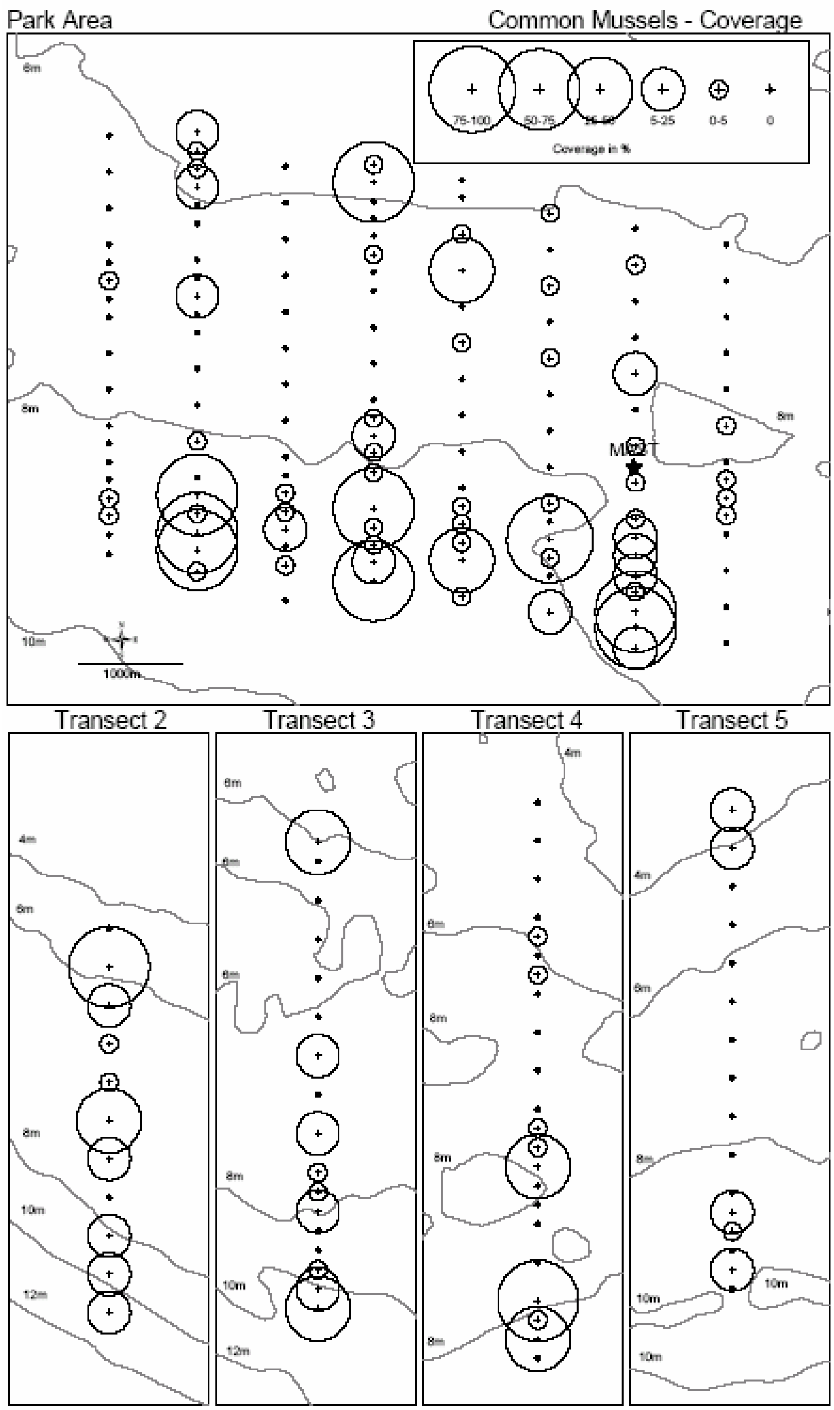

Figure 6.12. Coverage of Common Mussels estimated on the basis of photosampling in May 2001.

Survey along the cable connection

Photo sampling conducted in May 2001 provided data on the distribution and abundance of vegetation and fauna along the cable connection (DHI 2001a). The surveys along the cable connection also included collection of quantitative samples of bottom vegetation and fauna in August 2001 (DHI 2002a).

The composition of the sediment along the cable connection is highly variable and ranges from silty clay to coarse sand. The sediment consists of mud and muddy sand in deeper water in the interior and middle section of the alignment. The lagoon of Rødsand is separated from Femer Belt by shallow sand barriers. The sediment on the barriers and south of the barriers consists of sand with a low content of organic matter.

Eelgrass is mainly distributed in shallow water in the innermost section of the cable alignment (figure 6.13). The shoot density and biomass of rhizomes show a linear decline with increasing water depth. Low transparency of the water due to re-suspension of fine sediment and accumulation of detached macro algae on the seabed are limiting factors for development of Eelgrass in the area.

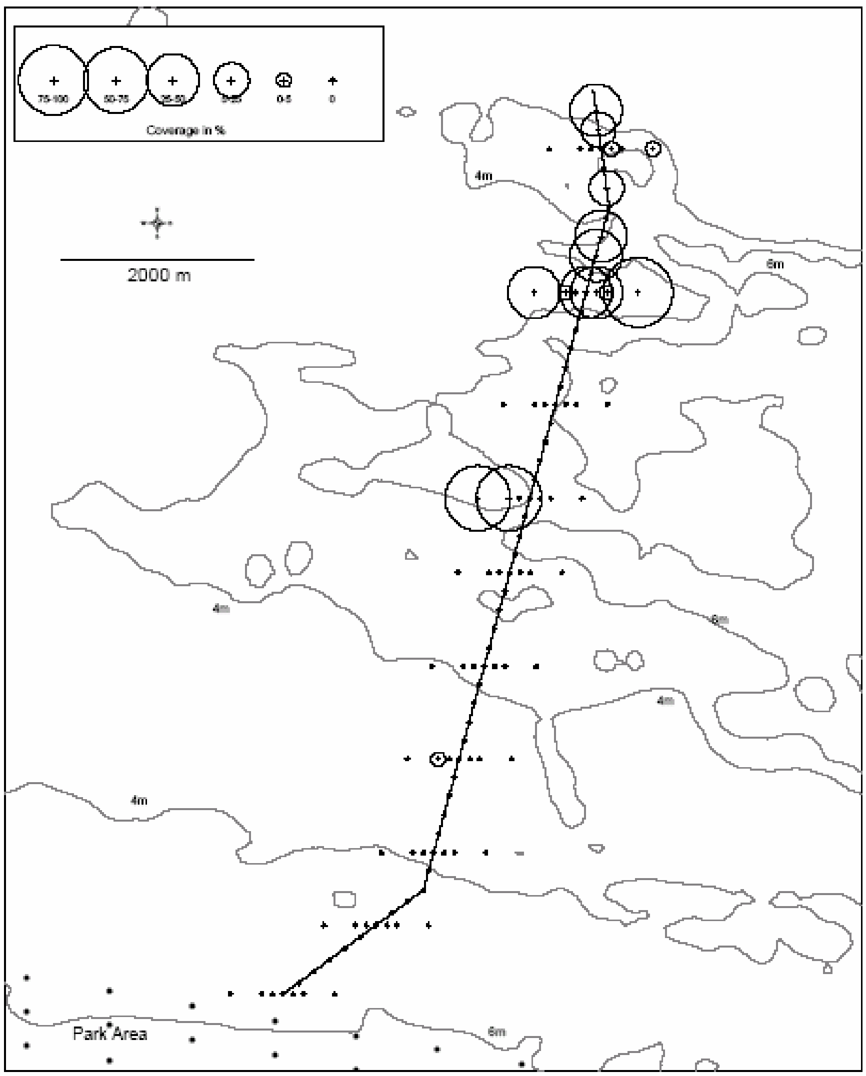

Figure 6.13. Coverage of eelgrass (Zostera marina) in the lagoon of Rødsand estimated on the basis of photo sampling in May 2001.

Attached macroalgae are mainly confined to the stony bottom in the middle section of the alignment. Red algae are abundant and *Furcellaria lumbricalis* is a dominant species. Brown and green algae are of lesser importance at the time of sampling, but annual filamentous brown algae may be more numerous during spring and early summer. Detached algae are most abundant in the innermost section of the alignment (DHI 2001a).

The bottom fauna in the lagoon of Rødsand is a *Macoma*-community characterised by low diversity and high abundance. The fauna is dominated by a few species of gastropods, polychaetes and bivalves. The Mud Snail *Hydrobia sp*. and the tube building polychaete *Pygospio elegans* account for almost 75% of the total abundance of the bottom fauna. The Common Mussel is scarce in the lagoon.

The bottom fauna is most diverse and abundant in the inner and middle section of the alignment and less diverse and abundant in the outermost section. Exposure and a low content of organic matter in the sediment are limiting factors for the bottom fauna in the outermost section of the alignment.

To provide baseline data on fish migration, four-pound nets were established around the cable connection. The composition of the seabed and coverage of benthic communities of Common Mussel, algae and Eelgrass at selected sites were also mapped in August 2001 using photo sampling. A homogenous sandy bottom with sand ripples dominated the seabed along the four-pound net sites. At most stations, detached filamentous algae were found. In general, only insignificant and scattered occurrences of attached living macroalga and Common Mussels were present.

5.3.5 Monitoring 2002 and 2003

Survey along the cable connection
Earthwork in connection with deployment of a power cable between Nysted offshore wind farm and Lolland via the Lagoon of Rødsand was conducted from September 2002 to February 2003. A backhoe was used to excavate a 1.3m wide, 1.3m deep and 10300m long cable trench during one month. The excavated sediment was placed alongside the trench and later used for the backfilling which took place from early 2003 to February 2003.

After the present surveys were completed in March 2003, it turned out that the optical cable inside the 132 kV cable was not functional and it was decided that a new optical cable should be placed above the 132 kV cable in the cable trench. Thus the sampling in March 2003 does not represent the final conditions after completion of the seabed works.

The total volume of seabed material excavated was approximately 17,000 m^3. The sediment spill was estimated to be 0.5-1 % of the amount excavated. Daily measurements of turbidity during dredging showed that the values were below 15 mg/l, which was the limit value stipulated by the environmental authorities.

Inspection of the trench after backfilling showed that the surface of the trench was below the surrounding seabed due to an inadequate filling of the trench. The lowered seabed level acted as a trap and the trench was filled with detached macrophytes (figure 6.14).

Figure 6.14. Photo showing the edge of the cable trench filled with detached macroalgae and the disturbed seabed adjacent to the trench. Station T2 in March 2003.

Studies of the benthic communities were carried out in September 2002, immediately before earthwork started and in March 2003, after the backfilling was completed. The objectives of the surveys were to examine the immediate impact of the excavation work (sediment spill and burial) on Eelgrass, macroalgae and benthic infauna as well as the basis of a BACI-design (DHI 2003b).

In March 2003 it was not possible to take samples in the trench because it was filled with detached macrophytes. It was therefore necessary to move stations located **in the trench** a few meters and take the samples **close to the trench**. However, a minor change in the positions of the sampling stations has only slight implications for the objective of the study because the changes in positions are mostly of the same magnitude as the accuracy of the positioning system. In addition, dredging has removed the benthic vegetation in the trench and it must be assumed that very few animals were present in the trench immediately after the backfilling.

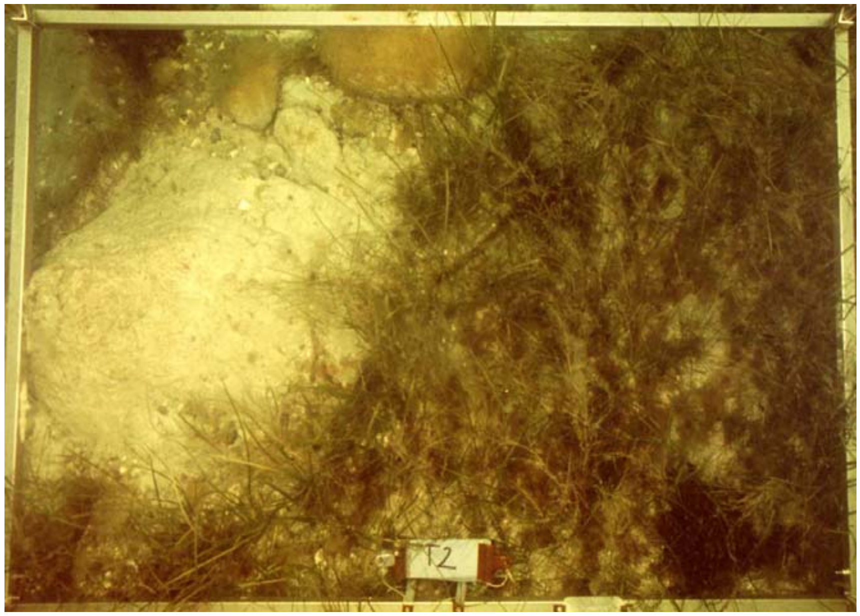

Figure 6.15. Eelgrass growing close to the edge of the trench. Station T2 in March 2003.

The impacts of the earthwork were as follows:

- The shoot density of Eelgrass and the biomass of rhizomes were reduced close to the trench as a combined effect of sediment spill during excavation and backfilling and temporary burial below sediment deposited alongside the cable trench (figure 6.15).

- The overall composition of the surface sediment was not effected. However, the silt/clay content of the sediment was higher at a few stations close to the trench, at the innermost section, after the earthwork. This increase was probably caused by local sedimentation of fine sediment spilled during dredging and backfilling.

- The structure of the benthic fauna changed significantly at the impact stations close to the trench but not at the control stations. The abundance of the benthic fauna was reduced 10% at the control stations and this change must be regarded as a natural seasonal variation. In contrast, the abundance was reduced 50% at the impact stations close to the trench. The further decline in benthic abundance compared to the expected seasonal change must be regarded as impacts of sediment disturbance caused by the earthwork close to the trench (table 6.2). The maximum size of the area with a disturbance of the seabed and a decline of benthic abundance was estimated to be 0.1 km^2. In addition, the immediate destruction of most of the benthic fauna due to dredging is assumed to have affected an area of 0.013 km^2.

Month and Year	Number of species (0.1m^{-2})	Abundance (m^{-2})	Biomass (gDW/m^2)
2001, August	14	6000	50
2002, September	11	5000	32
2003, March	9	2600	18

Table 6.2. Comparison of number of species, abundance and biomass of the benthic fauna at similar stations along the cable trench in 2001-2003. Rounded average values.

- The decline in shoot density and rhizome biomass of Eelgrass and abundance of benthic infauna appear to be confined to a narrow zone close to the cable trench. The recovery of the affected populations and communities depends on the renewed earthwork in 2003 and the consolidation of the sediment. However, a fast recovery is expected in the affected areas close to the trench. The recovery in the trench depends on accumulation of detached macroalgae in the future. A carpet of macroalgae is assumed to delay or prevent a colonisation of the sediment under the macroalgae, but crustaceans and mud snails may recolonise the surface of the macroalgae.

5.3.6 Monitoring 2004

Survey along the cable connection
The surveys in 2002-2004 (DHI 2004b) included potential impact stations close to the trench and control stations located 100-500m perpendicularly to the trench. Due to the unexpected accumulation of macroalgae it was not possible to take samples in the trench but only close to the trench.

The dredging destroyed the benthic communities in the trench, and the total area of the seabed affected was 0.013 km2. The visibly disturbed seabed along the cable trench was estimated to be up to 10m wide and the disturbed area of the seabed was probably about 0.1 km^2.

In addition to the direct destruction the earthwork may affect the benthic communities close to the trench due to sediment spill, burial, stirring and settling of fine sediment.

Eelgrass
The shoot density and the biomass of rhizomes of eelgrass were reduced more at the impact stations close the trench than at the control stations in March 2003 immediately after completion of the earthwork in 2002-2003. The changes were attributed to a combined effect of shading and burial on eelgrass populations close to the trench due to the sediment spill, deposition and prolonged stirring and spreading of sediment. Since March 2003 the shoot density and the biomass of shoots and rhizomes have increased more at the trench (impact) stations than at the control stations. This development is explained as a recovery of the eelgrass populations close to the trench.

Macroalgae
Dredging and back-filling in 2002-2003 did not affect the total biomass of macroalgae. The biomass of algae has decreased at trench (impact) stations and remained unchanged at control stations since March 2003. This could be an adverse effect of the renewed earthwork in 2003. However, the opposite responses of eelgrass and macroalgae to the earthwork were

unexpected and difficult to explain. The decline in biomass of macroalgae at the trench but not at control stations in 2003 and 2004 may be a prolonged response of previous and renewed sediment spill, which could smother the stony substrate, hamper the recruitment and eventually reduce the biomass of algae. However, the interpretation of the spatial and temporal changes in the biomass of macroalgae is speculative and no firm conclusion regarding the impact on macroalgae of the earthwork is possible.

Sediment

The seabed was visibly disturbed close to the trench but the earthwork in 2002-2004 did not affect the structure of the sediment. A local increase in the silt/clay content of the sediment at a few trench stations was attributed to the sediment spill.

Benthic fauna

The overall similarity of the shallow water (*Macoma*)-community in the Lagoon of Rødsand was high and significant differences in the structure of the benthic community were confined to the trench stations in 2002-2004. The abundance of the mudsnail *Hydrobia sp*. and a few other common species of polychaetes and bivalves characteristic of the Macoma-community mainly determined the spatial and temporal changes in similarity of the benthic fauna.
The abundance of *Hydrobia* declined more at the trench than at the control stations after the earthwork in 2002-2003. Since March 2003 the abundance of *Hydrobia* has increased but at a lower rate at the trench than at the control stations. The lower rate of increase of the abundance of mudsnails could be a subtle effect of the renewed earthwork and/or a prolonged impact of the disturbance of the seabed habitat, which delays recovery close to trench.

Recovery in the trench

Accumulation of detached algae in the trench prevents recovery of eelgrass and benthic in-fauna but mobile species of gastropods and crustaceans may live on the surface of the blanket of algae if oxygen deficiency is not developed.

Conclusions

- The negative impacts on eelgrass of dredging and back-filling in 2002-2003 were short term and the renewed earthwork did not hamper the recovery of eelgrass close to the trench in 2003 and 2004.

- The decline in biomass of macroalgae at the trench but not at the control stations in 2003 and 2004 may be a prolonged response of previous and renewed sediment spill, which could smother the stony substrate, hamper recruitment and reduce the biomass of algae. However, the interpretation of the spatial and temporal changes in the biomass of macroalgae is speculative and a no firm conclusion regarding the impact on macroalgae of the earthwork is possible.

- The abundance of the mudsnail *Hydrobia* was reduced at the trench stations after the earthwork in 2003-2003 but recovery was in progress in 2003. However, the lower rate of increase in abundance of *Hydrobia* at the trench stations compared to control stations may be a subtle effect of the renewed earthwork and/or a prolonged impact of the disturbance of the seabed habitat, which delays recovery close to the trench.

- Accumulation of detached algae in the trench prevents recovery of eelgrass and benthic in-fauna but mobile species of gastropods and crustaceans may live on the surface of the blanket of algae if oxygen deficiency is not developed.

- In summary: the direct and indirect impacts of the earthwork in the Lagoon of Rødsand on eelgrass, macroalgae and invertebrates were limited in space and time and a full recovery of the populations close to the cable trench is expected in the near future.

5.3.7 Monitoring 2005

Survey in the wind farm area

The baseline surveys carried out in 1999 and 2001 were followed by similar surveys in 2005 (DHI 2006). In spite of the limited disturbance of the seabed and the expected minor impacts on benthic communities the surveys in the operation phase of the wind farm were conducted with the following overall objectives:

- To examine the post-construction state in sediment composition and benthic communities and to assess changes in the benthic environment in between 1999, 2001 and 2005 in relation to disturbance during the construction phase and/or possible interactions between the fouling communities developed on turbine foundations and the seabed communities
- To document changes in the benthic communities which may be of importance for the forage opportunities of birds and demersal fish species feeding on benthic invertebrates

The surveys in May and August 2005 were conducted more than 2 years after the seabed work was completed.

The results of the surveys in 1999, 2001 and 2005 support the overall conclusion that spatial variation and temporal changes observed in the benthic fauna, common mussels (*Mytilus edulis*) and macroalgae have not been caused by the construction of the wind farm or the presence of the turbine foundations. This conclusion, however, is based on the spatial scale used in the surveys and does not exclude local impacts on the benthic fauna closer than 25 m from the cables between the turbines or in the vicinity of the foundations.

The abundance and biomass of the benthic fauna has declined steadily since 1999 both in the wind farm and at the reference transects east and west of the wind farm. The abundance of most of the characteristic species of the shallow water community off Rødsand was reduced. A polychaete (*Marenzelleria viridis*), which has colonized brackish estuaries in the North Sea and the Baltic Sea in the last 25 years, has colonized the survey area since 2001. A similar decline in abundance and biomass of the same characteristic shallow water species (and colonization of *Marenzelleria viridis*) was recorded at Kriegers Flak off Møn in the Baltic Sea between 2003 and 2005. However, no changes in the shallow water benthic community were observed in the enclosed Lagoon of Rødsand close to the wind farm in the period from 2001 to 2004.

The overall spatial distribution of common mussels was similar in the survey area in 1999, 2001 and 2005. However, the coverage and the average biomass of mussels around the sampling stations have declined in the wind farm since 1999 and at the reference transects since 2001. The condition and the meat weight of the mussels have increased in the same period. The improved growth is probably due to the decline in coverage of common mussels on the seabed and a reduced food competition.
The distribution and coverage of attached and detached macroalgae on the seabed is modest. The observed changes in coverage and distribution of macroalgae on the seabed between 1999, 2001 and 2005 are attributed to natural variations in the amounts of macroalgae and weather induced changes in the transport and accumulation of macroalgae on the seabed. The amounts of macroalgae are too limited to have contributed to the declining coverage of common mussels and the reduced abundance and biomass of the benthic in-fauna in the wind farm.

The causes to the decline in abundance and biomass of benthic fauna and the reduced coverage and biomass of common mussels in the survey area off Rødsand are not obvious. It is unlikely that the shallow water community in the survey area is affected by oxygen deficiency "imported" from the adjacent deeper waters or decaying macroalgae on the seabed. Nor is it likely that the decline of the benthic fauna is due to starvation caused by a reduction of the organic input to the seabed. The concentrations of chlorophyll-a (estimate of phytoplankton biomass), measured since 1989/1990 in Hjelm Bugt south of Møn in the Baltic Sea show no declining trend. This result is assumed to be representative for the development of the biomass of phytoplankton in the water column off Rødsand and the potential input of food to the benthic fauna.

5.4 Introduction of hard substrates

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

After three years the fouling community on the foundation of the monitoring mast was dominated by Common Mussels. Mussels formed an approximately 5 cm 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 macroalgae was insignificant, but many crustaceans, especially typical accompanying fauna such as Sand Hoppers (*Gammarus sp*.), are found with the mussels (DHI, 2000).

The concrete foundations and the scour protection of stones around the foundations of the 72 turbines in the Nysted Offshore Wind Farm have a total surface area of about four hectares. These new, hard physical structures have been introduced into the Rødsand area, in which the natural seabed consists mainly of sand, as mentioned in chapter 6.6.

When new hard structures are introduced into a marine environment, they act as a substrate for sessile organisms that will colonize it and develop a fouling community. This community may be more or less diverse, depending on the characteristics of the substrate and a number of environmental factors including salinity and exposure to waves. The community will include sessile animal and plant species as well as small mobile invertebrates. Small fish species are likely to be associated with the community too. Furthermore, larger benthic or pelagic fish as well as sea birds may be attracted from the surrounding areas. Because of this so-called reef effect, the construction of Nysted Offshore Wind Farm will cause changes in the biological diversity and production of the local ecosystem.

5.4.1 Monitoring 2003

An investigation of the fouling community in the Nysted Offshore Wind Farm was initiated in September 2003. The investigation will provide information about the importance of the introduction of hard substrate in the local ecosystem (DHI 2004).

Surveys of the fouling community of sessile and mobile invertebrates and attached macroalgae were conducted in October 2003, 19-49 weeks after deployment of the foundations and 16-28 weeks after the stones were placed in the chambers of the foundations and around the foundations, as scour protection.

The fouling community was investigated on:

- The vertical concrete foundations (also referred to as shafts)
- The stone filling inside the cells of the hexagonal foundations
- The scour protection areas of stones outside the foundations

Three different recording techniques were applied: Underwater video recording, photography and quantitative sampling. The investigation included the foundations of seven turbines and the transformer platform (figure 6.16 and figure 6.17).

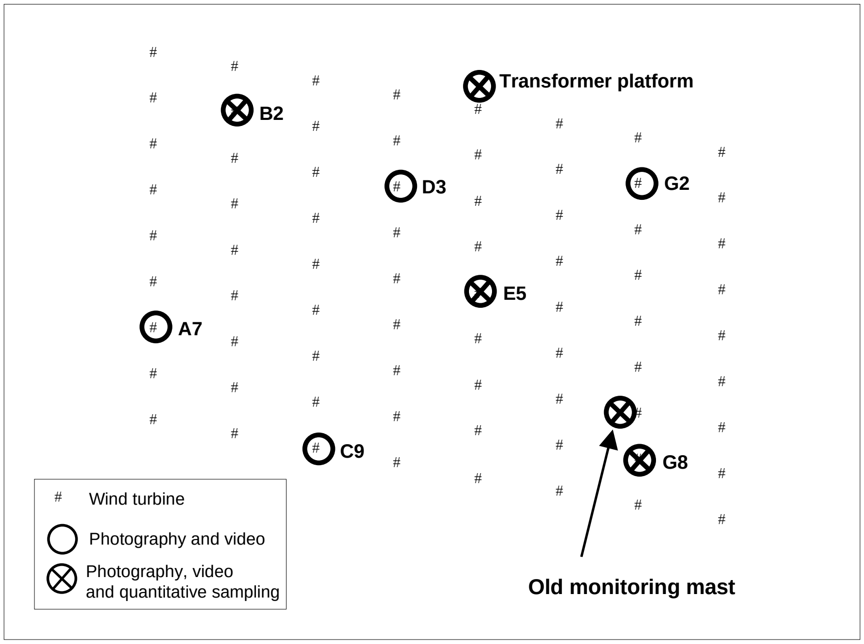

Figure 6.16. Locations used for the investigation of the fouling community at turbine foundations and scour protection areas in the Nysted Offshore Wind Farm in September-October 2003.

In addition to the ordinary foundations, the vertical steel foundation of the older meteorological monitoring mast located in the wind farm was investigated using all three techniques. The monitoring mast was already in place in 1997, and the fouling community on the mast was investigated previously, in 1999 and 2001. The mast was included in order to evaluate how the community on the vertical part of the concrete foundation (the shaft) may develop over a longer period of time.

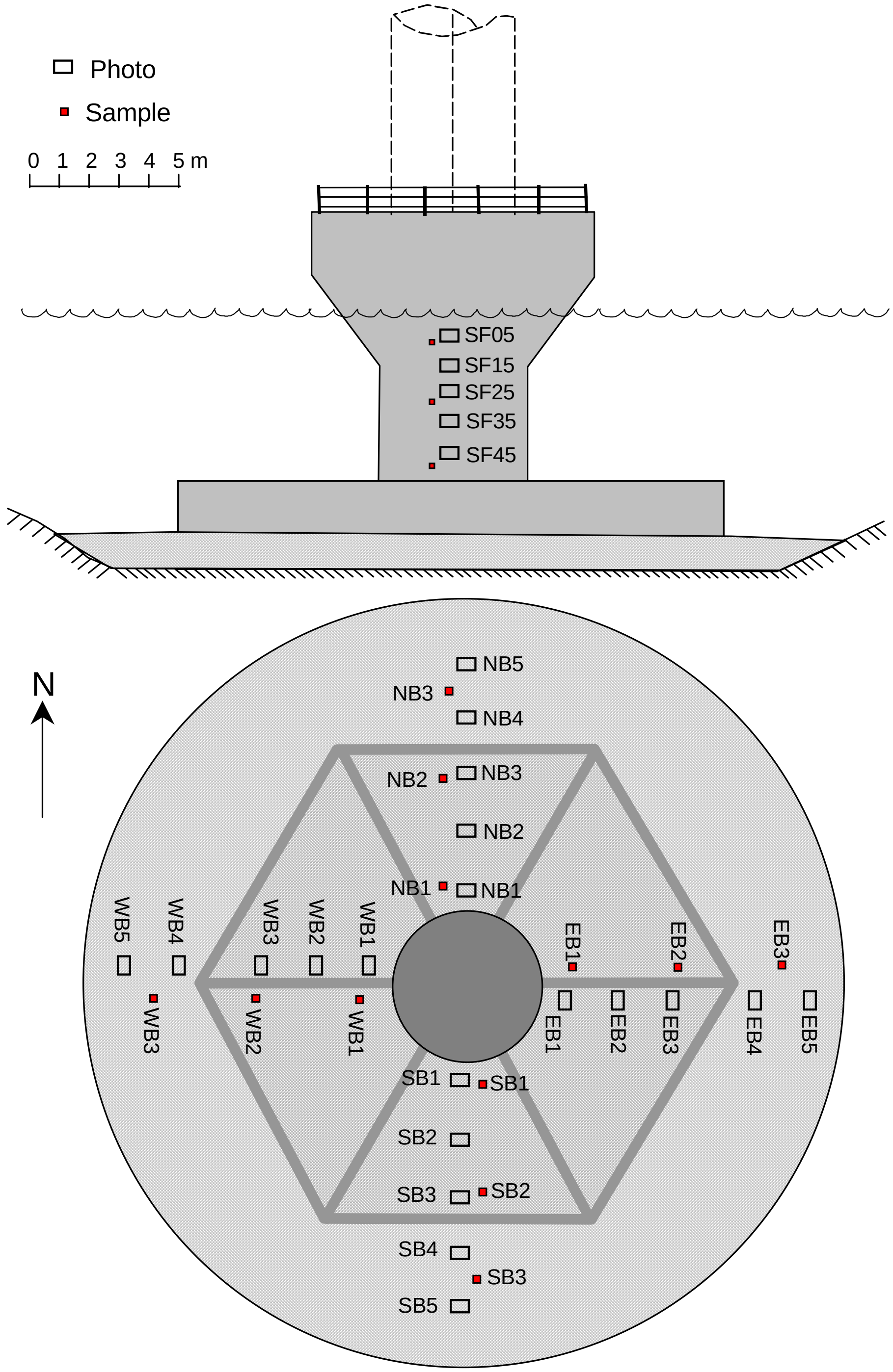

Figure 6.17. Investigation of the fouling community on turbine foundations and scour protection areas in the Nysted Offshore Wind Farm. Top: Side view. Bottom: Top view. Sample and image codes are indicated.

A dense layer of small Common Mussels covered the shafts (the vertical cylindrical and smooth concrete surfaces of the foundations). The shell length of the mussels was mostly below 10 mm, and the mussels covered a layer of barnacles (*Balanus improvisus*) except for a narrow barnacle zone close to the water surface.

The biomass of mussels and barnacles on the shafts was about ten times higher than on the stones. A few species of amphipods were also abundant on shafts and stones but the density and biomass of mobile species were far below the density and biomass of the sessile species. The biomass on the shafts and stones was not affected by the age of the substrates because the settling has been limited on foundations deployed late in 2002, after the end of the reproductive season.

A thick and dense layer of mussels covered the monitoring mast deployed in 1997. The biomass of Common Mussels on the mast was about four times higher than the maximum biomass of mussels developed on shafts of the turbines in 2003. The maximum shell length of mussels on the mast was similar in 1999-2003, but the biomass of mussels in 2003 was lower than in 2001. The biomass in 2001 was probably close to the maximum attainable in the area and it is believed that erosion of the old fouling layer has provided space for a renewed settling of mussels.

Macroalgae were scarce on the uppermost part of the shafts of foundations, and the coverage and biomass increased with depth. The biomass of macroalgae on stones (figure 6.18) was about twice the biomass on the shafts. A few species of red algae dominated the community, but the diversity and biomass were far below that measured on natural stones in the Lagoon of Rødsand in 2001.

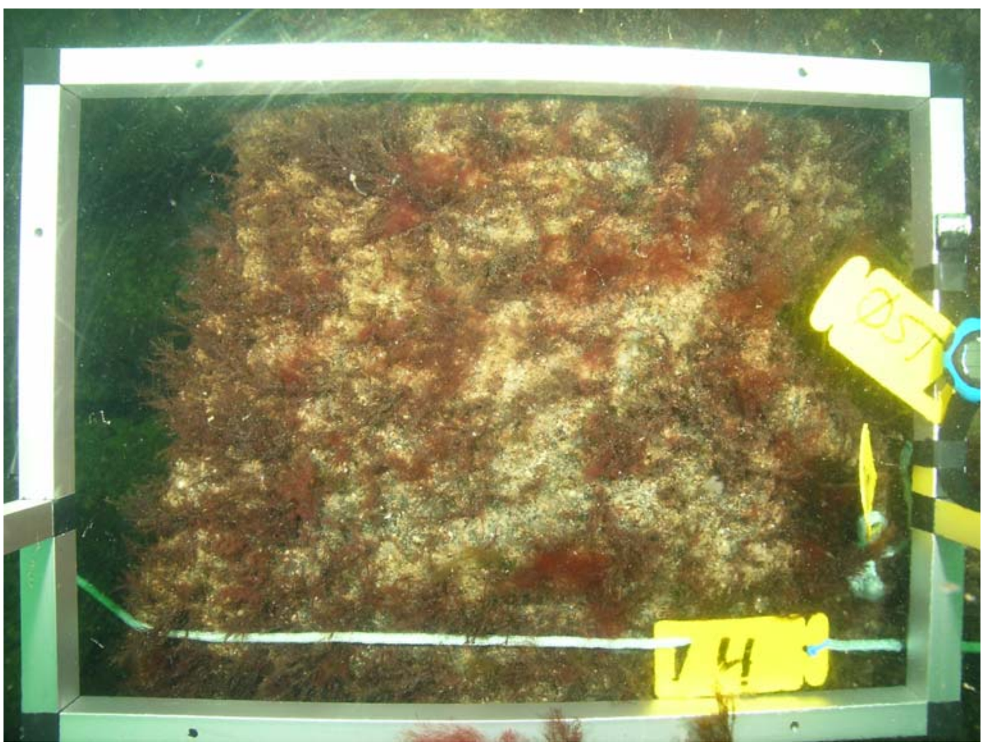

Figure 6.18. Stones with a dense coverage of macroalgae.

In conclusion, a fouling community of Common Mussels, barnacles and macroalgae has developed on concrete foundations and stones of the turbines and transformer station introduced in the wind farm in late 2002 and early 2003. The fouling community was not affected by the age of the substrates during the first reproductive season, in 2003.

A further growth, development and succession of sessile communities of invertebrates and macroalgae as well as mobile invertebrate species and fish are envisioned in the next years. The expectation is based on measurements of the fouling community on the monitoring mast in the wind farm deployed in 1997, and surveys of the natural community of macroalgae on stones in the Lagoon of Rødsand close to the wind farm.

The biomass and abundance of invertebrates and the biomass of macroalgae on the shaft and stones were reduced at the transformer station compared to the turbines. The seabed work and the traffic have been more intense around the transformer due to additional deployment of connecting cables on the seabed. The associated sediment spill of the extra earthwork and re-suspension of sediment caused by the propellers of the ships may have hampered the settling and growth of organisms and reduced the biomass and abundance of the fouling community in the first reproductive season.

5.4.2 Monitoring 2004

An almost similar investigation was carried out in October 2004 (DHI 2005) and supplemented with surveys at the stone reef Schönheiders Pulle with the aim of providing data on a natural hard bottom community on a stone reef close to the wind farm.

Common mussels (*Mytilus edulis*) and barnacles (*Balanus improvisus*) dominated the fouling community in the wind farm in 2004. The biomass of the community has increased significantly since 2003 due to a rapid growth of the mussels. However, the biomass on shafts and stones was still below the biomass at the monitoring mast deployed in 1997 and at the stone reef Schönheiders Pulle. It is expected that the biomass on the shafts will approach the maximum level for mussel populations in the area during 2005, see chapter 6.8.3.

The structure of the fouling community was uniform around the foundations but changed with depth on both shafts and stones. The number and biomass of the dominant species of mussels, barnacles and the amphipod *Gammarus sp*. was lower in deeper water and other species of crustaceans increased with depth. These changes in community structure were attributed to depth-related hydrographic changes, affecting the flux and settling of larvae, availability of food and growth and stirring of sediment form the seabed.

The community of macroalgae was dominated by redalgae but the number of species was low. Macroalgae has disappeared from the shafts since 2003 and excluded by the rapid growth of the mussels with the exception of the transformer station, where algae were attached to patches with no or few mussels on the shafts. The community of macroalgae at Schönheiders Pulle was similar, irrespective of the depth and similar to the community on stones in the wind farm when assessment was based on biomass. The dominant species of redalgae were the same but the species composition was different in the two areas because the distribution of the less common species varied. Two less common species of redalgae recorded at Schönheiders Pulle were not found in the wind farm. The future development of the community of macroalgae in the wind farm is expected to depend on the growth of the mussel population and the space competition between algae and invertebrates.

5.4.3 Monitoring 2005

The final investigation was carried out in autumn 2006 (DHI 2006a), thus this chapter summarise the findings from the investigations carried out 2003-2005.

Common mussels (*Mytilus edulis*), barnacles (*Balanus improvisus*) and a few associated species of crustaceans (*Gammarus sp., Corophium insidiosum* and *Microdeutopus gryllotalpa*) have dominated the fouling community at the turbines in the wind farm in 2003-2005.

The rapid growth of mussels since 2003 and the resulting competition for space, has almost led to an exclusion of other sedentary species of invertebrates and macro algae. A monoculture of mussels has developed on shafts and stones in the foundation chambers in 2005. The biomass of mussels on the vertical shafts of concrete was comparable to the climax community on the monitoring mast deployed in 1996 and to the amount of biomass of mussels on bridge piers in Øresund.

The biomass of mussels in the foundation chambers and at Schönheiders Pulle was comparable. However, the biomass of mussels on the scour protection stones around the foundations was only one third of the biomass of mussels at Schönheiders Pulle, probably because recruitment success and growth of the mussels has been hampered and delayed by smothering due to sediment-spill and re-suspension of sediment due to heavy ship traffic in the construction phase and natural re-suspension of sediment.

The development of the fouling community has been similar on all sides of the foundations (west, east, north and south) since 2003. However, the structure of the fouling community changes with depth on both shafts and stones.

The vertical zonation of the dominant species of mussels, barnacles and associated species of crustaceans is related to changes of physical and biological factors, which affect input of larvae and food, the growth rate of mussels and space competition.

The community on scour protection stones was in 2005 different from the community on the stones in the foundation chambers, mainly due to an extremely high density of common mussels and low numbers of the amphipod *Gammarus* sp. on the scour protection stones.

The diversity of macro algae at the turbines and Schönheiders Pulle is low and dominated by red algae. This is due to the low salinity in the area.

The species richness and biomass of macro algae culminated on shafts and stones in the foundation chamber in 2003 and 2004, respectively. Due to the growth and progressive expansion of mussels, macro algae have disappeared from the shafts since 2003 and were mostly confined to the scour protection stones in 2005. The biomass of macro algae on the scour protection stones and at Schönheiders Pulle was comparable in 2005.

The species richness was lowest on the shafts and highest on the scour protection stones. The species richness and the biomass of macro algae were highest on scour protection stones at

turbine G8 and the transformer, where the biomass in 2005 was similar to the biomass at Schönheiders Pulle.
However, the species composition is different. Some of the common species are more frequent at Schönheiders Pulle and perennial species of red algae found at the deepest station at Schönheiders Pulle are absent at the turbines.

During the next few years the biomass of common mussels on scour protection stones will probably approach the biomass of common mussels at Schönheiders Pulle and the biomass of natural populations of mussels on the seabed.

The space competition between mussels and macroalgae on scour protection stones will increase but macroalgae and mussels are expected to coexist on the scour protection stones in the future. Minor populations of macroalgae are also expected on stones in the foundation chambers and on the shafts near the surface.

5.5 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 Sand Eel (*Ammodytes tobianus* and *Hyperoplus lanceolatus*), and possibly Flounder (*Platichthys flesus*) (Bio/consult, 2000a).

The foundations comprise 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 in the capacity of the biotope 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 sandy bottom area.

5.5.1 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 excavation and spooling activities, underwater movements and other activities on the sea bottom. They are therefore expected to disappear from the relatively small construction area (Bio/consult, 2000a).

Calculations of the magnetic field from sea-cables buried 1 m below the seabed show that the magnetic field directly above the cable will be less than the naturally geomagnetic field (30-50 my T). It is therefore concluded 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. This includes Lumpfish, Cod and Eelpout, which are characteristic stone reef fishes. Flatfishes such as Plaice, Flounder, Turbot, Brill and Smear Dab which are in fact bottom dwelling 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 of sediment on pelagic eggs and fry 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).

For safety reasons, the construction area was closed off and access was prohibited; therefore all types of fishing in the wind farm site were prohibited during the construction period. The construction phase will affect the gill net fishery for Cod, Turbot, Silver Eel, Flounder, Plaice and Dab in the wind farm area (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 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 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 concluded that the construction of a wind farm at Nysted 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).

5.5.2 Baseline 2001 and 2002

Fish and commercial fishery in the wind farm area

Two baseline fish studies were carried out in 2001(Bio/consult 2003a). In spring, the program for "Baseline study of fish" was undertaken with two identical sampling sessions in May and June. In autumn, the sampling program "Baseline study of fry" was executed with three identical sampling sessions in September, October and November.

The objective of the baseline study is to provide enough data to enable the verification of possible changes in the fish population in the wind farm area during its operational phase, with a given degree of certainty.

The investigations carried out in 2001 did not provide sufficient data to draw conclusions about the fish population. The classic analytical techniques used in both the baseline study of fish and baseline study of fry could not accommodate with the number of empty samples recorded. Furthermore, high variation was recorded in many samples, which posed a problem concerning the use of the classic statistical methods in the BACI (Before After Control Impact) design, which require homogeneity of the variance. Therefore, further monitoring programs on fish and fry in the wind farm area have not been established since 2001.

Fish at the 132kV cable to land

The possible effects of electromagnetic fields created by underwater power cables on the fish fauna, particularly migratory species is not very well known. Due to this uncertainty, it has been decided to investigate potential effects of the electromagnetic field from the cable trace connecting the transformerstation with Vantore Strandhuse east of Nysted (figure 6.19).

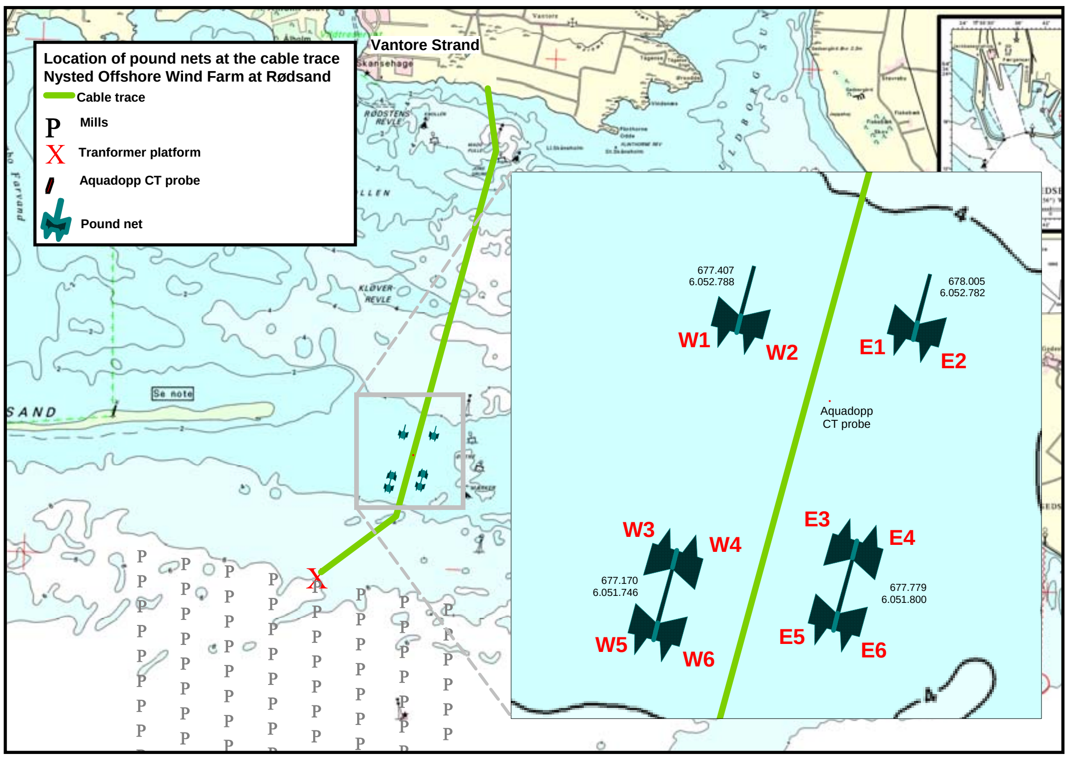

Figure 6.19. Map of the cable trace south of Nysted, the selected study area and the geographical positions of the four pound nets and the Aquadopp Current Meter. Both of the two northerly nets were designed as two-way directional pound nets with double fykes (see figure 6.21) and the two southern nets where designed as four-way directional pound nets with double fykes in each end of the leader (see figure 6.21). Geographical coordinates at centre of pound nets and the Aquadopp Current Meter are given in UTM32 ED50.

During autumn 2002, a baseline investigation was undertaken as a follow up to the preliminary baseline investigation during autumn 2001 (Bio/consult 2002, 2003b). The overall objective was to form the investigative foundation of a baseline study prior to the establishment of the wind farm. The planned continuity of the environmental monitoring was affected by an overall adjustment of the demonstration project and this resulted in a end in the field work before the baseline study was completed. Thus the objective was focused more on evaluating improvements in the utilized gear and methodology rather than the original objective of collecting baseline data.

The field study consisted of sampling every second day, from four-pound nets placed pairwise along the planned cable trace, in the outlet of Rødsand Lagoon. To comply with the considerations of the International Advisory Panel of Experts on Marine Ecology (IAPEME) of verifying the direction of the migratory route of the Silver Eel in particular, two of the ordinary pound nets were modified in 2002 into directional pound nets (figure 6.21). The purpose behind the modification was to separate the fish that most probably have crossed the cable trace from the fish originating from the other direction.

To compare fish behavioral patterns with local oceanographic parameters, an Aquadopp Current Meter with automatic and continuous logging was placed between the pound nets, and logged continuous measurements of conductivity, temperature, current speed and direction.

Results of the time series analysis for CPUE (Catch Per Unit Effort) and weight show different catches in the directional pound nets. The catch in the two eastward fykes of the directional pound nets were similar and the catch in the westward fykes were similar. The total catch on the west side was approximately two times higher than the total catch from the east side, indicating that the prevailing direction of migration is from west towards east. In conclusion, the new, modified directional pound net improved the ability to solve the basic question: Is the catch similar on the east and west sides of the cables?

For the two ordinary pound nets the two parameters CPUE number and CPUE weight indicates that catches of Common Eel, Atlantic Cod, Baltic Herring, Eelpout and Short-pined Sea Scorpion were identical over time. The catch was not significantly different in the ordinary pound nets on the east and west side of the cable trace.

It was not possible to relate the catch from the pound nets with hydrographical parameters because of abnormal meteorological conditions and because the area was mainly influenced by the diurnal tide.

5.5.3 Monitoring 2003

Fish at the 132kV cable to land

Monitoring of fish migration across the 132 cable alignment was also performed by pound net fishing during autumn 2003. The cable was in operation at the time of monitoring. The monitoring programme was performed with the same equipment and methods as used in the baseline monitoring of 2001 and 2002. However, in 2003, two of the four pound nets were made four-directional, enabling separation of catches from four different directions (figure 6.20), The remaining two pound nets were two-directional, as in 2002, enabling separation of catches from easterly and westerly directions (Bio/Consult 2004).

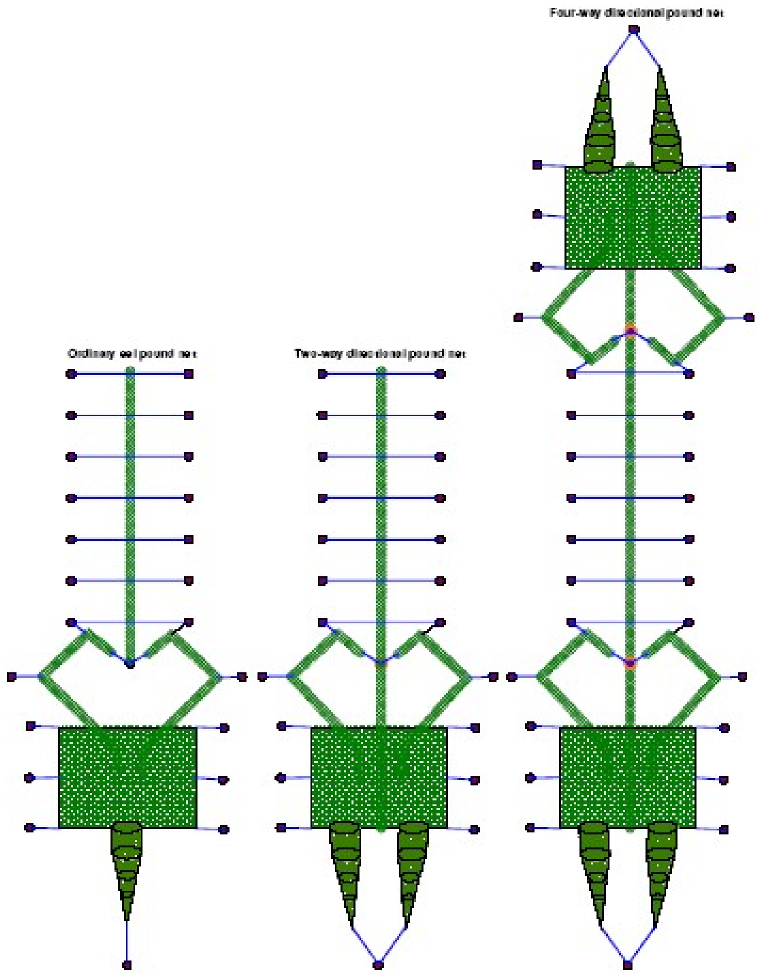

Figure 6.20. Three different pound nets, from left to right: Ordinary eel pound net, two-way directional pound net and a four-way directional pound net.

The following conclusion can be made:

- The cable trace did not cause a major change in the overall distribution of number and weight of the total catch before and after the cable was put into use in 2003.

- The combined number of each species was not significantly different between the catch on the west and east side of the cable in 2001, 2002 and in 2003, according to the multi-dimensional scaling analysis (MDS).

- A significantly (Chi Square) higher number of eel were caught on the west side of the cable in 2003 compared to the pooled data from 2001 and 2002. However, it was not possible to establish if this difference was caused by the magnetic field from the cable due to high variation of the data. Additional data will be needed to overcome this variation and that survey could be supplemented by an investigation in the very near vicinity of the cable to definitively establish if electromagnetic fields from the cable have a possible effect on eel.

- According to the catch in the directional pound net the prevailing migration was from west to east before (2002) and after the cable was put into use in 2003.

- The overall distribution of the indicator species has not changed beyond the level of natural variation since the establishment and activating of the cable.

5.5.4 Monitoring 2004

Fish at the 132kV cable to land

The investigations made at Nysted for detection of effects from the electromagnetic fields on migration and behaviour of fish were characterised by high complexity and many difficulties, both in the sampling phase and in the analysis phase. As a consequence, analysis including baseline data was not possible and the analysis includes only data from 2003 and 2004. As part of the data analysis, a conceptual model was formulated as depicted in Figure 5.20 The model represents an open system with bi-directional migration across and along the cable trace. Two effect measures were defined and subsequently used for the statistical test of possible effects on fish behaviour from the cable, here referred to as Effect1 and Effect2. Both measures were calculated from the catches in the inward and outward facing fykes on each side of the cable. Effect1 measures possible asymmetries in the catches across the cable trace indicating an east-west/west-east migration, depicting a hindrance or blocking effect from the cable trace. Effect2 measures the possible import or export of fish along either side of the cable trace but also indicating effects on fish behaviour.

On the basis of the combined data from 2003 and 2004, significant impacts were found for Effect1 for four species: Baltic herring, common eel, Atlantic cod and flounder. These results suggest that migration of some species across the cable trace may be impaired. On the other hand, the results do not suggest that the migration is completely blocked. Regarding Effect2, significant results were only obtained in two cases. The first case indicates that some of the common eels react by leaving the area along the cable trace when analysing the combined data. In the second case, the 2003 data indicate that Atlantic cod accumulate close to the cable trace. The electro-magnetic field around the cable was not measured. However, assuming that the power production at the wind farm is proportional to the strength of the electromagnetic fields, possible correlations between the Effect1 and Effect2 and the power production were examined. A significant correlation was found only for flounder. Flounder primarily crossed the cable when the strength of the electromagnetic fields was estimated to be low, i.e. during calm periods. Altogether, the investigations along the cable trace at Nysted show some effects from the cable trace on fish behaviour. However, the analyses of data have only to very limited extent, proven a correlation between these impacts and the strength of the electromagnetic fields. One alternative explanation may be that fish reacted to the physical conditions along the cable trace if the seabed was not fully re-established. migration direction for common eel.

In the mark-recapture study, 231 common eels were marked and 18 were recaptured. Of the recaptured eels, 13 (72%) were migrating towards west and the remaining 5 (28%) migrated towards the east. The results showed that 7 (39%) of the recaptured eels probably had passed the power cable during their migration. Furthermore, more than 50% of the eels probably changed direction after being captured. In the literature, migration of eel from the Baltic Sea is predominantly believed to pass through Øresund. However, the results from the mark-recapture programme at Nysted strongly indicate that eel west of Øresund migrate through Storebælt, i.e. the prevailing migration direction at Nysted is westward. Hence, there is no reason to assume any influence on the overall migration direction on common eel from the wind farm.

Hydroacoustic Monitoring of Fish Communities at Offshore Wind Turbine Foundations
Fish attraction behaviour to artificially created hard substrates has been demonstrated in several European countries. Most attempts to quantify fish stocks near such hard structures as well as natural reefs have used visual techniques. Hydroacoustic quantifications around oil fields and horizontal hydroacoustic quantifications in lakes have demonstrated the application of these methods in fish stock assessment. Knowledge of fish behavioural response to noise and vibration emissions from offshore power production activity is very limited.

Results of a pilot project approved carried out at Nysted OWF in April 2004, demonstrated that the hydroacoustic technique had the ability to monitor fish communities and their behaviour in relation to power generating activity (Bio/consult et al. 2004).

The aim of the study was:

- To investigate possible effects from foundations and power generation activity on fish behaviour.
- To demonstrate fish attraction behaviour to turbine foundations.

To meet the requirements of the objectives, two types of horizontal hydroacoustic surveys were conducted: 1) A static horizontal survey including underwater surveillance and gill net fishing to investigate fish attraction behaviour and effects from turbine activity on fish behaviour, and 2) a dynamic or mobile horizontal survey to investigate fish abundance along transects in the wind farm.

For the static horizontal survey, a split beam transducer and an Aquadopp CT-probe were mounted on a pan & tilt unit that was attached to a tripod placed on the seabed outside the scour protection at one turbine site.

Underwater video as well as traditional fishing techniques were used as a supplement to the hydroacoustic technique in order to identify fish and gather information on the fish community.

A dynamic horizontal hydroacoustic technique was used for the abundance study. Transects were surveyed with the transducer placed on the side of a rubber dinghy.

Due to poor water clarity during the survey period, the video recordings did not reveal any occurrence of pelagic fish. Though, fishing with gill nets revealed a fish community consisting of at least nine species. Of the nine species, only one species was pelagic, three were semi-pelagic and four benthic. Only the pelagic and the semi-pelagic species are potential species for hydroacoustic monitoring. No statistically significant differences were found in fish abundances between day and night or at different current directions. However, there were tendencies of higher abundance at night and in the leeward side of the turbine foundation. The abundance of fish close to the turbine structure was apparently higher than between the turbine foundations, indicating fish attraction behaviour. No statistical analysis was made on differences in abundance due to multipath induced errors in the calculated survey distance. Hydroacoustic analysis and results from test fishing have shown that most fish were less than 60 cm in length and that small fish less than 30 cm were most abundant.

The response of the introduced hard substrates as turbine foundations at Nysted OWF on the fish community and fish species was comparable to other studies on deployed hard substrates generating forms of artificial reefs.

The hard substrate habitat - as turbine foundations at Nysted OWF is - is still young of age, which could attribute to the fact that fish abundance and diversity is still low. Fish abundance and species diversity is expected to increase as the hard bottom substrate becomes more integrated.

5.5.5 Monitoring 2005

Hydroacoustic Monitoring of Fish Communities at Offshore Wind Turbine Foundations
A dynamic, horizontal hydroacoustic survey was carried out along transects inside and outside Nysted Offshore Wind Farm in autumn, 2005 (Bio/Consult as, Carl Bro as, SIMRAD AS 2006). In order to describe the species composition and calibrate the acoustic signals, supplementary fishing was performed simultaneously with the acoustic surveys. The supplementary fishing was carried out with the use of survey gill nets and a small specially designed pelagic trawl. Hydroacoustic data was sampled using a split beam transducer mounted on a pan & tilt unit on the side of the survey vessel. Hydrographic data was sampled by an Aquadopp CT-probe placed in the centre of the wind farm area. SCUBA divers made additional observations on fish species composition at one turbine foundation. Post processing and analysis of acoustic data was performed by Sonar5-Pro data application software.

A total of 16 different species were found during the supplementary fishing. Three semi pelagic species including the small sandeel, the great sandeel and the Atlantic cod were found together with three strictly pelagic species; sprat, herring and whiting. Large pelagic schools of two-spotted gobies were observed by divers close to and on the lee side of the turbine foundations. A total of 18,388 fish were registered during the hydroacoustic survey along the seven surveyed transects. Of the fish registered, 8,821 individuals were registered during daylight and 9,567 individuals during darkness.

A spatial distribution pattern in fish densities was found inside the wind farm area using CPUE corrected values. In general, there was a trend of fish density being higher in the western part and west of the wind farm during daylight with the opposite distribution pattern occurring during darkness with higher fish densities found in the eastern part and east of the wind farm. However, the distribution pattern of fish biomass does not reflect the distribution pattern of the fish density.

No unambiguous diurnal distribution patterns in fish density and biomass between daylight and darkness were found regardless of significant diurnal differences along all transects except along one impact transect concerning fish biomass.

Breaking down into samples, diurnal patterns in the fish distribution were found at a single sample, but differences in the behavioural pattern was different inside wind farm transects compared to outside wind farm transects. The differences in diel patterns might be a result of different communities inside and outside the wind farm and might partly reflect the nocturnal dispersion pattern of Atlantic cod inside the wind farm. Inside the wind farm area, statistically more small fish were found during darkness compared to the reference areas whereas no statistical differences were found during daytime. Overall, there was a statistically significant cross effects between temporal and spatial distribution patterns of fish density and biomass.

Local variations were shown in the spatial distribution pattern inside the wind farm but no general significant differences were found. The fish densities in the northern part of the wind farm were higher than in the southern part and the densities during darkness were generally 10 times the amount found during daylight.

Although no significant differences were found between the local distribution patterns of fish at turbine foundations or between turbines, fish aggregations were observed on the leeward side of some turbine foundations with respect to current. At some of these foundations statistically significant differences in density were found between the upstream and downstream position but no unambiguous results were obtained.

Diurnal behavioural variations of different fish species might affect the local distribution of fish investigated because of their nocturnal behaviour and unsuitable hydroacoustic ability during daytime.

The presence of current boundaries seems to play a major role in the distribution pattern of fish in the area. Aggregation of fish associated with hydrographic fronts or discontinuities are well documented. Fish aggregations were registered coincident with an observed current boundary within the wind farm area.

In conclusion the fish communities at Nysted Offshore Wind Farm are influenced by many abiotic as well as biotic factors besides a possible effect from the wind farm itself.
No general and unambiguous regional effect was demonstrated from Nysted Offshore Wind Farm in the distribution pattern of pelagic and semi pelagic fish communities when comparing impact and reference areas. However, one sample out of two revealed a significantly higher density of small fish during darkness inside the wind farm area with the reverse trend in distribution pattern during daylight. No local statistically significant differences were found in the temporal and spatial distribution of the fish communities inside the wind farm due to the presence of the turbine foundations.

5.6 Seals

5.6.1 Environmental Impact Assessment

Since 1977 the Harbour Seal (*Phoca vitulina*) has been a fully protected species in Denmark (Bøgebjerg, 1986). The seal area at Rødsand (Figure 6.21) is today and has historically been one of the most important seal areas in Denmark. However, during the past 15 years, only a few hundred Harbour Seals and up to 16 Grey Seals (*Haliocerus grypus*) have been counted in the Rødsand area. Today, the Rødsand area supports 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 western part of the Rødsand Lagoon (NERI, 2000c).

Figure 6.21. The sand bank at Rødsand with the seal sanctuary and seals on land in the lower left corner. The bird tower is seen in the middle of the picture.

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 moves onto land.

There are two periods during which the Harbour Seals are especially sensitive to changes in their environment. The first is mid-June to mid-July, which is the breeding season for the Harbour Seal. It is therefore especially vulnerable in the seal sanctuary during this period.

The second period in August, when the Harbour Seals moult and therefore must spend most of their 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 can 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 will be reduced to some extent 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 commercial fishermen 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. Six 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 μPa). In the immediate vicinity of a wind turbine foundation the Harbour Seal will be able to hear the noise. However, at distances greater than 20 m 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).

5.6.2 Baseline 2002

In 2002 three different types of investigations have been carried out to study the seals in the area around Nysted Offshore Wind Farm. These are aerial surveys (NERI 2003d), remote video registration (NERI, 2003e) and satellite tagging (NERI 2002b).

Figure 6.22 shows a map of the area and indicates the seal sanctuary at eastern Rødsand and the wind farm area.

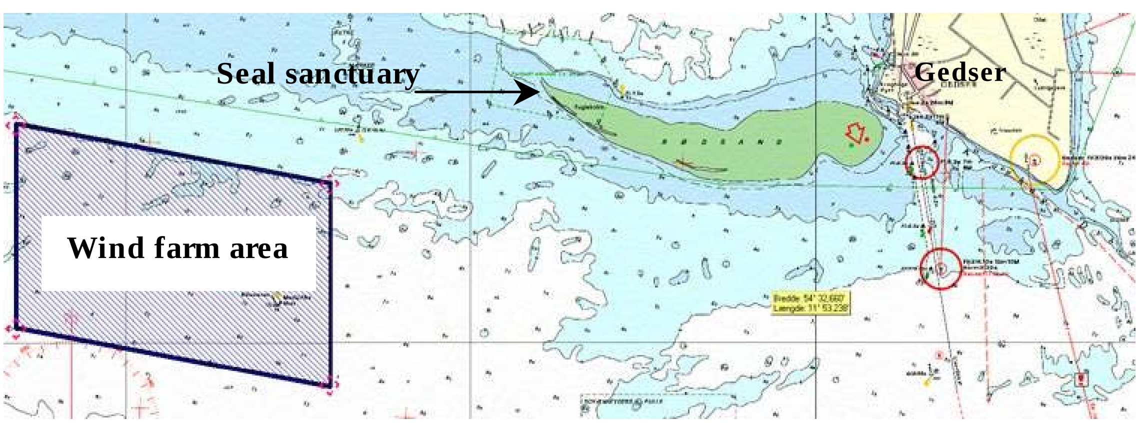

Figure 6.22. Map of the wind farm area and the seal sanctuary

Aerial surveys of seals

The objectives of the surveys are to determine the preference in haul-out sites in the Rødsand area, in particular by season, and to observe the effect on the use of the seal sanctuary during and after the construction of the wind farm (NERI, 2003d). The aerial surveys were carried out monthly from March 2002 to December 2002, with a pause between October 2002 and December 2002.

In 2002 the seal epidemic (Phocine Distemper Virus, PDV) struck the Danish seal population. Aerial surveys in the south western Baltic conducted in August 2002, revealed that about 44% of the expected number of seals were missing, corresponding to a mortality of 440 individuals.

The surveys in 2002 provided information on the use of the different seal haul-out sites, which are believed to have some level of exchange of animals. Based on the aerial surveys, an estimated stock of about 200 Harbour Seals used the Rødsand area during the moult in late August 2002. Rødsand seal sanctuary is found to be the most important haul-out site in the south western Baltic during summer while it is less important to the Harbour Seals in February-March.

Remote video registration

The main objective of the remote video registration is to assess the extent to which the erection of the wind farm will cause measurable, temporary or permanent changes in the presence and behaviour of Harbour Seals and Grey Seals in the Rødsand area (NERI, 2003e).

Two visible light cameras (figure 6.23) are mounted on a 6 m high tower (figure 6.24) on the sand 600 m from the seal's preferred haul-out site. With the use of microwaves the video signal is sent to the control centre in Gedser where a computer receives the signal. Using a remote control program the cameras can be controlled from a computer on land.

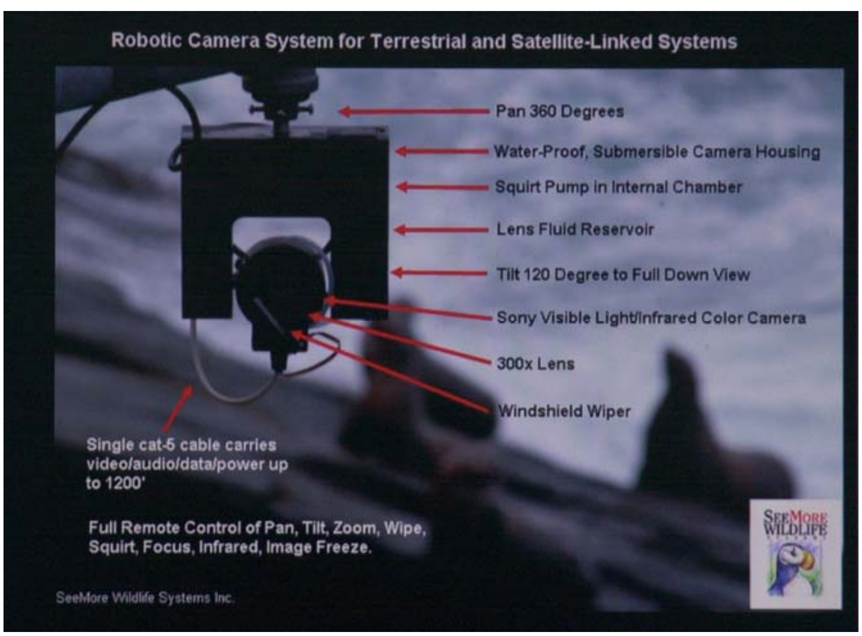

Figure 6.23. Camera similar to the ones used at Rødsand (picture from www.seemorewildlife.com).

Figure 6.24. Camera tower at Rødsand Seal Sanctuary with antennas, wind generator, solar panels and battery box.

The year-round video monitoring of the seals hauling out in the sanctuary is a method that requires little manpower.

With the data obtained in the period March 2002 until February 2003, the probability of the presence of seals on land over time and the time with seals on land, can be calculated and analysed. The results confirm that the seals use Rødsand as a haul-out site more frequently during the summer.

The probability of seals appearing on land was analysed together with the data on pile driving and vibrating of steel sheet piles at foundation A8, in the southwestern corner of the wind farm. Deterrents to scare both Harbour Porpoises and seals in the vicinity of the construction site into what is considered as a safe distance from the work site, were used. The analysis showed no systematic effect from the vibration or deterrent on seals hauling out in the sanctuary.

Satellite tagging

The objective of the study is to provide information on site fidelity, migration and kernel (a probability of density) home range (or area use) of Harbour and Grey Seals prior to the construction of Nysted Offshore Wind Farm. In addition, the study should help to determine the potential vulnerability of the two seal species to the construction and operation of the wind farm and provide information on haul-out and diving behaviour (NERI 2002b). Seals are caught in nets and tagged with a satellite transmitter on the head. The satellite transmitter transmits data movements, diving behaviour and transmitter status.

Four Harbour Seals and six Grey Seals were tagged in the period of November 16 to April 12, 2002. The results show that Harbour seals stay within the area of the lagoon and surroundings and that this area is of great importance throughout the year.

The wind farm area constitutes a relatively high percentage of the 95% kernel home range of Harbour Seals, whereas the wind farm area is of minor importance to the grey seals compared to the total kernel home range of these seals.

The satellite tagging of both Harbour Seal and Grey Seal has shown that the Harbour Seal is more resident in the area around Rødsand, while the Grey Seals utilize a much greater area during certain times of the year.

In the 2002 programme an ARGOS transmitter was used (Wildlife computers SDRT16). Due to technical limitations in the satellite system, the accuracy of ARGOS positions is not very high, in the range from a few hundred metres to several kilometres. This makes it difficult to draw strong conclusions on the seals' use of the wind farm area.

However, a new type of telemetry-transmitter has been developed in connection with monitoring of seals around Nysted Offshore Wind Farm. This new transmitter has a much higher accuracy in positioning the tagged animal. The transmitter was tested in 2003.

5.6.3 Monitoring 2003

Aerial surveys of seals

As mentioned in chapter 1.9.2 a seal epidemic killed between 11 and 44% of the seals in management area 4 (figure 6.25) but in 2003 the population was recovering by about 19%. Based on the aerial surveys conducted during the moulting period in late August 2003, the seal stock (corrected for animals not being on land) at Rødsand had increased 15% from about 200 in 2002 to about 230 in 2003. This indicates that the population increase at Rødsand was similar to the increase for the total area and that there was no effect on the population increase from the wind farm.

Figure 6.25. Map of management area no. 4 (Southwestern Baltic) with area names.

During the construction of the wind farm, Rødsand seal sanctuary was still the most important haul-out site (34%, 2003 estimate) in management area 4 during summer (figure 6.26) while the locality remains less important to the Harbour Seals during October-March.

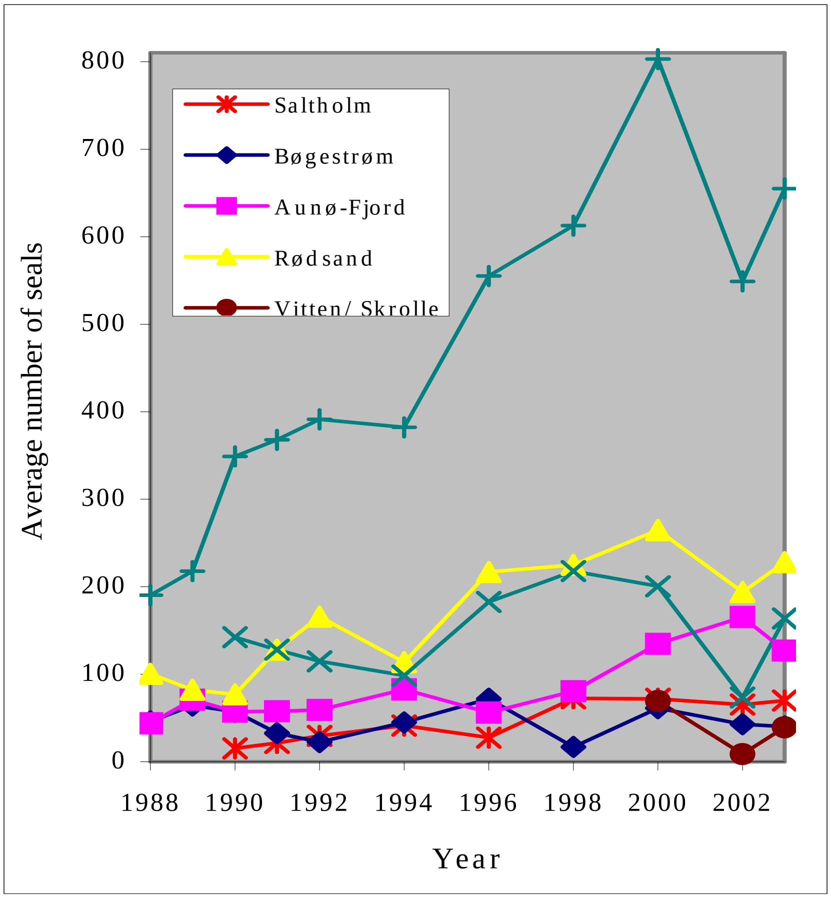

Figure 26. Trend in total stock size from the six most important localities in management area 4, as well as the total number of seals in the area. Each point is an average of the three counts made in late August each year, multiplied by the correction factor (2.22, see section 5.4) for seals not on land.

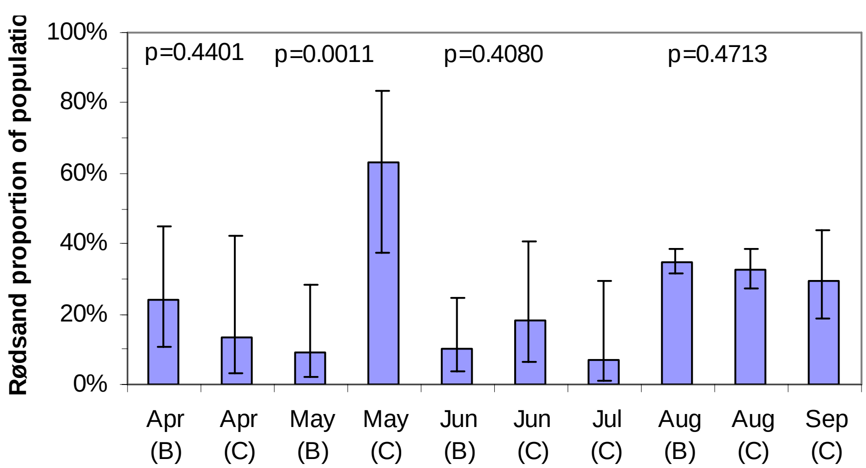

Figure 6.27. Estimated proportion of seals at Rødsand relative to all six localities for April-September 2003 (Rødsand, Vitten/Skrollen, Aunø, Bøgestrømmen, Saltholm, Falsterbo) separated into monthly variation for baseline (B) and construction period (C). The error bars show the 95% confidence limits of the estimated proportions. Differences in proportions from baseline to construction period were tested by calculating the contrast of the two estimates (p-values given above estimates in graph).

The seasonal proportion of seals at Rødsand relative to the other localities has changed significantly from baseline to construction, due to a large, positive change in proportion from baseline to construction period in May (figure 27). The other months did not show a significant shift. Also, there was no significant general seasonal variation over the entire period (1990-2003). The significant seasonal variation between Rødsand to Vitten/Skrollen suggest that at least some of the seals in the localized area move between these two localities in June and July, and return to Rødsand in August and September.

Based on the aerial surveys there are no indications that the construction activities may have affected the local Rødsand population differently from other population fluctuations in the southwestern Baltic Sea (NERI 2004a).

Remote video registration

With the data obtained between January 2003 and October 2003, the probability of the presence of seals on land over time and the time with seals on land, can be calculated and analyzed (NERI 2004b). The cameras were out of function for the months of November and December 2003 due to technical problems with the wind generator and the batteries, and no data is therefore presented for this period. In 2003 the camera tower was placed about 300 m from the seals preferred haul-out site without any notable effect on the seals. Figure 6.28 shows a recoded image of the seal sanctuary.

Figure 6.28. The image shows the seals preferred haul-out site on the tip of Rødsand seal sanctuary on June 13, 2003 at 10:13 after the movement of the camera-tower. The distance to the seals was 300 m.

The seasonal variations in the presence of seals in the Rødsand sanctuary were clearly distinctive, with a generally low presence during winter months, increasing in spring and reaching its maximum in August when seals were almost permanently present at the sand bank. The diurnal variation showed the highest presence during the middle of the day.

The distinct seasonal and diurnal patterns of seal occurrence (figure 6.29) were confirmed by the marginal category probabilities derived from a multinomial model. The diurnal variation corresponded to an overall mean of 6.3 seals around noon, decreasing to less than 1 in the early morning and late evening by translating the categories into mean number of seals.

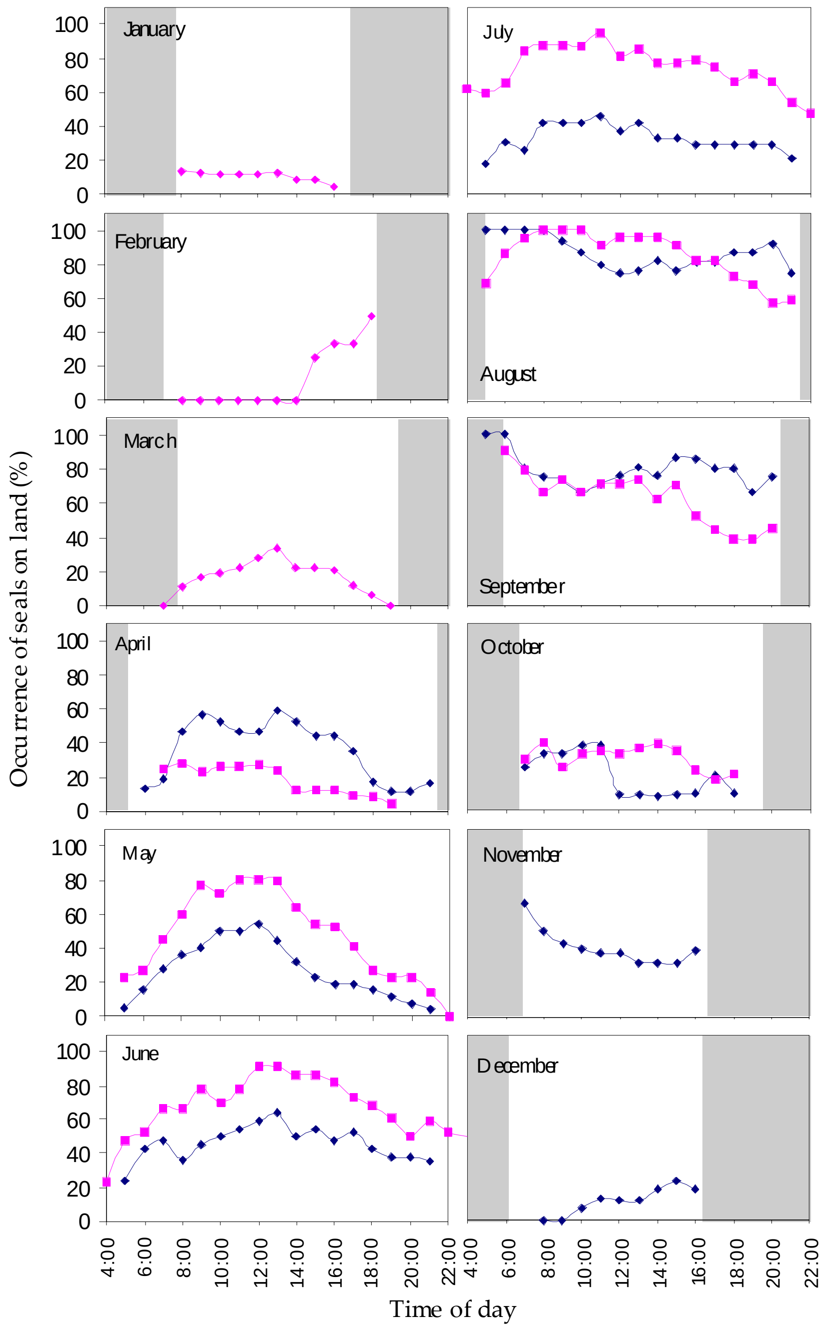

Figure 6.29. Diurnal variations in the presence of seals on land at Rødsand seal sanctuary for the different months found by averaging. Shaded areas represent hours where the seal could not be counted due to darkness. Data from 2002 (dark blue) and 2003 (pink).

Southerly winds of about 4-8 m/s increased the number of seals on land. If the wind came from the south (S) there would be a yearly mean of 5.0 seals on land, whereas if the wind was from the north (N) there would only be a yearly mean of 1.5 seals on land. The yearly mean number of seals on land increased from 2.0 seals at 0 m/s, reaching a maximum of 3.4 seals at 6.1 m/s and decreased to 0.2 seals at 20 m/s. Wind speed between 0 and 12 m/s generally resulted in high abundance, whereas strong winds did not favour seals on land. See figure 6.30.

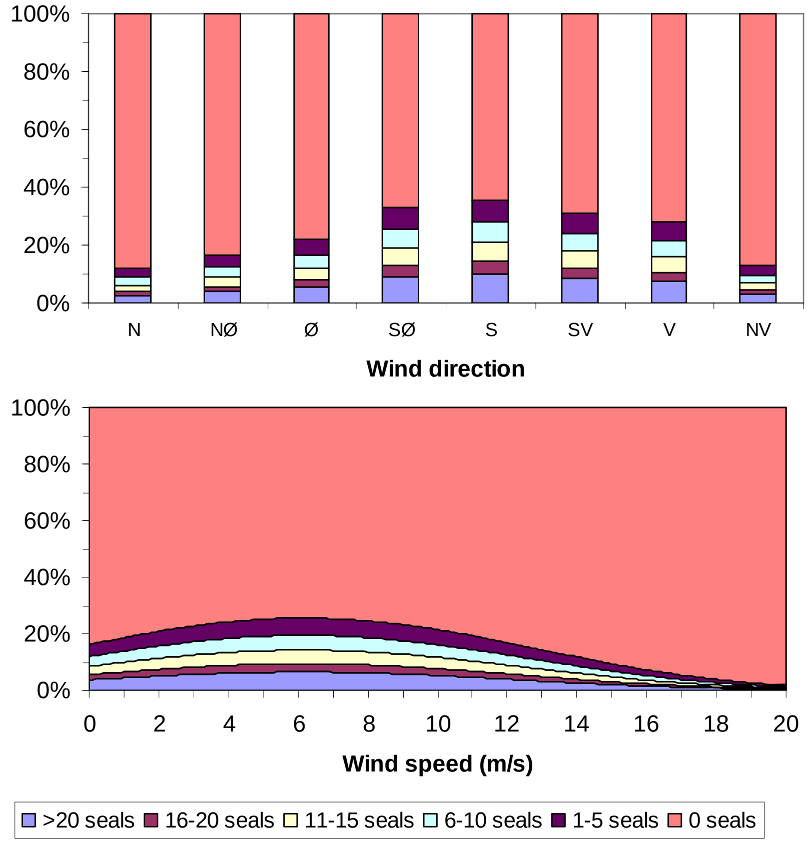

Figure 6.30. Estimated distributions for the 6 seal categories for different wind direction (top) and wind speed (bottom). The category probabilities were calculated as marginal means from a multinomial model describing yearly conditions for all hours between 4 and 23.

There was no change in the disturbance rate during the construction period, probably due to a restriction on boats passing the sanctuary at an adequate distance. This suggests that remote boat traffic and other activities that the seals have experienced previously, although intensified during construction, did not affect the number of seals on land.

The number of seals on land increased 12.5% from a yearly mean of 2.79 seals in the baseline period to 3.14 seals in the construction period. Five months had seal observations in both the baseline and the construction period, and four of these had a significant difference in the category probabilities for the two periods. There was a decline in the number of seals on land from April 2002 to April 2003, whereas data from May, June and July all showed increases from 2002 to 2003. August was not significant (figure 6.31).

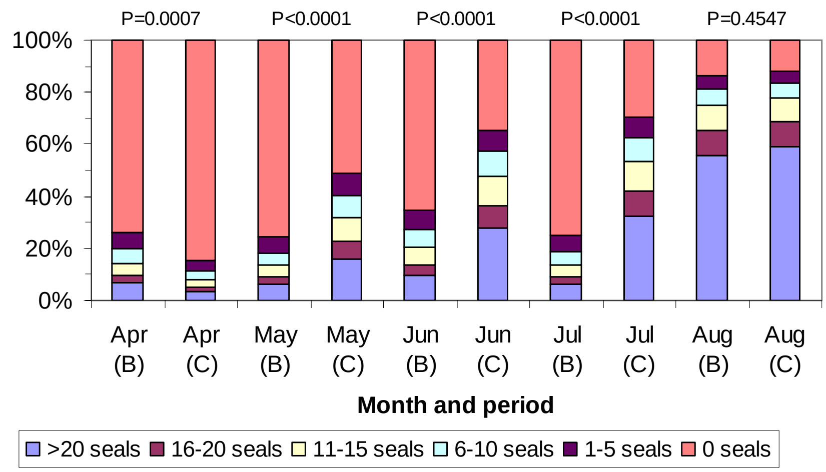

Figure 6.31. Estimated distributions for the 6 seal categories for months with camera in operation during baseline (B) and the construction period (C). The category probabilities were calculated as marginal means from a multinomial model. P-values above the columns give the probability that the distributions are identical for the two months.

There was, however, a significant decrease in the number of seals on land during periods with driving and vibrating of steel sheet piles at foundation A8 , located approximately 10 km SW of the seal sanctuary. The observed reduction of seals varied among months, ranging from 8 to 100%. When correcting for other variables in the model, the reductions varied between 31 and 61%. The seals may have chosen to stay in the water, swim away or haul-out further away from the wind farm than Rødsand.

The construction of the Nysted offshore wind farm, situated approximately 4 km away from the Rødsand seal sanctuary had in general little or no effect on the presence of seals. The appearance of two Grey Seal pups was also recorded during the construction period.

Satellite tagging

As mentioned it was decided to develop a more accurate transmitter. A combined GPS-receiver/GSM-transmitter was developed by Logic IO, Horsens, Denmark, in cooperation with NERI (National Environmental Research Institute), Arctic Environment, and Energy E2, with assistance from Elsam Engineering and the Fisheries and Maritime Museum in Esbjerg.

It was decided to conduct a preliminary test before the production of four transmitters intended for deployment on wild seals in the Wadden Sea and Nysted. The test would be carried out under controlled conditions on a seal in captivity at the Sealarium (Fisheries & Maritime Museum and NERI, 2004).

The unit consists of a GPS-receiver for positioning of the tagged animal, memory for storage of positions and a GSM-cell phone for transmission of stored information. In addition, the unit has a saltwater switch and microprocessor, which controls the activation of GPS and GSM-subunits. Communication with the unit takes place either through the GSM-connection or by means of two magnetic switches. The unit is cast in hard epoxy resin with a saltwater switch and GSM-antenna connected to the outside (figure 6.32).

Figure 6.32. GPS/GSM-transmitter (prototype) before and after encapsulation in epoxy resin. Length of transmitter (excl. antenna) 60 mm.

The unit was mounted on a Harbour Seal in the Sealarium in October 2003. Dive and haul-out behaviour of the tagged seal was observed for two days after the tagging. This was done in order to allow subsequent correlation of behaviour with information stored in the memory of the transmitter. The behaviour was recorded on video and the state of the animal was recorded continuously by means of a Psion Workabout computer. The behaviour was separated into three categories: submerged, at surface and hauled-out.

Within a few days it became clear that the transmitter was not functioning properly as SMS-messages were not received by Logic IO from the GSM-subunit. The error was most likely due to the fitting of the transmitter’s external antenna. Logic IO assessed that the problem with the external antenna is linked to unforeseen problems in the casting process.

It was possible to tag only one seal in spring 2003 with the original ARGOS transmitter, and the results from this tagging have therefore not yet been analysed.

Because the accuracy of the baseline data is quite low (in the range from a few hundred metres to several kilometres) a comparison with post-constructional data would be difficult, even if the data could be generated. Due to the technical difficulties with developing the GPS/GSM transmitter, and limitation of time and resources, the monitoring programme on satellite tagging of seals was suspended in 2003.

5.6.4 Monitoring 2004

Aerial surveys of seals

In 2004 the number of seal at Rødsand increased by 42%. This is more than the theoretical maximum rate of increase for harbour seals of about 12% per year and the 6.9% estimated as the average annual growth at Rødsand from 1990 to 2004 (NERI, 2005). These figures should be taken with some caution, as inter-annual variation in the number of seals on land during the survey days may vary. However, it indicates that seals have emigrated to Rødsand from the other seal sites, especially since the other sites combined only increased by less than 4% from 2003 to 2004.

During the construction of the wind farm Rødsand seal sanctuary was the second most important haul-out site after Avnø with 27% of the seals in management area 4 during August. This was the lowest proportion since 1990. During the operation of the wind farm in 2004 the proportion at Rødsand increased to 34% of the management area 4 population and again the most important seal site in southwestern Baltic. However, this temporary shift was not statistically significant.

In April and June 2003 significantly fewer seals were counted at Rødsand during the construction phase compared to the baseline and operation periods. However, in May 2003 the opposite picture was seen, as significantly more seals were seen during construction compared to the baseline. No significant shift in proportion of seals at Rødsand relative to the other localities was seen during July-March. The significant seasonal variation between Rødsand and Vitten/Skrollen suggest that a higher proportion of the seals stay at Vitten/Skrollen in June and July during the breeding period, and return to Rødsand in August. Rødsand remains less important to the harbour seals during October-March.

So far there are no indications that the construction activities and operation of the wind farm have affected the Rødsand seal population different from the other populations in the western Baltic Sea. Actually, the Rødsand population appears to thrive relative to the other areas and it has increased in size substantially in 2004, at least during the month of August. Whether there are any positive effects by the wind farm, e.g. by creating an artificial reef that attracts more fishes, remains to be investigated.

Remote video registration

The seasonal variations in the presence of seals in the Rødsand sanctuary were clearly distinctive, with a generally low presence during winter months, increasing in spring and reaching its maximum in August, when seals were almost permanently present at the sand bank. The diurnal variation showed the highest presence during the middle of the day (NERI, 2005a).

Southerly winds around 4-8 m/s increased the number of seals on land. Wind speed between 0 and 10 m/s generally resulted in high abundance, whereas strong winds did not favour seals on land.

There was no change in the disturbance rate (seals fleeing into the water) between baseline, construction and operation periods, probably due to a regulation on boats to pass south of the sanctuary in adequate distance. This indicates that remote boat traffic did not affect the number of seals on land significantly.

In management area 4 that covers the southern Sjælland and the islands of Lolland and Falster, about 20% of the population died in the summer of 2002 due to the PDV seal epidemic (Härkönen et al. submitted). Despite this unusual mortality, the seals increased in numbers at Rødsand from the baseline to construction. This suggests that there has been no overall negative effect of the construction work on the number of seals at Rødsand.

There was, however, a significant decrease in the number of seal on land during the ramming periods (August-November 2002), that was carried out at a single foundation located approximately 10 km SW of the seal sanctuary.

In accordance with the conditions in the consent to build the wind farm, an underwater seal scarer and porpoise pingers were used to scare the animals away from the site before the actual ramming started. Short term ramming at Gedser harbour (September 2002) and lighthouse (July 2003) did not affect the seals on land negatively. Whether this was because no scaring devices were used, because the disturbance was less intense and further away or because the Rødsand sand bar covered for sounds coming from Gedser is unknown.

Grey seal pups were recorded during the construction period in 2003 and during operation in 2004, which is the first time for decades that the grey seal has been breeding on a regular basis in Danish waters. Rødsand seal sanctuary is therefore of great importance for grey seals in Denmark. On the contrary it looks like more harbour seals are born on Vitten/Skrollen than in the sanctuary, which makes Vitten/ Skrollen of great importance for the breeding of harbour seals in the southwestern Baltic Sea.

The construction and operation of the wind farm situated approximately 4 km away from the seal sanctuary had in general no or only little negative effect on the presence of seals on land.

The observed general increase in number of both harbour and grey seals lies within natural reproduction, but whether there are any positive effects by the wind farm, e.g. by creating an artificial reef that attracts more fishes, remains to be investigated.

5.6.5 Monitoring 2005

Aerial surveys of seals

The final investigation was carried out in 2005 (NERI 2006a), thus this chapter summarise the findings from the investigations carried out 2002-2005.

The seal epidemic in 2002 killed about 20% of the harbour seals in management area 4, but in August 2003 the number of harbour seals had almost recovered completely. During 2003-2005 the population increased by almost 17%.

During the construction of the wind farm the relative importance of Rødsand seal sanctuary decreased slightly, but not significantly compared to the other five most important seal localities in the southwestern Baltic Sea area (Vitten, Avnø, Bøgestrømmen, Saltholm, Falsterbo). Figure 6.33.

During the operation of the wind farm in 2004 and 2005 the proportion of seals (harbour and grey seals combined) at Rødsand increased to 34 and 33% of seals from the entire management area 4, respectively, and thereby again became the most important seal site in south-western Baltic.

Except for an increasing importance of Rødsand during operation in May and June 2004-2005, no general shift in proportion of seals (harbour and grey seals combined) at Rødsand relative to the other localities was seen. Whether the increasing proportion of seals during operation in May and June 2004-2005 could be due to a positive effect from the wind farm is unknown. The significant seasonal variation between Rødsand and Vitten suggests that some seals move from Rødsand to Vitten in June and July, to return afterwards to Rødsand in August and September. Rødsand remains less important to the harbour seals during October-March.

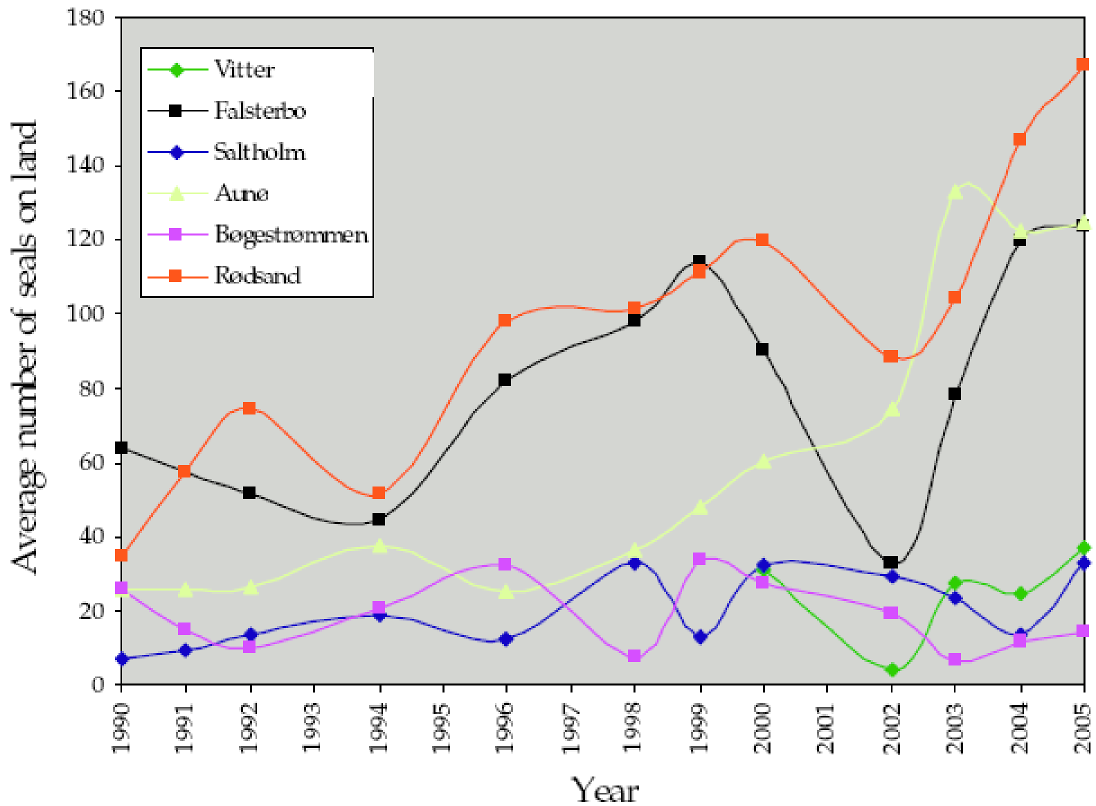

Figure 6.33. Annual mean number of harbour seals from the 6 most important localities in management area 4. Each point is an average of the three (1990: 5 and 2002: 4) counts made in late August each year. No correction for seals in the water is made.

There are no indications that the construction activities from late June 2002 to December 2003 and the first two years of operation of the wind farm in 2004-2005 affected the local Rødsand harbour and grey seal populations differently from the other populations in the western Baltic Sea. The Rødsand seal population has increased substantially in size in 2004 and 2005. Whether there are any positive effects from the wind farm, e.g. by creating an artificial reef that attracts more fishes, and hence more seals remains to be investigated.

5.7 Harbour Porpoises

Harbour Porpoises (*Phocena phocena*) use the Rødsand area throughout the year and it was 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 south of Lolland, Guldborg Bay, Bøtø Nor and Hyllekrog-Rødsand), which borders on the wind farm area, has been designated, among other reasons, due to the presence of Harbour Porpoises in the area.

The most important sources of stress on the species are disturbances from ship traffic, construction work, noise and loss of habitat (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. Calculations and field experiments indicate that Harbour Porpoises are able to hear individual turbines at distances up to a few hundred m (Henriksen, 2001).

Harbour Porpoises are especially sensitive to disturbances in May-June when they give birth, and in July-August when 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 construction period, 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 construction activities have been completed.

5.7.1 Environmental Impact Assessment

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

It has been concluded that no permanent reduction in the food sources of Harbour Porpoises is expected in the wind farm at Nysted. If the foundations improve the habitat for, among others, Cod, Herring and Eelpout, the food base for Harbour Porpoises can even be expected to improve 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 Nysted wind farm area was carried out in 2001 (NERI & Ornis Consult, 2001). The results showed that there is a medium level of activity of Harbour Porpoises in the wind farm area and Femer Berl area.

Calculations of the magnetic field from sea-cables buried one metre below the seabed show that the magnetic field directly above the cable will be less than the naturally occurring 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.

5.7.2 Baseline 2001-2002

In order to study possible effects from the erection and operation of the wind farm on Harbour Porpoises, stationary acoustic data-loggers, T-PODs (Porpoise click Detectors) have been used in the area at Nysted Offshore Wind Farm (NERI 2002c, 2003f).

In the area around Nysted Offshore Wind Farm, a total of six T-PODs have been deployed: Three T-PODs in the wind farm area and three in the reference area approximately 10 km east of the wind farm area, where the construction work is taking place (Figure 6.34).

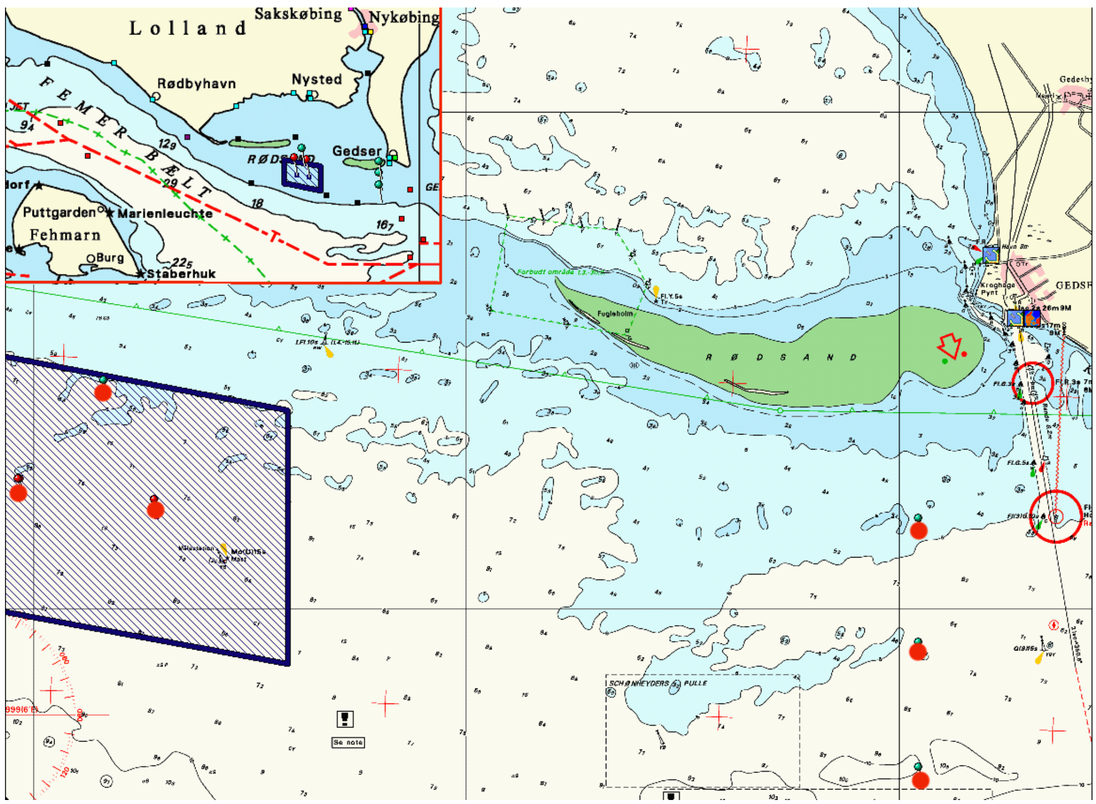

Figure 6.34. Map of the Rødsand area. The wind farm area is indicated by the blue square and the locations of the T-POD deployments are indicated with red dots. The position names are written next to each position

The gathered T-POD data were analysed together with data on the pile driving and vibration of steel sheet piles at foundation A8, in the southwestern corner of the wind farm. During periods of vibration at foundation A8 a pinger was deployed 30 minutes prior to the onset of the vibration activity. Pingers are deterrents used to scare Harbour Porpoises in the vicinity of the construction site into what is considered a safe distance from the work site. A deterrent to scare seals was used. A significant effect on Harbour Porpoises echolocation activity was found in both the wind farm area and the reference area during the vibrations.

The statistical analysis of the gathered T-POD data has shown that there has been a significant effect from the first months (July-October 2002) of construction of Nysted Offshore Wind Farm on the Harbour Porpoise echolocation activity within the construction site (impact area) compared to the control area. The echolocation activity is considered as a direct measure of the presence of Harbour Porpoises.

It is concluded that the construction has created a measurable, temporary decrease in the activity of Harbour Porpoises in the construction site.

5.7.3 Monitoring 2003

The data collected in 2003 shows similar results to the data from 2002 (NERI 2004c). Both data sets reveal a significant BACI-effect (Before After Control Impact) on Harbour Porpoise echolocation activity. It indicates that the decline in echolocation activity in the wind farm area (impact area) can not be explained by natural variations in porpoise density in the Baltic Sea alone nor as a response to other human-induced disturbances.

As porpoise echolocation activity is considered a direct measure of Harbour Porpoise presence, it can be concluded that the presence and behaviour of Harbour Porpoises were affected significantly by the construction of Nysted Offshore Wind Farm.

The median waiting time between Harbour Porpoise encounters in the wind farm area has increased from approximately eight hours in the baseline period to approx. 64 hours (more than 2½ days) in the construction period, while only a slight increase was seen in the control area. The wind farm area therefore appears to have constituted an exclusion zone for Harbour Porpoises during the construction period.

Such effects are not unexpected and were anticipated. A return to baseline levels of activity during operation of the wind farm is expected.

5.7.4 Monitoring 2004

Conclusions from monitoring during 2004 (NERI, 2005b), the first year of operation of the wind farm, must be considered preliminary, as monitoring continued in 2005. Conclusions on animal abundance and behaviour during 2004 are nevertheless very clear. No significant increase in abundance of porpoises in the wind farm area was seen in 2004 relative to the construction period and levels are still about a factor 5 lower than during baseline monitoring. Porpoises were not absent from the wind farm however, and when present, their acoustic behaviour was not significantly different from baseline behaviour. All indicators analyzed points to the wind farm as the direct or indirect cause of the decline (strongest effects consistently observed in wind farm area compared to reference area). The reason why fewer porpoises frequented the wind farm during its first year of operation is unknown and it is too early to establish whether the effect is permanent or recovery to baseline levels is slower than originally anticipated in the EIA.

A significant effect of pile drivings/vibrations has previously been demonstrated (Carstensen et al. 2005). The inclusion of data from pile drivings in Gedser Harbour in 2003 has strengthened this conclusion, as similar strong negative effects on porpoise abundance were observed. The fact that no mitigations were used at the pile drivings in Gedser Harbour demonstrates that impact on porpoises observed also from the pile drivings inside the wind farm were related to the pile drivings and not merely an effect of the mitigations (pingers and seal scarer). This does not however, imply that mitigations were not effective in fulfilling their purpose, which is deterring animals out to safe distances before onset of pile drivings.

5.7.5 Monitoring 2005

The final investigation was carried out in 2005 (NERI 2006b), thus this chapter summarise the findings from the investigations carried out 2001-2005.

During the baseline period there was no difference in either waiting time or number of porpoise positive minutes between the reference and impact area. During construction and first two years of operation waiting time increased and porpoise positive minutes decreased considerably in the wind farm area, indicating that fewer porpoises were present in the wind farm area in these periods. A smaller, yet still significant increase in waiting time and decrease in porpoise positive minutes was also observed in the reference area, possibly signifying a general effect of wind farm construction on porpoise abundance in the Rødsand area.

Although indicators are still significantly affected two years after completion of the wind farm, there is a tendency towards return to baseline (pre-construction) levels in waiting time and porpoise positive minutes in the wind farm area. Activity in the reference area was back to baseline levels two years after end of construction. This likely indicates that porpoises have gradually habituated and returned to the wind farm during the first two years of operation.

Encounter duration and number of clicks per porpoise positive minute decreased significantly from baseline to construction period in the wind farm area (see figure above), indicating that not only were there fewer porpoises in the area during construction, their echolocation behaviour was also affected. This effect disappeared in the second year of operation, indicating that the acoustic behaviour of porpoises in the wind farm area returned to baseline levels.

5.8 Birds

The Nysted wind farm area is situated along a very important migration route for waterfowl. Each autumn and spring high numbers of bird pass through the area. Migrating land-birds also pass the area in great numbers, especially during autumn. 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*). 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 are 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 the day in September-October. Spring migration peaks in April and May when daytime migratory Eiders and Brent Geese (*Branta bernicla*) occur in maximum numbers of 43,000 and 4,000 individuals, respectively (NERI, 2000a).

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). See figure 6.35 and 6.36.

Figure 6.35. 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)

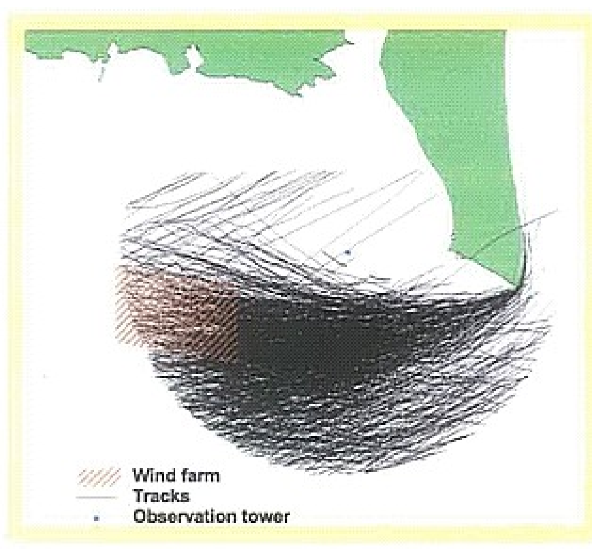

Figure 6.36 Radar registrations of 794 waterfowl flocks migrating at Rødsand during autumn 2000. Flocks that were not determined visually to species were classified as waterfowl on the basis of their migration speed exceeding 50 km/h. All flocks presented were migrating in a westerly direction (NERI, 2000b)

5.8.1 Environmental Impact Assessment

Migratory birds may be at risk of colliding with the blades of turbines. 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 the percentage of individuals passing within the critical rotor height is even higher than for Eiders. It is, however, not known whether the figures mentioned above are applicable to the Nysted Offshore 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 in flight (i.e. Terns and Skuas) occur in the wind park area. Normally, they forage between 0-20 m 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 the 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 entire 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 4 km) 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 for birds' ability to see under water and thereby search for food by sight (NERI, 2000a). Especially sea ducks depend on benthic invertebrates as food.

Noise caused by driving and ramming of monopiles or steel sheet piles is assessed not to have a detectable impact on breeding birds in the study area (Figure 3.8) (NERI, 2000a). Habitat loss caused by the wind farm at Nysted 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, shows 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).

5.8.2 Baseline 2001-2002

In 2001 and 2002 a baseline investigation of birds in relation to the wind farm at Nysted was carried out (figure 3.37).

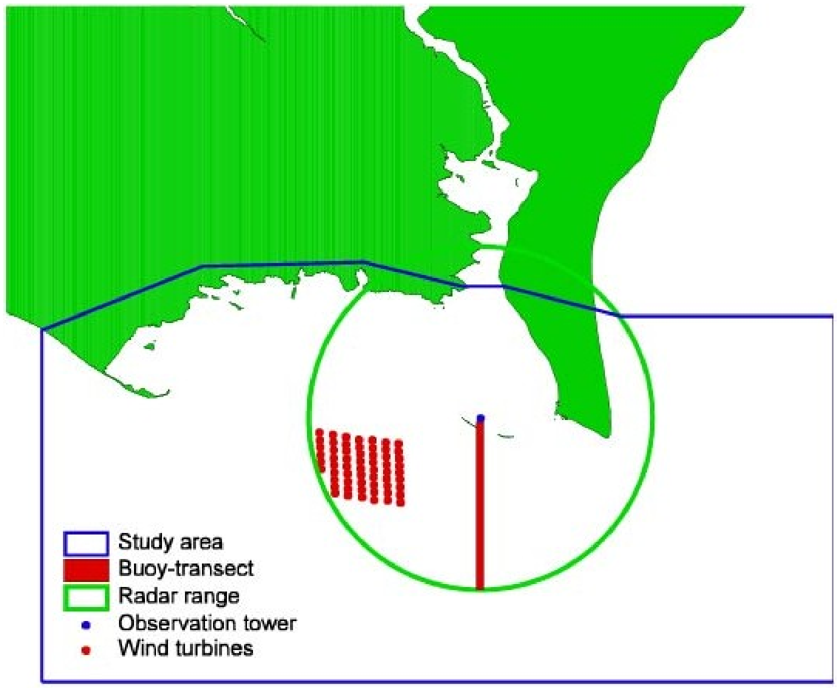

Figure 6.37. Location of the Rødsand study area covered by aerial surveys, the observation tower on which the radar was mounted, radar range, wind farm area and the Buoy-transect.

The investigation included mapping of migration routes by use of radar day and night combined with identification during daytime of migrating bird species by use of telescope. Waterfowl that included staging migrants, wintering or wing moulting birds in the study area at the wind farm, were monitored by aerial surveys (NERI 2002a, 2003a, 2003b).

The baseline study in 2002 has shown that between 26% (2002) and 49% (2000) of the waterfowl tracks registered by radar pass the eastern edge of the wind farm during autumn. Eider was still the predominant species among the migrating waterfowl.

The baseline study in 2002 provided the second year of mapping of the migration routes of waterfowl during spring and in both years the main spring migration route of waterfowl passed north of the wind farm area. During spring 2002, the percentage of waterfowl (mainly eiders) which passed the eastern edge of the wind farm, was in the same order of magnitude (25%) as in autumn.

Spring migration of raptors, passerines and pigeons was almost absent during 2000, 2001 and 2002. During autumn, Gedser Odde and Hyllekrog northeast and northwest of the wind farm area are on a major migration route of these bird species. Due to a temporary suspension of the study during autumn 2002, data of autumn migrating landbirds is absent in the 2002 report.

On the basis of the migratory bird mapping, a GIS-database of migration tracks was created. Subsets of data were derived from the database to establish a baseline, which describes migration routes before the wind turbines were erected. These baseline data will be used for comparisons with similar data obtained during the operational phase.

Count surveys of staging, wintering and moulting waterfowl have shown that Cormorants and moulting Mute Swans occur in internationally important numbers (> 1% of total population in the entire study area) on annual basis. Red-breasted Merganser has not occurred in international important numbers since November 1999.

On the basis of aerial count surveys, waterfowl preferences of predefined areas were calculated by the use of Jacob's selectivity index. Cormorant, Mute Swan, Mallard, Goldeneye, Herring Gull and Little Gull all show significant avoidance of the wind farm area. Red-breasted Merganser showed avoidance of the wind farm site, but preference for the area around the wind farm, while Eider showed neither avoidance nor preference for the wind farm area. Long-tailed Dusk and Common Scoter showed significant preference for the wind farm, making these species susceptible to disturbance effects from the wind farm.

Radar studies revealed that Cormorants might undertake social foraging events during early mornings and late afternoons. Social foraging flocks may contain up to 5,000 individuals and may occur inside the wind farm area. This behaviour makes the Cormorant a potentially high-risk species with respect to collisions with the wind turbines.

A project that deals with quantification of avian collision frequency has been introduced. Collisions will most likely occur as discrete events with low frequency, and previous studies have suggested that collision risk is higher at night and during periods of poor visibility. A Thermal Animal Detection System (TADS) meeting the above-mentioned requirements and based on infrared video techniques was developed to be used in an offshore environment and operated from land (NERI 2003c). In 2001 and 2002 preliminary tests were carried out to investigate and develop the performance of the system. In general it was concluded that the thermal camera and its related hardware and software are capable of recording migrating birds approaching the rotating blades of a turbine, even under conditions with poor visibility.

5.8.3 Monitoring 2003

The data collected in 2003 have been compared with data from the previous surveys (NERI 2004d). During autumn 2003 all turbines were erected in the offshore wind farm. Autumn migrating waterfowl showed significant differences in their mean orientation within the approaching area of the wind farm between all four years of investigation. The analyses of the orientation of individual bird flocks in relation to their distance from the wind farm showed that the year-effect differed across years, dependent on the distance from the wind farm. Due to small sample sizes and certain wind conditions, the wind effects found in the baseline studies could not be incorporated into the 2003 analyses. It was therefore not possible to demonstrate a convincing change in migration orientation at a specific distance from the wind farm following construction of the wind farm. However, the standard deviation of migration orientation increased significantly during the daytime at distances closer than 3000 m to the wind farm in 2003 and closer than 1000 m during the night. These results support the hypothesis that migrating birds show a natural response to the wind farm, specifically reacting by increased lateral avoidance to the north and south of the wind farm. They also conform to the predictions under that hypothesis that (1) the deflection will occur close to the wind farm and (2) the deflection will occur closer to the wind farm at night than during the day.

Observations in autumn 2003 offered no support for a severe avoidance response to the wind farm, in terms of a substantial reverse migration of birds, turning back eastwards from the eastern edge of the wind farm compared with the baseline. Baseline studies showed that between 24% (2002) and 48% (2000) of tracks registered in autumn by radar passed the eastern border of the proposed wind farm area (figure 6.38). After the wind turbines were erected in 2003, significantly fewer (9%) tracks of waterbird flocks registered by radar passed the eastern border. This result was confirmed even controlling for the effects of cross-winds, time of day (4-7% by day compared to 11-24% by night) and latitudinal position.

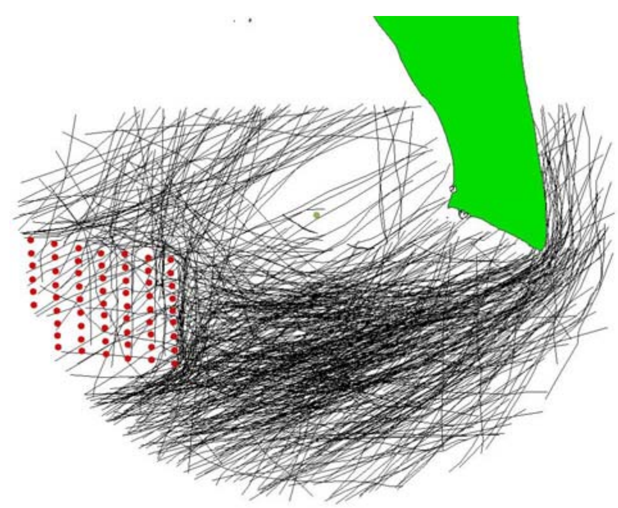

Figure 6.38. Radar registrations of 508 waterbird flocks determined visually migrating at Rødsand during autumn 2003.

Generally, the major spring migration route of waterbirds lies north of the wind farm area. During spring 2003, 11% of all migrating waterfowl tracks passed the eastern edge of the wind farm area, less than in 2001 (16%) and 2002 (25%), but the difference was not significant during the day. Hence, during daylight hours there was no support for the hypothesis that birds avoided the wind farm area during the construction phase in spring 2003.

Waterbird migration intensity within the wind farm area varied considerably with weather conditions both locally and on a flyway scale, making predictions at a local scale difficult to model, and statistical comparisons complex. Nevertheless, the results from spring and autumn 2003 clearly demonstrated reduced intensity of migration in the wind farm area, based on density of radar tracks.

Despite general support for the hypotheses outlined above, it is important to stress that these results provide little evidence for or against the effects of the construction of wind turbines on migrating waterbirds. The data were collected in just one year and the construction phase of the turbines extended over a relatively short period. It is therefore difficult to draw many hard conclusions from the single case study. Although the results suggest substantial avoidance (and provide data on the nature of that avoidance) by autumn-migrating waterbirds of the newly constructed wind farm, it is important to stress that these results come from one single monitoring year. They are gathered under the particular conditions prevailing in that year and before any likely effects of longer-term habituation or other behavioural responses to the wind farm's presence.

Four aerial surveys of staging and wintering birds were conducted in the study area in 2003, one in each of the months of January, March, April and December. Thus a total of 25 surveys have been performed since August 1999. The most numerous species recorded in 2003 were Tufted Duck (12,205), Eider (3,142), Mute Swan (2,882) and Long-tailed Duck (2,797). Of these, only Eider and Long-tailed Duck occurred frequently in the offshore areas.

To ensure maximum compatibility between base-line data and construction data, only data from March and April of the baseline phase were used to analyze construction activity impact on bird distributions. Given the small number of surveys during construction, no firm conclusion can be drawn about the construction phase. However, Long-tailed Duck and Eider showed reduced preference for the wind farm area during construction, whereas the relative number of Herring Gulls increased slightly in the wind farm area. Since only one count survey exists during operation of the wind farm, results must be supported by further surveys before conclusions concerning habitat loss for staging and wintering birds at Nysted Wind Farm can be drawn.

As mentioned, a project that deals with quantification of avian collision frequency has been introduced. Collisions will most likely occur as discrete events with low frequency, and previous studies have suggested that collision risk is higher in nocturnal circumstances and during periods of poor visibility. A Thermal Animal Detection System (TADS) based on infrared video techniques was developed to be used in an offshore environment and be operated from land (NERI 2003c). In 2001/2002 technical tests were preformed to evaluate and improve the performance of the system.

During autumn 2003 it was planned to collect data from a single infrared test system, but due to delayed mounting of the TADS at the offshore turbine, only one out of two project aims was achieved. This was the offshore test of the hardware, whereas the second aim of collecting preliminary information for an assessment of avian collision risk, could not be accomplished as the majority of the birds had already passed the study area on their autumn migration. The test of the physical stress of the thermal camera, when operating outside in an offshore environment and under the real time vibration conditions at the 2.3 MW turbine in Nysted Offshore Wind Farm was conducted to see how well the waterproof metal box, windscreen wiper, pan/tilt head, windscreen wiper and sprinkler system, water valve and rubber vibration absorbers worked. The criterion for success was a well working set-up during the testing period, which showed no significantly reduced image quality due to environmental impacts.

In general it was concluded that the thermal camera and its related hardware and software are capable of recording migrating birds approaching the rotating blades of a turbine, even under conditions with poor visibility.

5.8.4 Monitoring 2004

As in 2003 the study in 2004 (NERI 2005c, 2005e) showed that waterbirds (mainly eiders), which approached the wind farm would adjust their orientation at some distance of the wind farm, regardless whether they would fly in between the turbines or pass north or south of the wind farm. Minor adjustments of the orientation already started at 3,000 m. However, the most marked change in the orientation occurred at a distance of approximately 1,000 m.

It also appeared that the majority of the waterbirds deviated laterally from their original orientation as they approached the wind farm, and to the extent that they would finally avoid the wind farm area. During the base-line study before the construction, between 24% and 48% of the flocks passed the eastern edge of the wind farm. During the autumn operation period, the percentage was reduced to 9% in both 2003 and 2004. It could also be shown that the lateral avoidance response was associated with less migration activity in the wind farm area. It would be expected that the observed lateral displacement from the regular migration pattern is associated with a lower risk of collision for the birds. Hence, the results from the present study suggested that the nature of the avoidance response amongst waterbirds is very important to incorporate in models, which are developed to predict collision risk.

The study on migratory birds during operation of the Nysted wind farm in spring 2004 generally supported the results from the operation period during autumn 2003 and 2004. The consistency of the results describing the eider-dominated migration at Rødsand suggested that eiders can be expected to avoid crossing offshore wind farms. This general response was supported by a similar conclusion reached at a Swedish offshore wind farm (Petterson 2005). Avoidance occurred both during day- and nighttime. However, the extent to which eiders may show this avoidance response, their relative use of different migration routes around the wind farm are likely to be site-specific. Thus, the present study at Rødsand has certainly shown that the nature of the study area with its nearby mainland areas is an important factor, which guides migrating birds into certain corridors both during spring and autumn. In addition, prevailing wind and light conditions are also important determinants of the relative importance of migration routes, the volume of migration and the proportion of total migration that would cross in between wind turbines.

A preliminary assessment would suggest that the extra energetic costs as a result of a avoidance response may be considered as negligible at the Nysted offshore wind farm. For example, an eider duck, which breeds in the Gulf of Finland and winters in the German Wadden Sea would at least migrate 1,200 km on autumn migration, while passing the wind farm area. In this respect a linear avoidance response at 1 km from the wind farm and a similar compensatory adjustment of the orientation after having passed the wind farm would in the worst case lead to a detour of ca 4.5 km or 0.4% of the entire migration route. Evidently, if the eider has to pass several wind farms on the migration route, the energetic effect of several avoidance responses may add up (cumulative effects).

The results of the investigations of staging and wintering birds may suggest that long-tailed duck was displaced from the wind farm area during construction and the first operation period, although this interpretation should be considered with caution, given a limited data set. Furthermore, cormorants seemed to be attracted by the meteorological masts and the foundation of the turbines, which they used as roost sites. Finally, there were some indications that gulls occurred in higher abundance during operation in 2004 compared to the base-line study. However, there was no evidence that specifically the wind farm attracted them.

Thus, the data compiled from the first period of commercial operation showed some effects on the flight trajectories of migrating waterbirds as well as on the local abundance of a limited number of staging and wintering bird species. These effects could be permanent, as they resulted from the appearance of the wind farm or in the case of the cormorant more specifically from the presence of static superstructures. However, at the present stage, it is unknown to which extent habituation will lead to a higher abundance of birds in the wind farm or its vicinity in the years to come.

During operation in autumn 2003 and spring 2004 (NERI 2005d), the thermal trigger software saved 1,223 thermal video sequences on hard disc, of which only three were triggered by birds passing the field of view all in a 45° viewing mode (figure 6.39).

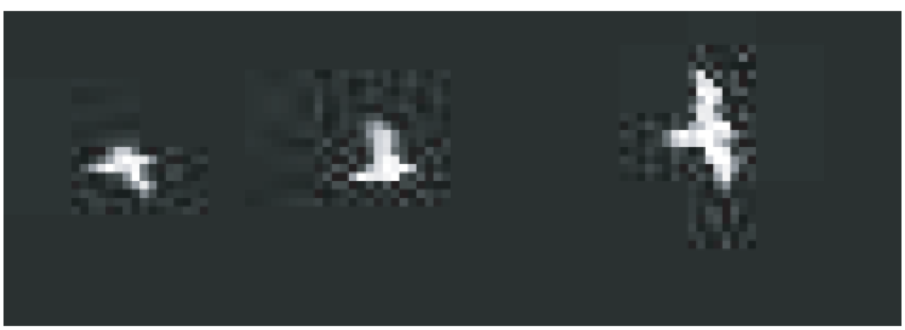

Figure 6.39. Three frames from the sequence recorded at event no. 1 showing a large gull passing the field of view from right to left (NERI, 2005a).

No birds were recorded as passing the sweep area of the rotating turbine blades or colliding with any part of the turbine during the 11,284 minutes of monitoring.

The fact that no birds were recorded as passing the sweep area of the A2-turbine could give rise to some doubt as to whether the TADS actually functioned properly during the trial. However, comparison with data gathered from other sources confirms the extremely low intensity of waterbird migration in the near vicinity of the turbines:

A) the 5-min long manual sequences of horizontal view successfully detected 52 birds despite the very restricted number of operation hours,
B) the radar data on bird flocks migrating within the wind farm show significant avoidance responses towards individual turbines, resulting in a higher probability of flying more than 50 m from the turbines than expected by chance alone.

Given the maximum coverage of c. 30% of the sweep area per TADS and the monitoring efficiency of 63.7% during the study period, it is considered highly unlikely that the single TADS used in the present study would have detected the single theoretically estimated flock of Common Eiders forecast by the probability model to be crossing the sweep area of a single turbine.

As a consequence of the extremely low estimated probability of Common Eiders passing the sweep area of the turbines, the level of coverage required to adequately monitor all 72 turbines would be extremely high, if a realistic and reliable measure of the daily number of avian collisions are to be registered by use of TADS only. Hence, it is considered that using TADS as the only method to measure actual collision rates of Common Eiders at the Nysted Wind farm is neither an economical nor practical option when it comes to estimation of the daily low number of collisions.

The results from the collision monitoring study of autumn 2004 confirm the findings from the same site in spring 2004, when a relatively low migration volume around the near vicinity of the turbines was also documented.

During autumn operation, the TADS recorded 1,944 thermal video sequences automatically at one turbine, of which five were triggered by birds passing the field of view. No birds were recorded as passing the sweep area of the rotor-blades nor colliding with any part of the turbine during the 28,571 minutes (equivalent to 476 hours) of monitoring.

A single passerine was observed approaching the rotor-blades, and ceased its onward flight hovering on its wings before it returned in the direction it came from.

The remaining five sequences showed three flocks of passerines and two flocks of waterbirds passing within the near vicinity of the turbine but beyond the reach of the rotorblades.

The values, which were imputed in a collision model, were obtained partly from the conclusions of the present study and from the literature. The model estimated that on average 68 Common Eiders would collide with the turbines in one autumn season, with a range of 3 to 484 individuals. The estimated average number of collisions of 68 individuals lies within range of the published estimates from the literature. The model in its present form, as a deterministic model, must be characterised as a preliminary solution. Before the preferred stochastic approach can be applied, enabling the variance of the data of the input parameters to be incorporated in the final collision estimate, the last radar data collected in 2005 will have to be included.

5.8.5 Monitoring 2005

The final investigation was carried out in 2005 (NERI 2006), thus this chapter summarise the findings from the investigations carried out 1999-2006.

Migrating birds

At Nysted, the proportion of autumn migrating birds (largely large waterfowl and mostly common eider) rounding Gedser Odde that avoided passing through the wind farm area varied little between 91 and 92% after construction compared to 52-76% during the baseline period when no turbines were present in the area. The latter comparison offers a more robust demonstration of avoidance, in that the data demonstrate a reduction of between 63 and 83% in the use of the wind farm airspace by migrating birds post construction compared to that prior to construction. A similar pattern was observed during the spring migration of waterfowl.

It can be concluded that the proportions of birds approaching the wind farm area post construction crossing the wind farm area have decreased relative to the preconstruction baseline.

Thus there was considerable movement of birds along the periphery of the wind farm, as birds preferentially flew around rather than between the turbines. Such avoidance was calculated to add an additional period of flight equivalent to and extra 0.5-0.7% on normal migration costs of Eiders migrating through Nysted.

From the patterns observed in the radar traces it was further more concluded that these patterns reflect birds making (i) gradual and systematic modification to their flight routes in response to the visual stimulus of the wind farm, with (ii) more dramatic changes in flight deflection close to the outermost turbines. At Nysted, amongst birds heading directly for the wind farm, it was possible to show slight deflections in flight orientation at 1.5-5 km distance, with a more radical deflection at less than 1 km from the outer turbines. However, the possibility that some birds (notably eiders rounding Gedser Odde in excellent visibility) react at 10-15 km by modifying their flight orientation cannot excluded. Such changes in flight route were not present in the baseline pre-construction data and hence can be interpreted as a direct consequence of the erection of the turbines

The lateral deflection tended to occur closer to the wind farm at night (0.5 km) than by day (1.5 km or more). At Nysted, although there was still a remarkable level of avoidance effect by night (6 out of 10 flocks), this was less pronounced than by daytime (9 out of 10). Observations using the TADS at Nysted provided unexpected evidence that despite the relative abundance of radar traces at night crossing the wind farm, infra-red monitoring over extended periods of night-time detected no movements of birds below 120 m during the hours of darkness, even during periods of heavy migration. This confirms the detection of bird flying at higher altitudes by night (up to 1500 m altitude using vertically mounted radar in the Nysted area, Blew et al. 2006 confirmed elsewhere in the scientific literature), and suggests that the lateral response that is also detected amongst night migrating birds may well occur above turbine height. The constraints of night time observation unfortunately mean that visual verification of the species involved is not possible, but at least some of these birds must be eider flocks which are known to migrate under cover of darkness, although in lesser numbers than by day.

Southward migration of non-waterbirds (largely birds of prey, pigeons and passerines) at Nysted also showed marked avoidance patterns approaching the northern fringe of the wind farm post construction compared to the baseline.

The avoidance responses documented above mean that although turbine construction at sea has an effect on the local distribution, abundance and flight patterns of birds, the corollary is that many fewer birds come within the risk zone of the rotor blade sweep zone. The avoidance responses at greater spatial scales resulted in reduced probabilities of birds approaching the risk zone of collision with turbines.

Staging birds
Long-tailed Ducks showed statistically significant reductions in density post construction in the Nysted wind farm (and in sectors 2 km outside) where they had shown higher than average densities prior to construction. This strongly suggests major displacement of this species from formerly favoured feeding areas, although the absolute numbers were relatively small and therefore of no significance to the population overall.

Attraction seemed to be highly species specific, with small numbers of gulls (especially greater black-backed and herring gulls) and cormorant attracted to a limited extent to the turbine foundations as loafing areas. There was little supporting evidence for changes in local abundance of these species in the vicinity of and within the wind farm based on the aerial survey data. There were frequent autumn mass social foraging events witnessed by cormorant at Nysted pre- and post-construction within the wind farm area, but there was no evidence of any attraction effect post construction. As no aerial surveys were undertaken in autumn here post construction, there is no support for this hypothesis from data on bird densities.

Physical habitat loss and gain was considered trivial, since the even accounting for the antiscour structures, the extent of the change equated to less that 4% of the total area of marine substrate enclosed within the total wind farm. Their effects would therefore be small and difficult to distinguish from other distributional effects described by monitoring changes in bird densities, except for the arrival of new species (which was not observed during the study) attracted to novel habitats post construction.

Thermal Animal Detection System (TADS)
In total, 123,6 days of TADS-operation, out of 180 days, was conducted during the study period, resulting in an operation efficiency of 68.7%. Monitoring was conducted in approximately equal proportions of the two viewing modes "vertical view" and "45 degree view".

During operation the thermal trigger software saved 5507 thermal video sequences, of which 11 were triggered by birds passing the field of view in the 45 degree viewing mode and one was triggered by the rotor blades showing a bird in the vertical view mode (Table 2). Additionally, two bats, one moth, and two birds/bats were recorded during the night.

	Bird	Bat	Moth	Bird/bat	Monitoring time (hours)
Spring 2004	3				412.5
Autumn 2004	6				1001.2
Autumn 2005		2	1	2	631.3
Spring 2006	3				399.8

Table 1. The species composition of the 17 thermal video sequences trigged automatically by animals during the 146,152 minutes of collision monitoring using one TADS mounted on a single turbine. Monitoring time is given as a total for the vertical and 45º viewing modes.

Of these 17 automatically triggered sequences, only one bird/bat was recorded as colliding with the rotating turbine blades as it was observed (in the 45º viewing mode) falling down from the sky without beating its wings. The fact that the bird did not use its wings suggests that it was a bird falling after colliding with the turbine blades and not a bird showing avoiding action by flying downwards.

During the four seasons, the airspace around the turbine could be monitored for 56% of the 180 days study period and here, with regard to monitoring efficiency, it was the weather (i.e. unfavourable wind directions, drifting clouds, rain) that acted as the constraining factor. Despite the relative low number of animals (birds, bats, moths) triggered automatically by the TADS, its performance at the wind farm was stable between years. Hence, the number of animals was triggered per season was rather homogeneous if monitoring period was taken in to account.

The Nysted Thermal Animal Detection System (TADS a remote infra red video monitoring system) and radar studies confirmed that waterbirds (mostly eider) reduced their flight altitude within the wind farm, flying more often below rotor height than they did outside the wind farm.

A stochastic predictive collision model estimated the numbers of Common Eiders, the most common species in the area, likely to collide with the sweeping turbine blades each autumn at the Nysted offshore wind farm. Using parameters derived from radar investigations and TADS, and 1,000 iterations of the model, it was predicted with 95% certainty that out of 235,000 passing birds, 0.018- 0.020% would collide with all turbines in a single autumn (41-48 individuals), equivalent to less than 0.05% of the annual hunt in Denmark (currently c. 70,000 birds).

5.9 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 the town of Nysted, the wind turbines will be strikingly visible. The wind turbines area relatively close to the shore and the wind farm occupies the greatest length on the horizon seen from Nysted (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).

5.9.1 Monitoring 2003

A questionnaire was prepared in 2003 to provide a quantitative analysis of the socio- and economic effects of the wind farm. It included an assessment of the attitudes and actions of people as a consequence of the construction of the wind farm. The sociological effects were subject to a qualitative analysis by assessing opinions in the area close to the wind farm.

Sociological effects
12 interviews about Nysted Offshore Wind Farm were conducted. The selection of interviewees attempted to provide variation in how they were involved in the local decision making process. The interviews included: local politicians, local and regional officers, members of NGO's, people with a business interest in the wind farm (i.e. tourism and fishing) and citizens that have participated in the public debate.

The study conducted at Nysted consists of two parts, a study before the wind farm was constructed and a study after the construction. Due to a delay in the study, this began during the construction of the wind farm. Due to this fact, the results from 2003 are only provisional, and a final report in 2004 will cover the whole study.

The study results from 2003 indicates that arguments for and against the wind farm were mostly focused on environmental concerns on the one hand and the positive effect on job opportunities on the other hand (Kuehn, in prep.).

Environmental economic effects
In 2003 a questionnaire was developed and testing of this questionnaire is expected to take place in the spring of 2004. Subsequent launching of the questionnaire will take place after the final approval of the questionnaire (KVL, 2004).

5.9.2 Monitoring 2004

The results from the survey finalized in 2004 are described in chapter 5.12.3 in the Horns Rev section.

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7 Appendix I: Literature on the demonstration projects

7.1 Horns Rev

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