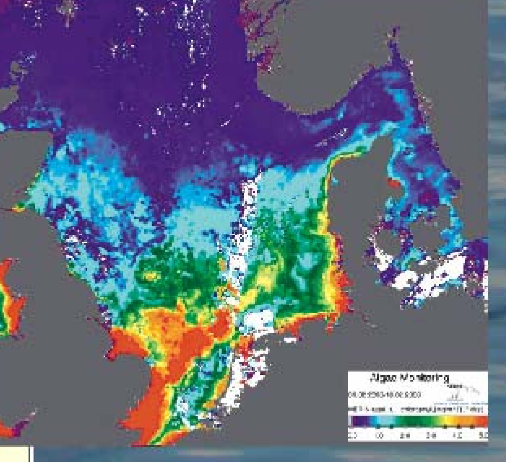
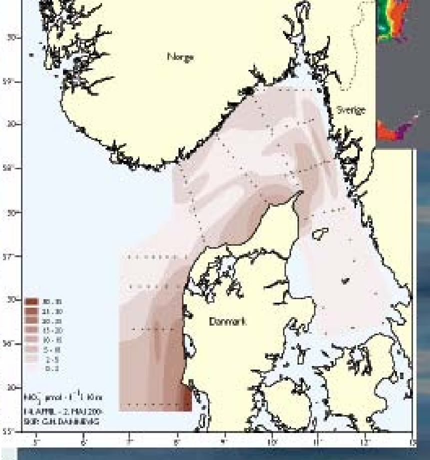
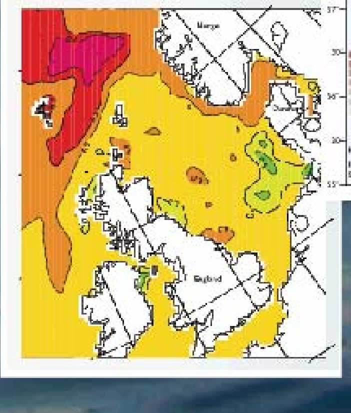
ENERGI E2

EIA Report
Water Quality

Horns Rev 2
Offshore Wind Farm







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EIA Report

Water Quality

Horns Rev 2 Offshore Wind Farm

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Summary

This report is part of the total EIA for the Horns Rev 2 Offshore Wind Farm. The following subjects are dealt with:

- Hydrography
- Water chemistry
- Phytoplankton and primary production

The report comprises an assessment of the potential impacts from the establishment of Horns Rev 2 Offshore Wind Farm on the water quality in the project area. The assessment is based on a description of the basic conditions of the area and experiences from the demonstration projects in Horns Rev 1 Offshore Wind Farm.

Impacts in the pre-construction phase, the construction phase, the operational phase, and during the decommissioning of the turbines are assessed; including the cumulative or the combined impacts from already established and from further development of offshore wind farms at Horns Rev.

Only impacts from wind farm construction and establishment inside the wind farm area are considered excluding effects of cable laying in the cable trace to shore.

The wind farm area is characterised by relatively high concentrations of inorganic nutrients, low transparency due to large amounts of suspended material in the water column, total mixing of the water column and generally good oxygen conditions. The water quality in the project area reflects the high impact of the in-put from the major European rivers to the adjacent southern part of the Wadden Sea in combination with the general coastal circulation and the shallow conditions.

Hypoxic conditions have been recorded in the adjacent waters, west to the project area. Recurring blooms of phytoplankton have been documented in the project area. These blooms can accumulate on beaches where they can create problems with smell, discoloration, etc. Several toxic micro-algae types have been recorded and can lead to accumulation of algal toxins in bivalves of commercial importance and/or can result in kills of fish, birds and mammals.

The significance of the impact on water quality in the project area from establishing the Horns Rev 2 Offshore Wind Farm are considered to be local and limited in time and space, and therefore to be of negligible/minor significance during all life cycle phases. No general changes in the water quality of the project area or cumulative effects are thus to be expected.

A temporary contamination with paint flakes and sandblasting waste, including sand from the maintenance of foundations and towers might be expected during the production phase. It is recommended that the toxicity of the paints should be minimized and that the amount of waste of paint and paint flakes should be minimised as well. It is considered that the spill of sandblasting sand will only have negligible effects on the water quality.

The assessment of the filtration impact of blue mussels on the foundations reveals a negligible impact on the phytoplankton present in the area. Likewise, the impact on the primary production and on the water quality as a whole are considered to be negligible. The filtration of the mussels might provide clearer water in the near vicinity of the foundations.

Sammenfatning

Denne rapport er en del af datagrundlaget i forbindelse med udarbejdelsen af den totale VVM vurdering af Horns Rev 2 Offshore Wind Farm. Rapporten omhandler følgende:

- Hydrografi
- Vand kemi
- Fytoplankton og primær produktion

I rapporten vurderes den potentielle påvirkning af vandkvaliteten i projektområdet ved etableringen Horns Rev 2 havmøllepark. Vurderingen baseres på en grundlæggende beskrivelse af de vandkemiske forhold i projekt området og erfaringer fra demonstration projektet i forbindelse med Horns Rev 1 havmøllepark.

Vurderingen omfatter påvirkningen af vandkvaliteten i forundersøgelsesfasen, etableringsfasen, driftsfasen, samt i forbindelse med afmonteringen af vindmølleparken. Vurderingen omfatter de samlede effekter af den allerede eksisterende havvindmøllepark Horns Rev 1 og de planlagte udvidelser i forbindelse med etablering af Horns Rev 2 havvindmøllepark.

Vurderingen omfatter kun påvirkninger af etableringen af vindmølleparken indenfor projekt området. Eventuelle effekter i forbindelse med etablering forbindelseskablet til land er således ikke omfattet af vurderingen.

Vindmølleparkens område er karakteriseret ved høje koncentrationer af uorganiske næringsstoffer og uklart vand som skyldes høje koncentrationer af suspenderet materiale i de frie vandmasser. Der er generelt gode iltforhold som følge af fuldstændig opblanding af vandmasserne. Vandkvaliteten i projektområdet afspejler belastningen fra de store europæiske floder som strømmer ud i den tilstødende sydlige del af Vadehavet og strømforholdene i den kystnære del af den syd-vestlige Nordsø kombineret med de lavvandede forhold i vadehavsregionen.

Der er registreret iltsvind i tilstødende vandområder, vest for projekt området. Opblomstringer af fytoplankton er et almindeligt fænomen i projekt området. Opblomstringerne af alger kan opkoncentreres på strandene i vadehavsregionen og kan have negative effekter i forhold til den rekreative anvendelse af området med problemer f.eks. i form af lugtproblemer og misfarvning af vandet,, hvilket er af betydning for blandt andet badegæster. Der er registreret en række giftige fytoplanktonarter i området som kan forårsage akkumulering af algetoksiner i skaldyr som fiskes kommercielt og/eller som kan forårsage fiskedød, samt slå fugle og pattedyr ihjel.

Det vurderes at etableringen af Horns Rev 2 havmøllepark kun vil medføre små og lokale påvirkninger af vandkvaliteten og at påvirkningen vil være ubetydelig/lille i alle faser af projektet. Etableringen af Horns Rev 2 havvindmøllepark forventes således ikke at medføre hverken generelle ændringer eller langtidseffekter i vandkvaliteten indenfor projektområdet.

Det forventes at vandkvaliteten kan blive påvirket lokalt og kortvarigt i forbindelse med sandblæsning af møllefundamenter og mølletårne i form af malingsrester og sand i driftsfasen. I den forbindelse anbefales det at der anvendes maling med lav toksicitet samt at sandblæsningen optimeres så mængden af malingsrester og sand minimeres. Det vurderes i øvrigt at sandblæsningssand vi være uden betydning for vandkvaliteten.

Vurderingen af størrelsesordnen af blåmuslingerne filtration viser at filtrationen på fytoplanktonet i projektområdet vil være ubetydelig. Ligeledes vurderes blåmuslingernes filtration at være uden betydning for primærproduktionsforholdene og for den generelle vandkvalitet i området i øvrigt. Blåmuslingernes græsning kan medføre klarere vand i umiddelbar nærhed af møllefundamenterne.

1 Introduction

1.1 Background

The Danish Government in 1996 passed a new energy plan, ”Energy 21”, that stipulates the need to reduce the emission of the greenhouse gas CO_2 by 20% in 2005 compared to 1988. Energy 21 also sets the scene for further reductions after the year 2005 (Miljø- og Energiministeriet, 1996).

The means to achieve this goal is to increase the use of wind power and other renewable energy sources from 1% of the total energy consumption in 2005 to approximately 35% in 2030.

Offshore wind farms are planned to generate up to 4,000 MW of energy by the year 2030. In comparison, the energy generated from offshore wind farms was 426 MW in January 2004 (www.offshorecenter.dk).

In 1998, an agreement was signed between the Danish Government and the energy companies to establish a large-scale demonstration programme. The development of Horns Rev and Nysted Offshore Wind Farms was the result of this action plan (Elsam Engineering & ENERGI E2, 2005). The aim of this programme was to investigate the impacts on the environment before, during and after establishment of the wind farms. A series of studies of the environmental conditions and possible impacts from the offshore wind farms were undertaken for the purpose of ensuring that offshore wind power does not have damaging effects on the natural ecosystems. These environmental studies are of major importance for the establishment of new wind farms and extensions of existing offshore wind farms like Nysted and Horns Rev 1 Offshore Wind Farm.

Prior to the construction of the demonstration wind farms at Nysted and Horns Rev, a number of baseline studies were carried out in order to describe the environment before the construction. The studies were followed up by investigations during and after the construction phase, and all environmental impacts were assessed. Detailed information on methods and conclusions of these investigations can be found in the annual reports (www.hornsrev.dk; www.nystedhavmoellepark.dk).

August 25, 2005 The Danish Energy Authorities issued permission to ENERGI E2 to carry out an Environmental Impact Assessment (EIA) at Horns Rev with particular reference to the construction of a new offshore wind farm at the site, Horns Rev 2 Offshore Wind Farm. The wind farm is planned to operate in 2009 and the installed capacity of this wind farm will be 200-215 MW, equivalent to 2% of the Danish consumption of electricity.

1.2 Introduction

This report is part of the total EIA for the Horns Rev 2 Offshore Wind Farm. In accordance with the requirements; the following subjects will be dealt with:

- Hydrography
- Water chemistry
- Phytoplankton and primary production

The report comprises an assessment of the potential impacts from the establishment of Horns Rev 2 Offshore Wind Farm on the water quality in the project area. The assessment will be carried out on the basis of a description of the basic conditions of the area and experiences from the demonstration projects in Horns Rev 1 Offshore Wind Farm.

Impacts in the pre-construction phase, the construction phase, the operational phase, and during the decommissioning of the turbines will be assessed; including the cumulative or the combined impacts from already established and from further development of offshore wind farms at Horns Rev.

Only impacts from wind farm construction and establishment inside the wind farm area are considered excluding effects of cable laying in the cable trace to shore.

2 Horns Rev

Horns Rev is an extension of Blåvands Huk extending more than 40 km to the west into the North Sea. Horns Rev is considered to be a stable landform that has not changed position since it was formed (Danish Hydraulic Institute, 1999). The width of the reef varies between 1 km and 5 km.

Blåvands Huk is Denmark's most western point and it forms the northern extremity of the European Wadden Sea, which covers the area inside the Wadden Sea islands from Den Helder in Holland to Blåvands Huk.

2.1 Topography and sediment

Larsen (2003) gives a detailed review of the geological formation of the Horns Rev area. In terms of geo-morphology Horns Rev consists of glacial deposits. The formation of the reef probably took place due to glacio-fluvial sediment deposits in front of the ice shelf during the Saale glaciation period. The constituents of the reef are not the typical mixed sediment of a moraine but rather well sorted sediments in the form of gravel, grit and sand. Huge accumulations of Holocene marine sand deposits, up to 20 m thick, formed the Horns Rev area as it is known today with ongoing accumulations of sand (Larsen, 2003). Horns Rev can be characterised as a huge natural ridge, that blocks the sand being transported along the coast of Jutland with the current. The annual transport of sand amounts to approximately 500,000 m^3 (Danish Hydraulic Institute, 1999) or even more (Larsen, 2003).

Despite the overall stability Horns Rev is subject to constant changes due to continuous hydrographical impacts such as currents and waves and sedimentations of sand, the latter of which cause the surface of the reef to rise over time (Larsen, 2003).

In the Horns Rev 2 Offshore Wind Farm area the sediment consists of almost pure sand with no or very low content of organic matter (<1%) (Leonhard & Skov, 2006). Formations of small ribbles are seen all over the area, caused by the impact from waves and current on the sandy sediment. Tidal currents create dunes and ribbles, showing evidence of sand transport in both northerly and southerly directions (observed by SCUBA divers, 2005). Larsen (2003) gives a more detailed review of the sediment flow at and around Horns Rev.

All structures in the area apart from those in the tidal channels indicate that the prevailing sediment transport direction east of the reef is towards south and southeast (Larsen, 2003). Large spatial variation regarding the sediment grain size distribution exists, Figure 2.2, and effects of strong currents is found on slopes facing larger depths. Here coarse sand can be found (Leonhard & Skov, 2006).

2.2 Hydrography

Horns Rev is an area of relatively shallow waters, strongly influenced by waves and situated in and area with large tidal fluctuations. The mean tidal range in the wind farm area is about 1.2 m (Danish Hydraulic Institute, 1999). Within the wind farm area the water depth vary from about 4 m to 14 m. The bottom topography in and around Horns Rev along with the shallow waters causes the waves to be breaking in the wind farm area. The average height of the waves height is about 0.6 - 1.8 m.

The hydrography in the Horns Rev area is mainly determined by the intrusion of Atlantic water into the North Sea. Due to the hydrography of the North Sea most water moves erratically in northern direction towards Skagerrak in what is known as Jyllandsstrømmen (Leth, 2003).

However, regarding currents the tide is the most important source of currents at Horns Rev. The prevailing currents move in the north to south direction (220º SSW) with a mean water velocity of 0.5-0.7 m/s. Water velocities above 0.7 and up to 1.5 m/s are not unusual at Horns Rev (Bech et al., 2004; Bech et al., 2005; Leonhard & Pedersen, 2004; Leonhard & Pedersen, 2005).

Due to the tidal currents, shallow water, rough waves and constant mixing of the water, stratification is not likely to occur in the Horns Rev area, and therefore oxygen deficiency is not likely to occur either (Danish Hydraulic Institute, 1999).

The salinity in the area is 30-34 ‰, the level being determined by mixture of the Atlantic water with freshwater from the German rivers and relatively saline water from the North Sea.

Low transparency of the water prevails at Horns Rev due to high concentrations of suspended sediments in the water column is characteristic for the Horns Rev area, and consequently high temporal variability in the water transparency induced by the tidal currents, wind induced currents and seasonal plankton dynamics is found.

For more details about hydrography, see chapter 5.1.

3 The wind farm area

3.1 Description of the wind farm area

The Horns Rev 2 Offshore Wind Farm will be located approximately 30 km west of Blåvands Huk. The distance to the north-western point of Horns Rev 1 Offshore Wind Farm will be approximately 14 km, depending on the exact location of the wind farm.

The area selected by the Danish Energy Authority for the preliminary surveys and studies is shown in Figure 3.1. The establishment of the wind farm is expected to be in one of the designated sites. The exact position of the individual turbines has not yet been decided, and there may be some minor adjustments regarding the positioning of both sites. However, the final placement will be inside the selected area of the preliminary studies.

For Horns Rev 2 Offshore Wind Farm two alternative sites are designated - a northern site and a southern site. The northern site extends northwards from the reef. The southern site extends from east towards west and covers the reef only partly. Both sites cover and area of 35 km^2, which is the maximum size of the Horns Rev 2 Offshore Wind Farm. The water depths at the two sites range from 4-14 m, Figure 3.1.

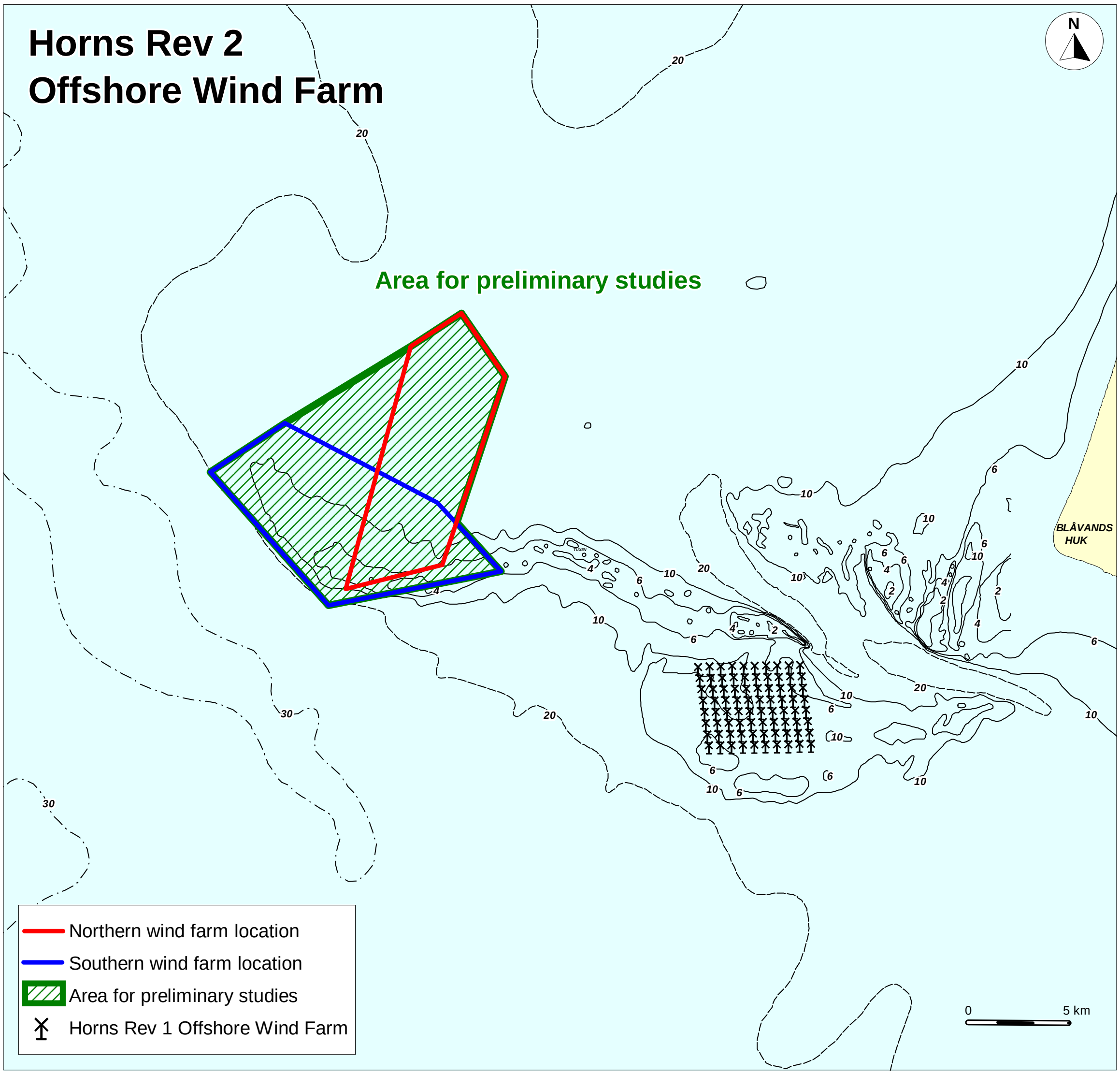


Figure 3.1. The area selected for the preliminary surveys and studies regarding the establishment of Horns Rev 2 Offshore Wind Farm.

3.2 The turbines

The type of turbine to be installed and the type of foundation has not yet been decided. Likewise the location of the turbines in either of the two designated sites has not yet been decided.

The wind turbine technology is undergoing rapid development with regard to design and effect as well as the physical size. In order to take advantage of this development until the commencement of the construction of the wind farm, the final selection of the turbine type will not take place until later. The basic scenario for this EIA is a set up comprising 95 turbines plus possibly 1-3 experimental turbines. The expected distance between the turbines in this set up will be approximately 600 m. However, with an installed total capacity of 200-215 MW for the wind farm, the factual number of turbines may be reduced if larger units are selected.

The experimental turbines are included in this EIA although they will not be part of the wind farm established by ENERGI E2. The maximum total capacity of the experimental turbines will be 15 MW. The maximum height will be 200 metres and the type of foundation will be selected and decided by the developer, independently of what type of foundations will be decided for the wind farm.

Figures 3.2 and 3.3 show the expected row patterns of the turbines at the two alternative sites. However, the exact position is not yet mapped out as some adjustments may still be made depending on the results of the preliminary project and design studies.

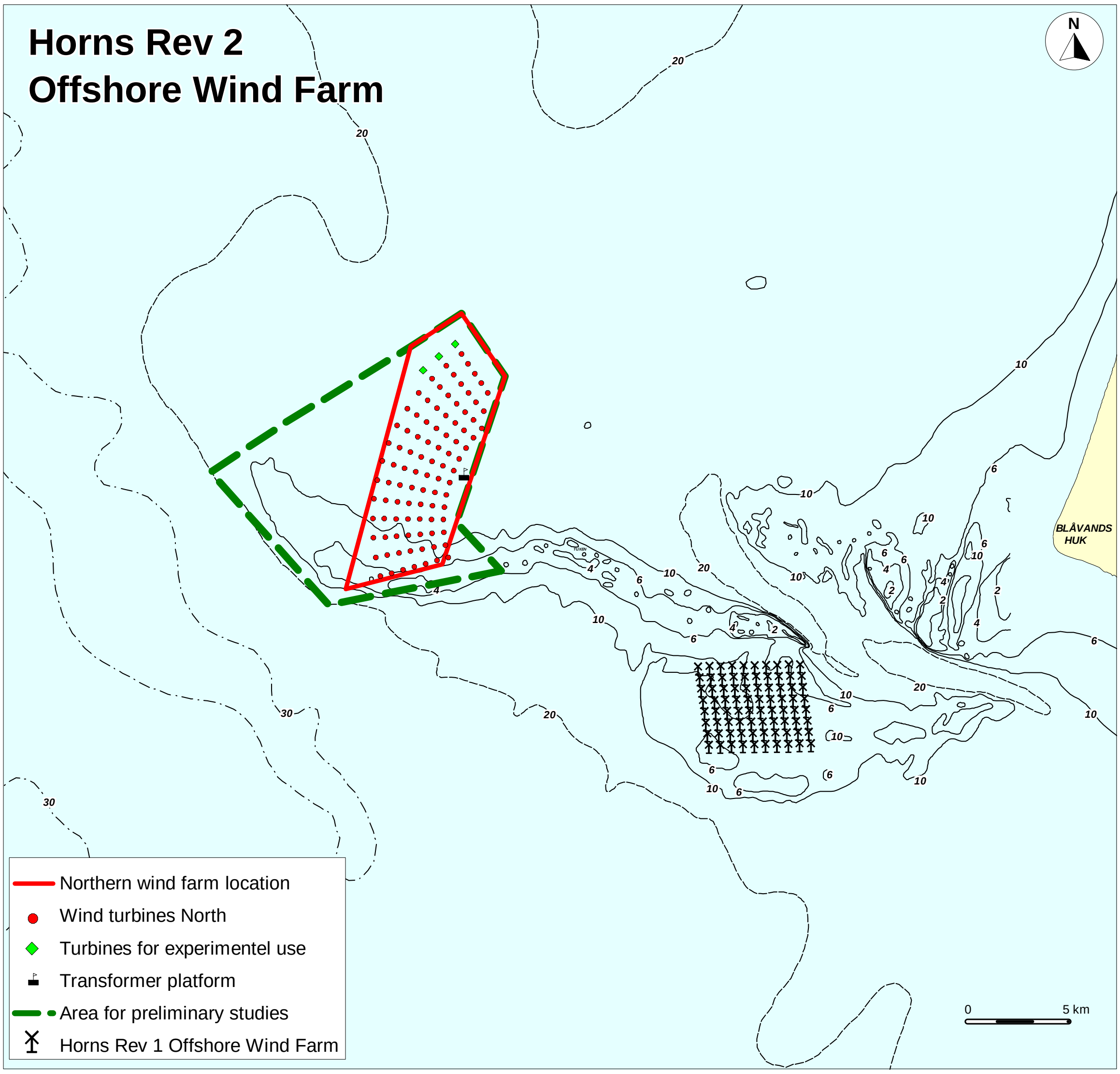


Figure 3.2. The proposed turbine positions at the northern site, the cable connecting the turbines and the transformer platform. Horns Rev 2 Offshore Wind Farm.

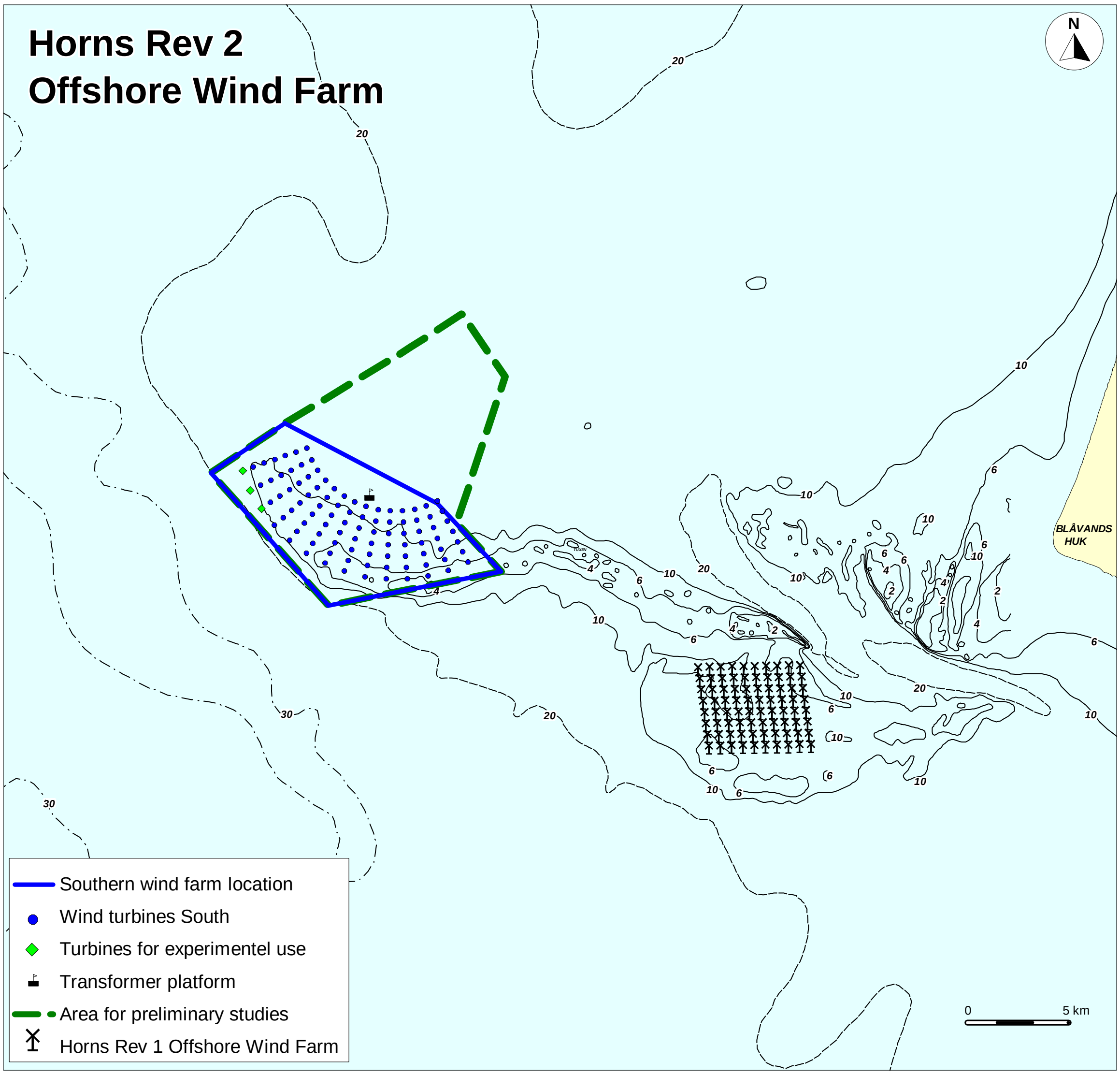


Figure 3.3. The proposed turbine positions at the southern site, the cable connecting the turbines and the transformer platform. Horns Rev 2 Offshore Wind Farm.

3.2.1 Foundation

The foundations of the turbines will either be gravitation foundations or mono-piles. For both types a scour protection is necessary to minimise erosion due to strong currents at the site. The foundations including protection will occupy an area less than 0.3% of the entire wind farm area.

3.2.1.1 Gravitation foundation

The gravitation foundation consists of a flat base to support the basis of the turbine tower. The size of the base is determined by the size of the turbine, but the weight of the basal disc is typically >1000 tones. The gravitation foundation is made of concrete or a steel case filed with heavy weight material such as stones, boulders and rocks. This type of foundation is typically used at water depths in the range 4-10 metres.

The establishment of a gravitation foundation requires preparation of the seabed. This preparation includes removal of the top layer of sediment and construction of a horizontal layer of gravel. Additionally, the gravitation foundation requires scour protection to prevent wave erosion. The scour protection is typically made from boulders and rocks.

3.2.1.2 The mono-pile foundation

The foundations of the existing wind turbines at Horns Rev 1 Offshore Wind Farm are so-called mono-pile foundations. The mono-pile foundation is a steel pile driven into the seabed. The pile is normally driven 10–20 metres into the seafloor, and has a diameter in the range 4-7 metres. The pile diameter and the depth of penetration are determined by the size of the turbine and the sediment characteristics. Opposite to the gravitation foundation no preparation of the seafloor is needed prior to the erection of the turbine. Pile driving is difficult if the seafloor holds large boulders hidden within the sediment. In such cases underwater blasting may be needed.

The mono-pile foundation also needs scour protection, especially when the turbine is situated in turbulent areas with high levels of flow velocities.

3.2.2 Scour protection

The scour protection is a circular construction with a diameter of 25-35m m depending on the type of wind turbine chosen. The scour protection is approximately 1-2m in height above the original seabed and consisting of a protective mattress of large stones with a subjacent layer of smaller stones.

3.2.3 The cable

The wind turbines will be interconnected by 36 kV cables sluiced down to a depth of one metre into the seabed. The cables will connect the turbines to a transformer platform. Each string of cable connects up to 14 turbines. From the transformer platform a submarine 150 kV power cable will be laid to shore. This cable is not included in the EIA.

The power cables are expected to be tri-phased, PEX-composite cables carrying a 50 Hz alternating current. The cables have a steel armament and contain optical fibres for communication.

3.2.3.1 Electromagnetic fields

Transportation of the electric power from the wind farm through cables is associated with formation of electromagnetic fields around the cables.

Electromagnetic fields emitted from the cables consist of two constituent fields: an electric field retained within the cables and a magnetic field detectable outside the cables. A second electrical field is induced by the magnetic field. This electrical field is detectable outside the cables (Gill et al., 2005).

In principle, the three phases in the power cable should neutralise each other and eliminate the creation of a magnetic field. However, as a result of differences in the distance between each conductor and differences in current strength, a magnetic field is still produced from the power cable. The strength of the magnetic field, however, is assumed considerably less than the strength from one of the conductors. Due to the alternating current, the magnetic field will vary over time.

4 Methods

4.1 Assessment methodology

The main effects of the establishment of Horns Rev 2 Offshore Wind Farm on the water quality are identified and assessed according to certain criteria shown in Table 1.

The significance of the impacts on the water quality has been evaluated by taking into account the status of the water quality and the magnitude of any potential impacts.

The magnitude is determined on the basis of the vulnerability, spatial and temporal incidence of any impacts and the ability of the conditions to recover.

In determining the significance of an impact, ‘magnitude’ is assessed against ‘importance’ to provide a range of significance from ‘negligible’ to ‘major’, table 4.2.

Table 4.1. Criteria for the assessment of impacts (after DONG, 2006).

Criteria	Factor	Note
Importance of the issue	International interests National interest Regional interest Local areas and areas immediately outside the condition Only to the local area Negligible to no importance	In physical and biological environment local area is defined as wind farm area
Magnitude of the impact or change	Major Moderate Minor Negligible or no change	The levels of magnitude may apply to both beneficial/positive and adverse/negative impacts
Persistence	Permanent –for the lifetime of the project or longer Temporary – long term – more than 5 years Temporary –medium-term- 1-5 years Temporary –short term- less than 1 year	
Likelihood of occurring	High (>75%) Medium (25-75%) Low (<25%)	
Other	Direct/indirect impact – caused directly by the activity or indirectly by affecting other issues as an effect of the direct impact; Cumulative –combined impacts of more than one source of impact	

Table 4.2. Ranking of significance of environmental impacts (after DONG, 2006).

Significance	Description
Major impact	Impacts of sufficient importance to call for serious consideration of change to the project
Moderate impact	Impacts of sufficient importance to call for consideration of mitigating measures
Minor impact	Impacts that are unlikely to be sufficiently important to call for mitigation measures
Negligible – No impact	Impacts that are assessed to be of such low significance that are not considered relevant to the decision making process

Residual impacts will be presented using the criteria outlined in table 4.3.

Table 4.3. Ranking of significance of residual impacts (after DONG, 2006).

Issue	Importance	Magnitude	Persistence	Likelihood	Other	Significance
Xxx	Local	Minor	Temporary	High		Minor

4.2 Baseline data

The main part of the background data originates from the County of Ribe's monitoring of the local coastal waters. Only very limited fieldwork to assess water quality has been undertaken in connection with the present EIA. During fieldwork in the project area secci depth readings were conducted.

Since 1998, the County of Ribe has monitored water quality by monthly visits to four stations south of Blåvands Huk. The four stations are named as Blåvand East, Blåvand West, Sønderho East and Sønderho West. The depths at the stations are approximately 4 m, 14 m, 4 and 14 m, respectively.

The station at the position Blåvand West (BW) (position: E 55º25,00 N 07º55,00 Ø) is situated approximately 5 nautical miles from the planned wind farm site. For this reason it can be regarded as representative of the area. Salinity, temperature, oxygen and transparency (Secci disc transparency) have been recorded throughout the water column at each of the stations. Water samples have also been taken from the surface layer for analysis of the plant nutrients nitrogen, phosphorus and silicate, and for quantitative analysis of the phytoplankton community and chlorophyll *a*. Primary production measurement are available for the period 1990-1998.

4.3 Additional background data

Additional information has been extracted from technical reports based upon monitoring activities carried out by the Danish Environmental Research Institute (NERI) as well as the Norwegian Institute for Marine Research (IMR) in the project area over a period of several years. The NERI winter cruises were conducted in February. The spring cruises conducted by IMR were conducted during the period March-April. Furthermore, modeled data on sea surface temperature, salinity, current speed and direction as well as in-situ satellite mappings of sea surface temperature and chlorophyll biomass have been provided from Internet based resources such as MONCOZE (http://moncoze.met.no.html) and NERSC (http://hab.nersc.no).

The hydrographic conditions of the project area, including salinity and temperature, are discussed in detail by the Danish Environmental Agency in a report from 1991 entitled "The Coastal Currents of Jutland", (Danish Environmental Agency, 1991).

The assessment will be conducted based upon available information on the water quality within the project area in combination with experiences gained from demonstration projects carried out in conjunction with Horns Rev 1 Offshore Wind Farm.

Impacts during the pre-construction phase, the construction phase, the operational phase and during the decommissioning of the turbines will be assessed. The assessment will include cumulative effects of the present wind farm and the planned new offshore wind farm at Horns Rev.

Only the impacts within the project area are considered. The impact of the cable laying in the cable trace from the project area to the shore will not be considered.

4.4 Assessment of cumulative effects

The assessment cumulative impacts in connection with the establishment of Horns Rev 2 Offshore Wind Farm are by definition impacts that may result from the combined or incremental effects of past, present or future developments in the Horns Rev area on the water quality.

Past, present and future developments will be identified from existing information as well as on expert judgement of the potential impacts on the water quality in the project area. A special focus will be on the existing offshore wind farm (Horns Rev 1 Offshore Wind Farm) and on existing marine aggregate extractions sites.

4.5 Designation of reference sites and areas

Reference sites might be appointed according to similarities in the physical setting as well as water quality characteristics with the appointed wind farm project area.

5 Hydrography, water chemistry and phytoplankton

5.1 Circulation and hydrography

As a result of the Coriolis effect, the water circulation in the North Sea is counter clockwise. The major part of the water in-flow to the North Sea is north of Scotland and the Shetland Isles. The in-flowing water passes southwards along the east coast of Scotland and England. Compared to this input the inflow from the English Channel to the Southern part of the North Sea is only approx. 10%. Freshwater run-off from the major European rives constitutes only a minor amount of water compared to the inflow from the Atlantic. However, it results in the formation of a distinct water mass, called the Continental Coastal Water, which flows like a coastal plume north-wards along the Wadden Sea coast and the Danish west Coast. As this coastal jet reaches the West Coast of Jutland it is called the Jutland Current. The major out-flow from the North Sea goes through the Norwegian trench, figure 5.1.

The project area at the Horns Reef is situated within the Jutland Current, which is neighbouring the Central North Sea water masses. The Central North Sea is situated in the transition zone between the permanently stratified water masses of the Northern part of the North Sea and the non-stratified water masses of the southern part of the North Sea. The Jutland current is separated from the Central North Sea water masses by a marked front.

The average current speed in the Jutland current can be calculated to 0.05-0.1 m/s, Richardson & Jacobsen 1990. However, during field investigations at the Horns Rev 1 Offshore Wind Farm it has been observed that local current speeds can exceed 1 m/s, Bio/consult as, unpublished results.

The development of the Jutland Current is strongly dependent upon wind speed and direction. During periods with southerly winds the Jutland Current continues all along the west coast of Jutland, north of Skagen into the Skagerrak. In situations with north and north-westerly winds the Jutland Current can be blocked and/or temporarily dispersed into the Central North Sea water masses, Richardson & Jacobsen 1990.

Due to the shallow depth at the Horns Reef the modelled current speeds at the reef is slightly slower than in the Jutland Current outside the Horns Reef area, figure 5.2.

Stratification is only likely to occur at the Horns Reef in very short periods with calm weather. This is due to the shallow water depth at the Horns reef itself in combination with wind/current induced turbulence. In contrary, stratification is rather common in the deeper adjacent waters in the front zone, bordering the Central North Sea as well as in the Central North Sea.

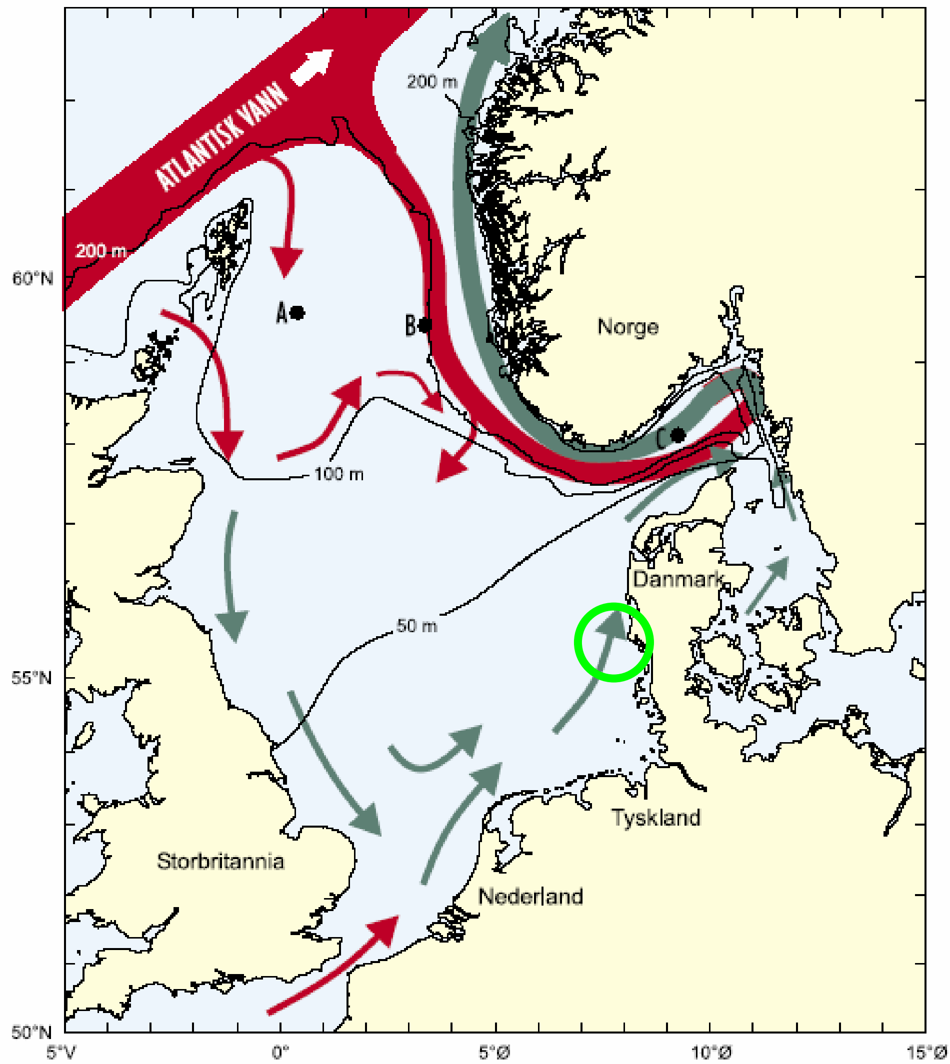


Figure 5.1. The general circulation of the North Sea. The Horns Reef area is marked with a green ring. From: Skjoldal, R. 2005. Havets ressourcer og Miljø 2005, Kapitel 4: Nordsjøen/Skagerrak.

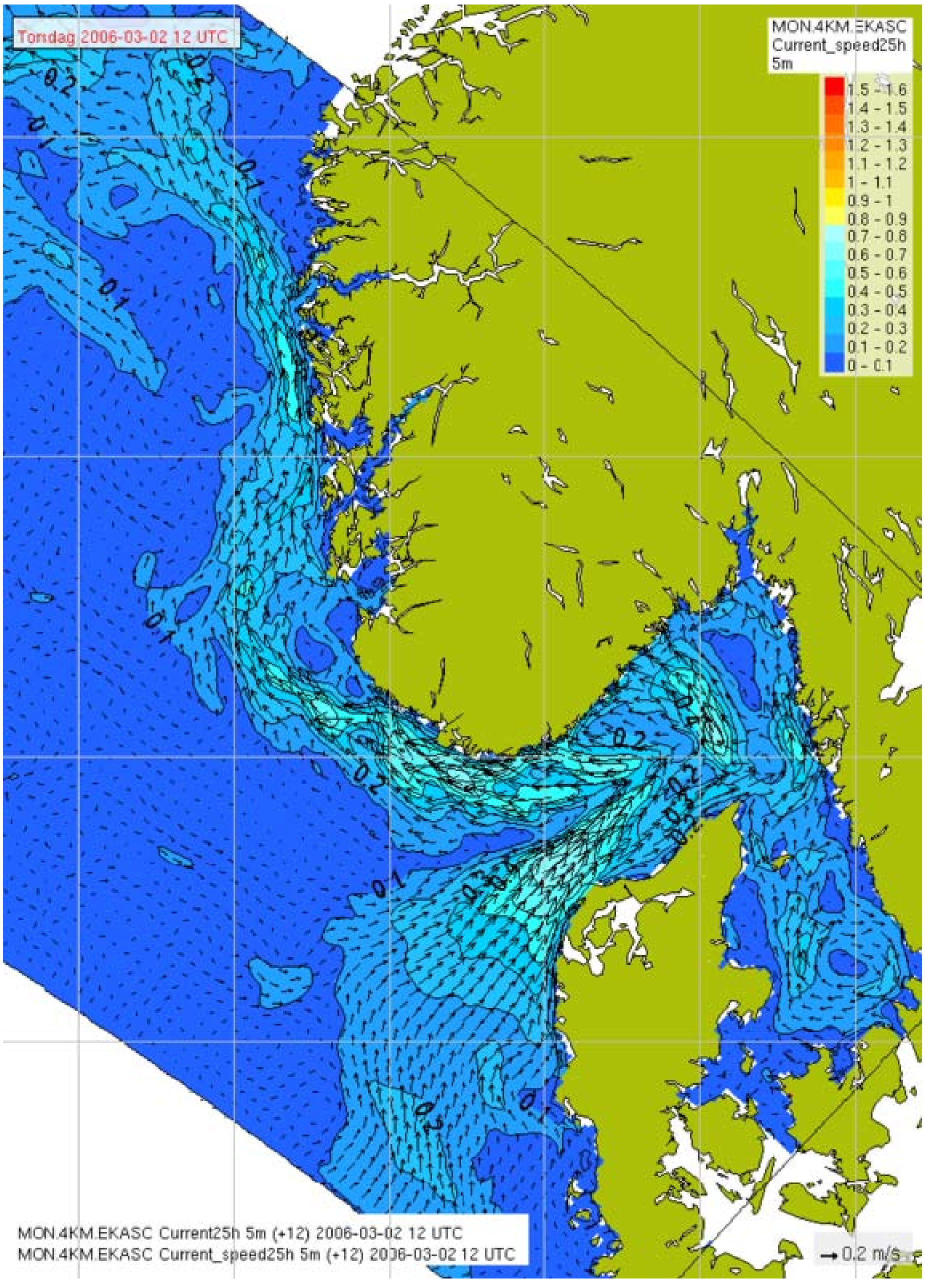


Figure 5.2. The modelled surface circulation of the North Sea on 2nd of March 2006. Source: **http://moncoze.met.no.html**

5.1.1 Salinity

The salinity in the project area is within the range of 30–34 psu. The salinity is partially determined by the inflow of fresh water from the German rivers to the German Bight, and partially by the supply of relatively saline water from the North Sea. As a result of the massive fresh water supply to the Wadden Sea region, the surface salinity decreases from north to south along the west coast of Denmark. The salinity of the project area is also dependent on the season, figure 5.3 and 5.4, and on the prevailing wind conditions.

There is no permanent halocline in the area. Small differences in salinity of 1–1.5 psu 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.

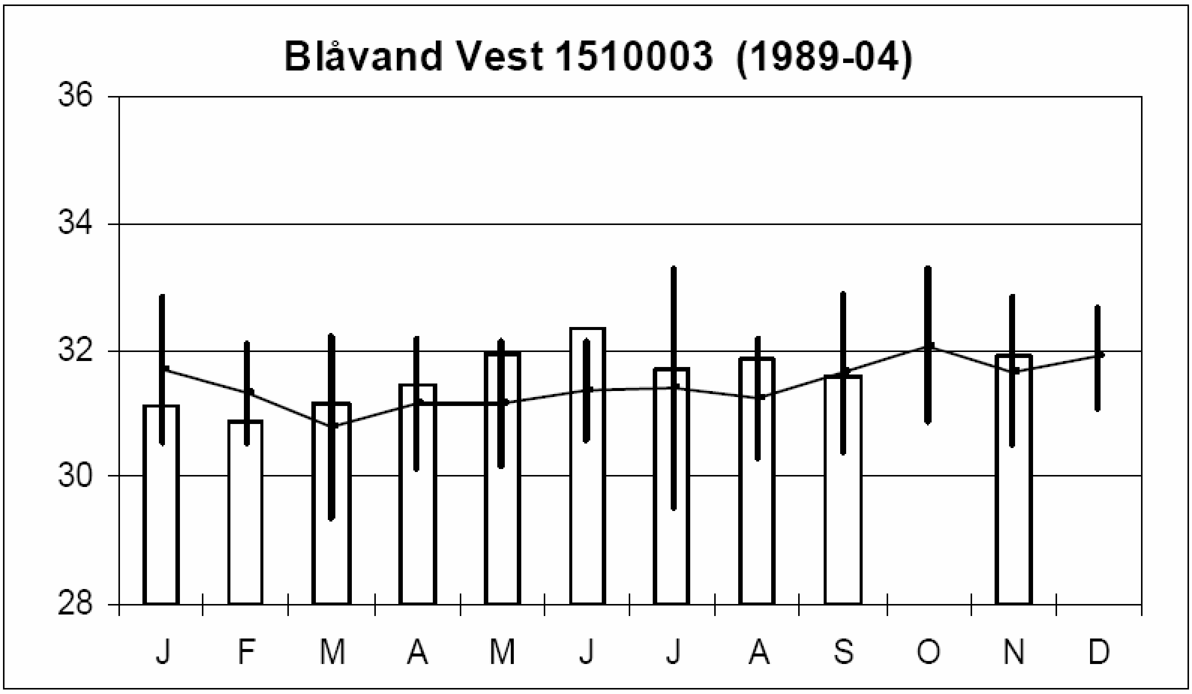


Figure 5.3. Surface salinity (depth 1 m) at the station at Blåvand West during 2004 as well as the average monthly salinities for the period 1989-2003 with indication of the SD, County of North Jutland, County of Viborg, County of Ringkjøbing and County of Ribe, 2005.

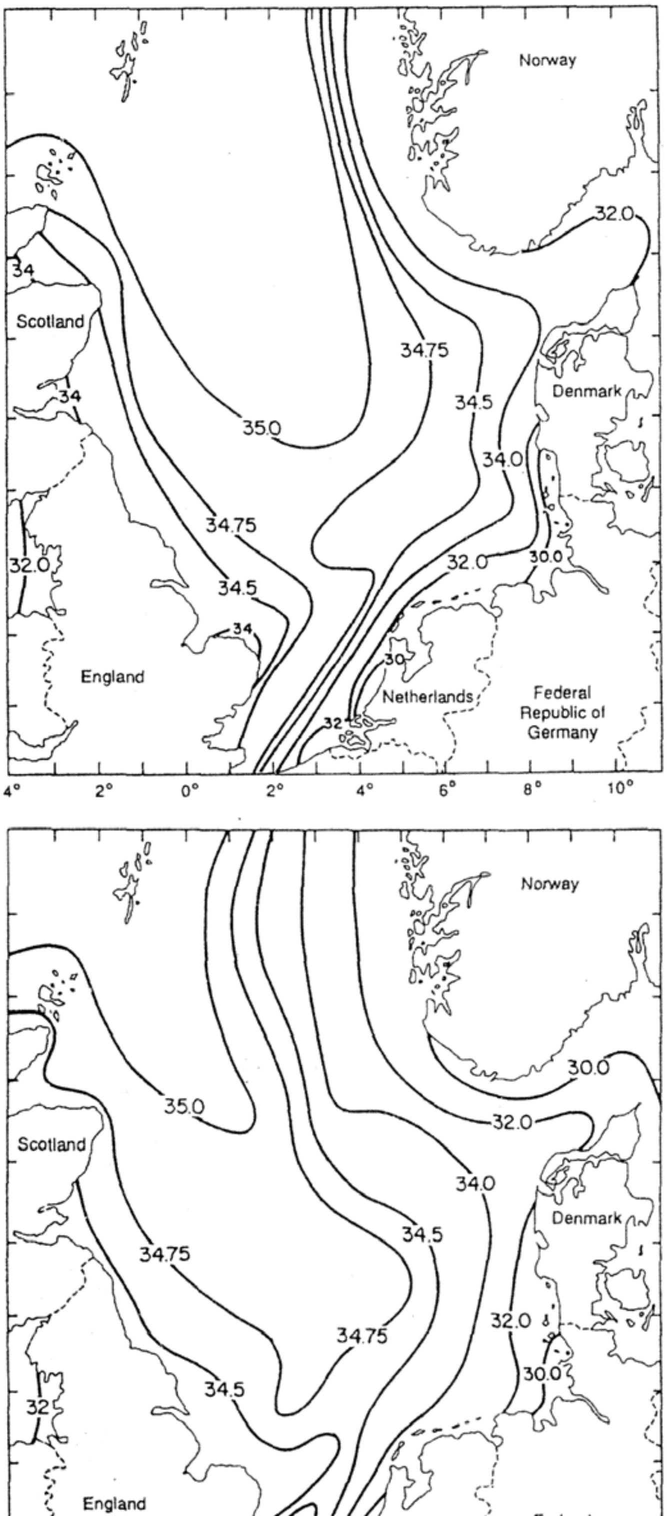


Figure 5.4. Surface salinity in the North Sea in February (upper panel) and August (lower panel), according to the Danish Environmental Agency (1991).

5.1.2 Temperature

Surface temperatures at the station at Blåvand West varies according to season, figure 5.5. The lowest temperatures are observed during winter/early spring and the highest during the period July-August. During the winter period the temperatures in the project are lower in the coastal areas including the project area compared to the central North Sea. During summer the opposite is the case, figure 5.6.

The County of Ribe's measurements generally observe the same temperature in the surface and the bottom layers at station Blåvand West. This is due to mixing by wind and tide. Thermoclines occur in the adjacent central part of the North Sea during most of the summer period.

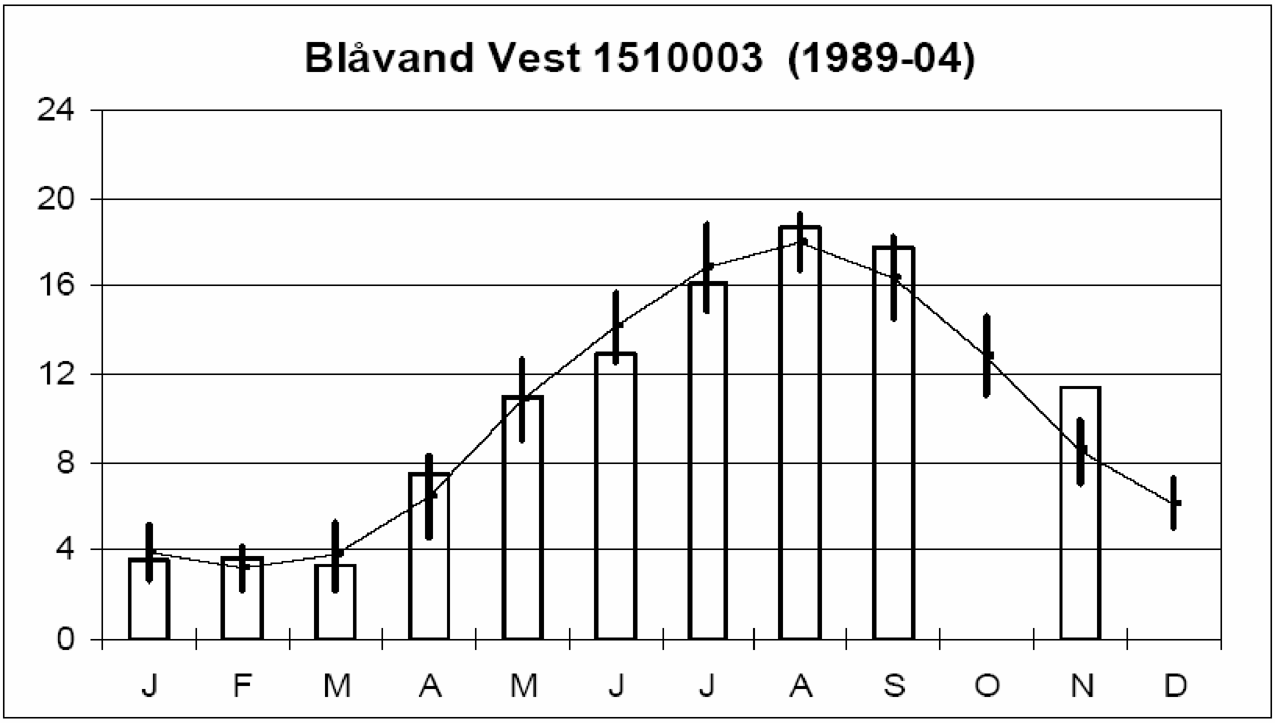


Figure 5.5. Surface temperature (depth 1 m) at the station at Blåvand West during 2004 as well as the average monthly salinities for the period 1989-2003 with indication of the SD, County of North Jutland, County of Viborg, County of Ringkjøbing and County of Ribe, 2005.

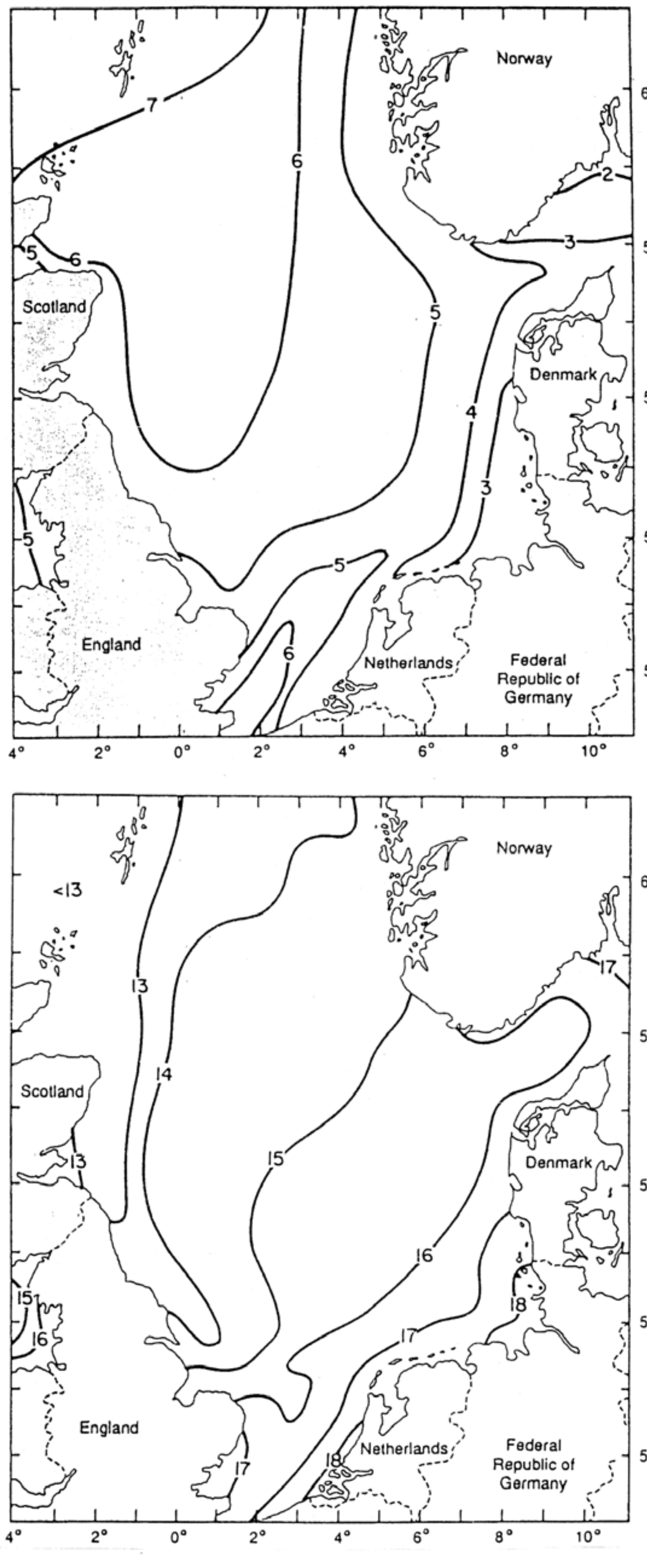


Figure 5.6. Surface temperature in the North Sea in February (upper panel) and August (lower panel), according to the Danish Environmental Agency (1991)

5.2 Water chemistry

The County of Ribe's monitoring of water quality at Blåvand West includes measurements of the inorganic plant nutrients nitrogen, phosphorus and silica in the surface layer. Analysis of the plant pigment chlorophyll *a*, which gives a rough measurement of the content of phytoplankton in the water, was also carried out at the station.

The general picture for most of the parameters used to determine the water quality is that there is a decrease in the concentrations moving northwards from the Wadden Sea along the west coast of Denmark. Winter levels at Blåvand West are between 1.5 and 2.0 times the levels at Hirtshals. The water-quality gradient, with the highest values for nutrients and chlorophyll *a* in the most southerly part of the North Sea, primarily reflects the discharge of nutrient-rich water from the German rivers. Other sources of nutrient loading that are worthy of mention are regional run-off from land, and atmospheric deposition over the North Sea. No quantitative partitioning of the various sources is available.

The conclusions made in the present report are primarily based on winter values for nutrient concentrations, since these are less affected by the influences of biological processes than summer values, and are thus more readily comparable.

There can be significant variation from year to year, even for winter levels. This is partly explained by differences in meteorological and hydrographical conditions at the sampling times.

5.2.1 Inorganic nutrients

The concentrations of the inorganic nutrients nitrogen, phosphorous and silicate display identical overall seasonal patterns. Accumulating and high concentrations are observed during the winter period where the phytoplankton activity is very low. The phytoplankton primary production increases during the spring. As a result of this the demand of inorganic nutrients by the phytoplankton soon increases beyond the supply of nutrients to the water and the consequently the concentrations of nutrients begin to decrease. The first nutrients which reach the level of limitation for the phytoplankton are silicate and phosphorous. Limiting concentrations (N = 28 µgN/l and P = 6.2 µgP/l) are reached for phosphorous in April, figure 5.10. For nitrogen, the decrease continues for another 1-2 months and in 2004 reach limiting concentrations in June, while the average monthly concentrations for the period 1989-2003 reach limiting concentrations not until August/September figure 5.7.

During the autumn period the phytoplankton become light limited and the consumption of inorganic nutrients decreases. This results in an increase in the concentrations in the inorganic nutrients which continue to increase until the following spring.

The winter concentrations of inorganic nutrients reflect the nutrient load to the area. Winter concentrations of inorganic nitrogen and inorganic phosphorus show more or less unchanged levels, although with a slight tendency to a decrease in the concentration level of nitrogen during the end of the period 1991-2004, while concentrations of inorganic phosphorous stays at the same level during the period. On the other hand there is a tendency to increased silicate winter concentrations during the period 1998-2004.

The marked nutrient load to the Wadden sea area and the Jutland Current from run-off from land is revealed by the horizontal distribution of nitrate at 10 m depth in the North Sea and Skagerrak in April 2004 which shows a marked concentration increase in the Jutland Current compared to the water masses in the Central north Sea, figure 5.9.

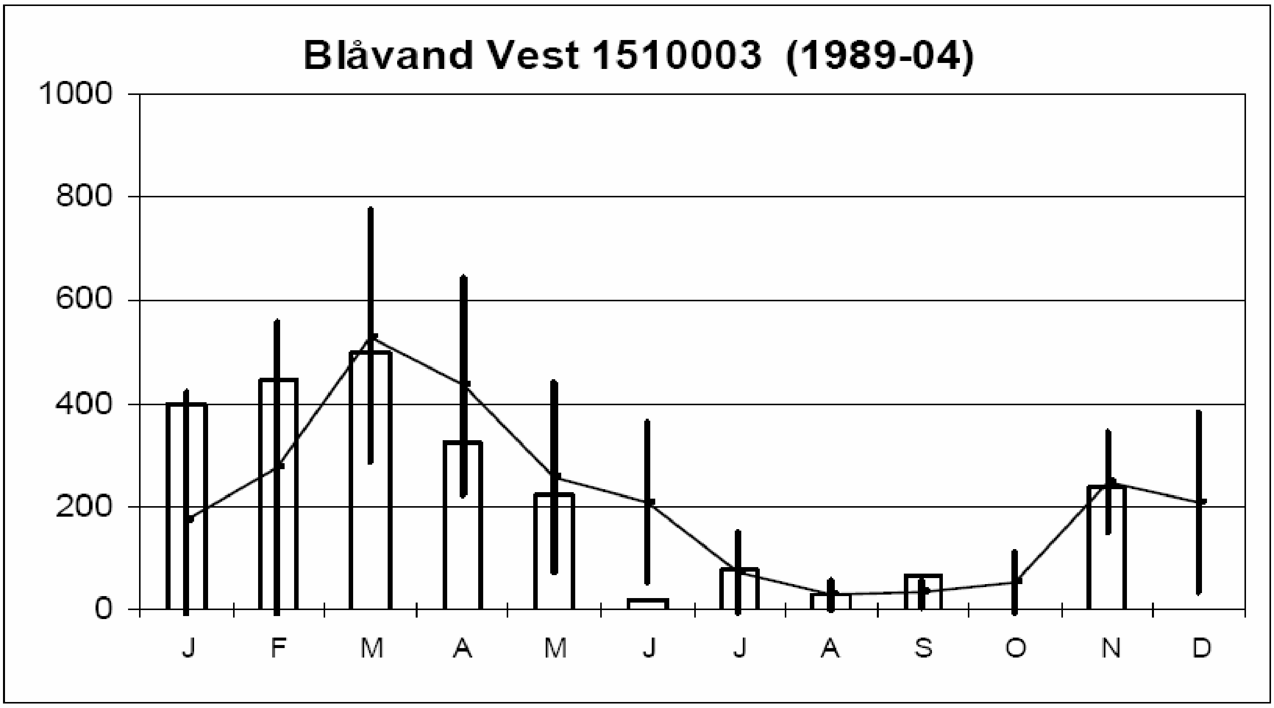


Figure 5.7. Surface (depth 1 m) concentrations of DIN (µgN/l) at the station at Blåvand West during 2004 as well as the average monthly concentrations for the period 1989-2003 with indication of the SD, County of North Jutland, County of Viborg, County of Ringkjøbing and County of Ribe, 2005.

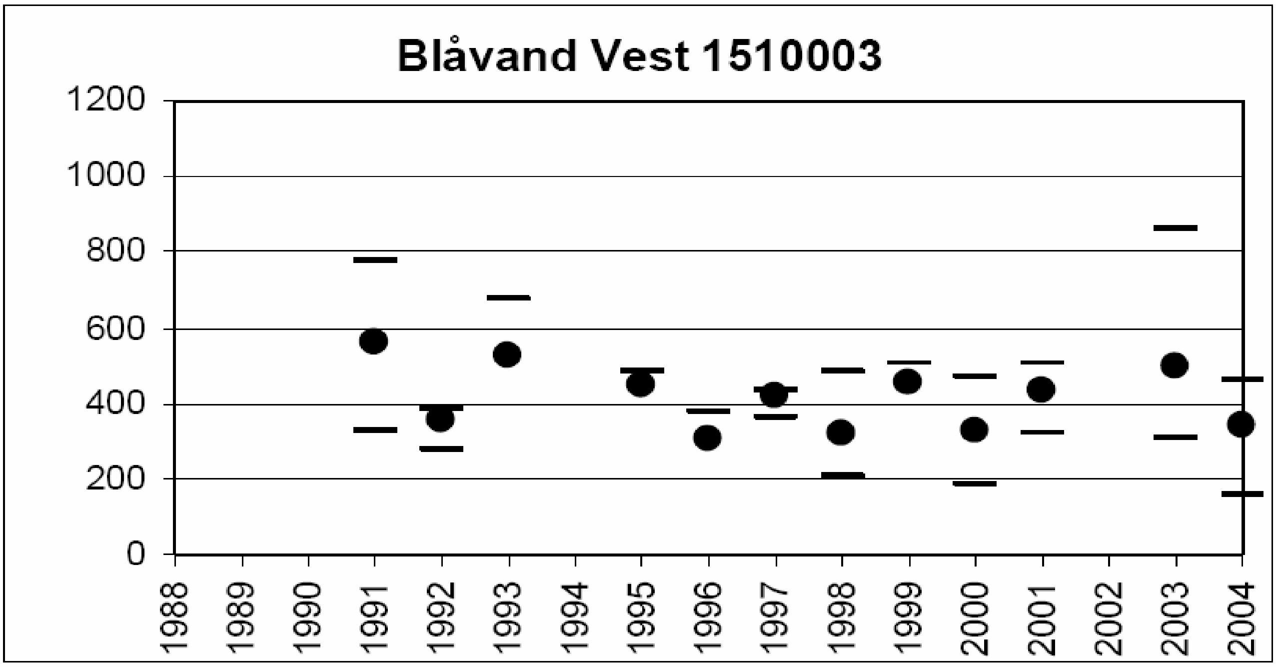
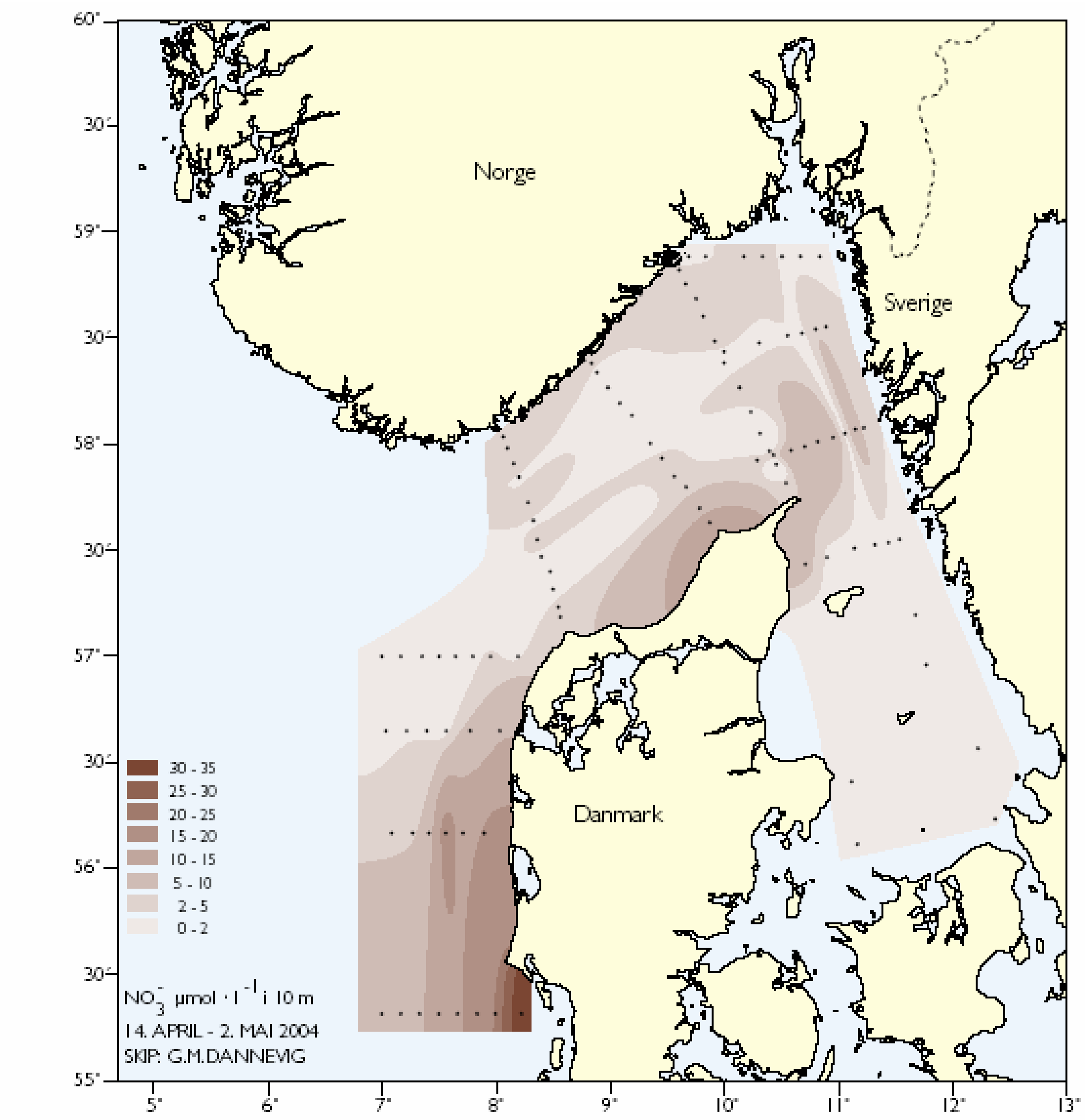


Figure 5.8. Time weighted winter (December-January) averages of DIN (µgN/l) at the station at Blåvand West, County of North Jutland, County of Viborg, County of Ringkjøbing and County of Ribe, 2005.



Figur 4.2.2.2
Horisontal fordeling av nitrat i 10 m dyp i Nordsjøen og Skagerrak i april 2004.
Horizontal distribution of nitrate at 10 m depth in the North Sea and Skagerrak in April 2004.

Figure 5.9. Horisontal distribution of nitrate at 10 m depth in the North Sea and Skagerrak in April 2004, from: Svendsen, E. et al. 2005. Havets ressourcer og Miljø 2005, Kapitel 4: Økosystem Nordsjøen/Skagerrak.

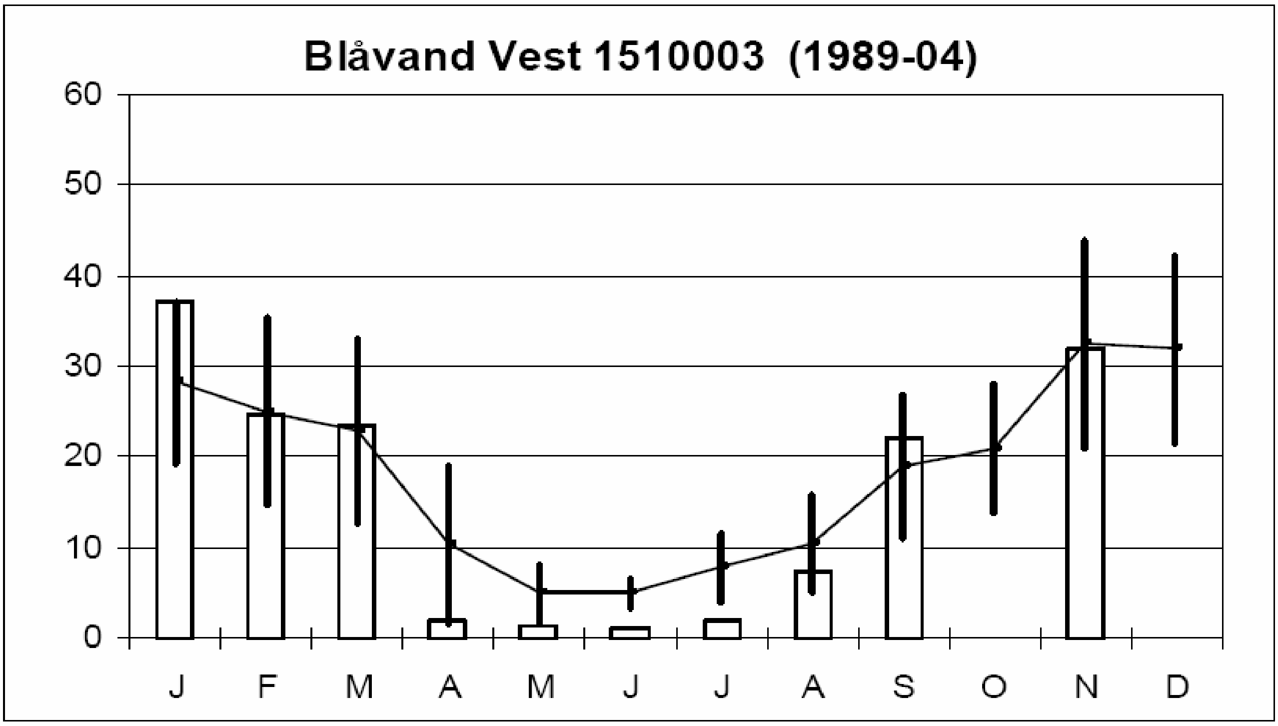


Figure 5.10. Surface (depth 1 m) concentrations of DIP = Ortho-phosphate (µgP/l) at the station at Blåvand West during 2004 as well as the average monthly concentrations for the period 1989-2003 with indication of the SD, County of North Jutland, County of Viborg, County of Ringkjøbing and County of Ribe, 2005.

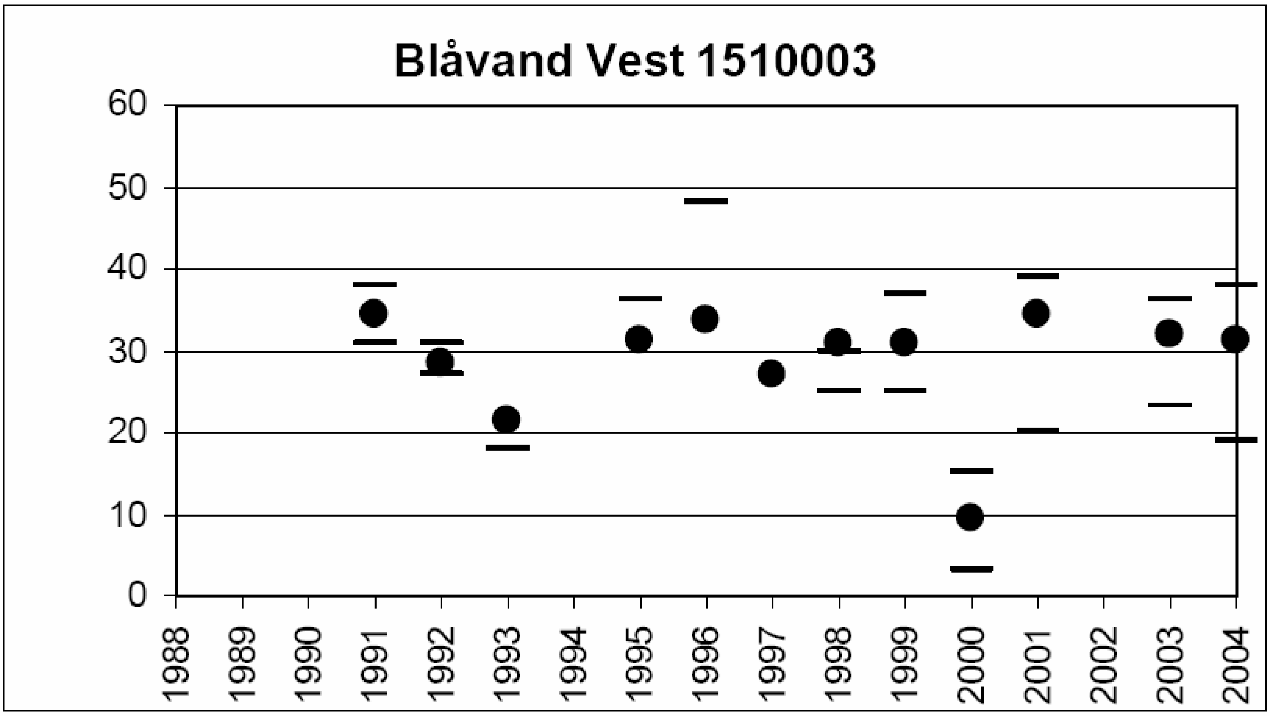


Figure 5.11. Time weighted winter (December-January) averages of DIP (µgP/l) at the station at Blåvand West, County of North Jutland, County of Viborg, County of Ringkjøbing and County of Ribe, 2005.

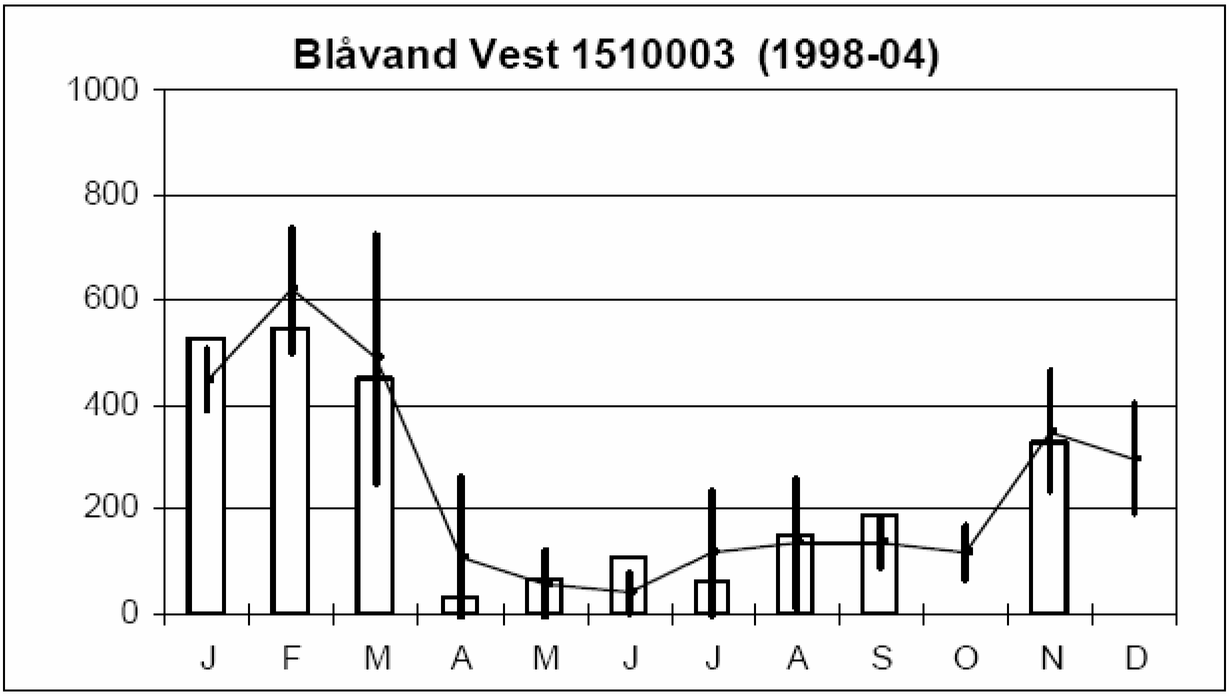


Figure 5.12. Surface (depth 1 m) concentrations of dissolved silicate (µgSi/l) at the station at Blåvand West during 2004 as well as the average monthly concentrations for the period 1998-2003 with indication of the SD, County of North Jutland, County of Viborg, County of Ringkjøbing and County of Ribe, 2005.

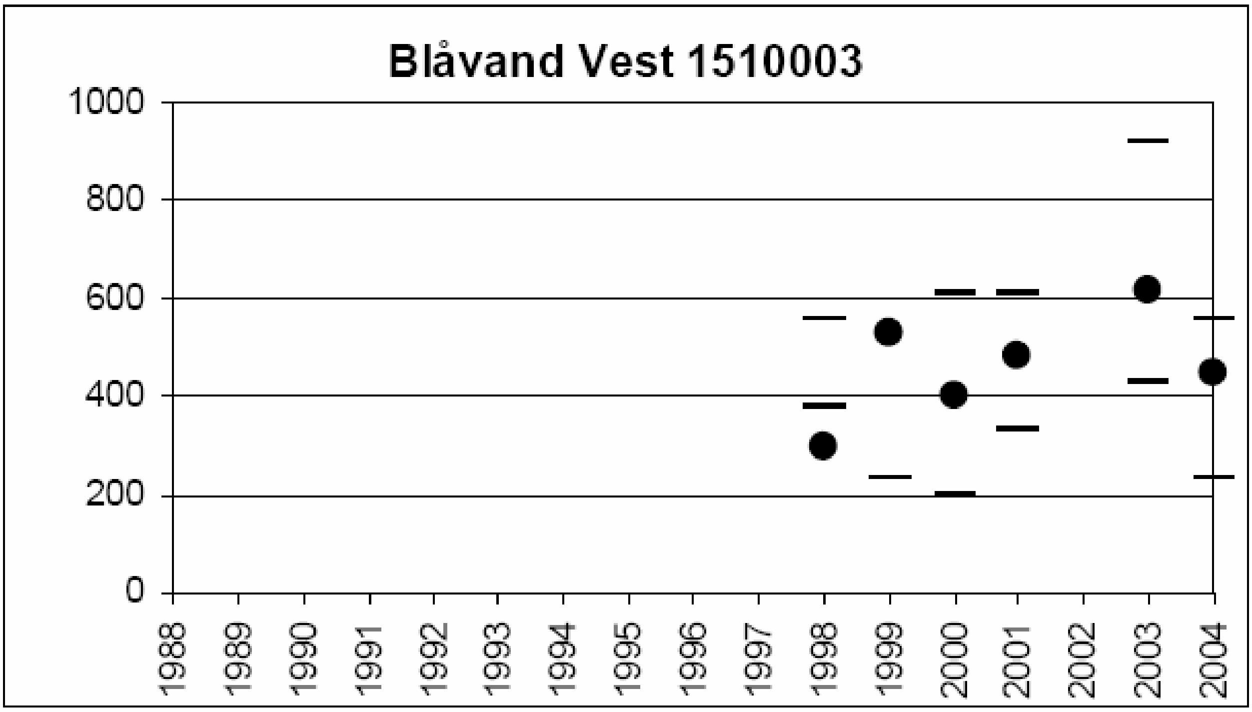


Figure 5.13. Time weighted winter (December-January) averages of dissolved silicate (µgSi/l) at the station at Blåvand West, County of North Jutland, County of Viborg, County of Ringkjøbing and County of Ribe, 2005.

5.2.2 Oxygen

Oxygen concentrations in the project area are high, as a result of the generally good mixing conditions in the coastal areas of the North Sea. It is however worth mentioning that low oxygen concentrations (4–5 mg O_2/l) and hypoxic conditions (<2 mg O_2/l) have been recorded along the west coast of Jutland and in the German Bight, in an area north and north-west of Horns Rev during 1981–86, and in Grådyb in 1995 (Gerlach, 1988 and North Sea Task Force, 1993). The potential of this part of the south eastern North Sea to develop low bottom concentrations of oxygen is also revealed by modelling the oxygen concentrations in the middle of august 2004, figure 5.14. Lowered absolute concentrations of oxygen during the summer period are observed in the surface waters at the station Blåvand West, figure 5.15, and is mainly caused by the high temperatures which decreases the solubility of oxygen in the water.

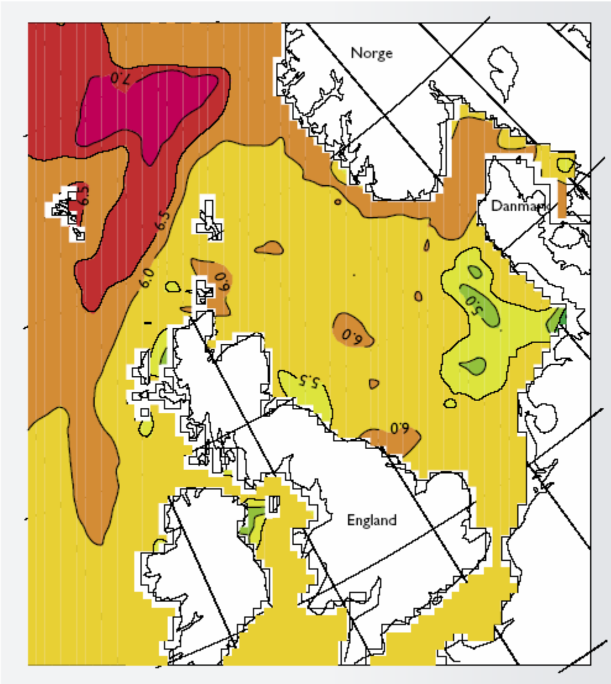


Figure 5.14. Modelled bottom oxygen concentrations in the middle of august 2004. Source: Svendsen, E. et al. 2005. Havets ressourcer og Miljø 2005, Kapitel 4: Økosystem Nordsjøen/Skagerrak.

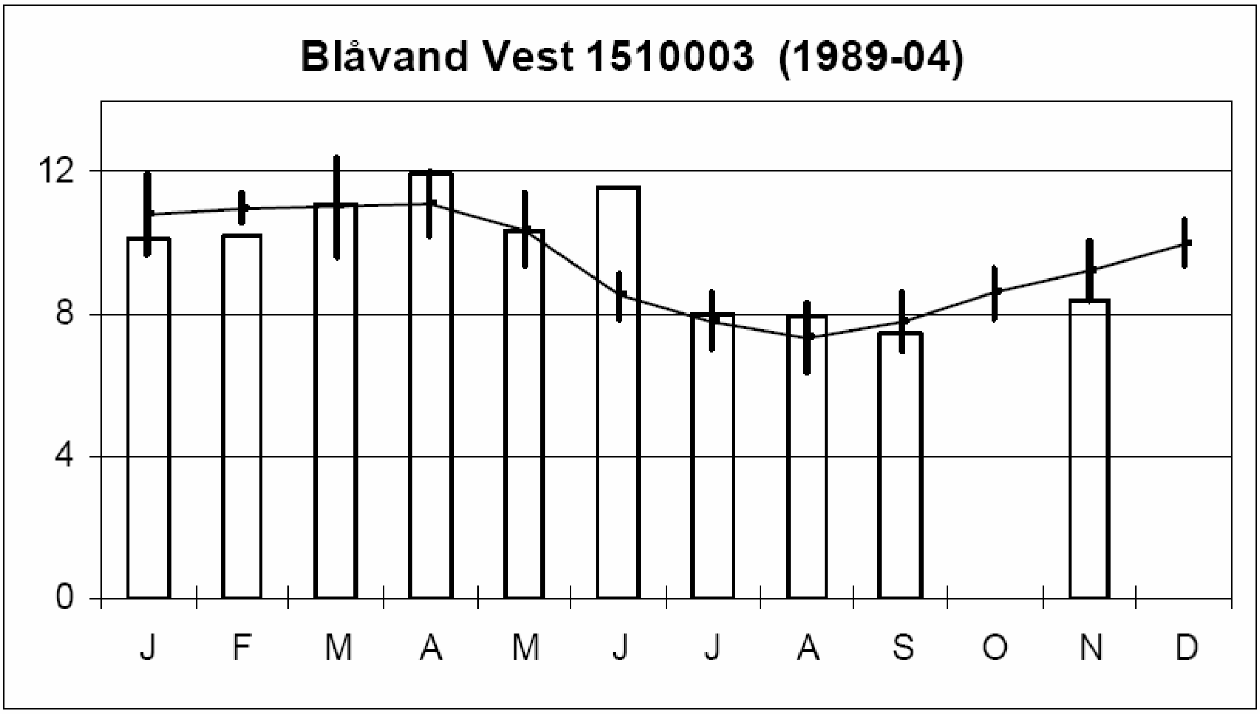


Figure 5.15. Bottom oxygen concentrations (mg/l) on the station at Blåvand West, County of North Jutland, County of Viborg, County of Ringkjøbing and County of Ribe, 2005.

5.2.3 Plankton, primary production and transparency

5.2.3.1 Phytoplankton

The County of Ribe has not collected or analysed phytoplankton samples from the station at Blåvand West. Chlorophyll concentrations have instead been measured. The chlorophyll concentration gives a rough measure of the phytoplankton biomass and has been found to lie in the region 3–5 µg Chl/l during the spring and 5–10 µg Chl/l during the summer. The yearly average concentrations of chlorophyll were recorded during the period 1989–2004. The yearly average chlorophyll concentrations lie in the region 2-10 µgC/l, figure 5.18.

The phytoplankton in the coastal area of the south-east covered by the Jutland current often contain enhanced phytoplankton biomasses compared to the Central North Sea, figure 5.16. The phytoplankton biomass of the North Sea is dominated by diatoms, dinoflagellates and naked flagellates, County of North Jutland, County of Viborg, County of Ringkjøbing and County of Ribe, 2005. Diatoms dominate the phytoplankton biomass during spring and late summer/autumn where as naked flagellates and dinoflagellates can dominate in the period may-july, figure 5.17. In most years the phytoplankton biomass is dominated by diatoms, but dinoflagellates and naked flagellates can constitute significant parts of the biomass in some years such as 1990 and 1999 and 2000, figure 5.19. Major blooms of phytoplankton causing discoloration of the water are a recurrent phenomenon in the project area, County of North Jutland, County of Viborg, County of Ringkjøbing and County of Ribe, 2005.

Harmful algae: Blooms of the colony-forming flagellate *Phaeocystis* are frequently observed during early summer. If wind and currents bring large amounts of algae onto the shore, foam can be formed along the coastline when the blooms break down.

Furthermore, major blooms of diatoms and dinoflagellates are often observed during the summer period.

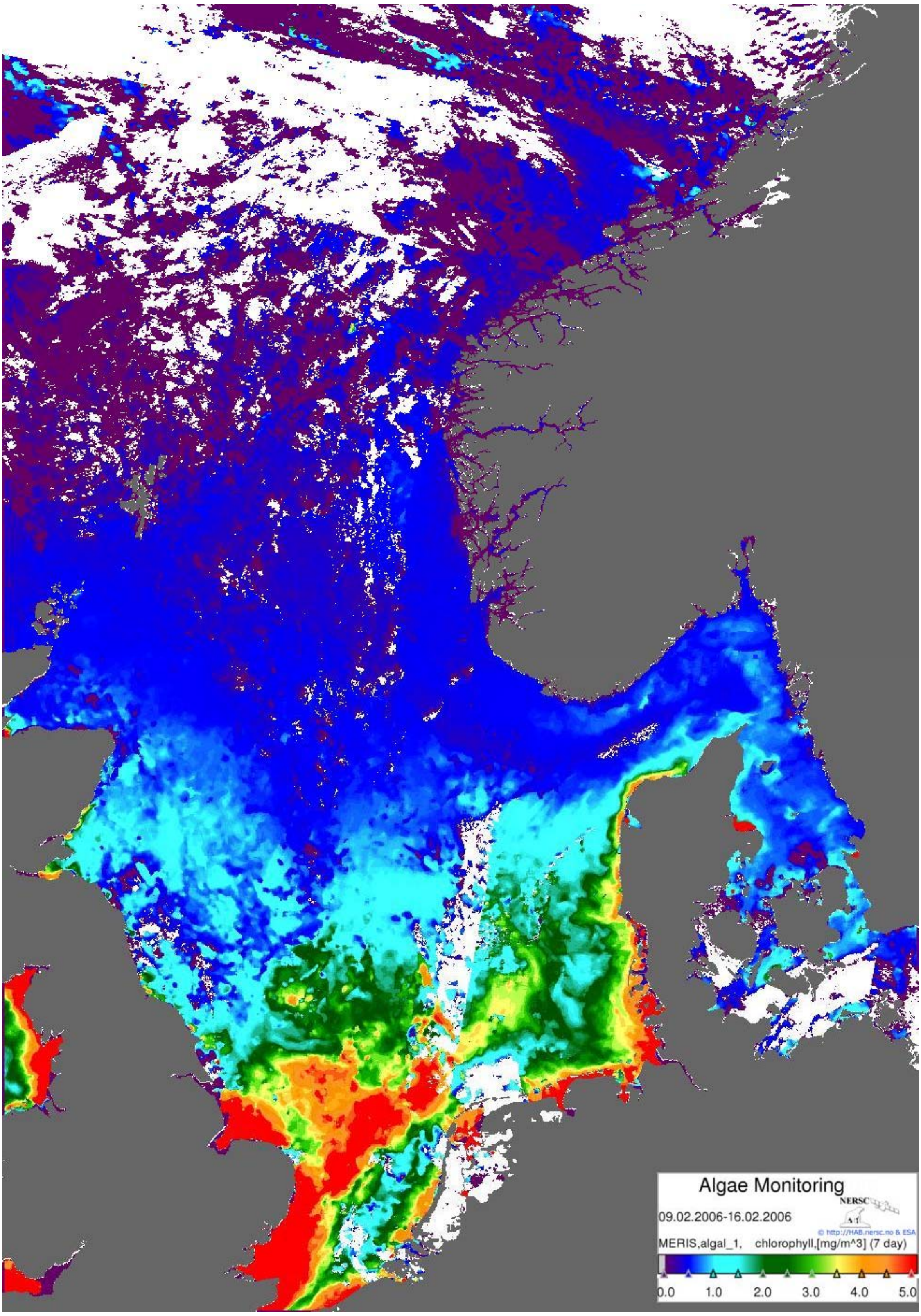


Figure 5.16. Distribution of phytoplankton measured as chlorophyll from satellite during the period from 9 to 16 of February2006 showing high biomasses in the North Sea coastal waters including the Jutland Current and the project area, Source: Lasse H. Pettersson, Nansen Center, Bergen, http://HAB.nersc.no.

Blooms of the heterotrophic dinoflagellate *Noctiluca scintillans*, which gives phosphorescence, are often recorded in the late summer. Local areas with hypoxic conditions can occur if there are calm weather conditions in connection with the build up of the bloom, and particularly at the time of its collapse. This can create unpleasant conditions on bathing beaches.

Toxic algae, including the genus *Dinophysis*, are common in the Wadden Sea area during summer. The presence of toxic algae can result in accumulation of algal toxins in shellfish such as the common mussel, the cockle and the trough shell. At present no negative effects from DSP toxins have been documented on fish, birds and mammals in the Wadden Sea area. Several instances of Diarrhoeic Shellfish Poison (DSP) above the regulatory levels have been recorded in bivalves from the Wadden Sea and from Horns Rev in the period 1991–03 (Andersen and Thorbjørnsen, 2004). ASP toxins, which, like DSP toxins, can accumulate in shellfish, are produced by toxic algae from the diatom genus *Pseudo-nitzschia*. Blooms of *Pseudo-nitzschia* are common in the Wadden Sea area but at present we have no observations of ASP toxins in shellfish from the Wadden Sea area. This indicates that we have yet to experience a bloom of a toxic *Pseudo-nitzschia* species in the area. Accumulation of ASP toxins in the food web during bloom situations could result in kills of fish, birds and mammals.

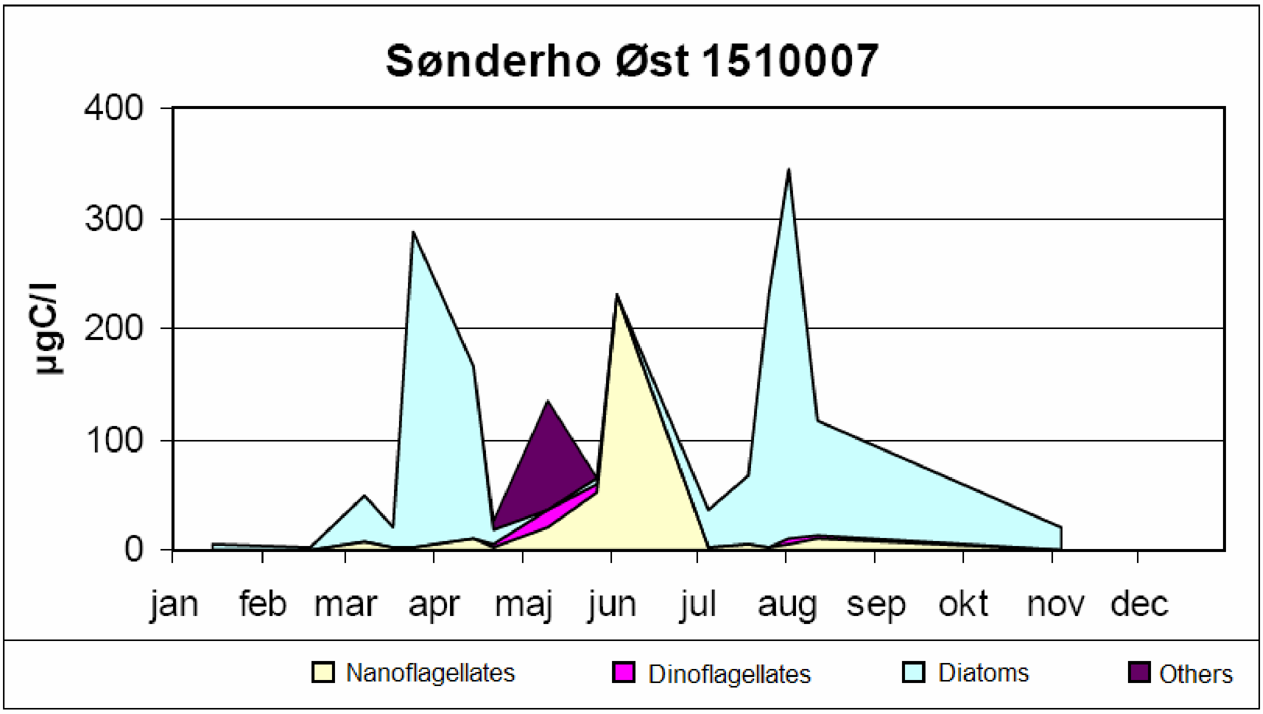


Figure 5.17. Seasonal development of the phytoplankton biomass (µgC/l) in 2004, divided into the major functional classes of species at the station at Sønderho East, County of North Jutland, County of Viborg, County of Ringkjøbing and County of Ribe, 2005.

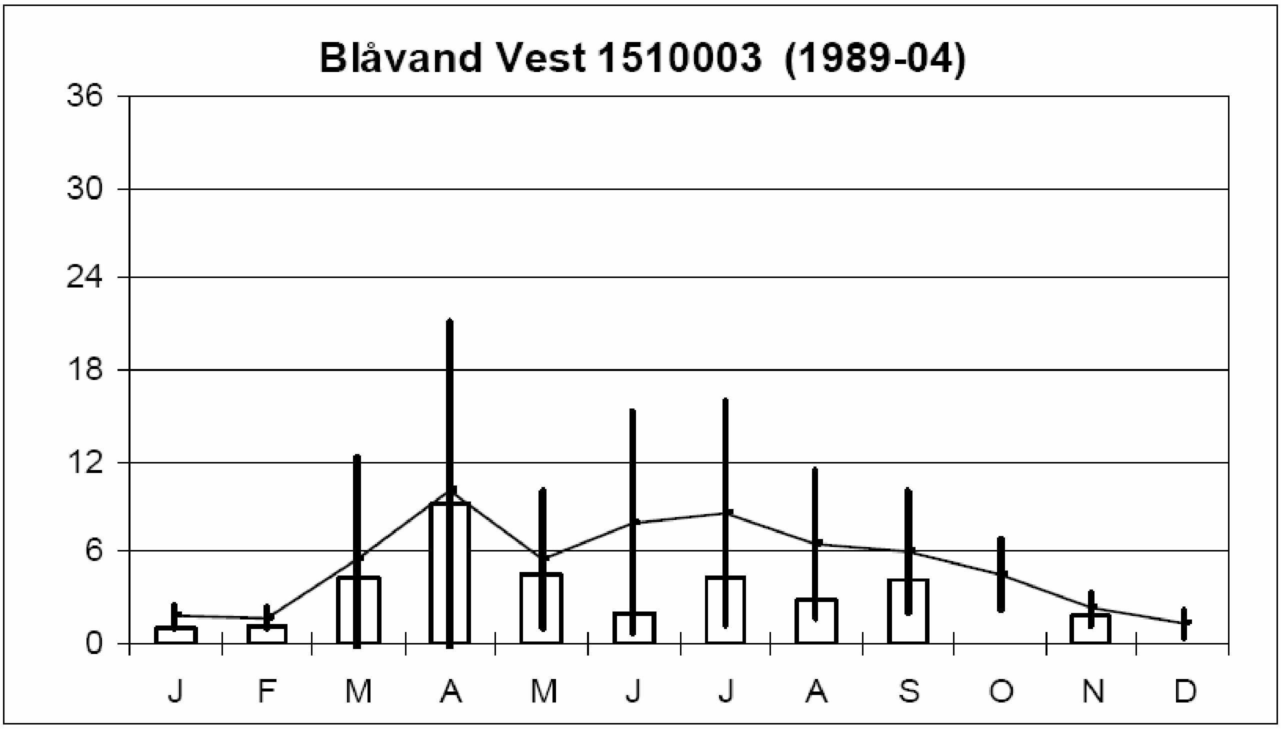


Figure 5.18. Seasonal development of chlorophyl (µg Chl/l) at the station at Blåvand West, County of North Jutland, County of Viborg, County of Ringkjøbing and County of Ribe, 2005.

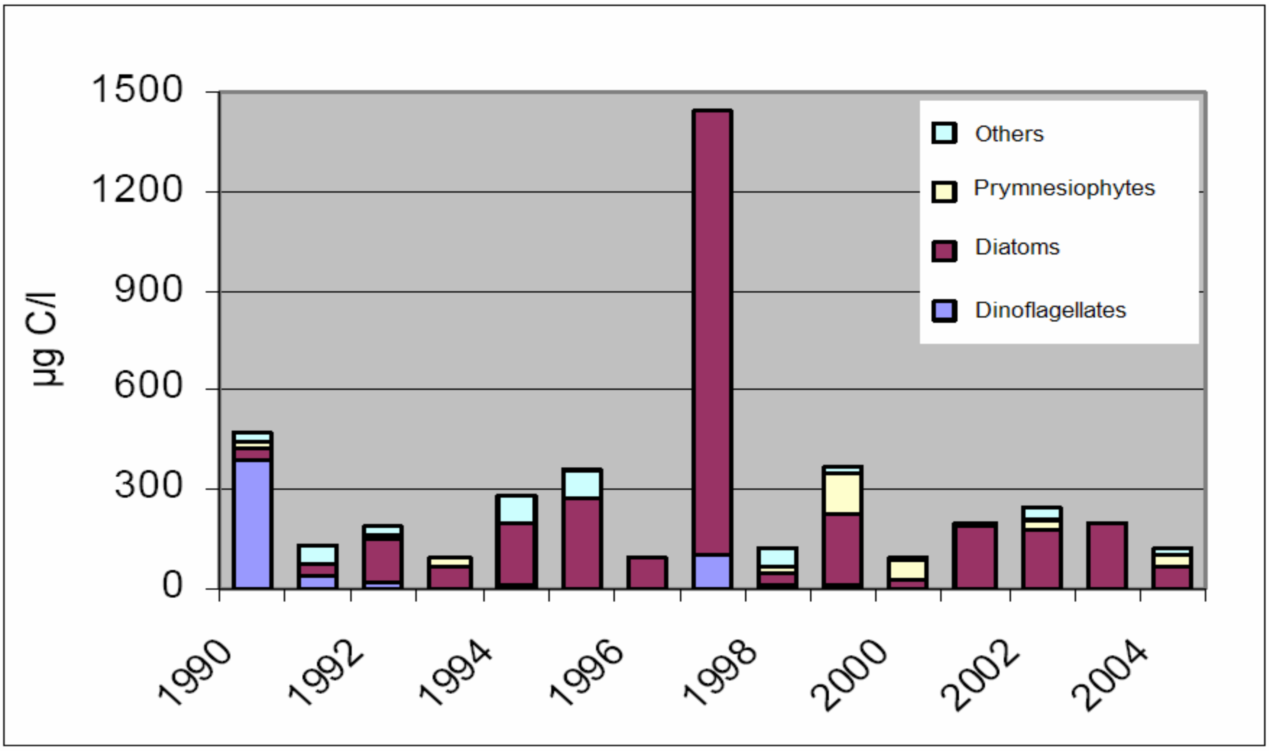


Figure 5.19. Yearly averages of the phytoplankton biomass (µgC/l) during the period 1990-2004, divided into the major functional classes of species at the station at Sønder Ho East, County of North Jutland, County of Viborg, County of Ringkjøbing and County of Ribe, 2005.

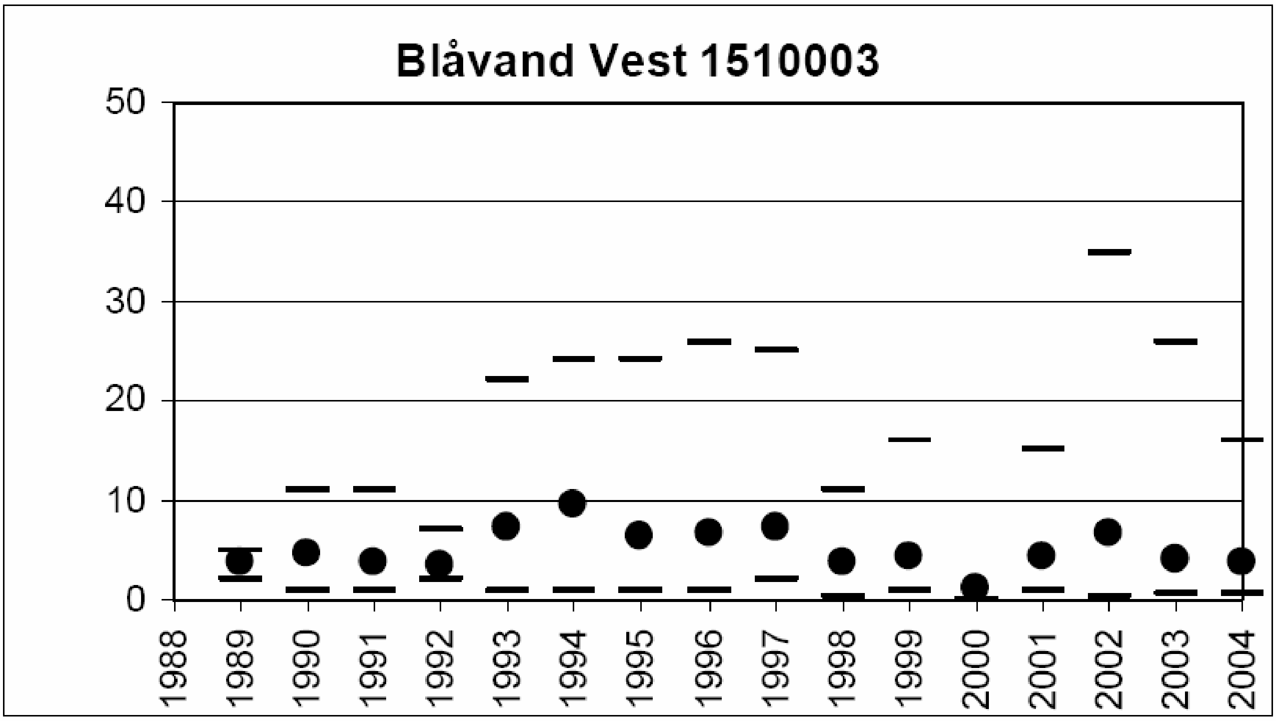


Figure 5.20. Yearly averages of chlorophyl at the station at Blåvand West, County of North Jutland, County of Viborg, County of Ringkjøbing and County of Ribe, 2005.

Primary production

The primary production at station Blåvand West shows a gradual increase over the period 1990–98. Average values lie between 500 and 1,300 mg C/m^2/d, County of North Jutland, County of Viborg, County of Ringkjøbing and County of Ribe, 1998. The primary production level in the North Sea as a whole lies in the range 150–250 g C/m^2/yr, while levels in coastal waters can be higher than 400 g C/m^2/yr (Cadée, 1992).

Transparency

The summer averages for Secci disc transparency measurements at the station Blåvand West and varies between 1 to 6 m, figure 5.21. The time weighted yearly average Secci disc transparency varies between 3 to 5 m. The relatively low transparency recorded in the project area is due to a high level of suspended material in the water column, including phytoplankton. Major resuspension of sediment during winter periods are revealed by the low secci disk transparency observed in the period November-January where the biomass of phytoplankton is low and can contribute very little to the reduction in the transparency. The resuspension of sediment in the project area is primarily a result of the relatively shallow water depths, combined with the regional current, wind and tidal conditions in the Wadden Sea.

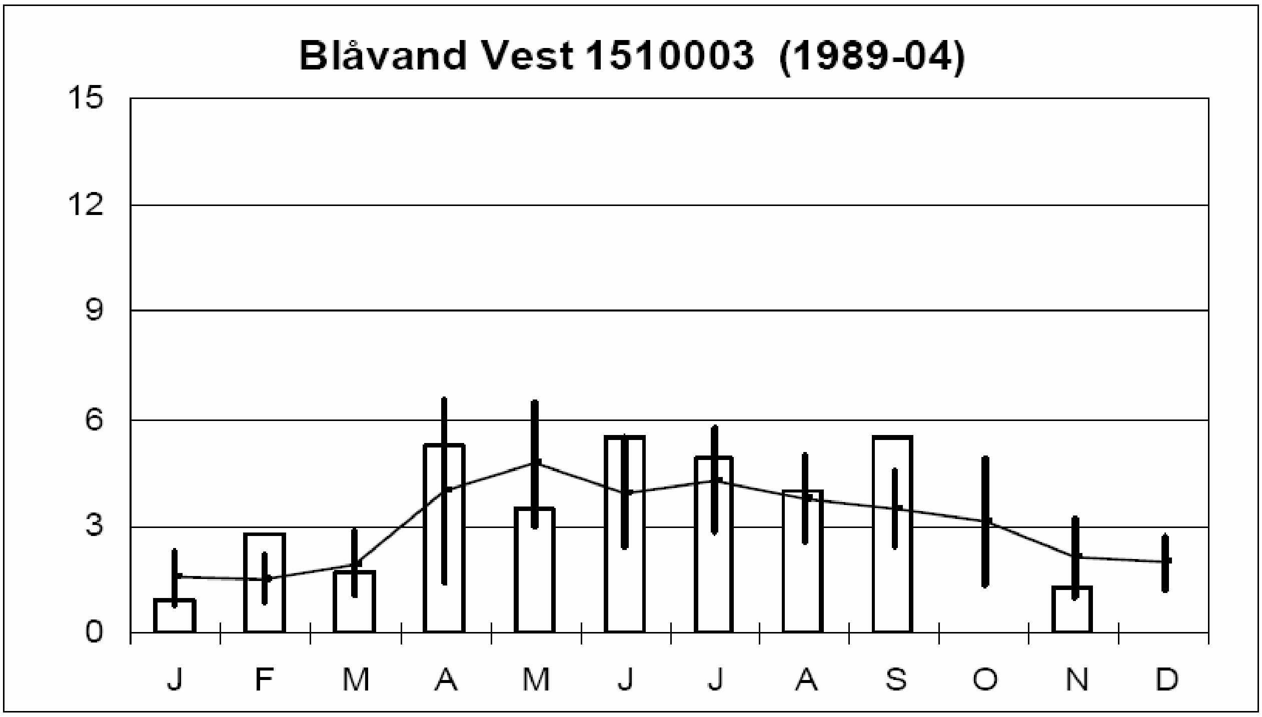


Figure 5.21. Seasonal development of the secci disk transparency 1989–2004 at the station at Blåvand West, County of North Jutland, County of Viborg, County of Ringkjøbing and County of Ribe, 2005.

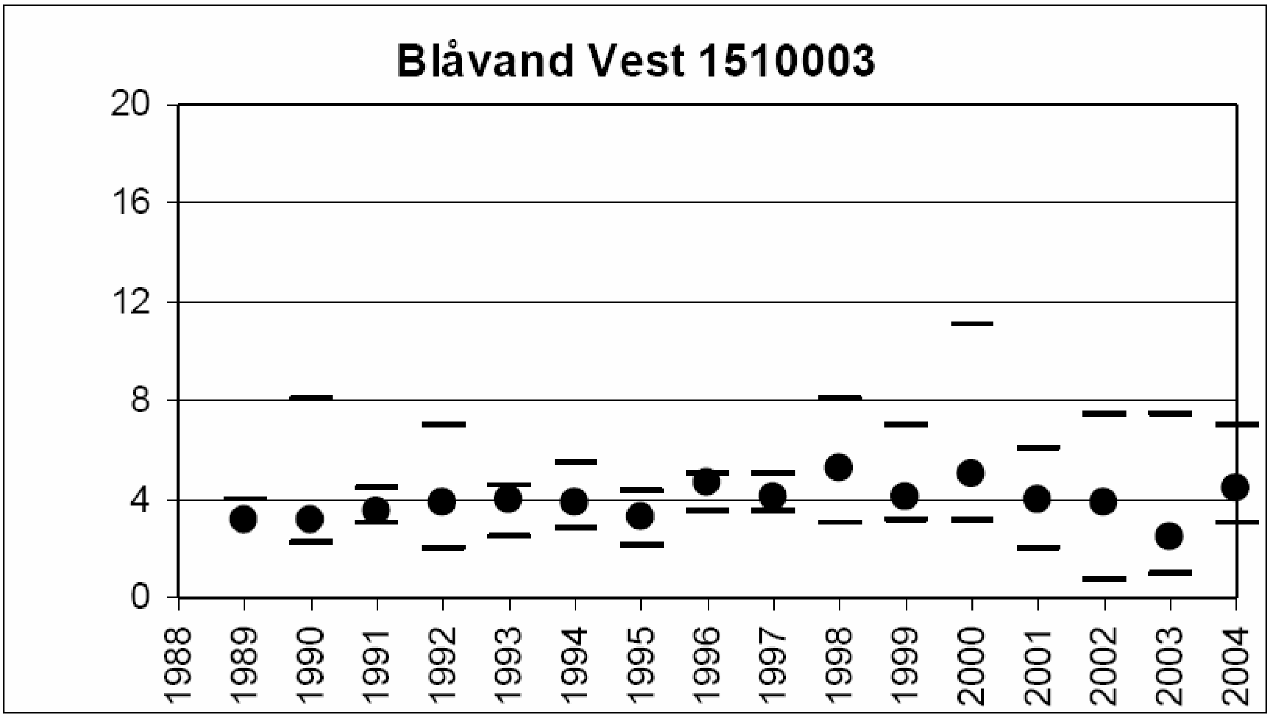


Figure 5.22. Yearly time weighted averages of the secci disk transparency 1989–2004 at the station at Blåvand West, County of North Jutland, County of Viborg, County of Ringkjøbing and County of Ribe, 2005.

6 Sources of impact

The life cycle of an offshore wind farm typically comprises four phases: 1) the pre-construction, 2) the construction phase, 3) the operation phase and 4) the decommissioning phase.

Each of these 4 phases is associated with various potential impacts or impacts of different magnitude on the water quality at the project site. The resulting effects will be reviewed and assessed in chapter 7.

6.1 Main impacts

The four phases in the life cycle of a wind farm are associated with the following main categories of impacts and effects, Table 6.1.

Table 6.1. Overview over the main sources of impacts with a potential effect on the water quality of the project site associated with the different phases or life stages of an offshore wind farm

Source of impact	**Phase**			
	Pre-construction	Construction	Operation	Decommissioning
Resuspension and displacement of sediments including nutrients	X	X	X	X
Discharge of pollutants incl. Oil spills	X	X	X	X
Introduction of hard substrate and subsequently suspension feeding invertebrates			X	
Electromagnetic fields			X	

7 Assessment of effects

7.1 General effects

7.1.1 Changes and alterations of bottom topography

As a consequence of the construction work prior to the establishment of wind turbine and later also the establishment of the wind turbines including the foundations the bottom topography will be altered. These alternations in the bottom topography have a potential impact on the general circulation on the Horns Rev and in the Offshore Wind Farm area. Model simulations on the impact on the circulation of the establishment of the Horns Rev 1 Offshore Wind Farm as well as the experience gained following the establishment of the wind farm show no or negligible impacts on the circulation at the Horns Rev and in the Horns Rev 1 Offshore Wind Farm site, DHI 1999.

7.2 Phase specific effects

7.2.1 Preconstruction phase

Potential impacts from the preconstruction construction phase on the water quality of the project area are negligible.

7.2.2 Construction phase

During the construction phase the following impacts are considered:

- Impact on the water quality, plankton and primary production as a result of sediment spill and resuspension of sediments
- Discharge of pollutants
- Temporary impact of oil spills etc.

The resuspension of sediments as well as discharge of pollutants and impacts of oil spills during the construction phase are considered to be temporary and to be very limited in time and space. The significance of the environmental impact is considered to be minor/negligible. Mitigation measures should be considered only in the case of incidents such as major oil spill.

7.2.3 Production phase

Potential direct or indirect impacts during the production phase are:

- Permanent impact on current, sediment, water exchange and wave conditions of the area
- Discharge of pollutants
- Temporary impact due to oil spills, etc.
- Grazing impact from filtering blue mussels on the phytoplankton
- Electromagnetic fields

7.2.3.1 Circulation and hydrography

Either the current speed down stream the project area or the water exchange in the project area on Horns Rev will be significantly affected by the construction of the wind farm (Danish Hydraulic Institute, 1999). For this reason no impact is expected on the water quality including phytoplankton and zooplankton. Alterations in the water exchange conditions of the area could otherwise lead to changes such as accumulation of plankton, effects on primary production, oxygen conditions or changes in the transport of inorganic nutrients between the sediment and the water column.

According to Danish Hydraulic Institute (1999), there will be minor local impact on current, wave conditions and sediment transport in the immediate vicinity of the foundations. However, this is not expected to have any effect on the water quality, primary production or plankton. The presence of the wind farm will not affect the regional wave conditions, currents or sediment transport along the coast of Jutland at Blåvands Huk and Skallingen. For these reasons, no impact is expected on the water quality or the plankton within the international protected area.

7.2.3.2 Water quality

The potential impact of discharge of pollutants during the production phase includes:

- Addition of paint flakes and sand waste in connection with maintenance of the foundations and towers
- Discharge of pollutants
- Effects of oil spills in connection with accident and cable rupture

Discharge of copper from the slip-rings of the wind turbines is considered to be a non-issue as the construction of the wind turbines eliminates this risk.

A temporary contamination with paint flakes and sandblasting waste, including sand from the maintenance of foundations and towers is expected during the production phase. It is recommended that the toxicity of the paints should minimized and that the amount of waste of paint and paint flakes should be minimised as much as possible. It is considered that the spill of sandblasting sand will only have negligible effects on the water quality.

The discharge of pollutants and impacts of oil spills during the production phase are considered to be temporary and to be very limited in time and space. The significance of the environmental impact is considered to be minor/negligible. Mitigation measures should be considered only in the case of a major oil spill.

7.2.3.3 Phytoplankton and primary production

The potential impact on the phytoplankton and primary production during the production phase includes:

- Discharge of pollutants
- Effects of accidental oil spills
- Grazing impact from filtering blue mussels on the phytoplankton
- Electromagnetic fields

The discharge of pollutants and impacts of oil spills during the production phase are considered to be temporary and to be limited in time and space. The significance of the environmental impact is considered to be minor/negligible. Mitigation measures should be considered only in the case of a major oil spill.

A model calculation of the filtration capacity of the blue mussel (*Mytius edulis*) on plankton, based upon information on abundance and biomass estimates from investigations carried out at the present Horns Rev 1 Offshore Wind Farm, (report: Benthic communities at Horns Rev before, during and after construction of Horns Rev 2 Offshore Wind Farm, in preparation) has been carried out. The model calculation shows, that in the case that the total area of foundation has a biomass and size structure of blue mussels as registered on Turbine 95 Horns Rev 1 Offshore Wind Farm, which holds the largest biomass of blue mussels observed at Horns Rev 1 Offshore Wind Farm, then the blue mussels will be capable to filter a water volume equivalent to approx. 1% of the water volume within the Wind Farm I area on a daily basis, see appendix 1. A filtration impact of this magnitude is considered to have a negligible impact on the phytoplankton present in the area; the primary production and on the water quality as a whole. At best the mussel filtration will provide clearer water in the near vicinity of the foundations. This will allow for better growth conditions for micro-and macro algae growing on the foundations. Furthermore, the production of blue mussels on the foundations may provide food for the fish and bird communities present in the area.

It has not been possible to identify any references on impacts on phytoplankton or primary production from electromagnetic fields. Such effects are considered to be most unlikely and therefore negligible.

7.2.4 Decommissioning phase

During the decommissioning phase of the Horns Rev 2 Offshore Wind Farm environmental impacts from removing the wind turbines such as sediment spill and from ships traffic including discharge of pollutants, effects of oil spills in connection with accidents and cable rupture are to be considered.

7.2.4.1 Traffic

The discharge of pollutants and impacts of oil spills during the decommissioning phase are considered to be temporary and to be very limited in time and space. The significance of the environmental impact is considered to be minor/negligible. Mitigation measures should be considered only in the case of a major oil spill.

7.2.4.2 Sediment spill/resuspension

Sediment spill and resuspension of sediments in relation to the removal of the wind turbines is considered to be temporary and limited in time and space. The significance of the environmental impact of resuspension is therefore considered to be minor/negligible.

7.3 Cumulative effects

Cumulative effects on the environmental water quality from the Horns Rev 1 and 2 Offshore Wind Farms during all life cycle phases are considered to be negligible.

7.4 Mitigative and preventive measures

As there is no or only negligible impacts on the water quality in the project area during all lifecycle stages of the wind farm no mitigative or preventative measurers are to be considered.

8 Conclusions

Present situation
The wind farm area is characterised by relatively high concentrations of inorganic nutrients, low transparency due to large amounts of resuspended material in the water column, total mixing of the water column and generally good oxygen conditions.

Hypoxic conditions have been recorded in the adjacent waters. Recurring blooms of phytoplankton have been documented in the project area. These can accumulate on beaches where they can create problems with smell, discoloration, etc. Several toxic micro-algae types have been recorded and can lead to accumulation of algal toxins in bivalves of commercial importance and/or can result in kills of fish, birds and mammals.

Impacts
The significance of the impact on water quality in the project area from establishing the Horns Rev 2 Offshore Wind Farm are considered to be local and limited in time and space, and therefore to be of negligible/minor significance during all life cycle phases, table 8.1. No general changes in the water quality of the project area or cumulative effects are thus to be expected.

A temporary contamination with paint flakes and sandblasting waste, including sand from the maintenance of foundations and towers is expected during the production phase. It is recommended that the toxicity of the paints should be minimized and that the amount of waste of paint and paint flakes should be minimised as much as possible. It is considered that the spill of sandblasting sand will only have negligible effects on the water quality.

The assessment of the filtration impact of blue mussels on the foundations reveals a negligible impact on the phytoplankton present in the area, the primary production and on the water quality as a whole. At best the mussel filtration will provide clearer water in the near vicinity of the foundations. This will allow for better growth conditions for micro-and macro algae growing on the foundations. Furthermore, the production of blue mussels on the foundations may provide food for the fish and bird communities present in the area.

Table 8.1. Conclusive assessments of effects from major impacts in connection with establishment of Horns Rev 2 Offshore Wind Farm. Criteria for the assessments are given in chapter 4.1.

Impact	Criteria	Pre-construction	Construction	Operation	Decommissioning
Suspension of sediments	Importance Magnitude Persistence Likelihood Other Significance	Local Negligible Temporary-short Low Direct/indirect Negligible	Local Minor Temporary-short High Direct/indirect Minor	Local Negligible Temporary-short Low Direct/indirect Negligible	Local Minor Temporary-short High Direct/indirect Minor
Discharge of pollutants including oil spils	Importance Magnitude Persistence Likelihood Other Significance	Local Minor Temporary-short Low Direct Negligible	Local Negligible Temporary-short Medium Direct/indirect Negligible	Local Negligible Temporary-short Low Direct/indirect Negligible	Local Negligible Temporary-short Low Direct/indirect Negligible
Electro-magnetic fields	Importance Magnitude Persistence Likelihood Other Significance			Local Negligible Permanent Low Direct/indirect Negligible	
Cumulative effects	Importance Magnitude Persistence Likelihood Other Significance	Local Negligible Temporary-short Low Negligible	Local Negligible Temporary-short Low Direct/indirect Negligible	Local-regional Negligible Permanent Low Direct/indirect Negligible	Local-regional Negligible Termporary/short Low Direct/indirect Negligible

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Appendix 1. Model calculation of filtration capacity of blue mussels (*Mytilus edulis*) on foundations.

Model calculation of filtration capacity of blue mussels (*Mytilus edulis*) on foundations.

Filtration potential of blue mussels (*Mytilus edulis*) on hard substrate (turbine sites)
Turbine 95 Horns Rev 1 Offshore Wind Farm

length (mm)	filtration potential/individual (l/day)	Abundance - no /m2	filtration potential/size class (l/day)
6	1	50	67
12	6	100	587
18	14	150	2098
14	8	140	1143
30	42	175	7302
36	62	240	14794
42	86	240	20576
48	114	130	14832
54	147	50	7340
		Total population	68739

Kiørboe & Møhlenberg 1981

$F=.0012*L^{2.14}$		2.14	0.0012
L	mm		
F	l/h		

Total area of foundation	38,265	m2
Area of wind farm	27,500,000	m2

Total filtration potential of blue mussels on foundations at Horns Rev 1 Offshore Wind Farm

Filtration potential /m2	69	m3/m2/day		
Total area of foundations	38265	m2		
Total filtration potential of blue mussels	2640285	m3/day		
Total area of the wind farm	27500000	m2		
Average depth	9	m	5-13 m	
Water volumen in the wind farm area	247500000			
Filtration potential as percentage of total volume of water			1.1	% /day
Current speed	0.1	m/s	8.64	km/day
length dimension of area	5	km		
Average retention time	0.6	day		