SEAS

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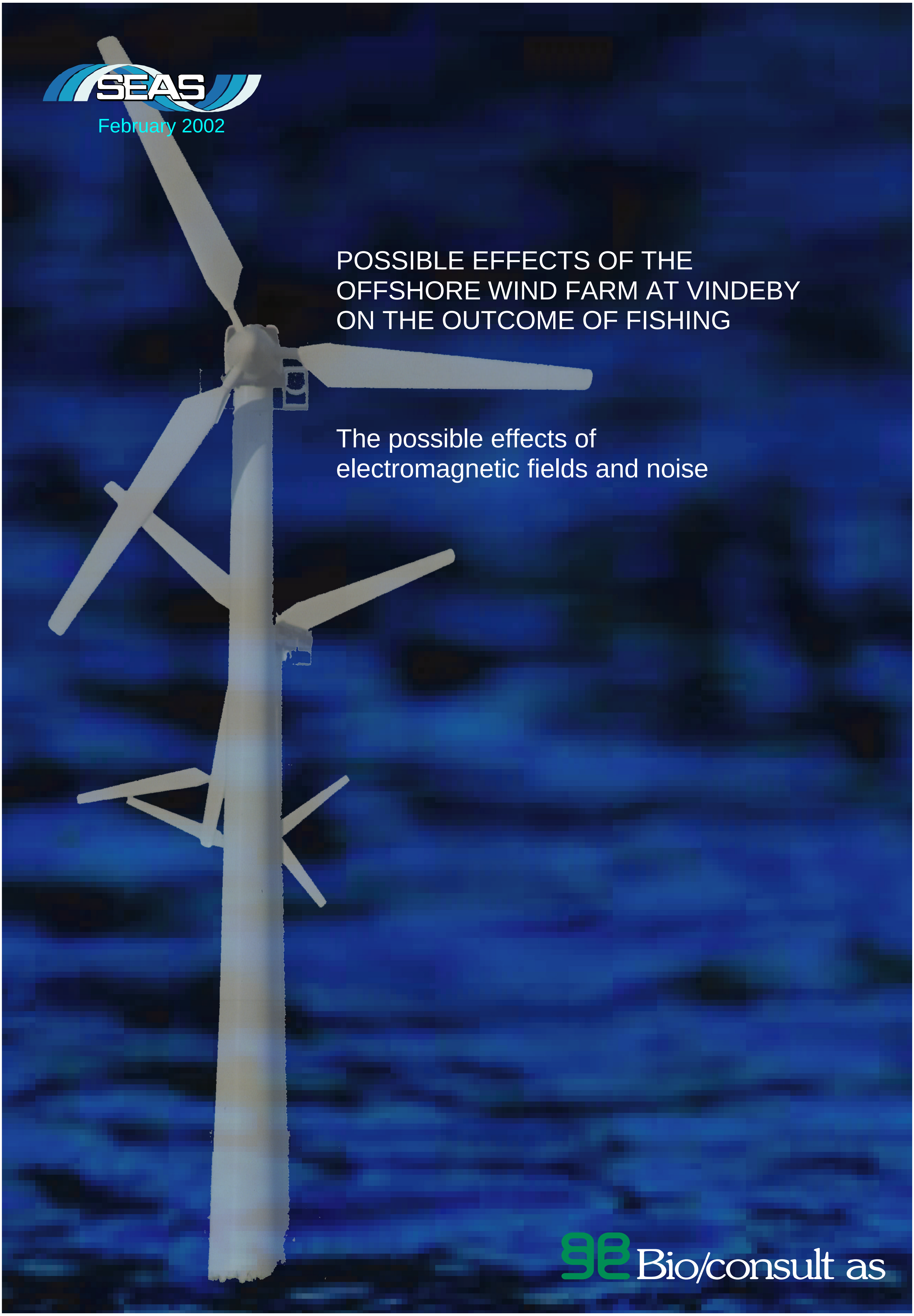

POSSIBLE EFFECTS OF THE OFFSHORE WIND FARM AT VINDEBY ON THE OUTCOME OF FISHING

The possible effects of electromagnetic fields and noise

Bio/consult as

POSSIBLE EFFECTS OF THE OFFSHORE WIND FARM AT VINDEBY ON THE OUTCOME OF FISHING

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1. Introduction

Vindeby Offshore Wind Farm, the worlds first commercial offshore wind farm, was commissioned in 1991. It is situated in the Great Belt, Denmark, a couple of kilometres NW of the island of Lolland. The offshore wind farm, build by SEAS, has a capacity of 4.95 MW and consists of 11 Bonus 450 kW stall controlled wind turbines in two parallel rows from NW to SE. According to SEAS, the cables (or power lines) interconnecting the 11 turbines and connecting the offshore wind farm to the shore are all 10 kV tripolar, 50 Hz alternating current cables. The turbines are founded in conical "Gravitation Foundations" built in concrete and filled with sand and gravel. The distance between the turbines is approx. 500 meters. The water depth in the turbine area varies from 2-6 meters. For a map of the wind turbine area, wind turbines and cables, Figure 2, page 15.

2. Background

A professional fisherman, Bjarne Kolath from Onsevig, who fishes around the northern part of Lolland, states that although there seems to be an increase in the number of fish near Vindeby Offshore Wind Farm since the establishment of the offshore wind farm, the flatfish, especially turbot *(Psetta maxima)*, do not migrate between the turbines when it is windy.

Bjarne Kolath has explained, that if series of gill nets designed for turbot are placed between the turbines perpendicular to the two rows of turbines (so that there are nets both between the turbines and outside the wind farm, on both sides) he will catch fish in both ends of the series but not in the middle of the series.

Bjarne Kolath claims that it is the alteration of the magnetic fields between the turbines when it is windy and associated electrical currents running through the cables, which are responsible for the lower catch inside the wind farm in windy weather since he does not observe a similar pattern in calm weather.

3. Objective

The objective of the investigation was to examine the observations of Bjarne Kolath regarding his catches of turbot in varying weather conditions and, on the basis of his observations and literature studies, set up an investigation to determine whether or not electromagnetic fields and/or noise from Vindeby Offshore Wind Farm affects fish and fishery within the turbine area.

An agreement was made between SEAS, Bjarne Kolath and Bio/consult, that Bio/consult should contact Bjarne Kolath and join him on a fishing trip, after which Bjarne Kolath should register all catches from the area.

The purpose of the investigation was as follows:

1. Is the observation of Bjarne Kolath correct, that there are no fish in the wind farm area when it is windy?
2. If so, more specifically, under what circumstances are catches reduced? For example magnetic fields, noise, altered hydrographical conditions, increased turbidity, shadow effects of the rotor blades etc. Wind turbines, like other tall structures, will cast a shadow on the neighbouring area when the sun is visible. When the turbine is operating the rotor blades chop the sunlight, causing a flickering (blinking) effect while the rotor is in motion.

4. Investigation design

SEAS initiated an investigation in order to assess whether catches of flatfish in nets situated between the turbines differed in calm weather and windy weather. The investigation included an interview of Bjarne Kolath to define the best possible set-up of the fish survey to define whether or not catches of flatfish in nets situated between the turbines were affected by the speed of wind (e.g. increased noise and/or magnetic fields).

Work tasks

1. Background literature study on effects of electromagnetic fields and noise on fish and fishery.
2. Interview of professional fisherman Bjarne Kolath.
3. Field investigations, e.g. gathering of information on the catch results of gill netting by Bjarne Kolath, when he sets his nets perpendicular to the rows of wind turbines.
4. Preparation of notes including literature study, results from interview and field observations. Conclusions on whether or not a reduced catch in the offshore wind farm area in periods with high wind speeds can be ascribed to effects from the operation of turbines (e.g. electromagnetic fields or noise).

5. Electro-magnetic fields

Electric charge in movement, electricity, results in a magnetic field. Electro-magnetic fields are only present when an electric current is actually present. Electricity involves both voltage (measured in volts) and current (measured in amperes). The higher the voltage the stronger the electric field. The higher the current the stronger the magnetic field.

The direction of the magnetic field is perpendicular to the direction of the electric current. Electro-magnetic field strength increases proportional to the current intensity and decreases by the square root of the distance from the cables.

The electro-magnetic field is in the immediately vicinity of the power lines. Time varying magnetic fields are induced in the vicinity of alternating power transmission systems.

Magnetic fields can be measured in microtesla (µT). 1 µT = 10 mG (milligauss) = 0.8 A/m. The Earth’s magnetic field is about 50 µT, and the magnetic field conducted 1 km from a typical lightning strike is approx. 10 µT (www.electricity.org.uk). The maximum magnetic field immediately below an 11 kV overhead power line, at ground level, is approx. 7 µT (www.electricity.org.uk).

5.1. Expected electro-magnetic fields from the power lines

According to SEAS the cables interconnecting the 11 turbines and connecting the offshore wind farm to the shore are all 10 kV tri-phased, 50 Hz alternating current cables.

The maximal magnetic field at varying distance from the 10 kV cables can be calculated from the maximal current in the cables:

H=my_nul*I/(2*pi*d)

my_nul is 1.26e-6 H/m.
H = magnetic field strength (Tesla)
I = current (ampere)
d = distance (meter)

Source: Silvester, 1968.

The cables are three-phased. According to SEAS the maximal current in each of the three phases of the cables is 260 Ampere. The magnetic field strength at increased distance from the cable can thus be calculated for one phase (Table 1).

In principle, the three phases in the cable should neutralize each other, resulting in a magnetic field strength of zero, but as a result of difference in the distance to each conductor a magnetic field is associated with the cables anyway. It can be assumed, however, that the magnetic field strength of the cables is less than the magnetic field strength of one of the conductors.

If the cables have alternating currents (as at Vindeby Offshore Wind Farm) the formed magnetic field varies over time.

Distance from cable (m)	Magnetic field strength (A/m)	Magnetic field strength (µT)
1	41,38	33,10
10	4,14	3,31
100	0,41	0,33
500	0,08	0,07
1000	0,04	0,03

Table 1. Calculated magnetic field strength at varying distances from the cables.

5.2. Sensitivity of bony fish to magnetic fields

The concern of the fisherman from Onsevig has to be considered in light of reports that whales use a magnetic sense for long distance navigation, and that whales are sensitive to small local variations in the Earth's magnetic field (Klinowska, 1990).

Sharks and rays also possess electro receptors used mainly to receive electrical information for detection of the electromagnetic fields of prey, magnetic compass headings (Kajlmijn, 1978) and ocean currents (Cleveland, 1982).

There is clear evidence, that some bony fish like salmonids (Chew & Brown, 1989; Walker, 1984; Taylor, 1986), plaice *(Pleuronectes platessa)* (Metcalfe et al, 1993), and eel *(Anguilla anguilla)* (Karlson, 1985) are capable of sensing magnetic cues during certain types of spatial activity. This could be due to the presence of biological magnetite that has been extracted from various species of fish (Kirschvink et al., 1985a; Mann et al., 1988).

Even though literature indicates, that some fish are capable of sensing magnetic fields, only sparse literature is available on field investigations of the sensitivity of bony fish to artificial alterations of the magnetic field. Yano et al. (1997) investigated the role of magnetic compass orientation in ocean migrating chum salmon *(Oncorhynchus keta)*. Four salmon were fitted with a tag that generated an artificial magnetic field and modified the geomagnetic field around the head of the fish, which were also equipped with stomach-implanted ultrasonic transmitters. The purpose of their study was to track down the position of the four migrating salmon while the magnetic field of the head was altered (alternating magnetic field intensity of app. 6 gauss (= app. 600 µT). The alterations did not produce any effect on the horizontal or vertical movements of the fish. But as the authors site, alteration of the magnetic field in their study were targeted the posterior part of the head, including the inner ear, and other salmonids have been shown to have a possible magnetic sensor in the dermatoid tissues or lateral line (Mann et al., 1988; Kirschvink et al., 1985b).

The fact that whales, sharks, rays and bony fish respond to and orientate to magnetic fields does not necessarily mean that the magnetic fields produced by the operation of the Vindeby Offshore Wind Farm will affect the fish in the turbine area.

Although the electro-magnetic field strength in the near vicinity of the cables (as calculated in Table 1) might be sufficiently high to affect the fish, less than 1 meter from the cables the magnetic field approximates that of the geomagnetic field of the earth.

Whether or not a change of the magnetic field affects the fish or the fishery in the area therefore still remains an open question.

6. Noise

6.1. Expected noise from wind turbines

6.1.1. Recordings from Vindeby

The underwater noise from Vindeby was recorded by Ødegaard & Danneskiold-Samsøe (2000) 14 meters downwind at a depth of 1.2 meters and frequencies from 10 Hz to 20 kHz while the turbine was operating and while stopped (see Figure 1). The water column had a depth of about 2.5 meters. The average wind speed was approx. 13 m/s both during operation of the wind turbine and when it was stopped.

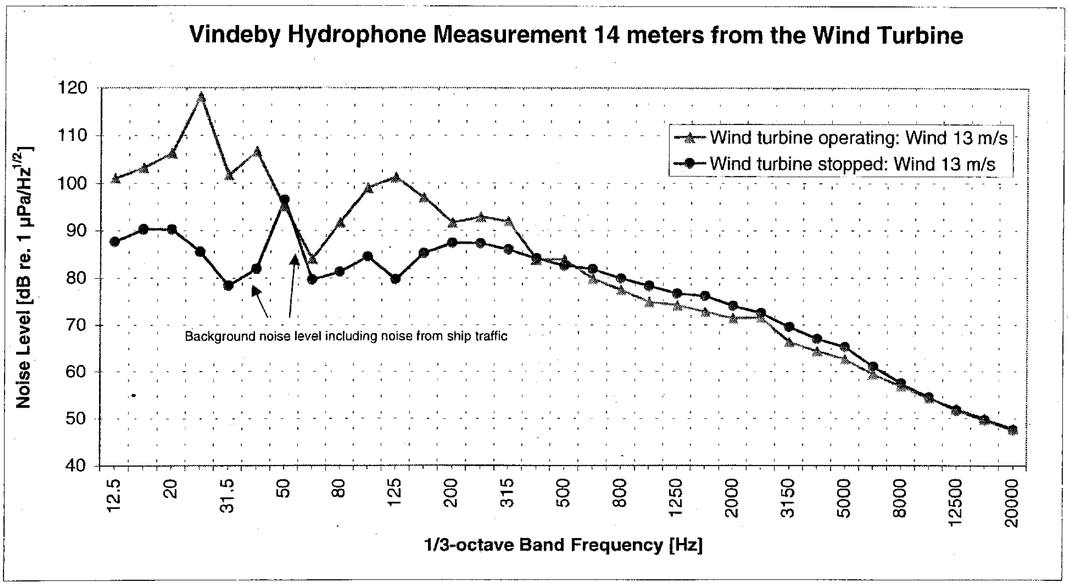

Figure 1. Underwater noise measured 14 meters from the wind turbine at a wind speed of 13 m/s. The frequency range from 10 Hz to 20 kHz is shown as sound pressures given in Power Spectral Density (PSD). Two graphs are presented, one for the noise level while the wind turbine was operating and one for the noise level when the wind turbine was stopped. The background noise during the recording was influenced by a ship passing 7 kilometres from the wind turbine (Ødegaard & Danneskiold-Samsøe, 2000).

From Figure 1, it can be seen that the noise coming from the turbines is 5-33 dB above background noise at frequencies from 10 Hz to 400 Hz. The difference between turbine generated noise and background noise is greatest at 20-40 Hz.

6.1.2. Distance related effects of noise from the turbines

The noise (spectre and intensity) generated from a 220 kW Windworld offshore turbine, "Svante 1" was also measured (Westerberg, 1994). The measurements were conducted at the depth of 4 meters at two different wind speeds (6 m/s and 12 m/s). The relative spectral noise level (dB) was measured at frequencies ranging from 1 Hz to 20 kHz. At frequencies above 50 Hz a wide spectrum of noise from approx. 160-500 Hz dominated. Below 50 Hz a spectral top at approx. 16.7 Hz was observed. The measurements at “Svante 1” showed that at a distance of 300 meter from the turbine the spectral top at 16.7 Hz was diminished from approx. 21 dB to 5 dB above background level. The noise diminishment can be described as a dispersal of an expanding cylinder of noise. A doubling of the distance will diminish the intensity by 3 dB (Westerberg, 1994; Ødegaard & Danneskiold-Samsøe, 2001).

6.1.3. Wind speed related effects on noise from the turbines

Measurements from “Svante 1” showed that at a wind speed of 12 m/s the noise level from the turbines was generally higher than at 6 m/s (Westerberg, 1994). But an increase of the wind speed also increased the background noise levels. At frequencies below 50 Hz background noise at wind speeds of 12 m/s would be 10-12 dB higher compared with background noise at wind speeds of 6 m/s, mainly as a result of breaking waves. At frequencies above 50 Hz, the background noise at wind speeds of 12 m/s would be 6 dB higher compared with background noise at wind speeds of 6 m/s. Westerberg (1994) concluded that noise from the turbines would elevate equally many dB above background noise at wind speeds of 6 m/s and 12 m/s.

The wind turbines at Vindeby are 450 kW Bonus offshore turbines, larger than the 220 kW Windworld turbine for which Westerberg (1994) did his investigations. Therefore the results of Westerberg (1994) can only infer the wind speed related effects on noise from the Vindeby turbines.

6.2. Sensitivity of fish to noise

For auditory sensing, fish use the lateral line, the ear and the swimbladder. However, not all fish have a swimbladder. Both the lateral line and the ear detect water motions; the lateral line is responsive to relative movements between the animal and the surrounding water; the ear is responsive to the relative motion between the otolith and the fish’s body, and to sound pressure (Popper & Fay, 1993).

The hearing ability to some extent enables the fish to avoid predator attack and thus constitutes an obvious survival value.

The sensing of lateral line and the ear overlap in frequency range, with the lateral line responding over a frequency range of several Hz to about 200 Hz, and the ear from several Hz to several thousand Hz in some species. The source distance over which the two systems respond differs, from a body length or two for the lateral line, to considerably greater distances for the ears (Popper & Fay, 1993).

6.2.1. Hearing ability of fish – awareness reaction

Different species of fish have different hearing abilities and the reason for this is mainly differences in physiology. Thus, in order to make a meaningful evaluation of the possible effects of noise on fish, it is essential to have an understanding of the hearing capability of fish, the physiology underlying this, and how it influences the behaviour of fish. For a more detailed description of the hearing abilities of different groups of fish see Bio/consult (2001).

Fish having specialisations that enhance hearing (e.g. Weberian ossicles, swimbladder diverticulae and gas filled bullae) are referred to as hearing “specialists”, where as fish without such specialisations are referred to as hearing “generalists”. Hearing “specialists” tend to detect sound pressure with greater sensitivity and in a wider bandwidth than “generalists”.

Hearing generalists without a swimbladder generally detect noise with greater sensitivity than hearing generalists without a swimbladder (Bone et al., 1995; Popper & Ly, 2000).

The auditory threshold is defined as the minimal level of sound that a fish can detect at a particular frequency 50% of the time. Different fish species have different auditory thresholds.

In bottom living flatfish, e.g. flounder *(Platichthys flesus)*, plaice *(Pleuronectes platessa)*, dab *(Limanda limanda)* and turbot *(Psetta maxima)*, the swimbladder degenerates after the larval phase. These fish are hearing “generalists” without a swimbladder and generally have high auditory threshold levels and will probably hardly hear the noise frequencies above 250 Hz (Westerberg, 1993). At frequencies below 250 Hz the lowest auditory thresholds for hearing generalists are approx. 90-110 dB (re: 1 µPa) (Popper & Fay, 1993; Popper, 2000b). Flounder *(P. flesus)*, dab *(L. Limanda)*, common sole *(Solea solea)* and turbot *(P. maxima)* have formerly been registered in the Vindeby area (Haumann, 1993).

In sea scorpions *(Cottidae)*, eelpout *(Zoarces viviparous)*, sandeels *(Ammodytes)* and gobies *(Gobiidea)* the swimbladder has also degenerated. Eelpout, sea scorpions and lumpsucker *(Cyclopterus lumpus)* have formerly been registered in the Vindeby area (Haumann, 1993).

Cod (*Gadus morhua*) and silver eel *(A. anguilla)*, also formerly registered in the Vindeby area (Haumann, 1993), have a swimbladder and can probably hear frequencies up to 300-500 Hz (Popper & Fay, 1993; Popper, 2000b). At frequencies below 300-500 Hz the lowest auditory threshold is approx. 50-100 dB (re: 1 µPa).

Cod *(G. morhua)* has auditory thresholds at about 80 dB from 50 to 400 Hz. Moreover cod is able to hear high frequencies at very high sound pressure. Silver eel *(A. anguilla)* has a swimbladder and can probably hear frequencies up to 300 Hz (Jerkø et al., 1989).

Herring (*Clupea harengus*), also formerly found in the Vindeby area (Haumann, 1993), has a specialised hearing with low auditory threshold levels and a broad hearing bandwidth (50-75 dB (re: 1 µPa) at 200-3000Hz), which is probably reflected in the avoidance threshold.

Turbot *(P. maxima)* and flounder *(P. flesus)*, reported by the local fisherman at Vindeby to be the two fish species avoiding the wind farm area when it is windy, are thus “hearing generalists” without a swimbladder. As mentioned above, the lowest auditory thresholds of hearing generalists at frequencies below 250 Hz is app. 90-110 dB (re: 1 μPa) (Popper & Fay, 1993; Popper, 2000b).

6.2.2. Physiological responses to noise

Some studies point out that intense impact of sound may result in damage of the sensory-hair-cells in the ears of fish.

Enger (1981) (as cited in Hastings et al., 1996) exposed cod *(G. morhua)* to frequencies between 50 and 400 Hz at 180 dB (*re*: 1 μPa), which is about 100-110 dB above the hearing threshold for cod. It was found that in the area of 150 to 250 Hz, which is the most sensitive to cod, such sound signals would cause repeatable damage (loss of ciliary bundles) in animals that were exposed to sounds for 1-5 hours.

Denton and Gray (1993) demonstrated that sound frequencies of 1 Hz to 200 Hz with a pressure of 153 dB to 170 dB resulted in damage to the hair cells of the lateral line of clupeid fish (herring and relatives).

Hastings et al. (1996) have investigated the effect of high intensity sound on the ears of the oscar (*Astronotus oscellatus*). They found that sounds lower than 180 dB (re: 1 μPa) and sounds not continuously on had no apparent impact on the sensory cells of the ear. However, when they subjected the fish to 180 dB signals 300 Hz pure tones for four continuous hours, and examined the ears after four days, there was some damage to the sensory cells of the lagena.

Hastings et al. (1996) suggest the hearing "generalists" must be exposed to a much higher sound intensity (dB) to destroy their sensory-hair-cells compared to hearing-"specialists".

Some studies have provided evidence that hair cells can be regenerated after damage (Lombarte et al., 1993).

Sound pressures have to be higher than 240 dB or explosion-like to result in severe damages to the tissue of fish (Bertel Møhl, pers. comm.). These noise levels are equal to the noise levels created by whales and dolphins during hunting (Astrup & Møhl, 1993).

6.2.3. Escape responses of fish affected by noise – avoidance reactions

Avoidance reaction by fish requires a higher sound pressure than awareness reaction (Popper, 2000b).

Avoidance by salmon – a hearing "generalist":
Knudsen et al. (1994) studied avoidance response by using intense sound as an acoustic barrier for downstream migrating smolt of Atlantic salmon (*Salmo salar*). They found that sound with a frequency of 5 to 150 Hz had an effect on juvenile salmon. Awareness reactions were strongest at lowest frequencies. The avoidance responses of free-swimming smolt to frequencies of 10 Hz and 150 Hz were stimulated at intensities 10-15 dB above auditory threshold for spontaneous awareness reactions (Knudsen et al., 1994).

A frequency of 150 Hz failed to evoke avoidance responses in salmon, even at 120 dB (Knudsen et al., 1994). At 10 Hz, salmon showed an avoidance reaction above approx. 70 dB. The heartbeat of salmon was 200-300% of normal heartbeat when salmon were exposed to 10 Hz sound. When exposed to 150 Hz sound, the heartbeat was only slightly elevated.

Ploskey & Johnson (1999) examined the effectiveness of sound for eliciting avoidance reactions by juvenile salmon. They found that 10-35 Hz infrasound did not elicit avoidance from two salmon juveniles, neither did a mixture of 300-400 Hz sounds. However, they did observe non-directional startle responses from juvenile chinook salmon exposed to 150 Hz and 180 Hz waves transmitted at 160 dB.

Avoidance by eel – a hearing "generalist"
Sand et al. (1999) found that migrating silver eels *(A. anguilla)* displayed startle behaviour and prolonged stress reactions (monitored as heart rate) as a response to intense infrasound at 11.8 Hz, corresponding to the threshold intensity for deterring effects on salmon smolts.

Avoidance by goldfish (Carassius auratus)– a hearing "specialist"
Popper & Clark (1976) demonstrated that a 4-hour exposure to 149 dB (re: 1 µPa) sounds at 300 Hz, 500 Hz, 800 Hz and 1000 Hz caused temporary threshold shifts lasting 2-4 hours. There was a complete recovery from this stimulation even after repeated exposure to the sound during daily experiments for several days or weeks.

6.3. Expected effect of noise from the Vindeby Offshore Wind Farm on local fish

The underwater noise 14 meters from the turbines at Vindeby is 85 dB to 120 dB in the frequency range 0 Hz to 400 Hz when the turbines are operating at wind speeds of 13 m/s (see Figure 1). The elevation above background noise is 5dB to 33 dB in the same frequency range.

Based on the information gathered from the literature, it is evaluated that the noise levels at Vindeby offshore wind farm are unlikely to cause any damage of the sensory-hair-cells in the ears of fish in the area (see section 6.2.2).

Whether or not fish present in the area actually have the ability to <u>hear</u> the noise from the wind turbines depends on their physiology.

Cod and herring are hearing "specialists" and will probably be able to detect noise generated by the turbines, but lower catches of these two species when the turbines were operating were not reported in the area.

Turbot and flounder have no specialisations that enhance hearing and are thus defined as hearing "generalists". Having no swimbladder, they are among those fish that show awareness response at sound intensities of above 90-110 dB (re: 1 µPa) at frequencies below 250 Hz (see section 6.2.1.). The sound intensity necessary to result in an awareness response of hearing generalists without a swimbladder overlap with the sound intensities from operating turbines (85-120 dB) at the same frequencies. This means that the turbot and flounder positioned close to the turbines (at a distance more than 14 meters from the turbines) will probably hear the noise from the turbines at wind speeds of 13 m/s.

If turbot and flounder (as other hearing generalists without a swimbladder) show awareness response at 90-110 dB (re: 1 µPa) at frequencies below 250 Hz and show avoidance responses at sound intensities 10-15 dB above the level of awareness response (see section 6.2.3), then the sound intensities necessary to result in an avoidance response of hearing generalists without a swimbladder (approx. 100-125 dB) also overlap with the sound intensities from operating turbines (85-120 dB). It thus seems possible, but not very likely, that noise produced by the turbines would elicit an avoidance reaction from turbot and flounder positioned less than 14 meters from turbines operating at wind speeds of 13 m/s.

At greater distances from the turbines the noise will diminish (see section 6.1.2.). The distance between the turbines is 500 metres. At distance more than 112 metres from the turbines, the noise will be 74-111 dB in the frequency range 10Hz to 400 Hz. An overlap between the noise intensities from operating turbines and the sound intensities necessary to result in an avoidance reaction still exists.

Data from the 220 kW Windworld turbine “Svante 1” indicated that at wind speeds of 6 m/s and 12 m/s the noise intensities from “Svante 1” (measured at frequencies from 2 Hz to 2000 Hz) would elevate equally many dB (from –5dB to 12 dB) above background noise at wind speeds of 6 m/s and 12 m/s (Westerberg, 1994). It therefore seems less likely that a noise related avoidance response from turbot and flounder should be more pronounced during rough weather compared with calm weather.

7. Former studies on fish and fishery in connection with the establishment of Vindeby Offshore Wind Farm

An investigation of possible effects on the fish fauna of establishing the wind farm at Vindeby has previously been conducted (Haumann,1993). Investigation of the fish fauna was performed in the area where the turbines were to be established and in a reference area before (1989) and after (1993) the establishment of the turbines. Possible effects taken into consideration were:

1. Impact in relation to the importance of the area as a spawning ground for important fish species
2. Impact in relation to the importance of the area as a nursery ground for important fish species
3. Impact on fishery

The nets were placed at the boarders of the wind turbine area and in a corresponding reference area; wind speed at the time of investigations is not mentioned in the report. According to local fishermen (ref. Bjarne Kolath) at least some of the investigations were done at a time with quiet weather and relatively low voltage in the cables connecting the turbines.

The conclusions, which unfortunately were not based on statistical analysis of the data, but purely on objective observations were (Haumann, 1993):

1. The area was not important as a spawning ground for herring *(C. harengus)*.
2. Due to low catches it was not possible to determine whether or not the establishment of the offshore wind farm had an effect on the spawning of herring.
3. The wind turbine area was not an important nursery area for fish fry before the establishment of the turbines. This situation did not alter after the establishment of the turbines.
4. Before the establishment of the wind turbines no quantitative or qualitative differences were determined between the turbine area and the reference area.
5. After the establishment of the turbines a considerable increase in the number of cod *(G. morhua)* present in the wind turbine area was noted. The increase was explained by the development of a reef fauna, namely a larger density of small crustaceans and fish.
6. There was no indication showing that noise or other physical influences from the turbines had an effect on the fish in the area.
7. The establishment of the offshore wind farm had no negative effect on the fishery in the area.

The conclusions of the above-mentioned investigation thus do not give the impression that fewer fish were caught after the establishment of the offshore wind farm. But the investigation does not supply any information on the relationship between wind speed and catches of turbot in nets placed between the wind turbines.

8. Field investigations and interview with a local fisherman

An interview with the professional local fisherman Bjarne Kolath and a field investigation of the Vindeby Offshore Wind farm were carried out by Bio/consult on 6th June 2001.

8.1. Interview

The following refers to questions asked by Hakon Regnar Jalk (HRJ)of Bio/consult, and answers given by Bjarne Kolath, Byskovvej 103, 4913 Horslunde. The objective of the interview was to map the fishing habits of Bjarne Kolath (BK). The questions were followed up by a telephone conversation between Bjarne Kolath and Kirsten Engell-Sørensen (KES), Bio/consult, on 22nd December 2001.

HRJ: The turbines were established in 1991. Under windy weather conditions, has the catch been worse in the past 10 years?
BK: Yes, before the turbines the area used to be a good fishing ground for turbot.

HJ: When did you begin to realise the possible effects the turbines had on your fishery?
BK: *Immediately after the establishment of the turbine park.*

HRJ: What kind of fishing gear do you use?
BK: Nets designed for turbot, 70 meter long.

HRJ: Where do you set the nets, both inside and outside the turbine park area? Are the fishing positions the same from one tending to the next.
BK: The positions are not the same, but they are set in the same way: directed east/west with a slight northeast direction.

HRJ: Are the setting of nets similar in windy and calm weather?
BK: Yes, the nets are directed east/west with a slight northeast direction. In that way the nets are set perpendicular to the cables. The nets are set like that because of the direction of water currents in the area. If they were not set like that the nets would be filled with dirt that would float into them.

HRJ: Will fishery be undertaken inside and outside the offshore wind farm area at the same time?
BK: Yes

HRJ: How many nets are set between the turbines compared to outside the turbines?
BK: There are approx. 12 nets in a row. Each net has length of 70 meters. As a consequence, each row of nets has a length of approx. 840 m. This means that some of the nets in a row are set outside the turbine park, and some of the nets in a row are set inside the turbine park. Approx. 7-8 rows of nets are set every time, each net having a length of 70 meters.

HRJ: At what time of the day do you fish?
BK: Most often the nets are set and stand for a couple of days before they are tended.

HRJ: Do you fish both inside and outside the wind turbine park at the same time?
BK: Yes, both inside and outside the turbine area.

HRJ/KES: Which fish species do you catch and what are the yearly landings of each species?
BK: Lumpsucker and turbot in the spring, cod in the winter.

Comments: The yearly landings are not calculated, and he is not required to complete logbooks because he sails under coastal water regulations.

HRJ: Are there certain species, which are not caught when it is windy?
BK: Yes, flatfish, especially turbot - they swim at the bottom, and the catch in the turbine area is reduced when it is windy.

BK: Lumpsucker swims higher in the water column, which is probably why they are not affected.

BK: From the end of October until New Year cod is caught. A reduced catch of cod in the turbine area is not observed when it is windy, compared to calm weather.

HRJ: Do you catch as much fish in the offshore wind farm area as outside the offshore wind farm area?
BK: Yes in calm weather, but in windy weather the catch of flatfish, mainly turbot, is reduced in the offshore wind farm area.

HRJ: In your opinion, do the wind speed and the wind direction have any influence on the catches?
BK: The wind direction does not seem to make a difference. At wind speeds above 5 m/s the catch is reduced inside the turbine area. The weather has to be calm for at least 24 hours before the fish are back in the turbine area.

HRJ: Above which speed of wind is it not possible to fish at all?
BK: At wind speeds above 10 m/s fishing gives problems.

HRJ/KES: How far away from the turbine area do you have to set the nets to catch fish when the turbines are operating.
BK: In the immediate vicinity of the cables (just outside the cables- at maximum 10 m).

HRJ: Have you observed a difference of the fishery between clear weather and cloudy weather (shadowing effect from the turbines)?
BK: ?

HRJ: Which species are not caught in rough weather?
BK: Flatfish, especially turbot.

KES: Are there, to your knowledge, any other fishermen who have observed the same effect?

BK: Yes, two recreational fishermen (Nikolaj Nikolajsen, Onsevig and Arne Rasmussen, Harpelunde) have observed the same pattern with flounder* (*Nikolaj Nikolajsen and Arne Rasmussen were not contacted by Bio/consult).

Additional information from Bjarne Kolath given on 6th June 2001.

- According to Bjarne Kolath, the increase of turbot catches in the area west of Lolland in the past years were possibly due to colder waters.
- According to Bjarne Kolath, the catch effort has increased in the area west of Lolland around Onsevig, especially in the area near the navigation route (T-route). The number of nets has increased and the nets stand closer to each other.
- Bjarne Kolath has been a professional fisherman since 1975. At the time of the interview he was the only professional fisherman left in Onsevig.
- In the past years the amount of bladder wrack (*Fucus vesiculosus*), a brown macroalgae, has increased in the area.
- Bjarne Kolath told that he had observed that turbot at the bottom close to the net did not move on one day - "to evaluate the danger", but he had observed that the turbot were caught in the net the next day.

9. Field investigations

9.1. Method

Bjarne Kolath agreed to observe and communicate to Bio/consult when turbot would appear in the area of the offshore wind farm. After appearance of the turbot, Bio/consult and Bjarne Kolath should conduct a test fishery. Series of gill nets designed for turbot should be placed between the turbines perpendicular to the two rows of turbines (so that there were nets both between the turbines and outside the wind farm, on both sides). After the test fishing, Bjarne Kolath should register all his catches from the area (for registration scheme, see Appendix 1).

9.2. Lack of turbot in spring

Unfortunately, the spring was extraordinary cold, with the possible result that the turbot had migrated to shallower water (including the turbine area) later than normally. The first turbot appeared in late April. The late appearance of turbot in the area combined with rough weather conditions resulted in a poor turbot fishery, and Bjarne Kolath evaluated that it was not worth the effort to set any turbot gill nets to investigate the turbot fishery inside and outside the turbine area. In the beginning of June Bio/consult decided to ask Bjarne Kolath to set turbot gill nets in the turbine area anyway, knowing that the catches might be poor.

9.3. Gill net fishery by Bjarne Kolath 5th – 6th June 2001.

9.3.1. Gill net settings

Three nets were set as shown in Figure 2. The nets were set along the current. The length of a net row was approx. 850 m (12 x 72 m, 110 mm mesh).

Only weak winds (less than 3 m/s) were blowing at the time of fishing. The water was clear. All the turbines except one (1E) were in function during test fishing.

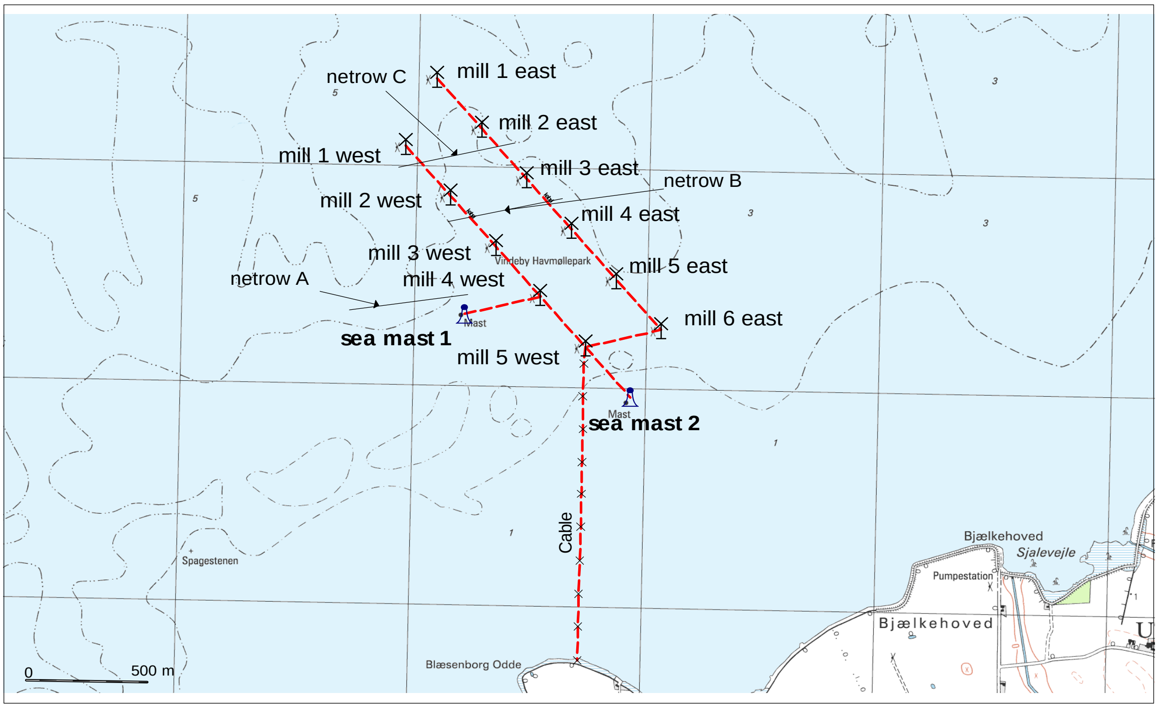

Figure 2. Map of Vindeby Offshore Wind Farm. P = wind turbine. The position of net rows used during the test fishing is also shown in the map.

9.3.2. Result of test fishery

All the nets were filled with annual macroalgae (*Pilayella spp.* and *Ectocarpus spp.*) Net A caught 3 turbot *(P. maxima)* outside the turbine area. Net B did not catch anything and Net C caught 1 turbot inside the turbine area. Two of the fishes were undersized.

As a consequence of the large amount of annual algae and the sparse catch of turbot, it was decided to cancel further fish investigations at that point in time.

10. Conclusion

A professional fisherman, Bjarne Kolath from Onsevig, who fishes around the northern part of Lolland, states that although there seems to be an increase in the number of fish near Vindeby Offshore Wind Farm after its establishment, the flatfish, especially turbot *(P. maxima)* do not migrate between the turbines when it is windy.

The objective of the investigation was to examine the observations of Bjarne Kolath regarding his catches of turbot in varying weather conditions and, based upon his observations and literature studies, set up an investigation to determine whether or not electromagnetic fields and/or noise from the Vindeby Offshore Wind Farm affects fish and fishery within the turbine area.

Literature studies on the shadowing effects from the mills were not conducted, since this effect was evaluated to be in dependant of wind speed.

From the literature studies it does not seem likely that noise from the wind turbines at Vindeby might result in avoidance reactions of turbot *(P. maxima)* and flounder *P. flesus)*, not in high nor in low wind speeds (see section 6.3).

The magnetic field strength in the near vicinity of the cables might be sufficiently high to affect the fish. However less than 1 meter from the cables the magnetic field equalled that of the geomagnetic field of the earth.

Whether or not a change in the magnetic field created by the cables connecting the turbines affects the fish or the fishery in the area remains an open question.

Due to the general lack of turbot in the area west of Lolland until late April, and the rough weather following the apparent arrival of turbot *(P. maxima)*, Bjarne Kolath did not consider it reasonable to start investigations and thus perform valid test fishing in spring 2001. When fishery became possible in the beginning of June, the turbot were apparently not present in the area.

The initiation of this investigation was the direct result of statements by Bjarne Kolath, the only professional fisherman fishing in the turbine area. The fact that Bjarne Kolath has now retired does not diminish the need to investigate his observations, but has complicated investigation of the fishery the area.

The future construction of 150 MW offshore wind farm at Rødsand south of Lolland in the Femer Belt has been the reason why environmental impact assessment (EIA) studies have been performed at Rødsand. The following monitoring programme includes a BACI (Before After Controlled Impact) test of the impact (e.g. electromagnetic fields) the cable leading from the designed offshore wind farm to the shore might have on migratory fish. Since the Vindeby offshore wind farm has already been constructed it is not possible to make a BACI test of the impact of the cables at Vindeby.

The present investigation has not been able to confirm or reject the statement of Bjarne Kolath that the flatfish (especially turbot) do not migrate between the turbines during windy weather. It is therefore recommended that the investigation of the potential effects from electric cables and noise from wind turbines are concentrated to future offshore wind farms, e.g. the offshore wind farm at Rødsand south of Lolland in the Femer Belt, where monitoring programmes are in progress on the basis of BACI-test (Before-After-Controlled Impact) strategy.

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Appendix 1

Translated questionnaire for registration of fish catches at Vindeby Offshore Wind Farm.

FISHERMAN:

DATE:

Weather:	Wind (Direction/strength)	Direction of currents	cloud cover	Rainfall	Are the turbines running (+/–)
At setting of gear					
At tending of gear					

Type of fishing gear

Unit no.	Length	Position start	Position end	Efficient fishing time	Weight of catch	Dominating species