Danish Off Shore Windpower Programme

International Advisory Panel of Experts on Marine Ecology (IAPEME)

Statement from meeting in March 2002

COLOPHON

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Cover:
Page Leroy-Cruce

Paper:
Cyclys Office 90 g

Printing:
Danish Forest- and Nature Agency

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PREFACE

Due to the special status of the Danish off shore windpower programme a measurement and monitoring programme is conducted to investigate the effects on marine ecosystems before, during and after erections of wind farms. So far baseline studies have been made and the monitoring is at the moment taking place during the construction phase of the farms at Rødsand and Horns Rev.

In relation to the programme the Danish Energy Agency in November 2000 appointed five international experts to the International Advisory Panel of Experts on Marine Ecology – IAPEME.

The members are

- Professor Rudi H. Drent, University of Groningen, NL
- Professor Robert W. Furness, University of Glasgow, UK
- Professsor Klaus Lucke / Professor Ursula Siebert, University of Kiel, DE
- Professor Antony Jensen, University of Southampton, UK
- Professor Henrik Gislason, University of Copenhagen, DK

The task of the IAPEME is to comment on the environmental measurement and monitoring programme before, during and after erections of wind farms and on the basis of the documented results from the programme to comment on the impacts of the wind farms on birds, mammals, fish and benthic ecosystems.

This report contains the statement from the second meeting of the International Advisory Panel of Experts on Marine Ecology, March 2002.

The Secretariat of IAPEME is placed in the Sea and Habitats Division, Danish Forest and Nature Agency. Contact persons are Anne Grethe Ragborg and Lars Bo Hansen.

Secretariat of IAPEME

GENERAL OUTLOOK

The panel wishes to commend the investigators concerned with birds and mammals and finds the work on these groups up to a high international standard. The results so far justify the choice of methods followed, with an emphasis on integration of complementary techniques (in birds, aerial survey plus radar surveillance, in sea mammals counts and satellite tracking). Some of the techniques employed are highly innovative and maintaining the research effort ensures strengthening a pool of expertise within the country. At present the sea mammals and bird groups are both involved in ongoing work in Greenland, and their participation in the wind farm projects is of direct benefit in gaining much needed experience in sophisticated methodology. As wind farms are developed offshore along the North Sea coastline of neighbouring countries (Germany, The Netherlands and United Kingdom) demand on specific expertise will increase greatly and Denmark can profit fully from its leading position in both research and technology.

With regard to fish, the panel is concerned that the work undertaken so far does not in all respects measure up to expectation. Although the survey work undertaken provides an impression of the species mix to be expected in the two areas, there appear to be major problems with the ability to obtain quantitative data of sufficient power to answer the questions posed. For this reason the panel advises submitting the catch data to an independent outside expert for statistical evaluation. If the upshot of this exercise is negative, other techniques and/or a change in sampling regime may be called for. Aside from this, the panel recommends to give priority to the Rødsand site in the theme project "Introduction of hard bottom habitat". (see below). The sandeel survey undertaken at Horns Rev is highly relevant both in terms of possible impacts on sandeels and as contextual information assisting interpretation of change in numbers/distribution of piscivorous seabirds and marine mammals, and the Panel is anxious that the data are worked up in preparation for the next survey (scheduled to take place after the construction work of the coming summer).

The benthic survey of Rødsand including the photo-plots appears promising, and the panel is looking forward to an updated report. The extensive musselbeds are of special interest and deserve additional sampling to investigate biodiversity of this community.

Although somewhat outside our remit, the panel submits that it might be useful to approach the local fishing community to ascertain their feelings on the visual and socio-economic impact of the wind farms. After all, these people will be out in and around the turbine area for the daily work and may well have very different views as compared to the shoreside community that only experience the wind farm on the horizon at a considerable distance.

Given the efforts in other countries the time seems ripe to consider approaching European sources of funding to collate the studies undertaken so far, and make the Danish studies more widely available. In addition, there will be a need to look at 'summation effects' resulting from development of marine wind farms along the coasts of North Sea and Baltic.

IAPEME recommended priorities:

1. Study of collision risk for birds at both sites, but especially Rødsand.
2. Monitoring impact of ramming at Horns Rev on marine mammals.
3. Studies of habitat loss for seabirds and marine mammals at both sites.
4. Gill net study of fish at Rødsand.
5. Sandeel survey around Horns Rev.
6. Benthic community development at Rødsand to maximise gillnet data use, as data use and techniques are cost effective.

BIRDS

Wind farms might affect birds by increasing mortality rates through collisions, by disturbance of birds from feeding habitat, or by altering the amount of feeding habitat. Large wind farms may also produce a barrier effect, deflecting bird movements away from their intended tracks. Of these potential effects, collision risk is likely to have the greatest impact on bird populations, so requires priority consideration.

Collision rates of birds

The Horns Rev wind farm seems likely to affect only quite small numbers of birds, though it could be a collision hazard for red-throated divers, gannets, and gulls, particularly during autumn and winter. In contrast, the Rødsand wind farm might affect very large numbers, especially having a high potential to kill sea ducks on migration. Collision rates are extremely difficult to predict since it is not possible to extrapolate with any confidence from experience with terrestrial wind farms to what will happen at marine wind farms. The high natural survival rates of seabirds and sea ducks, together with their low recruitment rates, make them vulnerable at a population level to even small increases in mortality rates of fully-grown birds. Therefore, it is not possible to be certain that the wind farms will have only trivial impacts on seabird populations. For this reason, a very high priority should be given to the quantification of bird collision rates at demonstration marine wind farms. Because risks appear to be very much higher at Rødsand than at Horns Rev, the measurement of collision rate should focus on the Rødsand site, but should not ignore Horns Rev, particularly because the species of birds at Horns Rev are very different from those predominating at Rødsand.

So far, no satisfactory technological solution to quantifying bird collision rates at wind farms has been developed anywhere in the world. At terrestrial sites, rates are usually estimated rather inaccurately by counting numbers of bird corpses found below turbines from time to time. The use of exclusion fences to reduce losses of corpses to scavenging animals such as foxes may help to reduce underestimates of numbers of collisions, but some carcasses will probably be missed and so rates are almost certainly underestimated by this approach. Collision rates at terrestrial turbines are often estimated at between 10 and 40 birds per year. No solutions have yet been developed for counting collisions at marine wind farms, and it is impossible to say if they will be higher or lower than at terrestrial sites. The development of a technological solution by this demonstration project will therefore be at the forefront of international research, giving Danish scientists a clear lead in this field in terms of applied science and technological development. Both these skills have considerable potential for export to other countries, and could be applied at terrestrial as well as at marine wind farms.

The use of an infra-red video system to monitor birds approaching turbines seems to have potential. The development of a heat threshold that triggers recording so that all bird movements are recorded would provide an efficient way of avoiding recording of large amounts of uneventful material and seems highly practical. However, it is not yet established that the video camera under consideration can discriminate birds at the necessary distance. Given that the proposal is to place cameras on one turbine pole in order to record birds approaching the neighbouring turbine, the system will need to be able to detect with high accuracy birds that are about 400 to 600 m away from the

camera and approaching the blades some 450 to 550 m from the camera (depending on whether the system is being used at Rødsand or Horns Rev). It is critical to test the camera to determine the maximum distance from which birds of different sizes can be detected. The detection distance needs to be suitable not only for large birds such as eider ducks and gulls, but preferably also for small passerines, since these may suffer collisions too, especially at Rødsand during autumn migration south from Sweden through Denmark. It might be possible to mount a camera on a meteorological pole to view an adjacent turbine, but this would severely restrict the selection of turbines and might miss higher collision rates on peripheral rows of the wind farm.

If the camera is unable to discriminate birds at these distances, then it might be necessary to attach a camera to view turbine blades from below, mounted on the same pole as the turbine. Such an arrangement would then present some practical problems due to the turning of the turbine to face wind direction and due to blind areas caused by the pole behind the camera.

Given that the turbine poles will probably cause the camera to vibrate, there may be a much poorer resolution of distant birds when the camera is mounted on a wind farm, and so there may need to be technological development of suitable mountings before the system can be used. Other problems, such as dirt accumulating on the lens or protective housing window, will also need to be overcome. Thus it can be anticipated that this technology will take some time to get to a condition where data can be collected.

It will then also be essential to validate such a system, and it seems that no plans for this have yet been made. Validation would be required not only of the ability of the technology to detect flying birds, but also of its ability to discriminate bird species or type, and its ability to record the number of collisions that occur. If collision rate is low, validation may require very long periods of direct observation by people, in order to register a useful number of collisions that can be checked with the details recorded by the video system. Such validation might be carried out at terrestrial wind farms more easily than at sea, especially if there are terrestrial sites where collision rate is known to be relatively high. However, validation of the technological solution would be crucial if it is to gain scientific acceptance.

Given that the two demonstration wind farms should start to generate electricity around 2003, there is not very much time remaining for all of the technological aspects of this development to be assessed, and solutions obtained. This work requires the highest priority.

Because of the high cost of cameras it would be sensible to develop and test the system using a single camera. However, because even a relatively low daily collision risk per turbine can add up to large numbers of birds killed per wind farm per year, in order to obtain an accurate measure of collision rate it would be preferable to install several cameras at Rødsand. Ideally these would be recording from commissioning of the turbines, since it would be highly desirable that data would be collected during the first autumn migration during which birds have experience of this new wind farm. Comparisons between collision rates in the first and subsequent autumn migrations would then indicate whether birds learned to avoid collisions as they gained experience of the site (since adult eiders may live for 10-20 years it may be possible that they could adapt migration behaviour to avoid dangerous locations, but this is specu

lation until studied). Continued radar observations of movements of birds on autumn migration past Rødsand, combined with collision data, may answer this point.

It should be remembered that individual turbines will probably differ in collision hazard depending on predominant direction of approach of birds and the extent to which birds might forage between rows of turbines at a risk of being scared to flight, for example by an approaching helicopter.

Impacts on the habitat of birds

Birds are likely to be displaced from foraging habitat by the disturbance caused by wind farms. They may habituate to such disturbance over time, and it is even possible in some cases that once such habituation occurs, some species might benefit from increased amounts, or concentrations, of food in the vicinity of individual turbines or wind farms. It is possible that invertebrate and fish populations may increase locally due to increased amounts of rock habitat and surfaces, and reduction in fishing mortality to fish within wind farm areas (especially if trawling was previously the main method used by fisheries in the area). Thus short term and medium term effects of wind farm development might differ, or effects may differ between species. Particularly sensitive species of birds might never habituate to wind farms, or might be continually disturbed from these areas by maintenance activity such as helicopter flights.

With regard to potential 'barrier effects', continued radar observations of movements of birds on autumn migration past Rødsand should provide a powerful test of this, as they will be able to detect small changes in flight lines used by birds once the farm is constructed compared with existing baseline data. Studies of flight heights of these birds might also be useful to measure the extent to which birds can avoid turbines by flying under, or over, these. Such data would also be relevant to collision risk assessment as discussed in the previous section. Since studies of flight heights are to be carried out in Germany in relation to wind farm developments there, international coordination of research, such as through EC 'Associated Measures' or 'Specialist Conference' funding might be appropriate.

The GAM approach to measuring wind farm avoidance, as outlined by Tony Fox, seems to be a very powerful form of analysis, and also of presentation of data. Indeed, this modelling approach may have considerable merit for other animals as well as birds. It would seem suitable for the porpoise distribution data from Horns Rev, for example.

Tony Fox raised the broad question as to whether most of the bird species that might lose habitat due to wind farms will be limited in population size by breeding season habitat availability. If so, their loss of winter habitat might, in theory, have little or no impact on population size. It might be appropriate to consider this question further by reviewing literature on the species concerned. If it can be shown that winter foraging conditions affect survival rates, or body condition of birds to an extent that subsequent breeding performance is influenced, then it is unlikely that winter habitat loss is unimportant. Evidence is accumulating that spring fattening at specific sites prior to long distance migration in sea ducks such as eiders and scoters may prove critical to subsequent breeding performance. For this reason, maintaining the aerial survey work over large areas to locate the spring concentrations may provide extremely valuable refer

ence data to assist planning of future offshore wind parks along both coastlines of Denmark.

Since the Rødsand wind farm is very close to Special Protected Area for marine birds, and contains large quantities of mussel beds and cockle communities that will be food for sea ducks, it is clearly a high priority to measure changes in foraging distributions of birds around that site. The Horns Rev site has lower densities of birds, but there are different seabird species around that site, including predominantly piscivorous seabirds rather than benthic-feeding seaducks. Since the two sites hold very different seabird communities that may be affected in different ways, it would be important to continue studies of bird distributions at both sites. For example, birds at Horns Rev may include relatively few individuals that remain in the area for prolonged periods or revisit in successive years, in which case habituation will be less likely to occur. However, the Rødsand site has a greater potential to affect bird distributions because of the high bird abundance at that site.

Changes in bird density or distribution might be expected to occur in response to large changes in abundance or distribution of food. If it is possible to obtain information on changes in sandeel abundance/distribution around Horns Rev, such data may be helpful in the interpretation of changes in seabird distribution/abundance. Similarly, data on hydrography may be important, for example in relation to diver distribution. While comparisons by BACI design might be made without the support of food and hydrography, the interpretation is likely to be improved if these contextual data are available. While a BACI approach, as planned for the birds around Horns Rev, may be successful, it might be worth looking at the development of a GAM analysis at that site too; it seems that GAM would make use of all of the existing data on bird distribution in that area, rather than using only data from within the wind farm and selected control areas.

Recommendations

- Effort should focus on the development of the infra-red video system to record bird collisions, as a top priority.
- The system should, if possible, be implemented at Rødsand from the first year of operation in order to obtain data on collision rate, especially during the autumn migration.
- Comparisons should be made over a series of years since bird collision rate may change as birds learn about the hazard.
- The GAM approach should be investigated to measure bird avoidance of Horns Rev as well as Rødsand.
- Again, it is important to examine how this may change over time, since birds are likely to habituate, which would only become evident if data are collected over several years following the commissioning of the wind farm.

MARINE MAMMALS

The environmental programme to evaluate the preconstruction status of marine mammal populations and the potential negative effect of building windmills in the two demonstration areas – Horns Rev and Rødsand – comprise a set of well designed studies at a high technical level. The target species – harbour porpoise and harbour seal are listed in Annex I. of the habitats directive and are keyspecies under several other international agreements (ASCOBANS, TMAP). The baseline studies on these two species have been conducted at both sites.

A major problem for prioritizing the continuation of the studies at the two sites results from the two different approaches to assessing these areas. As a demonstration project it might be possible to study any effect on each of the species at issue at the best suited site, and subsequently to generalize the results to ecologically comparable areas. As an impact study on species which are protected under diverse agreements and directives, it is required to define the ecological importance of each habitat as well as the potential impact of the planned activities on these animals at each site.

Given the ecological differences of the Horns Rev and the Rødsand areas, it is not appropriate to generalise results from harbour porpoise or harbour seal studies from one area to the other. The most recent analyses confirm the discrete nature of seperate populations found in the North Sea, western and central Baltic. Keeping this distinction in mind, even though the relative abundance at Horns Rev might be higher (therefore indicating a higher priority for studies in this area) the lower relative abundance of these animals at Rødsand is counterbalanced by the high ecological importance of the Baltic population. Rødsand is located in the transition zone between the apparently highly endangered harbour porpoise population in the central Baltic Sea and the western Baltic Sea population, of which the former is the focal population of an international recovery plan under ASCOBANS. The abundance and distribution as well as the importance of the habitats at issue (Horns Rev + Rødsand) need to be further investigated at both sites. As most of the required equipment is already accounted for, the continuation of the programme at both sites also seems cost efficient.

Horns Rev

At Horns Rev several ship surveys have been conducted and revealed a higher number of harbour porpoises than expected. Additionally this area seems to be important as a nursery area for this population. This result is being supported by data from the adjacent German area of Sylt and Amrum, where a breeding ground for this species has been identified. The application of towed acoustic detection devices (T-PODs) has so far been unsuccessful. A stationary deployment of such devices provided data on the 8 seperate locations in the impact area and 3 reference areas. A simultaneously conducted measurement of hydrographical parameters (salinity + temperature) provides important additional data.

A continuation of these investigations will enable the consulting agencies to get statistically solid data on the relative abundance and distribution of harbour porpoises in the area, as well as relative information on the habitat use (based on the T-POD-data). Since these devices have been deployed separately neither a spatial analysis of the habitat use, nor a quantification of the animals encoutered acoustically can be

achieved. The resulting T-POD data nevertheless provide valuable information on the importance of the areas covered. The main advantage of this method compared to the snap-shot type of data from visual and acoustic surveys is the continuous sampling of the data. While survey data will continue to give the necessary baseline data on the overall abundance and distribution of harbour porpoises around Horns Rev, the T-POD data will allow important conclusions about diurnal as well as the (relative) overall changes in habitat use.

The use of towed acoustic devices would increase the detection probability for harbour porpoises during visual sighting surveys. Using an array of two synchronised and coupled T-PODs even gives the opportunity to collect directional data and respectively to intercalibrate the visual and acoustic method - thus enhancing the declarative strength of the resulting data.

The seal study at Horns Rev concentrates on a telemetry study which started at the end of 2001. The resulting data are crucial for defining the type and amount of use of the anticipated windmill area by these animals. Accordingly this study should by all means be continued to collect the necessary amount of data to conduct a statistical powerful analysis. The development and application of the new GPS/GSM system could be beneficial to the programme as the quality of data can be improved and the relative cost for achieving the required sample size can simultaneously be cut. Such data also should be analysed for potential changes in the animals' time budget as a potential windmill-effect.

A strong behavioural effect of harbour porpoises and harbour seals is most likely to occur at Horns Rev as the ramming procedure for the monopiles is associated with intensive noise. The effect may either be short- or longterm and of an unknown spatial extent.

Mitigation measures for the construction phase at Horns Rev

The acoustic signals of the ramming process during the construction of the monopiles at Horns Rev will presumably have a sound pressure level comparable to the levels measured at other offshore windmill sites. The emitted energy within such a series of short signals is most certainly high enough to seriously impair harbour porpoises and seals in the surounding area. As spherical spreading should be assumed in a conservative approach the signals will have the potential to physically damage the animals tissues in the close vicinity (depending on the received peak pressure) or to impair the animals auditory sensitivity (i.e. hearing) over a medium range around the ramming site. The repetitive nature of this sound production is thereby increasing the potential negative effects as the threshold for impairing the auditory sensitivity is lowered accordingly.

Precautionary measures have already been considered to a wider degree. Since none of the measures will secure either the exclusion or the non-occurence of animals in the vicinity of the ramming site with a 100% safety (e.g. pingers don't scare seals away), additional measures should be applied. Comparable to the guidelines for conducting seismic surveys (see JNCC, U.K.) a ramp up procedure should be used for the ramming sound, i.e. the impulsive sound should be emitted into the water a few minutes before starting the ramming. Thus animals will be enabled to leave the area before the

impulses reach a dangerous intensity. This can be done by simulating the noise (with comparable, not necessarily identical spectral and temporal characteristics) and transmitting it over an omnidirectional sound source into the water. An equivalent effect of alternative sound sources and signals would have to be tested and proven before approving their application.

A bubble curtain could be used as an additional mitigation measure to dampn the sound intensity and reducing the range for potential impairments (such a device has been successfully used during the construction and associated ramming activities of an Asian airport being extended into the water, see Wuersig et al. 2000). The applicability is site specific and hence the use of such a deployment has to be considered carefully for Horns Rev.

A code of conduct should be developed for the deployment activities if animals are detected within distances short enough to potentially impair such animals.

Rødsand

Based on the above mentioned reasons the study on harbour porpoises should also be continued in the present design at Rødsand. Additionally to the importance of the Baltic population, the ecological and hydrographical regimes as well as the animals' habituation to existing anthropogenic sounds may be different in both areas. The effect of ramming noise can only be investigated at Horns Rev. It cannot be assessed to date whether and to which extent the installation at Rødsand has the same potential for causing a temporary or permanent habitat loss as the installation at Horns Rev. The different installation types (monopile vs. gravitational fundament) and the associated noise levels are likely to elicit different short- and long term reactions of the animals during the construction phase as well as during the operational phase of the windmills. A generalisation of the Horns Rev data onto the situation in Rødsand seems not possible. Hence the continuation of the T-POD programme and the visual observations at Rødsand seems necessary. To improve the declarative strength of the results data from telemetry studies on harbour porpoises in the Danish Belt area should be analysed additionally.

Based on the specific local situation with a seal sanctuary located in the close vicinity of the windmill area there is a strong need for a continuation of the seal telemetry study at Rødsand. A higher number of animals need to be studied in order to come to meaningful results. The intensive use of the to-be-developed GPS/GSM technology should seriously be considered for the same reasons as at Horns Rev. If the animals at both locations continue to show different pattern in using the surrounding habitat and if this is being supported by an analysis of the dive profiles it seems unlikely that conclusions can be generalised from one area to the other. The different amount to which the animals are already exposed to anthropogenic sound and potentially habituated to this disturbance makes a comparison of this important aspect between both sides impossible. It has been shown that the seals tagged at Rømø have to come back to their haulout site and therefore migrate through the Horns Rev area whereas the animals at Rødand don't rely on this haulout site but can choose between several other locations.

No further mitigation measures have to used for the installation of gravitational fundaments in Rødsand.

T-POD deployment during the construction phase
The T-PODs in both areas should remain deployed during the construction phase; this would allow for a comparative analysis for the potential effects on the relative use of the habitat by the harbour porpoises. Due to the above mentioned differences in potential noise related effects the construction effect has to be studied seperately at both sites. A negative effect is most likely at Horns Rev but due to a complete lack of comparable data a similar effect cannot be ruled out for the Rødsand area. The ecological importance of the Baltic harbour porpoise population increases the need for continuously conducting the investigations.

Negative effects on the animals' abundance and distribution can otherwise only be assessed by conducting visual and/or acoustic surveys in the area. Such surveys have so far only be carried out at Horns Rev at a sufficient level. As for any comparative analysis baseline data from the period before the installation are required. The only possible method for investigating the construction-effect on the harbour porpoises at Rødsand is continuous deployment. At Horns Rev both methods (surveys + T-PODs) can and should be used continuously in order to enable the consulting agencies to analyse the construction-effects on harbour porpoise abundance and distribution as well as on the habitat use in this area. Both aspects are important for the assessment of Horns Rev as a demonstration-site but also for the site-specific assessment.

Other data
A combined analysis of the marine mammal data with relevant information on the potential (fish-) preyspecies would be beneficial and should be considered as this is probably a key parameter for the occurence of marine mammals. Hydrpographical data should also be analysed in order to provide additional variable indicators which are varying in time for assessing the ecological value of the studied sites.

As all the analysis pointed out are based on a BACI design the studies should be continued over the whole programme period until 2005.

Recommendations
- Continue investigations on harbour porpoises and harbour seals at both locations
- Intensify efforts to apply the use of towed T-PODs to detect porpoises
- Explore means of collecting oceanographic data and information on fish with the marine mammal data
- Contact JNCC (U.K.) for guidelines on mitigation measures as propounded to the oil industry
- Instead of using a towed T-POD (which provides only off-line data) during the construction phase to detect harbour porpoises a towed hydrophone should be used in combination with an online clickdetector to get real-time data. Otherwise no adequate reaction to the occurence of animals in the vicinity of the ramming site will be possible.

Literature cited

Würsig, B., Greene Jr., C.R. and Jefferson, T.A. (2000): development of an air bubble curtain to reduce underwater noise of percussive piling. Marine Environmental Research, Vol. 49, pp.79-93.

JNCC / Joint Nature Conservation Committee: JNCC Guidelines for minimising acoustic
disturbance to marine mammals from seismic surveys;
http://www.jncc.gov.uk/marine/seismic_survey/default.htm

FISH

The windmills might affect the fish fauna in an area permanently by introducing new or additional hard substrate on which epibenthos can settle, by changing sediment characteristics, by introducing electric cables that might possibly interfere with fish migration and by the noise and vibrations generated by the mills during their operation. Additional effects may be generated during the construction phase.

Horns Rev

Due to the exposed nature of the Horns Rev area it is uncertain whether a persistent epibenthic fauna will develop on the windmill foundations and on the stones used for scour protection. In addition the exposed nature of the Horns Rev site makes it very difficult to monitor the changes in the fish fauna in the immediate vicinity of the mills. For navigational reasons it was reported that the nets had to be set 50 meters away from the mill and this makes it less likely that the fish associated with the foundations can be monitored. Provided that this problem cannot be satisfactory solved it was felt that more conclusive information about the possible effect of introduction of hard substrate could be obtained by conducting the gillnet surveys in the Rødsand area.

A baseline survey for sandeel has been undertaken, but the results have not yet been worked up. Sandeel is potentially an important prey item for the divers and gannets in the Horns Rev area. Sandeels bury in the sediment at night and throughout winter and are known to prefer sandy sediments with a low content of silt and fine sand. The density of sandeel may decrease as affected by the windmills if the sediment characteristics change within the park area. It is furthermore unknown known whether sandeels buried in the sediment are sensitive to the vibrations generated by the mills.

It is important that the samples obtained in this year's sandeel survey are analysed and that additional surveys are undertaken during and after the construction of the park. In addition to information about the average catch rate and its confidence limits the age composition of the sandeels caught should be reported. Previous investigations have shown that there is little migration between different sandeel grounds and changes in the age composition of sandeels within the windmill park will indicate whether the area is re-colonised by new recruits or by immigration of older sandeels from adjacent areas.

In the comments from the first meeting of the panel in 2001 it was recommended to monitor possible changes in the distribution of pelagic fish, in particular small herring and sprat. The panel notes that no such monitoring has been planned or carried out. As the park is now under construction the monitoring program will not be able to demonstrate any effects on the distribution of pelagic fish in the area.

Rødsand

The presentation of the statistical analysis of the results obtained from the fish investigations at Rødsand was discussed at the meeting. It was concluded that the number of samples had to be increased to enable statistically significant changes to be discov

ered. It was reported that the power analysis was unexpectedly sensitive to the number of zero catches suggesting the statistical distribution selected to describe the samples may not be appropriate. However, as recognised by the investigators the low catch rates obtained during the surveys limit the possibility for making a statistical assessment of the differences in catches and it may therefore be necessary to increase the number of samples. Without a re-analysis of the basic data using alternative statistical methods it is difficult to evaluate whether the survey design and the gears employed are adequate and whether increasing the number of stations will generate the necessary increase in statistical power. It is important that this problem is solved as soon as possible. The panel therefore recommends that an independent expert familiar with gill and fyke net surveys is commissioned to evaluate the baseline program and the statistical analysis of the results, before a decision is taken to increase the number of samples in the present survey design.

The Rødsand area is much less exposed to wind and waves than the Horns Rev area, and the panel was therefore of the opinion that a gillnet monitoring program similar to the one proposed for the Horns Rev area should be given a high priority. If gillnets are used to monitor the changes in the fish fauna on the foundations it is important that the total length of the gear does not place individual panels so far away that their catch is unlikely to reflect the fish assemblage associated with the foundations. Even though it should be possible to set the nets adjacent to the mills in the relatively quiet Rødsand area, it should be considered to supplement the gillnet surveys with other survey methods. It is not anticipated that the benthic fauna on the windmill foundations in the Rødsand area will differ significantly from the fauna of the adjacent mussel beds. It is therefore unlikely that the feeding habits of the fish will change sufficiently to enable a possible effect of the parks to be identified. Studies of changes in fish food habits should therefore be given a low priority.

It was proposed to investigate the effect of the electric cable on fish migrations by monitoring the catches obtained in four pound nets placed in the vicinity of the cable. The basic assumption was that silver eel from the Baltic would be migrating west to leave the area. It is, however, uncertain whether this is the case and it is therefore suggested to modify the gear by separating the pound net into two separate sections enabling catches of fish travelling east and west to be distinguished. Unfortunately this will not completely solve the problem of identifying species whose migration is affected by the cable. Fish migrating westwards may be diverted from their course, travel either north or south along the cable until they meet the pound net, where they might end up in the westwards facing part of the pound net placed east of the cable, suggesting erroneously that they would have travelled eastwards and crossed the cable. This problem cannot be solved without a major modification of the design.

Should an effect of the cable be detected it will be desirable to conduct laboratory trials where fish are placed in tanks with buried cables and effects of switching on and off currents are observed.

Monitoring of fishing activities

In both areas the monitoring program does not include plans for monitoring fishing within the parks. Even though no or little fishing is taking place within the park areas at present commercial and non-commercial fishing may commence or increase if fish

are attracted to the parks in significant quantities. Reliable data on fishing within the park areas will be important for interpreting the results from the fish monitoring programs and monitoring of fishing activities should therefore be included in the program.

Recommendations

- Conduct gillnet survey at Rødsand to monitor the fish fauna on and adjacent to the foundations and scour protection, and give lower priority to the gillnet survey at Horns Rev unless the nets can be set closer to the windmills.
- Work up the results from the baseline sandeel survey at Horns Rev and undertake additional surveys during and after the construction phase.
- Hire independent expert to evaluate the present survey design at Rødsand and the statistical analysis of the data; to re-analyse, if appropriate, the data sofar collected; to suggest criteria for monitoring the fish fauna in the area; and to suggest possible improvements in the survey design, the gears used, and the statistical analysis of the data.
- Give lower priority to studies of fish feeding habits.
- Modify the pound nets used for studying the migration behaviour of the fish in the vicinity of the electric cable at Rødsand.
- Consider ways of monitoring fishing activities within the windmill parks in order to detect whether possible increases in fish abundance will attract commercial and non-commercial fishing.

BENTHOS AND HARD SUBSTRATUM

The introduction of new hard habitat into the marine environment will allow the settlement of sedentary epibiota and in time development of a fouling community that will evolve over time. In temperate areas of Europe communities developing on new hard substrata are considered to take about 5 years to reach a state similar to mature communities on natural rock.

The precise nature of the community depends on, amongst other things, availability of larvae to settle, the physical complexity of the habitat and the time of year the substrata are deployed. In addition to sedentary life mobile fauna will enter the developing community both from the plankton and through migration, their inclusion will depend on the suitability of the habitat available. The overall complexity/diversity of the final biological community will depend on the habitat complexity available assuming that other parameters such as food availability, predation and physical disturbance are not the dominant force influencing the community development.

The two demonstration projects provide very different environmental situations for epibiotic community development, Horns rev appears to under go annual 'sand blasting' during autumnal and winter storms which effectively has removed the epifaunal community that developed on the experimental mast placed in the area that developed during the Spring and Summer. This will limitthe development potential for epibiota to portions of the scour protection that are sheltered from this 'sandblasting' and are not smothered by sediment accumulation. Rødsand provides a more 'normal' picture where the epibenthic community already evident on the seabed has been able to develop over a timeframe of years rather than months. A similar situation can be predicted for pylon and scour protection structures in the area.

Construction techniques will apparently vary between the two sites, Horns rev windmills will be pile driven into the seabed and the pylons surrounded by a 25 m diameter scour protection of rocks (maximum size15 cm diameter) providing an habitat with a promising niche diversity which in less physically dynamic circumstances would be expected to support a surface covering of epibiota as well as an animal biota within the crevices of the scour protection. Cryptic fish should be able to utilise the structure and crabs would certainly use the habitat for shelter and food. Given the physical disturbances expected it is unlikely that such potential for biological community development will be met, removal of surface biota on at least an annual basis seems likely and the crevices within the scour protection will probably fill with sand during storm events.

Rødsand will use caisson foundations. Caisson foundations will have exposed scour protection which appears to offer similar biological opportunities to the Horns rev scour protection.

Given the restriction in financial resources for environmental studies that the panel has been made aware of difficult decisions have to be made regarding the focus of epibenthic research/monitoring activity in the future. Both sites have very different but interesting biological community development possibilities. Horns rev will provide data on annual settlement only and seems to be the site with the least potential to

provide new information on long term development of biological communities on Danish windmill structures. The monitoring of environmental impacts of the construction phase on the infauna should be followed through to a conclusion using standard 'industry' approaches to data collection and data analyses that have already started. Whilst evaluation of biological community development, especially within the scour protection would be of academic interest it does not seem to be a high enough priority to recommend at this time.

Rødsand does appear provide opportunities for longer term community development studies.Whilst it may not be a wholly representative site when looking to extrapolate results to future windfarm developments in Danish waters, it does seem to offer the better option at present and so research effort should be focused on this site.

Future direction

The conclusion of impact monitoring does seem to be a sensible component of any demonstration programme, especially where the baseline has detailed sensitive and valuable communities such as seagrass. Survey work using the photosampling technique seems to be a pragmatic approach to the monitoring requirements and use of industry standard data analysis techniques should provide data on post construction phase community recovery (or not).

Research into the epibiotic community development, comparing existing benthic mussel community, development of community on scour protection and concrete should be developed following the general outline of suggestions made for the Horns rev artificial reef study in association with the DFU's KFG research gillnet study of near structure fish. This fish survey should move from Horns rev to Rødsand with the appropriate modifications to make it feasible at the new site.

Quantitative sampling using photography is a time/cost effective technique to provide data and can be used by scientific divers to maximise the data collection effort. Sufficient replicate images/sites will be required to facilitate statistical analysis and consideration needs to be given to the number of windmills studied and the habitat elements within each windmill that need to be considered. Horizontal and vertical surfaces need to be considered separately and depth/light penetration may well influence community structure on the windmill foundation.

Sampling of the existing, native, epibiota community to establish and quantify the species present needs to be undertaken and biomass estimations should be made so that the windmill communities can be properly compared to the surrounding biota. Whilst it is expected that *Mytilus* will eventually become the dominant animal in the fouling community and the mussel valves themselves and the spaces between shells will provide habitat for associated species which all contribute to the total biodiversity. Scour protection should be sampled (top & bottom) where it is exposed. Comparison of the new, 'windmill' and existing seabed communities will establish if additional species have been able to establish in the area because of the elevated settlement sites provided by the windmill. Knowledge of the community species composition may assist in the determination of fish foraging areas IF any linkage is possible with the proposed fish stomach contents analysis from the near structure fish survey origi

nally proposed for the Horns rev site. Caution is needed here as the expected fouling community is likely to be similar to the existing seabed mussel community.

Video footage describing the windmill communities would be a valuable tool in describing the development of the fouling community to interested parties and should provide a temporal record of change.

If underwater visibility allows, visual transects for mobile species associated with the windmill should be undertaken. Experience in other European studies shows that visual census often records species not taken in experimental fishing nets, especially the cryptic fish fauna and species such as crabs and shrimp.

Summary

Prioritisation of monitoring and research work at the two windmill sites must be achieved to meet financial restrictions. This is an unfortunate aspect of the programme as both site have separate biological merits

Recommendations

- Monitoring of construction phase impacts at both site are completed as planned

- Research into windmill fouling community development is focused at Rødsand using a mixture of remote sampling and direct sampling techniques. These should link with a near structure fishing survey based on that originally proposed for the Horns rev site.