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# Ecological Research on Offshore Wind Farms: International Exchange of Experiences

PART A: Assessment of Ecological Impacts





**Ecological Research  
on Offshore Wind Farms:  
International Exchange of Experiences  
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**PART A: International Exchange of Experiences  
on the Assessment of the Ecological Impacts  
of Offshore Wind Farms**

**Proceedings of the International Expert Workshop held at the  
TU Berlin, Germany, 17-18 March 2005**

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**Cover Pictures** (clockwise): Sea gull, research platform, benthic community (Krause & Hübner, BfN); Common Seal (Wollny-Goerke, Hamburg); windfarm Rønland (Steinhauer, TU Berlin); windfarm Nysted (background) (Krause & Hübner, BfN)

Editors' addresses: see list of participants in Annex I

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## 1 INTRODUCTION

The Berlin University of Technology and the German Federal Agency for Nature Conservation organised a workshop for an international exchange of experience on approaches for assessing the environmental impacts of offshore wind farms. The event took place in Berlin on 17 and 18 March 2005, and was commissioned by the German Federal Agency for Nature Conservation, on behalf of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. The main objectives of the conference were to promote international exchange on:

- Present knowledge of the impacts of offshore wind farms on marine biota
- National licensing or permit procedures, and legal framework for offshore wind energy projects
- Methods and criteria for the assessment of possible environmental impacts of offshore wind farms, which have applied for licensing in various countries
- Different approaches and criteria for the assessment of impacts of offshore wind farms
- Further development of basic principles and methods for the assessment of impacts on the marine biota due to offshore wind farms:
  - Feasibility of measuring and monitoring the impact of offshore wind farms on the marine biota and the effect on individuals and populations (e.g. habitat loss)
  - Application of population models for impact prognosis
  - Selection of suitable reference or judgement values (e.g. population size, bio-geographic area, number in national waters) as a standard for assessment
  - Methods for cumulative and trans-boundary impact assessment.

On the first day the participants were welcomed and an introduction to the conference was given. This was followed by presentations from various countries on concerns of marine nature conservation in planning and decision-making procedures for offshore wind farms. In the afternoon introductory presentations to the workshops on different marine biota were given by several national and international experts. On the second day the workshops focused on discussing and exchanging experiences on the assessment of impacts from offshore wind farms on marine mammals, benthos and fish, sea and resting birds and migrating birds. The results of the workshops were later presented in the main plenary.

This report includes the main results from the presentations (see chapter 'Proceedings of the Presentations') as well as the main conclusions which emerged from the four workshops and from the discussions in the main plenary.

The workshop constitutes Part A of a larger research project. A number of literature reviews were also carried out in the context of this overall research project "International Exchange of Experiences about Ecological Research on Offshore Wind Farms". Their purpose was to evaluate the results of the environmental research accompanying wind-farm planning, and also to settle various questions on the ecological impacts of offshore wind turbines. The literature reviews are to be published in a separate volume of the Bundesamt für Naturschutz (BfN) papers.

## **2 PROCEEDINGS OF THE PRESENTATIONS**

### **2.1 Introduction to the Conference**

#### **2.1.1 Welcoming Statement and Introduction to the Conference Topics**

Prof. Dr. Johann Köppel

For the licensing of offshore wind farms, a combination of both scientific factual knowledge and value judgements is of considerable importance for decision-making processes. Apart from evaluations based on specialised knowledge, the legal framework of impact assessments is of great relevance for the licensing of offshore wind farms. The first segments of the conference and the workshop addressed the interface between scientific facts, value judgements and decisions in terms of legal requirements. The main objective was to initiate an international exchange of experience with regard to various approaches and criteria for the assessment of environmental impacts on selected marine biota. For this, the Berlin University of Technology was grateful to have the opportunity to welcome many experts from various European countries, from both the scientific and the practical fields.

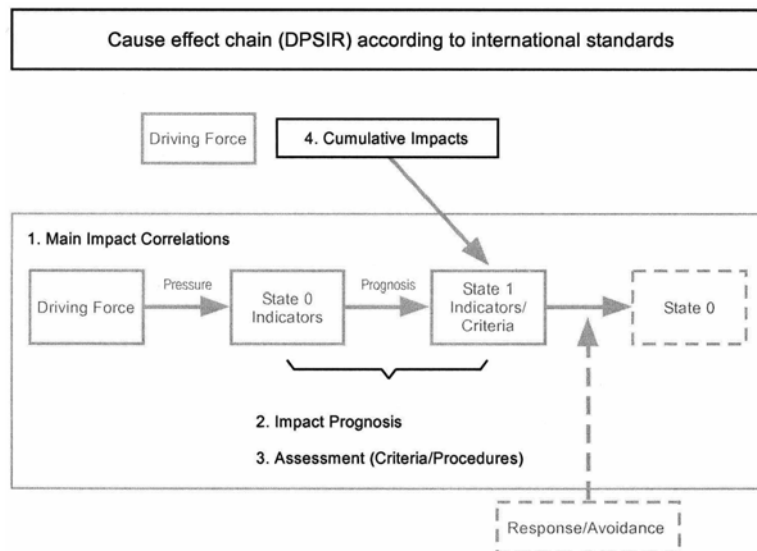
The event was structured as follows: First, the overriding objectives of the conference and the workshop were outlined. Subsequently, there were reports dealing with the different licensing procedures in various European countries. During the afternoon on the first day, science and research related presentations were given in order to prepare for the workshops on the second day. Individual workshops on marine mammals, benthos/ fish, sea and resting birds as well as bird migration sought answers to the following specific questions:

- What are the main conflicts/ adverse effects/ impact correlations/ categories of impacts (e.g. underwater noise, barrier effects, bird migration etc.)?
- What are the relevant scales of reference for the assessment (such as reference values for area and population size, e.g. bio-geographic, national, North/ Baltic Sea populations)?
- Which factors determine and influence the specific characteristics of impact (e.g. engineering techniques during the construction phase, turbine height, lighting)?
- What are the appropriate indicators or parameters for the collection of data and the assessment of impact intensity (feasibility of measuring and monitoring impacts)?
- Which assessment procedures are adequate for the assessment of the different marine biota and different types of impact?
- Is it possible to classify the intensity of an impact into different categories (e.g. high, medium, low)? How can assessment procedures dealing with various marine biota on the one hand, and with impact factors on the other, be connected?
- Which principles and methods should be used for the assessment of cumulative impacts?
- Which parameters could be used as a basis for establishing levels of significance?

- Are there any opportunities for establishing a convention on levels of threshold?
- What are the possibilities for intensifying international research co-operation and the international exchange of experience?

### Common Terminology:

Before the structure of the workshops is introduced, a common terminology should first be developed for them. The model (DPSIR) shows the relevant concepts and describes a typical cause-and-effect chain, upon which all planning processes are based.



A driving force, e.g. an offshore wind farm, exhibits corresponding impact factors, or “pressures”. A “pressure” might be the area required for the facility. In addition to the pressure, the existing character of marine biota (State 0) is relevant. Thus, in a certain area, the density of harbour porpoises might be a decisive indicator for this biotic character. Once such a pressure impacts upon the marine biota, it must be assumed that the biota will change, e.g. individuals will be driven out, the density of harbour porpoises will decline and a loss of habitat will thus be ascertainable. This can be accomplished with the aid of prognostic methods. With the aid of mitigation measures (response), these impacts may be counteracted if necessary in the planning. However, avoidance and mitigation measures (response) should not be the main focus of this conference. That should rather be on the ascertainment and assessment of the changes of State 0 to State 1.

### Workshop Structure:

The workshops were subdivided into four parts, with reference to the DPSIR model. The structure itself was oriented towards the following progression:

main impact correlations

impact prognosis

assessment (of state of marine biota and impacts)

cumulative impacts.

First, the most important cause-and-effect chains were determined and selected. For example physiological damage and loss of individuals due to sound emission impacts on harbour porpoises. Or the permanent reduction of the habitat area size due to sites or space consumption. The next part of the workshop dealt with the relevant factual aspects of the impact prognosis on specific marine biota. What are the indicators for an

impact prognosis? The third part specifically focused on the assessment, and therefore on value judgments. How the changes in marine biota (status 0 to status 1) might be assessed was discussed. What are the relevant criteria and reference values? In relation to this, questions of the assessment of threshold values were identified. The last part of the workshop (Cumulative Impacts) dealt with the question of how to manage cumulative impacts and impact interrelationships as well as combinations of projects. For example, which reference area and population size should be considered for the assessment of cumulative impacts? All the results of both, the conference presentations, and the workshop discussions are integrated in the following report.

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## 2.1.2 Objectives of the Conference within the Framework of the German Offshore Wind Strategy

Anna Hein

### Wind Energy in Germany

In total, approximately 16,600 megawatts of wind energy had been installed in Germany by the end of 2004. With this installed capacity, Germany remains the biggest wind energy market in the world, although we have a downward trend in the wind energy installations.

In a normal year, wind energy installations in Germany produce around 29 billion kilowatt-hours of electricity. Their contribution to net electricity production is thus about 5 %. This equals an electricity consumption of approximately 8.5 million households in Germany.

Development is currently slowing down, due to the fact that the development of onshore wind energy is already quite advanced and suitable sites are scarce.

### Offshore Wind Strategy

Apart from the continued slowdown in the expansion due to the growing scarcity of suitable onshore sites, the further expansion of wind energy will also include the replacement of old, smaller plants with modern and more powerful ones (so-called re-powering), and the gradual development of suitable offshore sites.

The German Government now has legally binding targets for the use of renewable energies. In order to reach these goals of increasing the share of renewable energies to 12.5% in 2010 and 20% in 2020, we definitely need offshore wind energy as an important component, along with other renewable energy sources.

In this context, the German Government has adopted the "Strategy of the German Government on the Utilisation of Offshore Wind Energy". The offshore-strategy was published at the end of January 2002, and constitutes part of the Federal Government's national sustainability strategy.

It states that the share of electricity consumption generated by wind power is to increase to at least 25 % over the next thirty years. A 15 % share of electricity consumption can be achieved by offshore wind energy alone.

We believe a total of at least 500 megawatts of installed offshore wind energy to be feasible by 2006; we expect 3,000 megawatts by 2010 of installed capacity, and in the long term, by 2030, as much as 20,000 to 25,000 megawatts.

### The Cornerstones of the Offshore Wind Energy Deployment

The expansion of offshore wind energy use should be – and can be – compatible with the marine environment and nature. It can also be economically viable.

According to the development on land, we will make sure to achieve these results by means of *planning/steering provisions* to make the deployment of wind energy in the offshore area compatible with marine and environmental protection.

- The Federal Nature Conservation Act includes key provisions for regulating marine nature conservation in the Exclusive Economic Zone (EEZ). This concerns the designation of *protected areas* in the EEZ, as well as provisions

governing *areas of particular suitability for wind farms* and the licensing procedure under the Offshore Installations Ordinance.

- Technical research, as well as environmental and nature conservation-related research, will accompany the expansion of offshore wind power use over a longer period during the start-up phase and beyond.
- In keeping with the precautionary principle, expansion is to be implemented gradually – step by step. Realisation of the next stage pre-supposes positive and well-founded results with regard to environmental compatibility and nature conservation.
- To support the balance between use of nature and nature conservation, the Renewable Energy Sources Act (EEG) has a regulation stating that there are to be no payments for electricity from offshore-wind farms in the Natura 2000 areas. Thus, there is no incentive for applicants to plan wind farms within these protected areas.

### **Assessment under the EIA and the Habitat Directive**

Another instrument to ensure that nature conservation issues are taken into account is the Environmental Impact Assessment (EIA). The applicants for offshore wind farms must submit very thorough EIA reports that follow a strict standard. For example, they must assess the marine environment and biota within the planned wind farm area, and in a control area not influenced by the wind farm, at least one year before approval can be given. Studies and surveys have to be continued during the construction phase, and at least three years after construction is completed. In addition we have the assessment under Art. 6 of the EU-Habitat Directive which is of course also incorporated if necessary. As part of the EIA and approval procedure, stipulating mitigation measures is a very important issue. It is also the topic of some research projects.

The most crucial issues of the EIA and of assessment under Art. 6 of the Habitat Directive are the methods and criteria for the assessment of environmental impacts. There are still many unanswered questions regarding these issues, some due to the fact that deployment of offshore wind farms is a very new technique. Just to name an example: For a transparent and comprehensible assessment, we need a standard approach for choosing a suitable reference size which could be the local population of birds in the planned wind farm area, the total population size in the German Bight or even the population in the bio-geographic area. An international exchange of information, such as the one carried out during this workshop, will help to tackle such problems.

We look forward to reaching broad and international agreement on standards for the assessment of impacts of offshore wind farms on marine nature and environment – if not today or tomorrow then, it is hoped, in the near future. The offshore wind energy sector is highly competitive, so that it is important to have similar basic conditions in regard to levels of significance or tolerance of impacts caused by offshore wind energy.

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### 2.1.3 Objectives and Requirements for Marine Nature Conservation with Regard to the Use of Offshore Wind Energy

Dr. Henning von Nordheim, Thomas Merck, Catherine Zucco

#### Introduction

Although it was almost 15 years ago that the first European wind turbines were installed at sea, the establishment of offshore wind farms in Europe (and worldwide) is still in its initial phase. Therefore, this presents an unique opportunity for the targets and requirements of nature conservation to be integrated into the development of this new technology right from the start.

The exploitation of offshore wind energy - like all human uses – should be applied in a sustainable and ecologically sound manner, and for this the application of the ecosystem approach is required. For the maritime areas of the OSPAR and HELCOM Conventions – which cover a large proportion of the European seas - the following definition of the ecosystem approach was adopted at the Joint Ministerial Meeting in Bremen in 2003:

The **ecosystem approach** can [...] be defined as “the comprehensive integrated management of human activities based on the best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of marine ecosystems, thereby achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity”. The application of the **precautionary principle** is equally a central part of the ecosystem approach.

By 2010, within the framework of OSPAR and HELCOM, a comprehensive set of measures based on the ecosystem approach has to be established for the management of all human activities which influence the marine environment and nature.

Under these preconditions and with respect to the exploitation of offshore wind energy compatible with nature, the following key points can be identified:

- In sensitive, ecologically particularly valuable or protected areas the establishment of offshore wind energy plants is to be excluded.
- Installations of wind energy plants should be limited to especially identified and designated “suitable areas”.
- From an ecological perspective only the Best Available Techniques (BAT) together with the application of Best Environmental Practices (BEP) should be employed.
- Further, mitigation measures have to be employed, so that negative effects of Wind Energy Plants can be reduced to a minimum.
- It is also essential to build up the use of offshore wind energy in an iterative approach.
- Extensive research and monitoring activities are necessary to further explore the main concerns relevant to nature conservation.

- It is essential that projects are assessed on a case by case basis which means that an environmental impact assessment has to be undertaken for each project. This should be supplemented if necessary by an appropriate **Habitats Directives Compliance** assessment.
- International cooperation and exchange of experiences and knowledge about impacts from offshore wind farms, should lead to the establishment of recognised international standards with regard to ecologically sound practices.

Most of these points mentioned here are also reflected in the „Offshore-Strategy“ of the German federal government published in January 2002. However, „Offshore“ activities in Germany had started some time before that date. The first application for Wind Energy Plants in the German maritime area had already been put forward in the nineteen-nineties. Now, in the German EEZ of the North Sea and Baltic Sea, environmental impact assessments (EIA) for more than 20 projects are in application. In addition, 11 projects with altogether more than 700 wind turbines and each up to 5 MW capacity have already been licensed.

In the last few years these EIAs had to be assessed thoroughly by the Federal Agency for Nature Conservation and the intensity of the expected impacts on marine biota had to be evaluated. The major problem was – and still is – the lack of long-term monitoring studies as references on which to base the impact prognosis. Especially with regard to various marine biota, questions were raised which could not be solved by the application of a strict scientific or nature conservation assessment based on current knowledge.

## **Assessing the environmental impacts**

### *Seabirds*

A variety of seabird species use the open sea to rest, as a feeding, wintering or moulting areas. It has always been assumed that at least some sensitive species such as divers will avoid wind farms and the area around them. For the EIAs carried out in German waters the habitat loss for such species was calculated on the basis of the expected avoidance reactions.

Preliminary results from monitoring carried out at established wind farms such as Horns Rev and Nysted in Denmark show evidence that such habitat losses do occur and that this is fairly easy to measure by carrying out visual surveys. Hence, it should be possible in the future to make more accurate predictions about species-specific habitat losses.

However, the following two questions will still remain:

1. what effect will the loss of these areas have on the displaced individuals if they are displaced into other marine areas which are already occupied by birds of the same (or different) species; and,
2. what proportion of a local population can be displaced until effects can be detected in the population as a whole?

In the course of the discussion in Germany, the Ramsar Convention was pointed out as an international consensus, where an area which supports more than 1% of a biogeographic population of a species – for example 1000 individuals - as a feeding or



resting area is worthy of protection. Therefore, using the same logic, it seems that the loss of habitat for 1000 individuals of that species cannot be insignificant. If this 1% criterion is accepted, then it is necessary to clearly define the rationale used in selecting the extent of the greater reference population.

In looking at a larger reference population, the issue of cumulative effects arises, whereby from a biological as well as a nature conservation point of view, all influences from all other projects should be included in an cumulative impact assessment if they could potentially have an effect on the reference population of a certain species.

The biogeographic population may biologically be the most sensible reference population for an assessment, though from an administrative viewpoint this is likely impractical, since it is hardly possible to include all projects within the area covered by the biogeographic population which may span several national jurisdictions. Furthermore, it is unlikely that a country will not licence its own wind farm applications because another neighbouring country has already reached the threshold impact level for the biogeographic population through its own wind farm projects.

Therefore, the Federal Agency for Nature Conservation in Germany regards the national (resting) population – separated into the marine areas of the North and the Baltic Sea – as a sensible population reference size.

### *Bird Migration*

The risk of collisions and barrier effects are the predominant negative effects to be expected on migrating birds from offshore wind farms. If there is sufficient knowledge about the population dynamics of a species the influence of additional mortality due to collisions can be established relatively easy by using appropriate population models. It can then be worked out if a reduction of a population would occur or whether the additional mortality could be sustained.

Unfortunately, it is very difficult to estimate the collision risk for different species. No sufficiently satisfactory methods have been established yet to record bird collisions at already established offshore wind farms. Therefore, substantial effort is still required to find a suitable system which will render reliable and quantitative information.

The impacts of barrier effects are comparable to the loss of habitat, at least no direct mortality will occur, but the fitness of individuals may be influenced. In addition, a series of wind farms can affect an individual cumulatively if a bird encounters them during its passage over the sea. Therefore, cumulative effects are of particular importance when evaluating effects of offshore wind farms on migrating birds.

Similarly, as with resting birds, the question of which population and area to reference when assessing cumulative effects is difficult to answer. For example, if we assess the effects on the biogeographic population then the influence of all projects in this area should be included – which is difficult to handle. On the other hand it has not been possible yet to limit the reference size to the “national” population or any other administrative area,. This is because bird migration is very variable and it has been difficult to obtain quantitative data on bird migration – especially regarding bird migration at night – for the German marine area. Therefore, currently the effects of offshore wind farms on migrating birds can not be sufficiently predicted. Nonetheless, when assessing

the impacts we will still have to develop some sort of criteria by which we can decide on whether a project can be licensed or not.

### *Marine Mammals*

Noise emitted during wind farm construction as well as operation is undoubtedly a major stressor on marine mammals. The range of the expected effects on these animals – which rely strongly on their acoustic sense for their orientation and communication – ranges from disturbance of communication, to general stress, behavioural changes, habitat loss due to avoidance reactions, through to physiological or even lethal damage.

There is still a significant need for further research and monitoring activities until questions about the extend of the effects on individuals and subsequently on the population of marine mammals can be answered on a scientifically-founded basis. As in the case of resting and migratory birds, it is necessary to relate the assessed impacts to a defined reference area and population. Only on this basis can sound decisions be made as to how many wind farms can be licensed without overstressing the threshold levels of a regional population.

### *Natura 2000*

For Natura 2000 sites a specific assessment has to be carried out as required by the Habitats and Birds Directives. For this the reference size should be the local population to be protected within the site. Furthermore, the parameters to be assessed are already defined by the conservation aims of the Natura 2000 site.

## **Closing Remarks**

During project assessments, it became apparent that there is a lack of widely accepted criteria by which the intensity or significance of effects from offshore WEP on the marine environment and nature could be evaluated. Appropriate definitions and the establishment of levels of tolerance or significance as well as the specific population or the area chosen as a reference size could not be determined solely on a purely scientific or nature conservation basis.

In Germany, several meetings and workshops were held where biologists, nature conservationists, representatives from government agencies etc. have come together with the aim to establish more precise assessment criteria and to determine levels of significance. Through this process the recognition developed that this aim could only be reached through the establishment of conventions for such levels. This should be based as far as possible on scientific evidence but when these data are lacking, might ultimately also require professional judgement.

Therefore the Federal Agency for Nature Conservation has initiated this international workshop with the intention to learn from the discussion with national and international experts and from approaches taken in other countries. To this end, the conference aims to improve the methodologies and justifications which can be used for developing appropriate assessment criteria and threshold levels, i.e. „levels of significance or tolerance“.

I would like to thank you for your participation and wish the workshop success in achieving its goals.

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## **2.1.4 Objectives and Requirements of Marine Environment Protection Concerning Offshore Wind Energy**

Dr. Anita Künitzer

### **Tasks of the Federal Environmental Agency**

Among the responsibilities of the Federal Environmental Agency (UBA) it is providing advice to the Federal Minister for the Environment, Nature Protection and Nuclear Safety regarding technical measures aimed at the reduction of environmental impacts of human activities. This includes the assessment of environmental impacts of human activities in the marine environment at the federal level.

With regard to the evaluation of environmental impacts of construction and operation of offshore wind farms and their cable connection to the onshore electricity grid, UBA focuses its assessments and advice on the following issues:

1. Impacts of wind farms on bird migration;
2. Impacts of cable temperature and disturbance of sediment during cable laying on benthos;
3. Impact of underwater noise on marine mammals and emission limit values, as well as mitigation measures;
4. Waste handling and decommissioning/removal of wind farms and cables;
5. Impacts of the electromagnetic fields of cables on fish, and emission limit values, including mitigation measures;
6. Impacts resulting from the collision of ships with wind farms, and provisions to prevent marine pollution.

The aim of the evaluations is

- to define threshold limits for damage to the most sensitive organisms in the marine ecosystem, and
- to identify emission limit values as well as the Best Available Technique/Best Environmental Practise (BAT/BEP) to minimise impacts.

This publication gives an overview of the current status of the assessments and recommended emission limit values by UBA. A recently published research project "Investigations to Avoid and Reduce Possible Impacts of Wind Energy Parks on the Marine Environment in the Offshore Areas of North Sea and Baltic Sea, Final Report, 2003, R&D plan 20097106" (<http://www.umweltbundesamt.de/uba-info-medien/dateien/2686.htm>) has provided major input to this assessment.

### **The Licensing Procedure for Offshore Wind Farms and Cable Routes**

The Ordinance on Marine Facilities (Seeanlagenverordnung (SeeAnIV), 1997) provides the legal basis for the regulation of constructions in the German exclusive economic zone in the North and Baltic Seas. Such construction may involve offshore wind farms, cables, pipelines etc. This ordinance requires an Environmental Impact Assessment for each application for a construction project (§ 2a SeeAnIV). According to § 3 SeeAnIV, a license could be refused for the following reasons:

- impairment of maritime transport,
- pollution of the marine environment,
- risks to bird migration.

Finally, the ordinance provides the legal basis for the identification of suitable areas for offshore wind farms (§ 3a SeeAnIV).

The Federal Maritime and Hydrographic Agency (BSH) is responsible for the licensing procedure. The UBA contributes to the assessments of the BSH as to whether there are any reasons for refusal of a license, by checking the individual applications and assessing them in the light of environmental background information. For this purpose, knowledge and experience are compiled in special research and development projects. Proposals for mitigation measures have been or are being developed. The aim of the UBA is to evaluate applications of the offshore wind industry critically, and to provide constructive proposals for best environmental performance. Various sections of the UBA are involved in this evaluation.

### Issue 1: Evaluation of Effects on Birds

Birds could react in different ways to disturbances caused by wind farms:

- **Displacement effects:** Sensitive species might avoid wind farms due to their noise and movement. If wind farms are built within resting and feeding areas, these birds would lose their resting and feeding sites, partially or completely.
- **Collision risk:** Research data show that each land turbine can kill 0 – 40 birds annually, due to collision with the rotor. On that basis, a total of up to 390,000 birds has been extrapolated for the planned offshore turbines.
- **Barrier effects:** If birds avoid flying through a wind farm, they have to fly around it, which causes additional energy loss due to increased flight distance. In cases of large wind farms, or with the cumulative effects of several neighbouring wind farms, this energy loss could be significant.
- **Illumination of wind farms:** Birds might be attracted by night, or during foggy conditions, by the illumination of the wind farm, which could lead to collision with the structures.

Our current knowledge base is not sufficient to give final figures to these disturbances, or to provide definitive solutions for mitigation measures. Research is being funded to improve knowledge on the impacts on birds. Initial proposals for environmental quality objectives and limit values on bird populations have been made, and require further verification.

### Issue 2: Evaluation of Effects on Benthos

The bottom fauna and flora, the benthos, is affected by the construction and operation of offshore wind farms in three major ways:

- **Physical disturbance of the bottom sediment:** During the construction of foundations, the pile jacking and jacking of cables, bottom organisms are damaged and the impacted bottom area must be re-colonised after the operation. In our opinion, this problem is currently overestimated in the North Sea and Baltic Sea, since impacts on benthos from other human activities are much more widespread: e.g. beam trawl fishery ploughs the sea floor 1 - 10 times per year. The

regeneration of benthos takes only 2 - 5 years. Special features, like mussel beds or *Sabellaria* reefs, are more sensitive and need special protection against physical disturbance.

- **Heat generated by cables:** High voltage underwater cables can become 70 - 90°C hot, and will heat the surrounding sediment and the overlying seawater. The bacteria and organisms living in the sediment close to the cable will be killed next to the cable and will live under warmer environmental conditions within 2-3 meters of the cable. The influence of such temperature increases on benthos and sediment bacteria is unknown. Research has been started to look into the matter. The precautionary limit value of a maximum heat increase of 2 °K in 20 cm sediment depth needs further verification to determine whether it is sufficient. There is risk that alien species from warm water ecosystems will be able to settle and survive in our cold water ecosystems, and that such species might interfere with the naturally occurring species.
- **New substrate:** Especially the North Sea has soft bottom sediment inhabited by soft bottom communities. Wind farms have a foundation of hard substrate and provide a basis for hard bottom fauna to settle, which includes species different from soft bottom fauna. With each wind farm, a new habitat for new hard bottom species will be created, the impact of which on the existing soft bottom communities is unknown. There are no recommended measures available against this change in habitat and species composition. It is also not known, whether such a change should be regarded as a positive or negative effect for the benthos.

### **Issue 3: Noise Emission during Construction and Operation (Effects on Marine Mammals)**

Ramming noise during the construction phase of wind farms can exceed 230 dB. This underwater noise could impact the fauna in the area of the wind farm:

- **Invertebrates:** Very little information is available on the acoustic and tactile perception of invertebrates, or the expected effects of acoustic noise on these animals: Squid will possibly be able to detect the low frequency signals during construction and operation of wind turbines; behavioural reactions are expected. Noise may also effect the settling, growth and survival of other invertebrate species.
- **Fish:** In fish, it is necessary to distinguish between hearing generalists, with relatively low acoustic perception, and hearing specialists, with high acoustic sensitivity. Some fish belonging of the latter group react even to infra or ultra sonic signals. The effects caused by acoustic noise range from rapid habituation through large-scale avoidance of the exposed areas, to physical injury of the auditory organs, depending on the acoustic noise level. Some fish are capable of regenerating injured auditory sensory cells.
- **Marine mammals:** The harbour porpoise and the harbour and grey seals are the marine mammals present in the North and Baltic Seas. The auditory sense is crucial for the survival of the harbour porpoise. Any interference or injury potentially endangers these animals. The effects caused by acoustic noise during construction include stress reactions, adverse behavioural reactions, masking of communication signals, and temporal interference of the acoustic sensitivity. It is not possible to preclude damage to hearing due

to ramming noises nor the likelihood of habituation or toleration of the operating noises. No information is available on the duration of effects, or on long-term effects. The harbour porpoises in the central Baltic require special attention, since they may constitute a separate threatened population. Due to the current existence of the distemper virus in harbour seals, they also need to be especially protected against any type of disturbance to avoid additional weakening of their immunological defence.

To protect marine mammals, wind farms should follow certain technical requirements regard noise emissions: The noise pressure as a function of the distance from source and frequency of signals should not exceed certain limit values. Such limit values should be set in such a way that the essential living conditions of the protected marine mammals are maintained. It is necessary to avoid any sound pressures which cause:

- a temporary threshold shift (TTS), a permanent threshold shift (PTS), or damage to tissue;
- masking of background sounds and of own acoustic signals;
- hindrance of the reproduction of the species, and/or expulsion from the natural habitat.

According to current knowledge, the main factor contributing to acute damage through sound pressure is the impact on hearing capabilities of marine mammals through the received energy, integrated over time. A critical dose is determined by the number, duration, and level of sound of the received pulses; i.e., the absolute sound level is not the only important aspect, but also the structure of the sound.

Since short signals can have very high sound pressure levels, we also need a limit value for maximum sound pressure.

During the **construction phase**, the UBA therefore recommends

- ensuring that, at a distance of 750 m from the noise source, the sound pressure level should not exceed 160 dB (re 1  $\mu$ Pa). Maximum values should not be more than 10 dB above the mean sound level. Relevant mitigation measures should be applied to assure that no marine mammals are within the area exceeding 160 dB (re 1  $\mu$ Pa).
- Compliance with these conditions should be demonstrated by measurements.

Moreover, no ramming operations should be undertaken from May through August, if the area has high importance for the birth and breeding of harbour porpoise.

During the **operation phase**, the UBA recommends ensuring that

- the sound pressure level (dB re 1  $\mu$ Pa) should not exceed the auditory threshold level of marine mammals at 25 m distance from the turbine foundations, when measured at a wind speed of 8 m/s.

More research co-operation, both at the national and international levels, will be required to verify these precautionary limit values.

#### **Issue 4: Waste Management Concept**

During construction of an offshore wind farm, a large quantity of waste is produced. This waste should not be discharge into the sea, but should be disposed of on land or recycled.

The UBA recommends that:

- The requirements for waste management should be defined;
- Dismantling of facilities be ensured when the wind farm is taken off line, according to a concept including a financial concept, drafted even during the construction phase;
- The use of cables containing lead should be avoided if possible, and that the correct disposal after dismantling of any such cables which are used to be assured.

### **Issue 5: Environmentally Friendly Cables (Effects on Fish)**

Offshore wind farms will be connected to the grid system on land via electric cables, which will be placed on the sea floor or into the surface layer of the sediment. Such cables can be alternating current cables or direct current cables. They can impact the marine ecosystem in various ways:

- Both types of cables produce magnetic and electric fields, which can impact the marine fauna.
- When the cables are in use, and especially when maximum amounts of electricity are transferred through them, they can reach temperatures of 90°C for alternating current cables, and 70°C for direct current cables. This causes an increase in the sediment temperature in the vicinity of the cable, which can impact the benthic animals and the sediment bacterial activity (see Issue 2).
- Usually, the cable will be placed in 1 - 3 m depth under the sediment surface to minimise damage to the cable by anchors, fishing gear and to minimise impact on the marine fauna. The laying technique itself and the digging of the cable into the sediment might impact the benthos in the vicinity of the operation by covering it with sediment.

The UBA is being supported by the Federal Office for Radiation Protection (BfS) in the evaluation of the impact of marine cables on the ecosystem:

- Sharks and rays are the most sensitive organisms which can detect electric fields: they can sense **electric fields** down to 0.5mV/m, i.e., including all cables. These fish use electric fields to find their prey in the surface layer of the sediment. Field strength causing irreversible damage to the ampullae of Lorenzini, which are the biological sensors to detect electric fields, is unknown.
- Some fish species are known to detect **magnetic fields** and use them for orientation during migration (eel, salmon). Impact of magnetic fields on fish migration is not proven.
- The impact of elevated **sediment temperature** needs further research. Possible impacts could include:
  - enhanced bacterial activity, which could cause oxygen deficiency in the sediment close to the cable; and/or
  - changes in benthos species composition due to higher temperatures and settlement of alien species along the warmer cable tracks.



In order to reduce the possible impacts of cables, the UBA recommends:

- reducing electromagnetic fields and bottom surface temperatures by burying cables deeper (and/or increasing the permeability and conductivity of the cable armour);
- minimising electromagnetic fields by using three-core Alternating Current cables or double conductor High Voltage Direct Current cables;
- placing cables only in restricted areas, and combining the cables of several wind farms in cable corridors;
- reducing temperature impacts by applying a precautionary limit value on temperature increase of 2°K at a sediment depth of 20 cm. This value can be obtained by burying cables deeper.

### **Issue 6: Preventing Marine Pollution by Ships**

There is a risk of collisions between ships and offshore wind installations. Such collision can cause marine pollution, especially from oil spills, due to damage to the ship and its cargo. Risk analysis of probability of accidents in the area of a wind farm is not sufficient to handle the risk. Instead and in addition, improved security standards are needed for ships and wind farms. A risk assessment and appropriate provision against marine pollution from shipping accidents is required for every offshore wind farm.

The UBA proposes that precautionary measures against pollution from shipping accidents be required prior to construction of an offshore wind farm. Such precautionary measures should include:

1. Avoidance of collision
2. Minimisation of leakage of hazardous substances
3. Removal of pollution
4. Protection of coastal areas.

### **Further Work**

The presented overview of the current status of the assessments and recommended emission limit values by UBA is being updated continuously as soon as new research results become available. Many units of the UBA are involved in the evaluation of offshore wind energy. Several research projects are still ongoing, and will hopefully solve several of the remaining questions. Where cause-effect relationships are not sufficiently demonstrated, the UBA will use and recommend precautionary limit values. The UBA works in close cooperation with other federal agencies and universities as well as with international organisations and conventions. The European Marine Strategy, which will most probably become an EU framework directive with regional ecological quality objectives, will have to consider the possible impacts of offshore wind farms.

## **2.2 Consideration of Concerns of Marine Nature Conservation in Planning and Decision-Making Procedures for Offshore Wind Farms**

### **2.2.1 Consideration of Concerns of Marine Nature Conservation in Planning and Decision-Making Procedures in Germany**

Christian Dahlke, Hartmut Heinrich, Manfred Rolke,  
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The construction and operation of marine wind farms requires large areas in coastal and offshore territories. The occupation of areas by wind farms is often in conflict of interests with other economic activities and aspects of marine nature conservation.

According to the law (Seeanlagenverordnung, § 3, Abs. 2, Nr. 4) permission has to be given unless one of two refusal reasons is identified: a) impairment of safety of shipping or b) endangering of the marine environment, involving bird migration.

#### **Standards for Environmental Impact Assessment**

The approval authority, Federal Maritime and Hydrographic Agency (BSH), in its responsibility for the Exclusive Economic Zone (EEZ) deals within the framework of procedures for licensing offshore wind farms with potential adverse impacts of planned facilities on the marine environment. Following the amendment to the Seeanlagenverordnung, an Environmental Impact Assessment (EIA) is mandatory for all offshore wind farm projects in the approval process. Content and technical minimal requirements for marine environmental surveys and monitoring, in order to assess compliance with Art. 3 Seeanlagenverordnung, are based on the Standards for Environmental Impact Assessment (SEIA) compiled by BSH (<http://www.bsh.de>). SEIA have been developed in extensive consultations with marine scientists as well as other agencies and experts. The frame of SEIA was built upon experience from the German Marine Monitoring Programme in the Baltic and North Sea, the Helsinki- and the OSPAR-Conventions for the Protection of the Marine Environments of the Baltic and the North Sea-Northern-East Atlantic respectively. All new scientific information and experiences, gained through monitoring surveys for EIAs, are regularly used to update SEIA. At present, the second update of SEIA (February 2003) is available.

According to SEIA impacts on biological features (benthos, fish, birds and marine mammals) have to be investigated in the pre-construction, construction, operation and removal phase. The main objectives of the investigations are: a) to support the decision-making by assessing the baseline situation and evaluating the monitoring results, b) to reveal the spatial and temporal variability of marine environment features in the pre-construction and operation phase and c) to look for possible effects of construction, operation and removal of wind turbines on biological features. Assessment areas generally consist of the actual project area (wind farm) and a suitable reference area. For investigations on benthos and fish both project and reference area have to be of equal size. For bird and marine mammal investigations large areas are considered for ship and aerial surveys. Baseline investigations have to be conducted for a two-years cycle before construction. Monitoring activities for birds and sea mammals will be conducted during the construction. Monitoring surveys will then be carried out for benthos, fish, birds and sea mammals for three to five years of operation phase. Justified deviations from SEIA are only allowed due to improved knowledge or in case

when investigations are inadequate for special locations. The approval authority may modify the monitoring programme to meet special requirements.

The main issues to be investigated according to SEIA are: a) benthos associations assessed in spring and autumn by means of grab, dredge sampling and video, b) quantitative determination of near-bottom stationary fish species in spring and autumn employing available methods, c) distribution of resting birds and sea mammals by means of ship and aerial surveys, d) occurrence of harbor porpoise employing acoustic methods (TPODs), e) Observation of migrating birds by means of visual and acoustic surveys parallel to radar registration.

BSH has established some general requirements, beside SEIA and EIA, for all planned projects: a) All large-scale offshore wind farm projects have to be preceded by a pilot phase of no more than 80 turbines and b) Reduction of emissions has to be considered as a main issue, particularly in the construction phase, e.g. underwater noise and light, cable temperature. State-of-the-art mitigation measures have to be employed in construction, operation and removal phase.

Main instruments for decision making in licensing offshore wind farms are, among EIAs: consultations with other agencies and experts, hearing of NGOs and the public, results of large-scale long-term studies (e.g. MINOS, 2004), literature sources and monitoring reports of offshore wind farm projects for construction and operation (e.g. Horns Rev, Nysted, Kalmarsund).

Main aspects in consideration of issues of marine nature conservation for decision making are: a) damage to single individuals does not necessarily mean a risk to the population level and b) a license must be overruled (SeeanIV., § 3, Abs. 2, Nr.4) when the number of individuals supposed to be in danger may cause significant damage to the reference population of a certain species.

### **Example of approval procedures**

It is given an example of approval procedures and decision-making by BSH for two offshore wind farms (Adlergrund and Pommeranian Bay) in the Baltic Sea. A first approach of issues of marine environment conservation, as documented in EIAs and literature studies as well as consultations with agencies and experts, revealed severe conflicts of interests in regard to the planned areas overlapping important wintering habitats of resting birds.

The evaluation, taking into account the precautionary principle, was mainly based on two criteria: I. potential loss of habitat in relation to the total resting habitat (geographical unit in regional and functional terms) and II. potential loss (>1 %) of reference population (e.g. bio-geographical, wintering, breeding) due to displacement, considered both on single species basis and cumulatively on a multiple species basis.

An analysis of habitat loss was run on a three step assessment, according to Percival (2001). Firstly, the sensitivity of a specific area of ornithological relevance is determined. Secondly, the likely effects of magnitude are taken into account. Sensitivity and magnitude, as revealed from these examinations are then, in a third step, cross-tabulated in order to achieve the overall impacts of the projects on bird habitats.

Estimations of population loss are adapted according to the 1 % criterion developed by the Ramsar Convention. Although this criterion was actually developed for the determination of the value of a wetland, it still remains a provisional but accepted approach nowadays for quantifying impacts on bird populations.

The project areas Adlergrund and Pommeranian Bay were thoroughly examined considering water depth, sediment type and, of course, the protection status according to national and European directives. Both projects are located in areas with special protection status: a) in IBA Pommeranian Bay, Code 081, b) in the BSPA (Baltic Sea Protected area, HELCOM Recommendation 15/5) and c) in the SPA "Pommeranian Bay" (German nomination to the EC Directive on the Conservation of Wild Birds). Here are some of the principal characteristics of the areas: a) limited availability of food because of patchy seabed structure, type of sediment and water depth, b) probability of sea ice leading to restricted access to food and c) role as refuge when in severe winters the eastern Baltic resting area is completely covered by ice.

With regard to species of resting birds three of them were recognised as species of main concern: long-tailed duck (*Clangula hyemalis*), velvet scoter (*Melanitta fusca*) and black guillemot (*Cephus grylle*). Estimations based on most recent data from the EIAs and on data by Durinck et al. (1994) and Skov et al. (2000) revealed that both project areas belong to the main resting habitat of the above mentioned species of concern and of black scoter (*Melanitta nigra*). Reference population of all considered species was the wintering population (Durinck et al., 1994). Both project areas were considered including a 2 km surrounding buffer zone, respectively only 1 km for long-tailed duck.

Final analysis revealed significant losses of both populations and habitat. Habitat loss for resting birds varied between 1 and 5 %. Population loss was for some bird species of concern greater than 1 %. Cumulatively, negative impacts were predicted for 5 to 7 species of birds resting in the area. The approval authority (BSH) denied the license for both projects Adlergrund and Pommeranian Bay.

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## **2.2.2 Consideration of Concerns of Marine Nature Conservation in Planning and Decision-Making Procedures in Denmark - Experiences from Horns Rev and Nysted Offshore Wind Farm Demonstration Projects**

Steffen Nielsen

The installed capacity in 2004 was approx. 3100 MW of wind power which covered almost 20% of the present electricity demand in Denmark, of which approx. 420 MW are off-shore. The Horns Rev Demonstration Wind Farm was renovated during 2004, and is now again in full operation, so that the potential share of wind power in the electricity supply is actually larger. The 1076 GWh produced from wind power in the windy January of 2005 was equal to 32 % to the total demand. In the western Danish supply area of Eltra, the proportion climbed to 41 % during that same period.

The Danish wind turbine industry has gained an increasingly important role in Danish economy.

In 2004 the industry employed some 20,000 persons, and sold turbines for almost €3 billion, most of which were exported; the Danish wind turbine industry has a world market share of about 40 %.

The Danish State has full authority within the 12 NMZ and in the Danish EEZ. The legal authority over use of wind, water and waves for energy purposes has been delegated to the Danish Energy Authority (DEA) by the Minister of Transportation and Energy. Off-shore wind-power plants are authorised and approved by the DEA in co-operation with other authorities, under a "one-stop shop procedure". The legal bases are the Electricity Law, authority delegated by other authorities, and suggestions and objections emerging from Environmental Impact Assessment (EIA).

For authorisation and approval, two options are possible under the Electricity Law: either a public call for tenders, or an announcement of application, combined with a simultaneous call to other parties to submit bids ('open door'). When a "winner" (operator) has been identified, permission to conduct pre-investigations within a limited time-frame is granted. The operator then drafts an EIA document on the basis of concession terms and the results of a preliminary investigation. The DEA in turn conducts an EIA-procedure and public consultations.

If the project is found to be acceptable under EIA-procedure and public consultation, the DEA will authorise the establishment of an electricity production plant. The permission is submitted with a range of obligation to the operator, among which a detailed plan for construction work has to be presented. Furthermore the consent includes a guidance of administrative appeal possibilities. If the project is not appealed and an adequate construction plan has been presented, the green light is given for construction. During the construction phase the operator must submit a report sufficiently documenting compliance with all stipulations of the authorisation. Thereupon, the operator will receive permission to produce electric power and to feed it into the grid.

### **The Demonstration Programme for the Horns Rev and Nysted Offshore Wind Farms**

Due to the special demonstration status of the large offshore wind farms at Horns Rev and Nysted, a measurement and monitoring programme was carried out as an extension of the EIA in 1999, to investigate the effects on marine ecosystems before, during and after construction of the farms. Environmental studies are being carried out at Nysted and Horns Rev during the period 1999-2006 under the terms of the

authorisation of wind farm construction at the two sites, granted by the Danish authorities. The programme is financed by €11 million in the period from 2001-2006 as a public service obligation.

So far baseline studies and monitoring during the construction phase have been carried out. The farms are now in operation, and continued monitoring is ongoing. The International Advisory Panel of Experts on Marine Ecology (IAPEME) is evaluating the programme continuously. In its latest statement of 2004, the panel underlined that much of the research being carried out is cutting-edge science worldwide.

The entire wind power industry was looking forward to the results of the studies of environmental adaptation to the physical presence of operating offshore wind turbines. Since several offshore wind projects have been proposed and are awaiting approval, in Europe and worldwide, the experience from the Danish projects provides valuable input for the environmental debate on offshore wind farms.

These eagerly anticipated preliminary results from the environmental impact studies, both during the construction and the post-construction phases are now available. The issues investigated include bottom flora and fauna, introduction of hard substrate habitat, fish, marine mammals, birds, electromagnetic fields and socio-economic issues.

It should be stressed that the installation of the wind turbines in Horns Rev and Nysted was completed in the autumn of 2002 and the summer of 2003, respectively. Hence, the results available represent data from the initial operational phases of the wind farms; no natural variation between years, seasons, species and sites, or possible habituation effects during the operational phase could yet be assessed. The results in all individual presentations from our consultants must be considered preliminary, and must await further compilation of data before firm conclusions can be drawn with respect to the impact on the biological environment. The conclusions from the programme are to be published in the context of a final conference, to place from 27 to 29 November 2006.

The preliminary conclusions on marine mammals so far show that seals' behaviour does not seem to be affected. Harbour porpoises left the construction sites after the use of "pingers" and during a "ram-up period", but have apparently returned, as their activities have been registered during the operational phase. Almost all registered bird flocks changed their flight trajectories so as to by-pass the wind farms by a relatively great distance. Thus, the collision risk of migrating birds is expected to be diminished. Certain foraging and resting birds have avoided the vicinity of the wind farms sites, and investigations into their displacement and possible habituation are ongoing. As a significant artificial wreck effect has been observed, it is not unlikely that the artificial structures and scour protection may have a positive effect on the abundance of fish. Finally, no electromagnetic field effect has been observed for the eels caught in pound nets established on either site of the Nysted sea cable.

The public perception of offshore wind power has also been investigated under the monitoring programme, and tends towards acceptance. The social and environmental economic monitoring programme is conducted in two parts: a sociological part, based on a qualitative analysis of articles and letters to the editors of local newspapers, and on qualitative interviews of selected persons; and an environmental economic part, based on a quantitative willingness to pay analysis for moving the wind farms further from shore. The latter analysis was conducted as a questionnaire, with one nation-wide poll and two local polls at Nysted and Horns Rev, respectively.

The planning phase for the Horns Rev Wind Farm began in 1994. At that time the local information level can be characterised as low, and there was general scepticism towards a project. When permission to conduct preliminary investigations was granted in 1999, more concrete resistance was observed as the information level rose. The

perception was that the visibility of large wind turbines could cause an economic decline at the local level, with specific reference to the tourist industry. Also, the fishery community had feared that the project could result in an economic decline. Moreover, environmental issues involving possible negative effect on birds were debated.

The preliminary findings have shown that now, after the park has been established, the visual aspect is not as negative as feared, though the illumination on the nacelles remains an issue on nights with good visibility. On the other hand, no economic decline has been observed, and a clear indication of acceptance has now emerged. The low level of local attachment to the project indicates for a need for enhanced information work in future projects, especially during the initial phase leading up to the EIA.

### **Tendering for New Offshore Wind Power**

Currently in Denmark, rounds of tenders for two offshore wind-farms, each with a capacity of 200 MW, are underway to ensure that the licenses are awarded to the economically most competitive project and that all applicants are on an equal footing. The DEA states the terms for the evaluation of the various projects in advance. Allocation of "slots" for offshore wind power is based on e.g. economic, technical and environmental considerations. Licenses are expected to be awarded during 2005.

It is presupposed that the wind farms will be accessible for test turbines for experimental research and that the expense of grid expansion in connection with offshore wind-farms will be defrayed by the new state-owned System and Transmission Company – Energy.dk.

The locations proposed are Horns Rev in the North Sea and Rødsand in the Baltic Sea both near the existing demonstration wind farms. An EIA according to EU Directive 85/337 has to be carried out by the winner of the tender. The criteria for the EIA are based on the public screenings of the offshore areas conducted during 2003 and 2004 by the DEA.

Leading up to the public tender a selection of new sites was assessed as an "updating" of the action plan for offshore wind from 1997. The issues considered was especially on grid connection, security for shipping, new designated nature protected areas, and the preliminary results from the environmental programme. Upon the initial assessment a detailed screening for seven selected sites including a public consultation was conducted. The screenings included an environmental assessment, visual aspects presented as a visualisation of fictive wind-turbine sizes located in fictive configurations and distance to shore. The security question for shipping obviously also was assessed along with coordination with other marine interest. Further the public consultation also called for ideas and suggestions to the EIA. The consultation answers from screening Horns Rev 2, show that a long distance to shore and large turbines and thereby fewer turbines are preferred. Suggestions to be included in the forthcoming EIA, points out that an evaluation of aviation marking should be undertaken along with assessment of cumulative effects before final decision. Fishing "at" the cable to the shore with no exclusion zone was another claim worth mentioning from the consultation answers. Not surprisingly the visual aspects remain to be the issue – the Not In My Back Yard phenomenon. The preliminary assessment is nevertheless that no apparent significant local resistance is the case.

### **An Environmental Perspective**

Despite the intuitive appeal of taking wind power to sea, offshore wind farms are faced with an additional number of environmental issues compared to land-based production

facilities. But on the other hand dealing with nature conservation issues, one have to bear in mind that wind power including wind power off shore, is a nature conservation measure in it's very self. This is not least the case in relation as a climate change mitigation measure in the energy sector and thereby a mitigating measure on the marine environment, but also as off-shore wind power is an alternative that in turn can mitigate the environmental impacts and potential risks in the conventional energy supply system e.g. the oil and gas infrastructure activities at sea.

### **The European Agenda for Offshore Wind Power**

The EU Council of Energy Ministers at its meeting on 29 November 2004, welcomed the Danish offer to organise a policy follow-up seminar on the Egmond Declaration on "Development of Offshore Wind Energy" in 2005, as stated in the EU Council conclusions. The European Policy Seminar on Offshore Wind Power will be held in Copenhagen on 27 October 2005, chaired by the UK, which holds the EU presidency, as a "back-to-back" event with the Copenhagen Offshore Wind Conference and Exhibition 25-28 October 2005.

The stakeholders involved in setting the agenda include the EU Commission, energy and environmental authorities of member states, the wind power sector, transmission system operators, R&D institutions, financiers and NGOs.

It should be noted that the possibilities of establishing a Wind Power Technology Platform with an independent chapter for offshore wind power is one of the issues in the programme along with the aspects of market, grid integration and environment. The aim is to give the conclusions from the European Policy Seminar on Off-shore Wind Power as much political support as possible and also to gaining the widest possible acceptance of all Member States.

For more information on the Danish offshore wind-farm tender and links to background reports on the environmental programme for the demonstration farms Horns Rev and Nysted as well as the European Policy Seminar on Off-shore Wind Power and the Copenhagen Offshore Wind Conference and Exhibition see [WWW.ENS.DK](http://WWW.ENS.DK).

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### 2.2.3 Consideration of Marine Nature Conservation Concerns in Planning and Decision-Making Procedures in Great Britain – Proportional Distribution Mapping as a Tool for Assessing Potential Impacts (A Case Study)

Tim Norman and Allan Drewitt

#### Introduction

Aerial surveys of Liverpool Bay, carried out in part by developers (including Scottish Power, Shell WindEnergy and Elsam) to inform the environmental assessment of the proposed Shell Flat Offshore Windfarm identified a population of Black Scoter *Melanitta nigra* of international importance. Black Scoter is known to be a sensitive species (e.g. Garthe & Hüppop 2004), and it was anticipated that the construction of a windfarm within its known wintering grounds would potentially result in the displacement of a significant number of birds.

Discussions with key consultees, including English Nature and RSPB, indicated the need to relocate the original proposed site, and it was recognised that a method was required to evaluate the likely magnitude of displacement effects of alternative locations and site configurations. A distinction here is made between the displacement *effect* (i.e. the extent to which birds are disturbed) and any *impact* that may result (e.g. reduction in the carrying capacity of feeding grounds).

Estimating the number of birds likely to be displaced was problematic. The main data available at an appropriate spatial scale were obtained from aerial surveys which, in their raw form, give an imprecise estimate of the population present. They do, however, provide a good indication of relative density of birds over a wide area.

#### What Does the Proportional Distribution Map Show?

It was decided that a simple measure would be to estimate the proportion of the Black Scoter population within Liverpool Bay that would potentially be displaced by the wind farm. The basis for this estimation was a proportional distribution map produced by the Joint Nature Conservation Committee (JNCC) tasked with selecting a site for a Special Protection Area (SPA) within Liverpool Bay. The data supplied by JNCC comprised aerial survey data interpolated to 100 m x 100 m cells, using a geostatistical kriging technique (e.g. McSorley *et al.* 2004) and presented as a *proportional distribution* map. This type of map provides a convenient way of identifying the proportion of a population likely to be found within any given area.

In the proportional distribution map, cells are ranked to reflect their contribution to the total number of birds observed, categorised and then plotted as a series of colour-coded grid cells. The map shows the *relative importance* of the region within which surveys have been undertaken by highlighting those areas that make a disproportionately high contribution to the population present. For planning purposes the most important cells (those in the highest ranking categories) can be given a distinctive colour to highlight the 'hotspots' that should be avoided in wind farm siting.

#### Using the Proportional Distributional Map to Assess Impacts

If it is assumed that the proportional distribution map shows the contribution that any particular area makes to the total population, then the map can also be used to identify what proportion of the population that might be affected by a wind farm proposal. Using GIS, the footprint of the proposed wind farm can be overlain on the proportional

distribution map, and the proportion of the population potentially affected can be calculated by summing the number of squares of each category overlain. One advantage of this approach is that it can be used to identify the proportion of the population potentially affected, even if the population size is not known.

In practice the displacement effect is not known but for assessment purposes (particularly in relation to sensitive species) it will probably be assumed to be 100% within the wind farm itself. The displacement effect is likely to extend beyond the wind farm area, due to a reluctance of birds to approach turbines, disturbance from maintenance vessels, or a combination of both factors. At Shell Flat, it was anticipated that this effect could extend up to 2 km. An approach, however, that assumes the disturbance level will be constant throughout this 2 km area was considered to be unrealistic, as it seems reasonable to speculate that fewer birds would be disturbed at greater distances from the wind farm.

At Shell Flat, it was therefore assumed that all Black Scoter would be displaced from within the wind farm. Beyond the wind farm, the effect was expected to diminish progressively until, at some distance from its perimeter, the effect would become undetectable. The response of Scoters to boats has been measured in Liverpool Bay. It has been shown that small flocks (less than 25 birds) react differently to boats than larger flocks (greater than 25 birds). For small flocks, most birds are flushed within one kilometre of the boat, with around 80 % of flocks flushed within this distance. Larger flocks, however, are more wary, with disturbance remaining high and flocks flushing up to 1.5-2 km from the boat.

An examination of flock sizes in the Shell Flat area indicates that the majority of flocks within 2 km of the proposed wind farm area comprised less than twenty-five birds. Although it is not possible to quantify disturbance levels precisely, this information can be used to produce a generalised disturbance response for the wind farm, plus a 2 km buffer. This indicates that the majority of disturbance occurs within 1 km. Displacement within this zone was, therefore, assumed to be 80 %. From 1 km to 2 km, occasional larger flocks are also likely to be disturbed, and the displacement for this zone was assumed to be 20 %.

Using the proportional distribution map, the proportion of the population in the wind farm was calculated as 0.6 % within the wind farm, 1.5 % within the region extending out 1 km from the wind farm perimeter, and 3.5 % in the region between 1 km and 2 km from the wind farm perimeter. Using the assumed displacement levels of 100 %, 80 % and 20 %, simple calculation indicates an overall displacement (or *interaction*) of 1.72 %. The interaction figure derived by this method can be used to compare the expected displacement effect (for a particular species) of alternative sites and site layouts. As further information becomes available about the response of birds to wind farm construction and operation, the assumptions about the magnitude of displacement within the wind farm and within adjacent areas can be refined.

## **Conclusions**

The advantage of this approach to assessing potential impacts of proposed wind farms on bird populations is that it can be used to 'score' the relative effects of different layout options: the higher the total interaction, the greater the expected impact due to displacement. Scoring proposed wind farm layouts using a proportional distribution map provides both a relative indication of impact (comparison of alternative proposals) and, if maximum thresholds of displacement can be agreed upon, an absolute means for assessing impacts on bird populations.

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## **2.2.4 Consideration of Marine Concerns of Marine Nature Conservation in Planning and Decision-Making Procedures for Offshore Wind Farms in Sweden**

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### **Background**

The Swedish government has set a goal for wind energy production of 10 TWh to be achieved by 2015. The most suitable places for wind energy facilities are considered to be the mountainous areas in the northern part of Sweden and at sea. The problem with building wind energy plants in the northern part of the country is that most of the energy has to be transported to the southern part of the country, where the majority of the people live, and the major share of industry is located. Therefore, the main focus in wind energy construction is on facilities at sea.

To date the Swedish experience of the environmental effects of wind power facilities at sea is low and mostly involves individual plants. So far, knowledge of the possible environmental effects of many plants in a farm is lacking. However, experience from sea based Danish wind farms are available.

Currently, Sweden has two minor sea-based wind farms: one in Kalmarsund between the island of Öland and the mainland, and the other outside Näs, at the island of Gotland. There is a licensed wind farm site of around fifty turbines situated at Lillgrund in the Öresund, just south of the bridge to Denmark. The construction of that farm will probably start in 2005 or 2006. Another farm of around twenty turbines is on the way to Utgrunden in the Kalmarsund, south of the Öland bridge.

*The weaknesses of the Swedish wind energy policy so far are:*

- A lack of national overview of, or overall responsibility for integrated planning of activities at sea
- Weak strategic planning and management
- Weak priority setting
- Weak knowledge of the legal stipulations and the prerequisites for exploitation among the authorities
- Uncertainty as to how the planning work is to be carried out in practice in coastal and offshore areas.

Generally, offshore wind energy facilities in Sweden are not considered a major problem with regard to impacts on marine flora and fauna. However, there is a lack of scientific knowledge to verify that assessment.

### **Inventory of Offshore Banks**

The Swedish government has commissioned the Swedish Environmental Protection Agency to undertake an inventory of marine species and habitats in those offshore banks where an interest for establishing wind energy has been announced. This is to be a habitat mapping project encompassing marine geological, hydrological and marine biological aspects. The inventory is to address twenty offshore banks from the Skagerrak on the west coast to the Bothnian Bay in the Baltic Sea. It was initiated in 2003, and will to be completed and submitted to the government in late 2005.

## **Vindval – the Swedish Research Programme on Environmental Effects of Wind Energy**

In order to promote the establishment of a knowledge base on the technical issues and environmental effects of both sea and mountain based wind farms, the Swedish government has commissioned the Swedish Energy Agency to start a pilot study. With regard to the environmental effects of wind power facilities at sea the sea based studies will probably be focused on the planned farms at the Öresund and the Kalmarsund. The environmental effect studies will cost between €2 and 3 million. Their goals:

- The promotion of wind energy facilities;
- Generation of results which, together with those of earlier studies, can be used for environmental impact assessments and as basic information for better planning and management in coastal and marine areas;
- Clarification of uncertainties regarding the environmental impact on marine species and habitats through sea based wind farms;
- Building of a knowledge base on the environmental and technical issues connected with wind farms at Swedish universities and high schools.

A special environmental research programme has been developed with a focus on underwater studies. The environmental effect studies of the programme will address fish, marine invertebrates, marine mammals, specifically Baltic harbour seals and hydrographic studies. In addition, effects on migrating bats and wintering sea birds will be addressed. The investigation will encompass studies before, during and two to three years after construction has been completed. Furthermore, the studies will be directed towards knowledge in which society has a certain interest, and from which generalisations relevant to geographical areas other than the pilot area can be made.

Fish, bottom living invertebrates (crustaceans, molluscs, sea worms, starfish) and macro-algae may be affected directly and indirectly during construction and operation of a wind farm. Sound, vibrations and light flicker generated by the wind farm and its individual turbines may disturb and stress the species, and possibly make them leaving the area.

There are indications that migrating bats may be hit and killed by the rotor blades; the effects on migrating bats are to be studied in Kalmarsund.

The hydrographical conditions around the foundation of a turbine may generate increased turbulence and change the sedimentation pattern.

In addition to the environmental programme, a second programme aimed at the effects of wind energy facilities on the landscape/seascape and the human living space will also be carried out.

### **EIA studies**

In conjunction with an application for establishing a wind farm, consultation with other concerned interests must be carried out and an environmental impact assessment (EIA) undertaken. The first step in such an assessment consists of detailed site-specific inventories of flora, fauna, and habitats of high conservation value. It is essential that these surveys be representative of the area concerned and that the EIA includes a description of the natural state of the site, so that any effects of the wind power installation arising during the construction or operational phase can be detected.

On the basis of an EIA, the necessary steps to safeguard the environment can be taken. The design and siting of foundations and other technical aspects of wind turbines can be optimised, both from an energy point of view and in biological terms. In addition,

during the construction and operational stages, an EIA can serve as a basis for establishing criteria defining what measurable environmental impacts and possible effects on species and habitats are to be regarded as acceptable. In the event of any impacts significantly exceeding these criteria, the authorities will then be able to intervene.

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## **2.2.5 Consideration of Concerns of Marine Nature Conservation in Planning and Decision-Making Procedures for Offshore Wind Farms in Belgium – Defining Criteria and Levels of Significant Impact on the Marine Environment when Assessing Offshore Wind Farms**

Marisa Di Marcantonio

The Management Unit of the North Sea Mathematical Models and the Scheldt estuary (MUMM) is a department of the Royal Belgian Institute for Natural Sciences (RBINS), a federal scientific established under the Federal Science Policy. For projects involving the marine environment (e.g. offshore wind farms) the MUMM is the advisory board of the Minister of the North Sea.

The project developer hands in an environmental report or statement (EIR/EIS) which the MUMM uses to evaluate the project and write an environmental impact assessment (EIA). Initially, the MUMM ascertains whether the document is complete. If information is lacking, MUMM can obtain the requisite scientific information, or ask a third party to do so. The goals of the EIA, performed by MUMM, are to determine whether a project is acceptable for the marine environment, and if so, under what conditions. The EIA is used as a decision support tool by the Minister of the North Sea. The general wind farm vision of the MUMM focuses on the efficient spatial management of the Belgian part of the North Sea with respect to other activities and within the wind farms themselves. In 2001 after thorough research, the MUMM came to the conclusion that the degree of activity in the territorial sea (TS) was reaching its limits. It was decided that for proposals submitted before 2001, only the Vlakte van de Raan in the TS was a suitable location. For projects introduced after 2001, it was advised that they be located on the Thornton Bank in the Economic Exclusive Sea (EES). In 2004, a policy decision was made designating one offshore wind farm area in the Belgian Exclusive Economic Sea. Future wind farm projects can only be located in that area.

Over the past five years, five proposals for wind farms in Belgian waters (TS and EES) were submitted. Two projects were granted: one in the TS and one in the EES. Due to current court procedures, the project in the territorial sea has been suspended. The other project, called C-Power 2 (CP2), will be built in 2006. Here, this project is to be examined more closely, in terms both of the criteria used to evaluate it and those used to evaluate the previous wind farm proposal by the same developer, C-Power 1 (CP1), which was refused. The MUMM criteria were an attempt to allow an objective evaluation and to ensure fair treatment for various applicants. It also gave MUMM an instrument to evaluate cumulative impacts. The developed criteria were used as a decision support tool with the emphasis on “support tool”, not on “decision”. It is always necessary when evaluating projects to bear in mind that criteria are necessary, but not sufficient.

### **The C-Power 1 Project**

This proposal was submitted in 2001, and consisted of fifty of 2.3 MW wind turbines (for a total of 115 MW) located 6 km off the coast on the Wenduinebank. The domain concession was granted on 26 February 2002. The environmental permit was refused on 5 August 2002 because the EIA indicated a risk of significant negative impacts. The criteria used in the EIA for this project were developed for the TS, and focused on maximum spatial occupation, birds, landscape and noise. After comparison of the spatial occupation of existing activities in the North Sea, it was decided that a maximum spatial occupation for one type of activity of 8 % could be used as a criterion. Based on ecological and best available nature conservation data, a maximum specific habitat loss

of 25 % was defined as a criterion combined with a maximum occupation of one third of the width of the specific migration corridor. These criteria were used for the most vulnerable species under the Bird and Habitat Directives. The migration corridor was determined for each species, and the greatest possible impact of the wind farm was calculated. For the Great Crested Grebe (*Podiceps cristatus*) the migration corridor is situated between 0 and 8 NM from the coast. The wind farm would have occupied 45 % of the migration corridor, which is more than one third of the criterion. Due to the low density of the birds over a large area, the impact on the habitat was estimated 7 %, and seen as not extremely important. For the Common Scoter (*Melanitta nigra*), whose migration corridor is situated between 0 and 6 NM from the coast, 37.5 % of the corridor would be occupied by the wind farm. The habitat loss is unknown, as the majority of the population is located on the western part of the coast and the wind farms would have been located off the middle part of the coast. The distance from the Natura 2000 zone was of only 4 km, and the uncertainty as to the number of birds involved in falls lead to negative conclusions on the impact of the wind farm on birds. For the evaluation of the landscape, it was decided that the horizon occupation of one wind farm from any point at the coast could be 20° of the view, out of 180° of human horizontal vision. The cumulative occupation for different projects (including non-wind-farm projects) could not be more than 36°. The establishment of these criteria proved to be a useful working instrument. The maximum calculated view occupation from the coast for the C-Power project was 48°. These view angles were calculated for several locations on the coast (every km). Under the Espoo convention, part of the Dutch coast was also evaluated. The view angles were combined with the distance to the coast. Obviously the worst case situation would be one with a high view angle combined with a small distance. For the C-Power 1 project, 24 % of the locations on the coastline, or a 19 km stretch of coast, would have had view occupations of more than 20°, and 12 % of the locations, or a 9 km stretch of coastline, would have a view occupation of more than 36°. A total of 28 km of the Belgian coast, which is only 67 km long in total, would have had a negative visual impact due to the C-Power 1 project on the Wenduinebank.

No criteria for noise assessment were developed, since such a criterion had already been established by the Flemish community. The acceptable noise level according to this criterion is 45 dB for living areas. The noise level of 50 WT in operation was simulated, and the results showed a minimal negative impact in certain weather conditions.

In conclusion: the C-Power 1 project was not acceptable and the permit refused. The most important negative impacts to be expected involved birds and the landscape. Other negative impacts that could have been expected for noise, fishery and risks.

### **The C-Power 2 Project**

The above criteria seemed, at the time, to constitute an upper limit above which the impact could not possibly be regarded as reasonably acceptable. When in 2003 C-Power submitted a proposal for a new project 27 km off the coast on the Thorntonbank, consisting of sixty 3,6 MW wind turbines, a new assessment system had to be developed to be able to assess the possible impact of the wind farm outside the TS. Here, the above mentioned criteria no longer reflected the requirements of ecological and environmental protection: the Thorntonbank is a zone of limited interest for (migratory) birds, and the zone is too far off the coast to produce a major landscape impact. Therefore the assessment of the second project did not refer to absolute criteria, but rather focused mainly on the need for a monitoring programme and on



defining restrictive conditions as a precautionary measure for all uncertainties regarding the possible effects of the project.

To evaluate the landscape impact, the Thomas Sinclair index proved to be a useful instrument. This index is used in Great Britain; it estimates what the potential visual impact of the wind farm will be at a certain distance. Furthermore, visibility data and the impact of the lights and marking on the wind turbines were studied. Research indicated out that even at a distance of 27 km, a problem could arise with the lights on the wind turbines: in certain weather conditions, they might be visible from the coast. For this reason, a filtering of lights will be imposed on the developer if a public investigation indicates that there may be negative impact for the people on the coast.

It was decided that the C-Power 2 project is acceptable under strict conditions. The most important of all conditions is the implementation of a programme to monitor the environment during the first five years of construction (possibly longer, if the monitoring indicates negative environmental effects). General conditions involved installation of a guidance committee which includes members of various ministries, the obligation to consult a certification agency and to foresee a financial liability. Also such stipulations involving risks and safety as the drafting of an emergency plan, and maintenance of a safety ship on site during the entire construction period and of a multipurpose ship during the operational period. Other stipulations involve with hazardous and toxic substances, the landscape, marine mammals and birds, and the decommissioning of the wind farm. The project developer is also obliged to build the wind farm in two phases, so that, based on the monitoring results of the first phase, permit conditions can be changed and/or mitigation measures can be established.

It can be concluded from these two projects that it is difficult to define absolute criteria for a large area: often criteria are project specific. The monitoring process should help assess the impact of the wind farm, and may also help develop absolute and/or relative criteria that can be used outside the TS in the future. Meanwhile the marine experts of the MUMM will continue to evaluate new projects using adopted criteria for each specific project and, in case of acceptance of a project, focus on restriction conditions, mitigation measurements and built-in safety breaks such as a pilot phase.

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## **2.3 Introductory Presentations to the Workshops on Various Marine Biota – Present Knowledge, Factors of Influence, Impact Categories**

### **2.3.1 Effects of Offshore Wind Farm Construction and Operation on Harbour Porpoises and Seals in Denmark**

Dr. Jonas Teilmann, Jakob Tougaard, Jacob Carstensen, Susi Edrén, Rune Dietz, Henrik Skov and Oluf Damsgaard Henriksen

Offshore wind farming is a new emerging field within renewable energies. In Denmark, the world's first two greater offshore wind farms (>100 MW) at Horns Reef (80 turbines) in the North Sea and Nysted (72 turbines) in the Baltic were constructed in 2002/2003. At Horns Reef the facilities were built by ramming mono-piles into the seabed, while at Nysted the turbines were built on gravitation foundations. Since 1999 several studies on harbour porpoises and harbour and grey seals have been carried out to investigate the impact from the wind farms.

#### **Harbour porpoises**

Acoustic porpoise detectors (T-PODs) and ship surveys were used to monitor changes in presence and behaviour of harbour porpoises.

#### *T-PODs*

Acoustic porpoise detectors (T-PODs) were deployed year round to monitor their echolocation activity. The monitoring program was established in both wind farms as a modified BACI design with six monitoring stations, placed both inside the wind farm area and in adjacent reference areas. At Nysted Offshore Wind Farm the mean time between two consecutive encounters of echolocation activity (waiting time) increased significantly compared to the reference area during the entire construction period and during the first year of normal operation (Tougaard et al. 2005a). During construction and first year of operation the porpoise acoustic activity was reduced to about 20% of the baseline level. The porpoise activity in the reference area (10 km from the wind farm) was also lowered during the construction and operation periods. If we assume that the porpoise population in the general area was stable during the study period, the effect on the porpoise seems to extend further than 10 km from the wind farm. At Horns Reef offshore wind farm no general change or a decrease in waiting time between two acoustic porpoise recordings was observed during the whole construction period and first year of operation (Tougaard et al. 2005b).

#### *Ship Surveys*

Ship surveys were conducted at Horns Reef to provide information on the spatial use of the area by harbour porpoises. Results from surveys showed that porpoises are abundant in the Horns Reef area, with most animals observed from spring to fall and generally few during winter. Porpoises were observed in all areas of the reef, including the wind farm area. In contrast to the T-POD data, only few porpoises were sighted during surveys inside the wind farm area. This difference may be explained by a bias in observations since surveys were only carried out in calm weather where the

construction activity (i.e. disturbance) was high. After construction during the normal operation (although the initial operation period was affected by technical problems) of the wind farm porpoises were often observed in the wind farm (Tougaard et al. 2005b).

### *Pile Driving*

Pile driving of foundations at Horns Reef and steel sheet piles at one foundation at Nysted, were associated with significant increase in waiting time between acoustic recordings, in both construction and reference areas at both wind farms. Pile driving generates very high underwater sound pressures that may injure the animals, therefore mitigation procedures, in the form of ramp-up and acoustic alarms (porpoise pingers and seal scarer) were deployed to displace the animals out of the damage zone near the ramming. The effect of the mitigation compared to the pile driving itself was not tested. However, other pile driving in the Nysted area (not associated to the wind farm construction and without mitigation procedures) showed a similar displacement of the porpoises, supposing that pile driving sounds alone may cause the detected effects on porpoises (Tougaard et al. 2005a). A change in behaviour in visually observed porpoises at Horns Reef was observed during pile driving, from predominantly non-directional swimming (presumably associated with feeding) towards predominantly directional swimming. This effect was observed at distances up to 15 km from the wind farm during ramming (Tougaard et al. 2005b).

### *Why are Porpoises Affected in Different Ways?*

These results show that the effect on porpoises from wind farms may depend on the type of wind farm, differences in the behaviour of different porpoise populations, and/or ecological differences between areas. Although pile driving were performed mostly at Horns Reef and had a more pronounced effect on the porpoises, it was limited in duration compared to the construction time of gravitation foundations. How these differences in construction method affected the porpoises is unknown. Another reason for the differences in response to construction and operation could be that the Nysted area in general could be less important to the porpoises than Horns Reef and that porpoises at Nysted thus are less motivated to remain in the area when disturbances occur. It could also be, that porpoises living in the more dynamic and noisy environment at Horns Reef are less sensitive to disturbances. Alternatively it could be that porpoises around Nysted are part of a smaller more resident sub-population in the area while porpoise at Horns Reef are part of a larger and highly mobile population. This could mean that porpoises travelling through Horns Reef, unaware of the existence of the wind farm, come into the area highly focused on feeding. Satellite telemetry has shown that both porpoises and seals are generally more mobile in the North Sea compared to the Baltic (Teilmann et al. 2004; Tougaard et al. 2003).

### **Seals**

To study the effect of the wind farms on harbour and grey seals, aerial surveys (Teilmann et al. 2005), satellite tracking (Dietz et al. 2003) and video monitoring (Edrén et al. 2005) were implemented at Nysted Offshore Wind Farm and satellite telemetry at Horns Reef (Tougaard et al. 2003). Satellite telemetry and aerial surveys were conducted to study the possible shift to other haul out sites away from the wind farm as a result of disturbance. Satellite telemetry also provided information on the use of the wind farm area and general home range. Finally the video monitoring gave data on the behaviour and disturbance of seals on land. The studies shows that the effect of the

wind farms on the seals seem to be limited. The only significant effect on the seals was detected during construction of Nysted Offshore Wind Farm during pile driving operations, where significantly fewer seals were observed on land about 10 km away. Other ramming activity in the Nysted area (not associated to the wind farm) did not affect the seals on land. It is unknown why seals reacted to the pile driving in the wind farm, and also why the various pile driving affected the seals differently.

### Final remarks

The studies of harbour porpoises and seals at the Danish wind farms are ongoing and conclusions are therefore preliminary. The studies will end in 2006 when the final results will be available. It should also be noted that not all effects may have been discovered. Hence, the studies do not show how and why the animals are affected, and what the implications may be for the animals on individual or population level.

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### 2.3.2 International Exchange of Experience on the Assessment of the Ecological Impacts of Offshore Wind Farms – Marine Mammals

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The ecological impacts of offshore wind farms on marine mammals are one of the objectives of an ongoing research and development project funded by the German Federal Agency for Nature Conservation through of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. In order to assess such a potential impact, it is necessary to identify the relevant ecological parameters and to collate the available information with regard to each of these parameters. As a first step, the currently available knowledge on the potential impact of offshore wind farms on marine mammals has been collected within the scope of a literature review and international consultation. Based on assessment reports, peer reviewed and grey literature as well as information provided by various research groups, agencies and stakeholders, the goal of the study is to provide an overview of available ecological data and to identify important factors and research needs. Examples from windmill related studies on marine mammals which have been conducted so far are presented.

Offshore wind farms are now being planned all around the world. However, one focal point is the southern North an Baltic Sea area, where numerous wind farms are planned. Within the German Exclusive Economic Zone (EEZ), the number of wind farm projects has now risen to more than thirty. Eight projects have received final authorisation, while two have been rejected. An interesting aspect is a comparison of the scale of the pilot projects, with no more than eighty windmills per wind farm, and of the final scale as planned and proposed by some developers, which may include hundreds of turbines.

Three marine mammal species are live and breed within the German EEZ, and are hence of major concern in this context: the harbour porpoise (*Phocoena phocoena*), a small toothed whale species, the harbour seal (*Phoca vitulina*) and the grey seal (*Halichoerus grypus*). Most important in relation to the potential impact of offshore windmills is that those species are bound to the coastal areas and that they have a highly developed sense of hearing and depend strongly on this sense. Due to this fact, which is pointed out in most of the assessment studies and resulting reports, windmill related acoustic emissions are likely to have very great effect on these animals. Therefore, the acoustic sensitivity of the species at risk has received great attention recently. The hearing curves for these marine mammal species show that the hearing sensitivity or threshold depends on frequency. In general, hearing sensitivity is species specific and also differs between individuals of the same species. Harbour porpoises have a wide functional hearing range (below 1 kHz to 160 kHz), with best sensitivity in the ultrasonic frequencies. The functional hearing range of the seals also stretches from low frequencies (below 1 kHz) into the ultrasonic range, albeit not as far as for porpoises, and with less sensitivity at the higher frequencies. However, at lower frequencies the hearing sensitivity of seals is higher than that of porpoises.

A small but growing number of recordings of windmill related sounds have been conducted and published to date. The recordings are useful for understanding the acoustic dimensions of windmill related noise. At present however, only limited information can be derived from these recordings, as they generally consisted of various windmill types and sizes, had different types of foundation, and were located at different depths. All this results in significantly divergent sound pressure levels and spectral

densities, especially due to different bottom substrate. Thus, systematically conducting further recordings during all phases will be one of the research requirements.

During the construction phase, the noise emissions from the impact pile driving are short (between 100 - 200 ms) and intense (up to 227 dB re 1  $\mu$ Pa in 1 m). The main energy of the sound is concentrated below 1 kHz, but as measurements at Horns Rev have shown, the ramming impulses also have contents of up to 100 kHz. The number of impacts differ from 1 to up to 30 per minute. It is important to notice that the maximum sound pressure level – or “SPL” – as well as the spectral content strongly depend on the bottom substrate. Recordings from installation into hard bottom substrate showed SPL's of up to 262 dB re 1 $\mu$ Pa at 1 m.

Other techniques, such as vibratory pile driving, exist for installing piles. The analysis of a sound recording of this installation method made at a distance of 400 m resulted in a theoretical SPL for the vibro pile driving of approximately 190 dB re 1 $\mu$ Pa at 1 m. There is no information available to date on the duration of vibratory pile driving compared with impact pile driving. Systematic recordings of this technique would be useful in order to clarify whether or not this technique is more favourable from an ecological point of view compared with impact pile driving.

Some recordings have also been made during the operational phase of the turbines. Almost all of these were made near windmills which are relatively small, compared with the larger windmill types that are to be installed in the future. The noise level and spectral content of these larger windmills will be different from the current and older windmill types. So any analysis based on these recordings is limited in this respect. The measurements published so far show that the operational sound is clearly above the background noise, sound emissions differ according to weather situation, and there are major components in the frequency range below 500 Hz (varying among the different recordings, but all below 500 Hz).

What could be the potential effects on marine mammals? In general the sounds, especially the construction sounds, will be audible over wide ranges; at closer range animals will show behavioural reaction; even closer and at higher received sound levels, the noise emitted by the sound source could mask biologically important sounds. Masking means that a given sound cannot be perceived because of the presence of other – usually louder – sounds. At close range, it is possible that intense sounds can lead to impairment of the hearing (called TTS), hearing loss or other physical injuries.

One factor that is hardly ever mentioned in assessment reports is stress. However, stress can be elicited over the full detection range and will very probably increase with increasing SPL. Stress can be acute or chronic, depending on the exposure situation and duration. It can lead to reduced reproductive success, a reduced function of the immune system, and to reduced general fitness of the animals at risk.

At which distances these effects occur depends upon the relevant thresholds. Numerous thresholds have been proposed, some are based purely on scientific information, others also biased by political or other considerations and approaches.

The detection threshold for a sound is more or less equal to the hearing threshold of the perceiving animal. It may differ by some dB due to special auditory features. Behavioural reactions of animals to sound are in general unpredictable. The type and strength of any reaction by marine mammals has been found to be individual and highly context specific (e.g. a foraging animal is less susceptible to disturbance than a nursing female with her offspring). Habituation and sensitisation are important factors too in this respect. Most threshold values cited in the literature are based on incidental observations of non-controlled acoustic situations. Only Controlled Exposure Experiments (CEEs) have been suggested as useful for arriving at thresholds for the

elucidation of a given behaviour. Thus, any prediction and threshold value would hardly be plausible at present. In this context, the question has been raised as to which kind of behaviour, and subsequent change of behaviour, will be biologically significant.

Masking involves the intensity of a given sound compared to masking noise. If noise is too loud or has specific acoustic components, an animal can no longer hear the sound.

An increasing number of thresholds exist for injury or impairment of animals. The most relevant values at present are those of the US-NRC (180 dB for whales and 190 dB for seals).

In order to address the question of whether or not any of these effects are biologically significant, it is necessary to look at the problem on a larger scale, not at individual animals. But should one look at local stocks, within administrative boundaries, or at populations? All three marine mammal species of concern here can travel long distances on a daily basis, migrate within seasons between distant areas, and are by no means limited by national borders. It is therefore suggested that, from a biological point of view, it is useful to make observations at the population level.

Density distribution maps (e.g. for the harbour porpoises in the German EEZ) clearly indicate that there are habitats of different importance for the animals. This may vary seasonally, as animals may use certain areas for breeding in summer, and others as migratory pathways or feeding grounds in other seasons. The important factors remain unclear, but it is likely that a combination of biotic and abiotic parameters is important. There is also no information available on the extent to which important habitat loss can be compensated elsewhere.

Another important issue is that of cumulative effects: Most environmental impact assessments are concerned with the effects of a single wind farm; there is no information available to date on the cumulative effects of several wind farms. A variety of already existing anthropogenic activities are proven to have a substantial effect on marine mammals. Amongst the most important is the by-catch of harbour porpoises in the bottoms of set gill nets, which cause a mortality of several thousand animals per year. Other factors are the depletion of fish stocks in European waters, chemical pollution, etc. The effect that each of these factors has on a population may or may not remain at a level sustainable for that population. Every wild population can cope with a certain level of additional anthropogenic induced mortalities, but beyond a certain level, mortalities can no longer be compensated, and the population level decreases. It may be trivial to point out that none of these factors stands alone; all are cumulative, and must be assessed together by discussing the significance of effects.

Since the situation is complex, and a management scheme for the marine environment based on incomplete or non-existing data sets is needed, it would be useful to build theoretical models of effects, which could provide an understanding of the correlation of various factors, and help identify important factors. A first step could be the identification of the parameters necessary for a model. Of course, a model is necessarily based on assumptions, but the better the baseline data of a model, the more robust are its results.

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### 2.3.3 Impacts of Offshore Wind Farms on Benthos and Fish Communities. Experiences from the Danish Offshore Wind Farms.

Dr. Simon Leonhard

#### Introduction

As part of the monitoring programme concerning the ecological impact of the introduction of hard substrate related to the Horns Rev Offshore Wind Farm (OWF) and Nysted OWF, Denmark, results from 1999 to 2003 of the surveys on benthos communities and fish communities are presented. Results from 2004 will be published in the spring of 2005, and the sampling programmes will be continued in 2005.

Horns Rev OWF is located in the North Sea 14 - 20 km off Blåvands Huk, Denmark's westernmost point. The reef consists primarily of gravel and sand. Nysted OWF is situated 10 km south off Nysted in the Baltic Sea. The seabed in the area at Nysted consists mainly of sand, gravel and stones. The water depths in the two OWFs are largely similar, between 6 - 11 m. The main differences between the two sites are differences in salinity and wave exposures. Mono-pile foundations of steel are used for turbine foundations at Horns Rev OWF, whereas gravity foundations of concrete are used at Nysted OWF. At both wind farm sites, protective mattresses or scour protections of stones are arranged around the foundations to minimise erosion.

Surveys on both infaunal communities as well as epifaunal communities were performed at the two OWF sites. No specific criteria were established, and the studies were designed only to assess major impacts from the introduction of hard bottom substrates on the infauna communities, and to demonstrate the theory of fish attraction behaviour to artificial hard structures in developing fish communities associated with hard substrates.

Further objectives included assessment of the impact of "aliens", of possible hydraulic impacts, and of the possibility of controlling abiotic or biotic factors. The goals of the monitoring programmes were also to monitor the development and succession in epifaunal communities.

#### Results

##### Infauna

Distinct differences in benthic communities were found between the two different wind farm sites. The native infauna community at Horns Rev can be characterised as an *Ophelia borealis* or *Goniadella-Spisula* community typical of sandbanks in the North Sea. This community displayed great spatial and temporal variability in species composition, abundance and biomass. At Nysted, the native infauna community was characterised as a *Macoma* community with patches of stones and an epifauna community of the common mussel *Mytilus edulis*, both typical of shallow coastal areas. Character species such as the bristle worms *Ophelia borealis* and *Goniadella bobretzkii* and the mussels *Spisula solida* and *Goodallia triangularis* were found to be indicators for environmental changes in the Horns Rev area.

At Horns Rev, no impact on the infaunal benthic communities were found with respect to differences between the wind park area and a reference area, but new "aliens" were introduced in the "infaunal" community, and no hydraulic impact on the infaunal benthic community was found. No results of the impact of the Nysted OWF on the benthic infaunal community are available.



diversity of species were found but a few main primary colonisers contributed to more than 99 % of the total abundance, and to more than 91 % of the total biomass. The cosmopolitan amphipod *Jassa marmorata*, not previously recorded in Denmark, was the most frequent species found at Horns Rev on turbine mono piles in abundances as high as 640,000 ind./m<sup>2</sup>; whereas at Nysted the barnacle *Balanus improvisus* and the common mussel *Mytilus edulis* were found to be the most abundant species at the concrete foundations with abundances up to 40,000 ind./m<sup>2</sup> and 361,000 ind./m<sup>2</sup>, respectively; see Figures 4 and 5.

Distinct vertical zonation in the faunal assemblages on the turbine mono-piles and concrete foundations were observed. The common mussel *Mytilus edulis* dominated the biomass, and was found in dense aggregations of spat, or, larger individuals, in the sublittoral. At Horns Rev, the vertical distribution of *Mytilus edulis* was typically controlled by the keystone predator, the starfish *Asterias rubens*. Due to lower salinity, this predator was not found at Nysted, and no controlling predator was registered. In the splash/wash zone at the turbine mono-piles at Horns Rev, monocultures of the “giant” midge *Telmatogeton japonicus*, not previously recorded in Denmark, were typically found feeding on the green epilithic algae. At Nysted, almost monocultures of *Balanus crenatus* were found in the splash/wash zone at the concrete foundations; whereas at Horns Rev, the barnacles were less abundant and, due to higher salinity, dominated by *Balanus crenatus* and *Balanus balanus*.

Spatial and temporal differences between sites, sample locations and substrate types were found in the immature epifaunal communities on the turbine mono-piles, concrete foundations and scour protections. Greater similarities between some of the turbine sites were shown in September 2003, compared with March 2003, which might be a result of succession approaching stability in the fouling communities. Attraction behaviour and utilisation of the hard substrates at Horns Rev as nursery grounds was shown for mores species, such as the edible crab *Cancer pagurus*.

Wind farms may become a sanctuary for endangered and preserved species, such as the European oyster *Ostrea edulis*, considered as threatened in the Wadden Sea area. We might expect to find species like the bristle worm *Sabellaria spinulosa* and the white weed *Sertularia cupressina* as well.

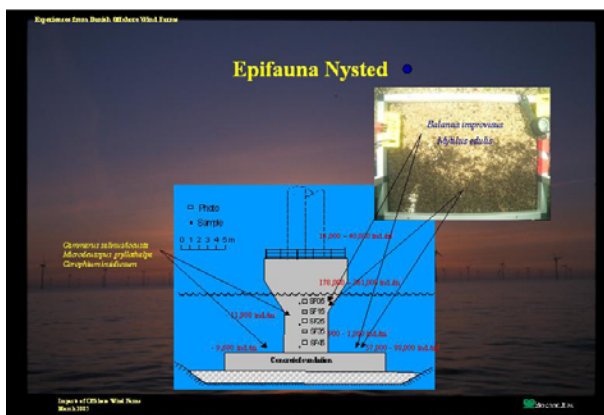


Figure 5. Epifauna community at Nysted OWF.

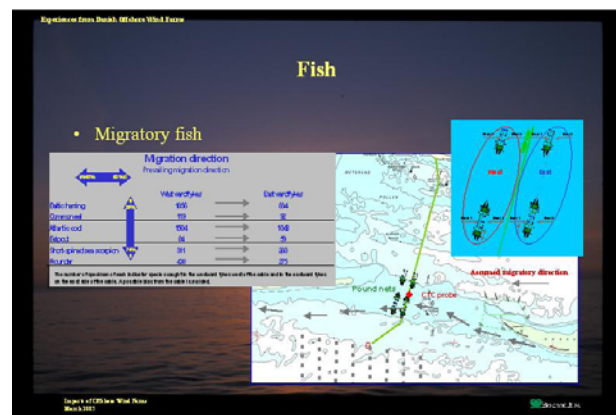


Figure 6. Study at Nysted OWF on migratory fish.

The introduction of hard substrate structures at Horns Rev and to some extent at Nysted have introduced new habitats, new species, increased species diversity, hatchery and nursery grounds for mobile benthic species and have increased benthic biomass and prey availability.

## Fish

Other studies have shown fish attraction behaviour to artificial hard structures in developing fish communities associated with hard substrates, and fish communities of more mobile pelagic species feeding on available epibenthic organisms.

The hypothesis of fish attraction was the main hypothesis for the screening study on fish communities carried out before establishment of the Nysted OWF. Results have shown that traditional methods were useful, but the data sets collected were statistically insufficient to support significant conclusions. Only one literature study had been published on the fish community at Horns Rev prior to the establishment of the wind farm, due to practical difficulties caused by generally severe weather conditions.

Results from observations and test fishing at Horns Rev OWF have already shown colonisation of benthic fish species. Few observations of e.g. the hooknose (*Agonus cataphractus*) and the rock gunnel (*Pholis gunnellus*) were made in March 2003, eight months after deployment of the foundations was completed. In September 2003, a total of fourteen species were recorded, and shoals of pelagic and semipelagic species e.g. the Atlantic cod (*Gadus morhua*), were observed on or near the scour protections with several feeding on epifouling organisms.

A study at the Nysted OWF has shown no impact on migratory fish from electromagnetic fields from power cables. The introduction of a new methodology approach using hydroacoustics for detection of fish communities on the scour protections and near the turbine towers and concrete foundations has provided useful results during a test study carried out at Nysted.

## **Concluding Remarks about Research on the Development of New Habitats in Denmark**

In general, experience from the large-scale offshore facilities in Denmark, including the two OWFs at Horns Rev and Nysted, demonstrate the need for establishing operational criteria for impacts on benthos and fish communities. Before establishment of baseline and drafts on monitoring programmes, specific criteria for selected predictor variables must be established in accordance with the objectives and hypotheses. Further preliminary sampling to provide a basis for evaluation of sampling design and statistical analysis options must be carried out before a baseline is established.

The results of the monitoring of hard substrate habitats introduced at the Horns Rev and Nysted OWFs have demonstrated that the applied methods for studies on and sampling of epibenthos are useful. The epibenthos communities differed between the two farm sites, although a few dominant species were found on both sites. Immature epifouling communities in succession were recorded at both farm sites. Succession in primary colonisers was indicated, and newly introduced species were ascertained. It was determined that offshore wind farms might be regarded as sanctuary for endangered and preserved species.

### **2.3.4 Present Knowledge about Ecological Impacts of Offshore Wind Farms on Benthic Organisms**

Dr. Karin Meißner, Prof. Dr. Holger Sordyl

#### **Background**

The Background of this study is a project funded by the German Federal Agency for Nature Conservation (BfN), commissioned to undertake a literature review of available information about ecological research regarding impacts associated with wind farm development on benthos and marine habitats. A similar study was undertaken by KNUST ET AL. (2003) at a time when first offshore wind farm developments in Europe had just begun to be realised. Now, two years later, new information should be available and possibly allow a better-founded risk assessment.

#### **Sources of Information**

The most valuable source of information is expected to be the realisation of offshore wind farm projects. Meanwhile several smaller and a few larger farms have started power generation, the latter including North Hoyle and Scroby Sands in Great Britain, with thirty 2 MW turbines, Nysted Wind Farm in the Danish Baltic Sea, with seventy-two 2.3 MW turbines and Horns Rev in the Danish North Sea, with eighty 2 MW turbines. To date however, reports from benthic surveys during the construction and post-construction phases are scarce, and have been provided to a broader audience only from Nysted and Horns Rev.

Another source of information on the possible impacts of offshore wind farm developments is such practical approaches as the construction of research platforms or field studies at offshore facilities of the oil and gas industries. An example from German waters is the research platform FINO I in the North Sea, which serves as a study site for the research project BeoFINO. That project is conducted by the Alfred Wegener Institute for Polar and Marine research (AWI) and financed by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The main goal of BeoFINO is to develop methods and criteria to investigate the potential effects of offshore wind farms on marine life. The results of the benthic surveys, together with information related to abiotic parameters, are expected in the summer of 2005.

An example for gathering empirical data is the measurement of sediment temperature along power cables at Nysted Wind Farm. This project is funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), and is being carried out by the Institute of Applied Ecology GmbH in Neu Broderstorf. Data will be available to the public in 2005.

There have also been several research projects, such as SCARCOST and GIGAWIND, which have developed theoretical models to predict changes in sediment or hydrographic conditions, current and wave regimes or coastal processes. Other authors have compiled reports describing the potential effects of offshore wind farm developments on marine habitats and species or coastal processes, based on conclusions by analogy, or on the results of modelling. Conclusions can be corroborated by the scientific literature, although recent scientific publications on wind farming have dealt almost exclusively with technical aspects. But there are other publications which address topics involving information applicable to wind offshore issues, such as disturbance of benthic communities caused by the activities of fisheries, oil and gas industries or aggregate extraction, studies on reefs and of reef effects, epibenthic

colonisation of artificial hard bottom, or the effects of temperature rise, electromagnetic fields or noise.

### **State of Knowledge**

Various effects on benthic communities and marine habitats have been identified to occur in the course of an offshore wind farm development. During the construction phase activities related to site preparation, foundation and cable installation will result in physical disturbance, damage, displacement and removal of benthic organisms. Also, sediment re-suspension, at some sites together with redistribution of chemical contaminants, smothering and habitat loss will affect the benthic community.

Based on present knowledge, changes of current and wave regimes as well as alterations of sediment characteristics attributable to the presence of wind farms are expected to occur in the near-field although extrapolation of these findings to larger developments (> 90 turbines) can only be tentative (Cooper & Beiboer 2002, Baker 2003). Prediction of scour has proven difficult, since the level of scientific understanding is still developing. However, all changes of sediment characteristics are very likely to be reflected in the composition of the benthic community.

Another major concern relates to epibenthic colonisation of foundation structures and turbines. There is no doubt that epifaunal communities will establish themselves on the artificial hard bottom. Assessing the significance of that fact requires consideration of the question of whether a natural hard bottom is present or absent at the wind farm site, and hence of whether an establishment of local or of non-local fauna will take place. If natural hard bottom is absent, the existing benthic community will have to face the introduction of new faunal components, attraction of predators and scavengers, and modification of the surrounding seabed. This scenario applies to large areas of the German Bight, which is dominated by soft bottom communities. But even if hard bottom is naturally present and local fauna will populate the introduced artificial hard bottom, the so-called "reef effect" and the increase in biomass should not be neglected.

In the past not much attention has been paid to potential effects due to heat emission from power cables. In sedimentary substrata, cables will usually be buried whereas on rocky or other solid substrata, cable may need to be laid on the surface. According to a guideline set by the German Federal Agency of Nature Conservation, the temperature rise above the buried cable in 0.2 m sediment depth should not exceed 2°K. A temperature rise of 2°K is obviously regarded as non-harmful to benthic organisms, most of which inhabit the first 35 cm beneath the surface. On the basis of theoretical models for predicting sediment temperatures in the vicinity of power cables, this guideline can usually be followed if a cable burial depth of 1 m is realised (e. g. EOS Offshore-AG 2003, Worzyk & Böngeler 2003). But the models also calculate that sediment temperature in greater depths closer to the cable will be much higher, and that the temperature rise may even exceed 30°K directly at the cable. A permanent temperature rise may lead to changes of physico-chemical conditions of sedimentary substrates, e. g. alteration of redox, O<sub>2</sub>, sulphide profiles, changes of nutrient profiles and increase in bacterial activity. This might also affects the composition of the infaunal community.

### **Conclusions**

In summary, changes of the benthic community composition and even the loss of existing benthic communities have to be expected in the course of offshore wind farm developments. The significance of these expected changes is difficult to assess.



Aspects to consider here are extent and intensity. For example, the area covered by foundation structures, cables etc. is usually known whereas the area affected due to factors like smothering, scour, reef effects is vague. The same applies to duration. The duration of the influencing factors can usually be estimated but the duration of the resulting effects are not foreseeable. Here, the recovery potential of benthic communities plays an important role. However, appropriate monitoring concepts can help to shed light on these issues. Monitoring concepts for the construction and operational phase have to be planned carefully to allow the documentation of effects on benthic communities. Regarding the assessment of such effect intensity aspects as habitat and species sensitivity, rareness of species and habitats, naturalness, importance of key stone species, protection status and cumulative effects must be considered. Further research and data analyses are required to provide a basis for discussion.

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### 2.3.5 Assessment of the Ecological Impacts of Offshore Wind Farms on Fish

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The effects of offshore wind farms on the marine environment have been the subject of investigation for the past ten years. However, little focus has been placed on the fish fauna (ZUCCO & MERCK 2004). Basically, there are three different approaches for detecting possible impacts:

1. Field investigations
2. Conclusions by analogy
3. Specific research.

**(1.) Field investigations** take place in the direct surrounding of the project area. Their goal is to detect changes in fish biocoenosis. One advantage of this is that the possible effects are directly detectable. On the other hand, effects can only be seen after the construction of wind turbines. There is no way to improve the applied technique as a result of the investigation. Furthermore, no discrimination of a singular triggering factor is possible. Several factors are acting at the same time, but only the sum of their effects is visible.

In Germany, field investigations are to be performed by the applicant in accordance with the "Standards for Environmental Impact Assessment" issued by the Federal Maritime and Hydrographic Agency (BSH 2003). The standards have been developed by the approval authority in consultation of several external scientists. They constitute a framework of minimum requirements for marine environmental surveys and monitoring. For each environmental feature to be protected, investigations prior to the start of the construction (baseline studies), and investigations accompanying and monitoring the construction, operation and removal phase, are mandatory. Depending on the marine habitat, investigations of fish fauna are to be performed with various fishing equipment (beam trawl, otter trawl, or a combination of both).

At the national scale, the only available field investigations for offshore wind farms in Germany are still limited to baseline studies. They are carried out and paid for by the applicants. However, these results are not open to the public. At present, the approval authority compiles all the collected data in order to optimise the regional planning.

At the international level, the first direct investigations of offshore wind-plant-induced effects on fish were available from WESTERBERG (1994). Between 1990 and 1993, the author investigated the effect of a single 220 kW wind turbine at Nogersund (Svante) on the distribution and migration pattern of the local fish fauna. Larger offshore wind farms, with several single turbines, have been investigated at Horns Reef, with a special focus on sand eels and clams (JENSEN et al. 2004). Other investigations have been performed at Vindeby and Nysted (both Denmark), but the statistical base of the collected data was too weak to deduce meaningful conclusions (SMITH & WESTERBERG 2003, ENERGIE E2 A/S 2004).

**(2.) Conclusions by analogy** can be drawn from the results of comparable situations or from fundamental research. In order to assess the reef-effect of offshore wind farms on the local fish stock, e.g. investigations of oil and gas platforms (VALDEMARSEN 1979, SOLDAL et al. 1998) can be used. An advantage of conclusions by analogy is that the basis of knowledge is extended by means of a literature study. A disadvantage is that there will always remain uncertainty as to whether or not the results involving regionally



differing fish stocks and environmental conditions are really transferable (PICKEN & MCINTYRE 1989, JØRGENSEN et al. 2002, LØKKEBORG et al. 2002).

An example for the use of analogical conclusions for the assessment of wind-farm-induced impacts on the marine environment involves sound emissions during construction (piling) and operation. Even though sound detection by fish has long been a subject of investigations, knowledge of possible effects of wind-farm-induced noise is still somewhat obscure. The hearing of many marine fish species is in the range between 30 Hz and 1,000 Hz (Figure 1). Sensitivities in the infrasonic range below 20 Hz have been detected for some species (KARLSEN 1992, KNUDSEN 1997, SAND et al. 2000) as well as sensitivities in the ultrasonic range over 20 kHz. (MANN et al. 1998, POPPER et al. 2004). Measurements of operational noise of existing wind turbines (WESTERBERG 1994, DEGN 2000, DAMSGAARD HENRIKSEN 2002, BETKE et al. 2003, LINDELL 2003, DEWI 2004) reveal that sound emission of wind turbines will overlap with the hearing of fish especially in the low frequency range up to 1,000 Hz.

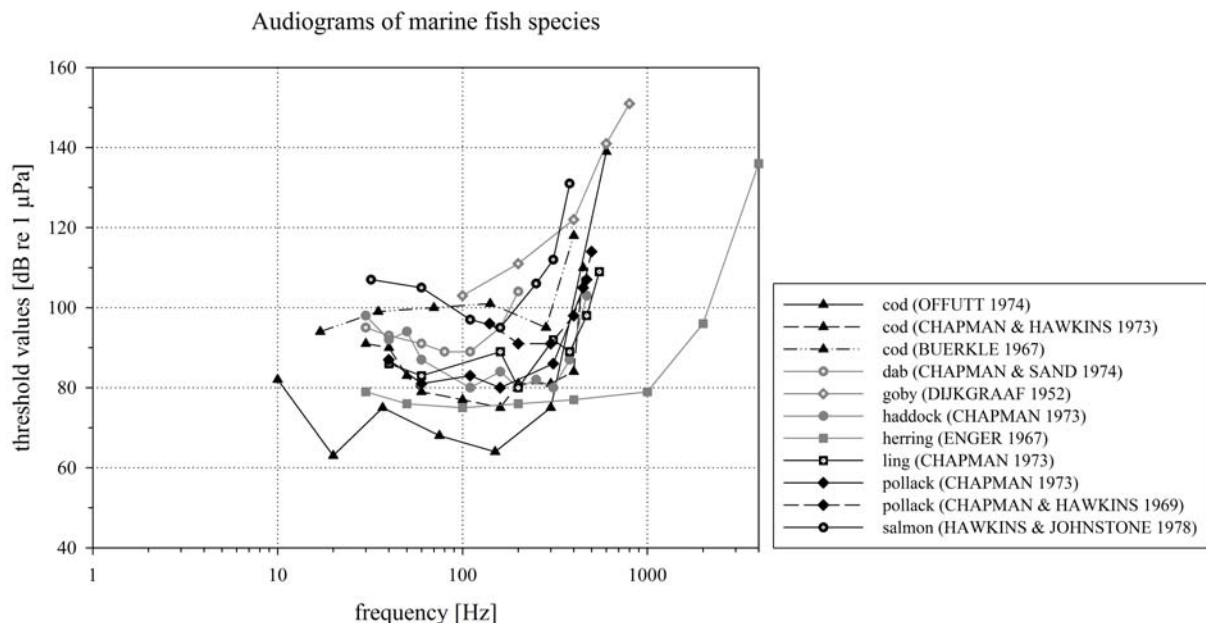


Figure 1: Audiograms of various marine fish species (cf. NEDWELL et al. (2004), modified)

The effects of various sounds on different fish species have been investigated. Flight and startle responses have been provoked (BLAXTER & HOSS 1981, BLAXTER et al. 1981, DUNNING et al. 1992, NESTLER et al. 1992, ROSS et al. 1993, KNUDSEN et al. 1994, 1997, GREGORY & CLABBURN 2003). On the other hand, attraction response has been seen as a reaction to low frequency sound in other circumstances (RICHARD 1968, MYRBERG et al. 1972, CHAPMAN et al. 1974). To date, the question of habituation to sound remains speculative. It has been assumed that fish are capable of recognising that wind farms pose no danger and therefore habituate to their sound (WAHLBERG & WESTERBERG 2005).

**(3.) Specific research** is a third way to gain the required knowledge. Based on the identification of gaps in knowledge the appropriate test conditions can be designed. A direct investigation will provide answers to the most relevant problem oriented questions, but that is painstaking and time-consuming. Therefore, if such research is required, time pressure for decision making may result.

An example for specific research has been performed by WESTERBERG et al. (1996). The authors studied the avoidance behaviour of cod (*Gadus morhua*) and herring (*Clupea harengus*) to turbidity, and the effects of sediment plumes on the buoyancy and mortality of cod eggs and larvae. The investigations were performed in a large saltwater flume constructed from two adjacent, concrete aquaculture raceway basins. Among others the results of this study were used to predict the environmental impact for the Øresund Link (APPELBERG et al. 2005) as well as for the Danish offshore wind farm Nysted at Rødsand (ENGELL-SØRENSEN & SKYT 2001).

Currently the German Federal Agency for Nature Conservation is funding a number of specific research projects. Among others, the Institute of Applied Fish Biology is investigating the effects of operational noise from wind turbines on fish. The reactions of plaice (*Pleuronectes platessa*), cod (*Gadus morhua*) and herring (*Clupea harengus*) to artificially emitted sounds are being investigated in tank and field experiments. The results of this research will give further insight into the complex manner in which wind-farm-induced sound affects the local fish fauna.

In conclusion, a combination of these three methods is a suitable manner for detecting the possible impact of wind farms on fish. With the current level of knowledge, the combination of all available sources of information is necessary to optimally assess any impact. In cases where no specific results are available, conclusion by analogy offers the best estimate of possible effects. However, for a well founded Environmental Impact Assessment which meets the requirements, a separation of the single sources of potential impact as well as specific research on their effects is indispensable. After the construction of wind turbines, monitoring investigations must be performed to evaluate, and if necessary, improve the quality of the preliminary predictions.

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### 2.3.6 Assessing the Effects and Impacts of Offshore Wind Farms on Sea Birds and Resting Birds

A.D. Fox, M. Desholm, J. Kahlert, I.K. Petersen and T.K. Christensen

Long-distance migratory birds are an internationally shared natural resource, protected under international legislation, conventions and agreements. The current upsurge in proposals to construct large numbers of turbines in extensive wind farms in marine offshore areas throughout the world, with their potential adverse effects on birds, has drawn particular attention to the need to better understand avian interactions with such structures erected out to sea. In particular, focus has been placed upon the information gaps that need to be filled to support the effective development of environmental impact assessments drafted in association with such constructions. We here attempt to define the hazards presented by turbines and offer suggested methods to measure their ecological costs, especially to resting birds and seabirds generally. We base this brief review on the combined experience from detailed pre- and post-construction studies carried out at two Danish offshore wind farms (e.g. Christensen et al. 2003, Kahlert et al. 2004, Petersen et al. 2004) and associated experiences from other projects around Europe.

Our knowledge of birds offshore is poor compared to those studied on land, but nevertheless, it is important to establish at the earliest possible stage the key avian species/populations present in an area and to which the construction of turbines is likely to present a hazard. Key species/populations which should be subject of particular attention can be defined as those (i) for which the area is important at some stage in the annual life cycle, (ii) which enjoy special protection measures, (iii) that are vulnerable to wind farms in some way and (iv) which exhibit high annual survival and low reproductive output.

The consequences to birds resulting from the construction of offshore wind turbines are many and varied, but should be considered in two different contexts. Firstly, they can be categorised as local **effects**, namely shifts in distribution and abundance as a response to a specific stimulus, but which do not necessarily have an **impact** at the population level. Alternatively, such **effects** may ultimately result in changes to fitness measures (such as breeding success or annual survival), which affect overall abundance and hence have an **impact** at the population level. Overall, the hazards presented by wind turbines in the sea are many and varied, but most can be summarised under three major categories, namely (a) avoidance responses to a disturbance stimulus, (b) physical loss or gain of habitat and (c) collision mortality, each is briefly outlined below.

Avoidance can be subdivided into (1) barriers to movement (i.e. interruption or prolongation of migratory flights or movements between foraging and nesting sites) and (2) the displacement of feeding birds from an ideal feeding distribution on the sea. In the case of the former, we can assess the ecological effects of increased flight distances incurred as a result of turbine construction. This can be achieved by measuring the enhanced energetic costs relative to pre-construction routes through modelling of the energetics of additional flight (e.g. Pennycuick 1989) in the context of the overall energy budgets in a seasonal and annual cycle context. The length of such avoidance flights can be measured by comparison of pre-construction bird flight trajectories with those post construction, using azimuth or (preferably) three dimensional radar tracking. Although the flights costs of undertaking an extra 5 - 10 km flight to avoid flying between turbines of a wind farm may cost an Eider *Somateria mollissima* extra energy, it is

unlikely to add significantly to the energetic costs of migration compared to the extra energy expenditure of flying into headwinds versus migrating with tailwinds. However, the cumulative energetic costs of avoidance of many such wind farms constructed along the flyway corridor of a population may begin to contribute significantly to annual energy expenditure, and such effects need to be modelled to establish the additive effects of many such developments.

Water birds displaced from their preferred feeding distribution (either by the visual stimulus of rotating turbines or by the boat/helicopter traffic associated with the maintenance of the wind farm) experience effective habitat loss in the vicinity of the turbines. For instance, if birds are reticent to approach turbines to within half the distance between each turbine, the entire area of the wind farm is lost as a feeding area, even though the habitat and food resources remain almost intact. Where food supply is limiting, this will have an effect on the displaced individuals, since not only may they be forced to feed in less suitable conditions, but may experience increased competition in areas to which they are displaced. To determine the effects of such processes requires a fundamental knowledge about feeding opportunities throughout the migratory range of the population concerned, a detailed knowledge of the feeding ecology of the species, and some assessment of the behavioural implications for feeding at different prey and predator densities (e.g. as developed for geese, Pettifor et al. 2000). For critical species, it may be possible to gather such data to construct individuals-based spatially explicit population models to test for the effects of such "effective habitat loss" on energy intake, and ultimately on fitness consequences (i.e. breeding success and annual survival). Such effective habitat loss can be measured using bird densities as a proxy measure of bird habitat. To this effect, aerial survey has proved a valuable tool for sampling bird distributions using distance sampling techniques to correct bird densities for the declining detectability of individuals with increasing distances from the observer. Spatial modelling techniques can then be used to generate bird density surfaces with confidence intervals over large areas of open sea based on transect samples to compare pre- and post construction distributions and abundance.

As well as such effective habitat loss, physical habitat loss will result from the construction of the turbine foundations, with additional loss of feeding habitat where additional anti-scour structures are created. Equally, the provision of turbine superstructures and the creation of anti-scour defences provide novel substrates and structures, which may in themselves represent new habitats and substrates for a flora and fauna formerly absent prior to turbine construction. For instance, where boulder protection is introduced to reduce scour to purely sandy substrates, such artificial reef structures may attract fish species (and hence piscivorous birds) where these formerly did not exist. Gulls (*Laridae*) and cormorants (*Phalacrocorax carbo*) may well be attracted to turbine maintenance platforms simply to use them as loafing structures. Hence, wind farm construction may both remove and add structures and habitats that affect the abundance, distribution and diversity of the local avifauna. To date, because these modifications affect habitats in less than 5% of the total wind farm area, and because the bird species associated tend to be abundant, widespread and those of little conservation concern, these effects have not been considered of great importance. Nevertheless, such changes in habitat can be measured using bird density measurements as outlined above.

Collision mortality is often considered to be the most important hazard presented to birds by wind turbines constructed in the sea because the impact of such additional mortality can be seen as having an immediate consequence at the population level. It is

axiomatic to state that more deaths through collision with the turbines (or mortal injury caused by the turbulent airflows associated with the blades around the sweep area) will reduce population size. For this reason, it is important to measure collision rates to determine the extent of this source of mortality. So far, such measurement has proved difficult, with the only effective method using infrared thermal imagery technology to gather data from sampled sections of the turbine sweep area, triggered by warm-bodied objects entering the field of view (Desholm 2003). Again, whilst it may be possible to estimate collision rates at turbines using this approach, it is necessary to model the effects of such mortality over longer time periods to assess the impacts of such mortality on different populations exhibiting different sensitivities. Short-lived species (such as passerines) tend to be highly fecund, and in situations with strong density dependent effects, it may be that the reproductive potential of a population can replace lost individuals relatively quickly and maintain population size in the longer term. This is not the case for long-lived species (such as Eiders or divers *Gavia* spp.) which raise very few young throughout their lifetime. These species are less able to replace lost numbers over short time intervals, such that additional mortality is more likely to cause sustained declines in numbers over time. It is therefore essential to establish the level of collision rates associated with turbines at sea, the species and population involved and to undertake population modelling (incorporating different strengths of density dependence) to assess the sensitivity of a given population to the levels of observed collision mortality. This is especially important to enable the assessment of the potential cumulative impacts of more than one wind farm development along the flyway corridor of a given population.

Given the logistical difficulties of working at sea in a harsh environment, we still face many challenges in our ability to determine even the effects of the construction of wind farms at sea on birds. The use of aerial survey to map avian densities and the use of remote techniques such as radar (to track increases in flight distances and avoidance responses) and infra-red thermal imagery (to measure collision rates) greatly enhance our ability to measure the local effects of marine wind farms by pre- and post construction data comparisons. However, we do need to invest greater efforts in modelling tools to convert these measurements of local effects into impacts at the population level. This is especially important given that the European Union Directive relating to environmental impact assessment procedures (85/337/EEC as amended by 97/11/EC) requires some assessment is made of the cumulative effects and impacts of multiple wind farms and other developments scattered throughout the flyway of migratory populations. Such approaches are essential in order to offer mechanisms for assessing the cumulative effect of many wind farms and the combined effects of other anthropogenic factors, which affect population processes in migratory birds.

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### 2.3.7 Sea Birds and Offshore Wind Farms – A Summary of Results of Studies at Operating Turbines

Dr. Volker Dierschke

Seabirds – defined as birds breeding in colonies at the coast or on islands and foraging at sea, as well as birds wintering, moulting or stopping over in offshore areas during migration – are considered to be possibly affected by the construction and operation of offshore wind farms. There are three main adverse effects which may impact on seabirds: (i) habitat loss caused by disturbance or avoidance, but also by introduction of hard substrate in soft bottom areas; (ii) habitat fragmentation due to barrier effects; and (iii) additional mortality caused by fatal collisions (e.g. Exo et al. 2002). Despite an enormous amount of offshore turbines planned, commissioned or already built, information about their effects on seabirds at sea is rather scarce. Apart from a detailed study conducted at the Danish wind farm at Tunø Knob in the mid-1990s, which addressed Common Eiders during the winter almost exclusively, increasing knowledge is available from investigations at two Swedish and two Danish wind farms, all built between 2000 and 2003. Therefore, a much better assessment of wind farm effects and impacts on seabird populations appears to be possible. However, generalisation is limited as yet by their short period of operation, which has not allowed consideration of possible habituation processes. This paper reviews the recent results of seabird studies at offshore wind farms, and can be regarded as a short version of an extensive review (Dierschke & Garthe in prep.). Most results are from the Swedish wind farms Utgrunden and Yttre Stengrund (e.g. Pettersson 2003) and the Danish wind farms Horns Rev and Nysted (e.g. Christensen et al. 2004, Kahlert et al. 2004, Petersen et al. 2004).

A total of thirty-five seabird species live regularly in the German parts of the North Sea and the Baltic Sea (territorial waters and Exclusive Economic Zone; Garthe et al. 2003). With respect to the effects of offshore wind farms, their behaviour is known to a greatly varying extent. Habitat loss due to strong avoidance and/or disturbance was observed for six species (Table 1). These seabirds almost never occurred in the wind farms investigated, even in areas in which they had lived prior to construction. Long-tailed Ducks do not show a general avoidance, but in two wind farms their densities decreased considerably. Seven species occur commonly in wind farms, with no obvious effects, and three species even increased following the construction of turbines. Little nothing is known about the behaviour of eighteen species.

As to barrier effects, the same species which have experienced habitat loss, and also the Velvet Scoter, usually do not fly into wind farms, but rather avoid them (Table 1). Detours also occur for four more species, whereas fifteen species were commonly observed to fly through wind farms (including those wind farms constructed at the coast on seawalls or piers). However, for some species the reaction of flying birds is known only for migrating birds, but not e.g. for local movements of staging individuals.

A fatal collision of seabirds with an offshore turbine was only observed once (four Common Eiders at Yttre Stengrund, Sweden). Because birds colliding with turbines at sea, fall into the water, evidence of collisions is very difficult to obtain. Studies at coastal wind farms found twelve seabird species as casualties, including different types of seabirds (Table 1).

Because it is largely unknown to which extend density-dependent mortality occurs in seabirds, the impact of habitat loss and habitat fragmentation is difficult to assess. However, evidence from waders suggests that after displacement intake rates may be reduced in replacement habitats, leading to a deterioration of physical condition. In

addition, detours flown both daily during staging and during migration may further affect energy balance. On the one hand, deteriorating body condition can cause an increase in the mortality rate, but on the other hand, the reproduction rate may be influenced as well: it is known from five species of geese that negative effects on the body condition in winter and during spring staging carry over into the breeding season and result in poor breeding success (e.g. Madsen 1995). An example for a strong population decline due to reduced adult survival and decreased reproduction rate is the population of Red Knots wintering in South America, which suffered from an extensive loss of food resources in a bottleneck situation at a spring stopover site (Baker et al. 2004). A high connectivity of events in the annual cycle can also be assumed for seabirds, and because of the precautionary principle the impact of offshore wind farms must be assessed carefully.

With regard to the assessment methods used or proposed so far, the results help to apply them more precisely. In one approach of assessment, offshore wind farms are assumed to affect protected areas such as SPAs, i.e. the distance between a wind farm and a protected area should therefore be as long as the avoidance distance of seabirds (NERI 2000). Recent results would allow a better estimate of avoidance distances and thus determination of a wind park location compared to protected areas. Another part of the NERI proposal (mortality rate should not increase by more than 5%) is still not applicable, because neither collision rates nor the impact of wind farms on population dynamics can be quantified.

The Scottish Natural Heritage and the British Wind Energy Association developed a method for impact assessment, which combines the sensitivity of the seabird species (legal status and proportion of the national population) with the magnitude of the disturbing effects (proportion of the local population which will lose habitat; Percival 2001). This method has commonly been applied by German authorities in the commissioning of offshore wind farms. The magnitude is easier to assess nowadays, because the species concerned as well as the potential habitat loss are better known. However, the question as to which reference area to use when determining the proportion of affected birds is still at issue.

It has further been proposed to use threshold levels in the assessment of impacts on seabirds (Dierschke et al. 2003). Regardless of which threshold levels are used (e.g. proportions of national or bio-geographic populations), the results from studies at operating offshore wind farms again give a much better impression of which species have to be treated and how long their avoidance distances are.

Finally, the wind farm sensitivity index developed by Garthe & Hüppop (2004) can be used to assess the vulnerability of seabird communities to offshore turbines. This index includes nine factors of flight behaviour, general behaviour and status. All these factors are parameters which can be related to offshore wind farms, but cannot be measured directly at them. Therefore, this method and the sensitivity indices calculated for a number of seabirds are not affected by the outcome of the studies at operating turbines.

In conclusion, it has become clear that some, but not all, seabirds avoid offshore wind farms, because they neither forage in nor fly through them. This knowledge is restricted to about half of the species living in German waters, and to calm weather conditions, because methodological problems prevented studies e.g. during storms. Another major gap is the lack of information about collision rates. In addition, the impact of avoidance behaviour on population dynamics remains difficult to estimate, underscoring the need for further studies on the biology of seabirds at sea.

Table 1. Summary of effects of offshore wind farms on the 35 seabird species regularly occurring in German waters, according to studies from Denmark and Sweden. Species listed in Annex I of the EU Birds Directive are printed in bold. Categories: Habitat loss: 00 strong avoidance, 0 reduced numbers, + occurring with few or no effects, ++ increased numbers. Barrier effect: 00 strong avoidance, 0 detours occur, + (commonly) fly through wind farms (\*includes information from coastal wind farms). Fatal collisions: 00 casualties at offshore and coastal wind farms, 0 casualties at coastal wind farms.

		Habitat loss	Barrier effect	Fatal collisions
<b>Red-throated Diver</b>	<b><i>Gavia stellata</i></b>	00	00*	0
<b>Black-throated Diver</b>	<b><i>Gavia arctica</i></b>	00	00	?
Great Crested Grebe	<i>Podiceps cristatus</i>	?	?	?
Red-necked Grebe	<i>Podiceps grisegena</i>	?	+	?
<b>Slavonian Grebe</b>	<b><i>Podiceps auritus</i></b>	?	?	?
Northern Fulmar	<i>Fulmarus glacialis</i>	?	0	0
Sooty Shearwater	<i>Puffinus griseus</i>	?	?	?
Northern Gannet	<i>Morus bassanus</i>	00	00	?
Great Cormorant	<i>Phalacrocorax carbo</i>	+	0*	0
Greater Scaup	<i>Aythya marila</i>	?	0*	?
Common Eider	<i>Somateria mollissima</i>	+	0*	00
Long-tailed Duck	<i>Clangula hyemalis</i>	0	+	?
Common Scoter	<i>Melanitta nigra</i>	00	00	?
Velvet Scoter	<i>Melanitta fusca</i>	?	00	?
Red-breasted Merganser	<i>Mergus serrator</i>	+	+	?
Pomarine Skua	<i>Stercorarius pomarinus</i>	?	?	?
Arctic Skua	<i>Stercorarius parasiticus</i>	+	+	?
Great Skua	<i>Catharacta skua</i>	?	?	?
<b>Little Gull</b>	<b><i>Larus minutus</i></b>	++	+	?
Black-headed Gull	<i>Larus ridibundus</i>	?	+	0
Common Gull	<i>Larus canus</i>	?	+	0
Lesser Black-backed Gull	<i>Larus fuscus</i>	?	+	0
Herring Gull	<i>Larus argentatus</i>	++	+	0
Great Black-backed Gull	<i>Larus marinus</i>	++	+	0
Black-legged Kittiwake	<i>Rissa tridactyla</i>	+	+	0
<b>Caspian Tern</b>	<b><i>Sterna caspia</i></b>	?	?	?
<b>Sandwich Tern</b>	<b><i>Sterna sandvicensis</i></b>	?	+	?
<b>Common Tern</b>	<b><i>Sterna hirundo</i></b>	+	+	0
<b>Arctic Tern</b>	<b><i>Sterna arctica</i></b>	+	+	?
<b>Black Tern</b>	<b><i>Chlidonias niger</i></b>	?	+	?
Common Guillemot	<i>Uria aalge</i>	00	00	0
Razorbill	<i>Alca torda</i>	00	00	?
Black Guillemot	<i>Cephus grylle</i>	?	?	?
Little Auk	<i>Alle alle</i>	?	?	?
Puffin	<i>Fratercula arctica</i>	?	?	?

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### 3 WORKSHOP A: MARINE MAMMALS

**Chair:** Dr. Wolfgang Wende, Katrin Vogel

**Rapporteurs:** Justin Cooke, Mareike Treblin, Dr. Wolfgang Wende, Katrin Vogel

**Participants:** Justin Cooke, Zoe Crutchfield, Barbara Frank, Irene Köchling, Sabine Lattemann, Klaus Lucke, Denise Risch, Dr. Ursula Siebert, Sandra Storch, Jonas Teilmann, Dr. Frank Thomsen, Dr. Henning von Nordheim, Dr. Ronald Warmenhoven

#### 3.1 Main Impact Correlations

The main adverse effects on marine mammals due to offshore wind farms are characterised by the following potential impact correlations and pressures:

- Physiological damage due to pile-driving noise leading to direct loss or injury of individuals (e.g. acute hearing damage)
- Temporary reduction of habitat size and displacement of species due to construction and maintenance activities
- Permanent reduction of habitat size due to operational noise emissions from the wind farm and other activities
- Disturbance of intra-specific communication (e.g. masking of communication)
- Barrier effects for migrating animals due to noise emissions during the operational phase, or to electro-magnetic fields.

The first three issues were stated as being highly relevant for the workshop on marine mammals. Electro-magnetic fields were not a major interest in this discussion, since they were not seen as the one of the major impact correlations. Hence, the focus was on noise emissions as the main aspect for the workshop, since most of the listed impact correlations are caused by noise emissions (especially from pile-driving activities during the construction phase). However, not only the construction phase should be taken into account; pre-construction impacts, such as those from sea-floor exploration by sonar for the foundations are also important factors. But the focus of the present discussion was agreed to be on noise caused by pile-driving for the wind-power-plant foundations. In connection with a discussion about noise emissions as the main factor, some participants mentioned that from a conservationist point of view, the wind industry should find techniques other than pile-driving for setting foundations.

Another reason to focus on noise-emission impacts is that this factor is measurable, and it is also the most obvious one. There might be other factors, such as turbulence or electro-magnetic fields, which may have long-term effects, but there is almost no knowledge about their actual effects on marine mammals. The participants agreed that no significant barrier effects for migrating animals are known to date.

#### 3.2 Indicators for Impact Prognosis

Indicators for an impact prognosis should be characterised by three main impact factors:

- Specific impact intensity (e.g. impact area of noise-emission, type of equipment used for the installation, timing and duration of the construction activities)
- Specific sensitivities of marine mammals (e.g. stage in life cycle, hearing range, avoidance reaction)

- Status and occurrence of marine mammals in the impact area (e.g. density, concentration area, possible seasonal variation).

In addition to these indicators, the prognosis of impacts should also consider the substrate on which the wind farms are built, the water depth in the wind farm area, the type, and the size of the foundation. Oceanographic features as well as background noise which may reduce, overlap or cumulate the noise-emissions should also be taken into account. Specific sensitivities of marine mammals involve mainly mother-calf groups. One important annotation during the workshop was that female harbour porpoises are specifically sensitive most of the year, since they are always pregnant or nursing or both at the same time (they nurse until they give birth to their next calves). Therefore specific sensitivity is not only seasonally related. It was suggested that impact prognosis should focus on areas with high concentration of mother-calf-groups.

Another very important aspect is the fact that the sensitivities of the animals can be ascertained, but not in detail. At present therefore, impact prognosis must operate with the indicator of “areas with high concentrations of harbour porpoises”. These areas should be regarded as important for the animals, since the animals have their reasons for choosing these spots. Therefore, the indicator of high concentration of individuals should be taken into account during prognosis, regardless of whether or not scientists know the reasons for this concentration. The question as to which habitats are of high importance for the marine mammal population can be determined by investigating spots with high animal densities. But we also need more knowledge about habitat functions and habitat use (e.g. satellite tracking). Possibly, an impact on feeding success might have a greater influence on the population than direct disturbance effects such, as the installation of wind farms. Or animals may return to the area after construction, but maybe only because they have no other alternative. Other habitats may be occupied by other porpoises, which could augment the stress level of the animals. Thus, cumulative or additive effects on these animals which might have the long-term effect of reducing their fitness must be discussed.

### 3.3 Assessment

Criteria and parameters:

Different criteria for the assessment were pointed out during the workshop:

- Functional significance of the affected habitat (e.g. important feeding areas, nursing grounds)
- Conservation value of the marine mammal population (e.g. rarity, endangerment of species)
- Natural population dynamics / ecology of the affected marine mammal population (e.g. limiting factors for the population and its development)
- Availability of habitats and habitat requirements
- Proportion of individuals, and habitat loss or displacement of individuals compared to the size of the reference population (e.g. particular reference scales are needed as a basis for an assessment)
- National responsibility (e.g. proportion of the national population in relation to total population size)
- Statutory importance of the marine mammal population (e.g. ASCOBANS, laws, Habitats Directive).

Due to lack of time, the workshop focused only on the main question of which population should be used as a reference size for impact assessment and for evaluation respectively. The impact assessment should be based on the proportion of individuals affected, e.g. by displacement or on habitat loss, i.e. area size compared to the size of the reference population for evaluation. For example:

- Northeast Atlantic population of harbour porpoises
- A national population of harbour porpoises, broken down into administrative units
- North Sea / Baltic Sea harbour porpoise populations
- Genetically different sub-populations (western/ eastern Baltic populations of harbour porpoises).

With regard to the question of how to choose the appropriate reference population for evaluation, a discussion about trans-boundary impacts is necessary, as is a discussion on cumulative impacts. From a legal point of view (e.g. Habitats Directive), countries have to take responsibility for “their” respective national share of the population, in terms of licensing authorities and appropriate regulations. Thus, for the determination of the significance of impacts from offshore wind farms, the reference population of e.g. harbour porpoises for evaluation should refer to administrative units. However, this aspect was discussed controversially. Some participants pointed out that it is not acceptable to “reduce” the size of an impact by increasing the size of the reference population. By the same token, however, it should also not be acceptable to increase the size of the impact by reducing the size of the reference population. The national portion of the population should be an appropriate reference scale to keep the legal assessment procedures manageable for decision-makers (lawyers) and national authorities.

Another option would be to choose an appropriate assessment area for each project development. Impact criteria for assessment areas should be such that when they are met for each project, the desired cumulative population criteria are also met, regardless of the extent of future developments. For this purpose, the assessment area selected should not be too small; otherwise some impacts might be missed. However, there is as yet no agreement as to how to determine such an assessment area. Results from Denmark show that a 5-km radius around a wind-power plant would seem to be too small for an appropriate appraisal of noise impacts on harbour porpoises.

With respect to grey seals, it was stressed that this species is currently in the process of building up its population in the German North Sea. This special situation must be considered in the assessment of impacts upon the grey seal population. Wind-farm projects could prevent grey seals from further increasing their population in Germany, and as a result, impacts would have to be classified as highly significant.

### **3.4 Cumulative Impacts**

Cumulative impacts can be defined as combinations of offshore wind farm impacts against the background level of already existing adverse impacts, e.g. pollution, by-catch, and affects of such other projects as sand and gravel quarrying. The projects that should be included either already exist or have already progressed very far in the planning process. Furthermore, additional impacts from the project itself, e.g. increased shipping, should also be considered. The participants agreed that it is not admissible just to add impacts together. Combination effects are not the same as cumulative or merely additional effects. Impact synergies and interrelationships must be taken into account, and one should find a mathematical formula for addressing this problem.

Trans-boundary impacts should always be discussed in combination with cumulative effects.

In the workshop it was agreed that the background stress level which, especially for harbour porpoises, is caused by noise cannot be quantified. Therefore, background noise mapping should be applied for the whole exclusive economic zone. In order to achieve a comprehensive assessment of cumulative impacts it is necessary to take the reduction of originally 'quiet' habitat areas into account.

### **3.5 Main Conclusions for the Workshop**

**Physiological damage due to pile-driving noise leading to loss of individuals, and temporary/permanent reduction of habitat size are stated as being highly relevant impact correlations. Indicators for an impact prognosis should consider specific impact intensities, specific sensitivities of marine mammals and the occurrence of marine mammals in the impact area. Impact prognosis must operate e.g. with the indicator 'areas with high concentrations of harbour porpoises'. However, more knowledge about habitat functions and habitat use is necessary.**

**For the assessment of impacts, the appropriate reference population should be defined. It was discussed controversially whether the national portion of a population could be an appropriate reference scale or not. However, it was stressed that legal assessment procedures by national authorities and the Habitats Directive require this approach.**

**In the discussion on cumulative effects, it was agreed that it is not admissible just to add impacts together. Also, impact interrelationships must be taken into account. The background stress level, especially that caused by noise, must also be considered in licensing procedures.**

### **3.6 Discussion in the Main Plenary**

In the plenary discussion on marine mammals, it was first stressed that there are problems in choosing the national share of a population as a reference scale for evaluation. It was pointed out that this was the drawback of the discussion, and that in practice, the assessment already goes much farther as trans-boundary impacts are considered. Wind-farm projects near the Dutch or e.g. Swedish boundary will also have direct impacts on the national population shares of the other countries, so that if reference populations are only chosen on the basis of each country's own national share of a marine mammal population, this would be a shortcoming.

From the biological point of view, there is little to dispute about this argument, and it would be logical to consider bio-geographic populations. The interest of scientists is in the cumulative effects on total population. Of course, there is no such thing as a "national population." Yet it is necessary to distinguish between a purely scientific approach and the legal requirements. In order to limit all the impacts on the total population, impacts must be assessed and reduced separately. So the conclusion would be to ensure that separate impacts do not have a major effect on any national share of a population or even on a local share of a population. This would in turn ensure that the total population, too, will be taken into account.

Another aspect is that application and licensing procedures conducted by national authorities have to consider national legal requirements or EU legal obligations transferred to national legal criteria. Therefore, from a practical point of view, it makes very much sense to look at the national share of a population. The specific case of



having a project that affects impacts along or across the border must be addressed in any case, due to the Espoo Convention or trans-boundary agreements.

The European Habitats Directive requires that every member state take measures to protect endangered species (e.g. harbour porpoises) at the national level. It is required that special precautions be taken to safeguard the well-being of species in special areas. This is another argument for implementing the national share of a population size as an appropriate reference scale for evaluation. Seen from a purely administrative viewpoint, it makes sense to refer to the legal means we have at the national level, while not forgetting trans-boundary aspects and international cooperation which is also necessary; perhaps this is the only approach that is manageable in practice.

It was stressed that this approach could be feasible, but it was also shown that this could lead to different levels of activity in various EU member states. The EU should be involved in the process of finding appropriate reference scales for evaluation.

## 4 WORKSHOP B: BENTHOS/FISH

**Chair:** Elke Bruns, Ines Steinhauer

**Rapporteurs:** Dr. Alexander Schroeder, Dr. Hakan Westerberg, Lars Michaelsen, Leena Morkel, Elke Bruns, Ines Steinhauer

**Participants:** Dr. Andrew Birchenough, Jan Busse, Kjell Grip, Tanja Joschko, Adrian Judd, Oliver Keller, Dr. Anita Künitzer, Dr. Joachim Kutscher, Simon Leonhard, Karin Lüdemann, Dr. Karin Meissner, Dr. Covadonga Orejas Saco Del Valle, Dr. Blanka Pophof, Dr. Alexander Schroeder, Jan A. van Dalssen, Dr. Hakan Westerberg

### 4.1 Introduction

This workshop was topically divided in two subjects: benthos and fish.

Contrary to the original intention of focusing the discussion on one major impact correlation, the participants did not consider this workshop appropriate for a discussion of one selected impact complex. Participants agreed that there is insufficient data/knowledge to discuss threshold levels, impact prognoses etc. Therefore, the first decision taken in this workshop was to change the prepared structure of the discussion.

After discussing the main impact correlations, the workshops mostly focused on monitoring procedures and related questions. Aspects of impact prognosis and assessment were not discussed in detail, as many participants expressed the opinion that more basic research is first needed.

### 4.2 Workshop Benthos: Discussion and Results

#### 4.2.1 Main Impact Correlations

At the outset, the main potential impact correlations so far defined regarding benthos and offshore wind-energy farms were presented:

- Change of species composition due to the introduction of artificial hard substrates
- Change of sediment and current regime
- Long-term elimination of benthic communities or benthic species
- Habitat loss
- Change caused by the increase of sediment temperature in the area of power cables.

The discussion first addressed the question of whether these are the only main impact correlations for benthos. The experts were of the opinion that additional impact correlations need to be taken into consideration:

- Electromagnetic fields, especially regarding crabs and molluscs
- Impacts on surrounding soft-bottom fauna from the artificial hard substrate
- Increase of biomass caused by the introduction of artificial hard substrate
- Impacts caused by vibration.

### 4.2.2 Monitoring Procedures

In connection with the discussion on the main impact correlations, it was already mentioned that there is a great need for more data. It therefore seemed more reasonable to talk about monitoring procedures.

After general problems of monitoring had been mentioned, the discussion focused on special needs and obligations concerning the selection of reference areas and on matters of standardisation. The results of the discussion on monitoring procedures were: More than only one reference area (at least two) is needed, because there is a possibility that natural fluctuation could distort the results of research. Additionally, the problem is that conditions in the chosen reference area often differ from those in the pilot area. This can also be solved by using more than one reference area. Within the monitoring procedure it is necessary to, first, define assessment criteria and goals for any changes and, second, to focus on measuring changes due to the wind farm.

- There is a need to combine data from several wind farms (international scale) in one research project, so as to increase the reliability on observed effects.
- To obtain comparable results the monitoring programme approach should be standardised, and then adapted as necessary to every single case (site-specific), in agreement with regulating authorities.
- It is important to carry out a screen survey before establishing wind farms, so to be able to establish criteria for the assessment.
- Impact assessment should be based on a standard monitoring programme (e.g. BACI-design = **b**efore vs. **a**fter / **c**ontrol vs. **i**mpact).

### 4.2.3 Conclusive Statements

Toward the end of the workshop, several conclusive statements and questions were formulated which especially emphasised the need for more research to gain knowledge about the baseline situations:

- Much more basic research on several research platforms, and later on real wind farms, is needed (different sites, different water depths, etc.).
- It was discussed by some speakers that there is not enough knowledge to be able to differentiate between natural fluctuation, effects really caused by wind farms, and other impacts on benthos. Others did not agree with this opinion. Appropriate monitoring would allow the application of modern multivariate statistics (enabling analysis and assessment of several impact factors).
- Creating assessment indicators will be possible when there is more knowledge from e.g. the FINO-platform, Horns Rev and Nysted.
- The final goal could be to answer the question as to which changes will occur if thousands of wind turbines are built (cumulative effects).

## 4.3 Workshop Fish: Discussion and Results

### 4.3.1 Main Impact Correlations

The workshop on fish started similarly to the workshop on benthos. First, proposals on the main potential impact correlations were presented:

- Change of the state of fish occurrence due to the introduction of new habitats (artificial hard substrate)
- Displacement effects due to vibrations, noise (e.g. for sound-sensitive species like herring)

- Effects due to exclusion of fisheries
- Barrier effects due to electro-magnetic fields
- Effects due to sediment plumes (e.g. on spawning areas).

The question of whether these really are the main impact correlations was discussed. The experts were of the opinion that some additional correlations should be investigated, and that some of the above ones might be disregarded:

- The question of impacts on spawning and migration of fish must be prioritised. Measures to avoid impacts on spawning during the construction phase need to be developed. Investigations are needed if there are impacts on spawning suitability during the operational phase.
- The displacement effects due to vibration must be considered for every site individually, because there are site-specific effects (e.g. type of substrate).
- It is important to assess the impact of electro-magnetic fields, especially in regard to sharks and rays, as there have been few investigations on the effects of undersea cables upon them, and this problem has been raised in the discussion of wind farms.
- The effect of the exclusion of fishery should not be seen as an effect of a wind farm, but rather as a matter of fishery itself, and should be considered separately. It is not an international issue, because not in every country is it mandatory that fishery be excluded. In this respect, the assessment of effects must be carried out in dependence on the uses permitted within the wind farm (no permits for uses in Germany, but other countries require permits for special uses, such as boating, fishing, tourist visits).

#### **4.3.2 Monitoring Procedures**

The main focus of the discussion turned, again, to the question of monitoring. In particular, difficulties with establishing methods and procedures for monitoring changes related to the wind farm as well as the need to develop standards for monitoring procedures. In this context, the following issues were raised:

- The necessity to conduct basic studies on behavioural effects, as there is not enough knowledge to be able to differentiate between natural fluctuation, other impacts, and effects really caused by wind farms.
- The problem that the standard fishery monitoring methodology is not well adapted to the small spatial scale of wind-farm studies, which means that the relevance of the statistical data provided tends to be low.
- The need to find alternative methods for monitoring. The use of existing statistical methods is highly commendable, but it is difficult to obtain the necessary amount of data. Therefore, the careful planning of the experimental design applied is highly recommended.
- The necessity to conduct basic research on singular impact complexes, since monitoring can only show the sum of all effects.
- Furthermore, it was recommended that monitoring should focus on the main changes in diversity and species composition.

#### **4.4 Main Conclusions for Both Workshops**

**The state of research on impacts on benthos and fish due to offshore wind energy farms seems not to be sufficient to standardise assessment methods. Currently, it is not possible to specify methods of evaluation that could help to find thresholds for the intensity of impacts, because of the lack of research.**

#### **4.5 Discussion in the Main Plenary**

Various opinions were outlined during the main plenary discussion about benthos and fish. First, based on present knowledge, e.g. from few environmental impact studies in different countries, it seems that it has not yet been possible to prove negative impacts on benthic organisms and their habitats or fish species from wind farms. In addition, the question as to whether the impacts will be negative or maybe even positive – e.g. due to the creation of a hard substrate as a new habitat for new and more numerous species – still cannot be answered.

Baseline studies also show the enormous changes in benthic structures after only a few years' investigation period, changes due on the one hand to a number of natural effects, and on the other to human activities other than wind-farm development. So in comparison with e.g. natural variations, it seems to be very difficult to find a direct correlation between a wind farm and changes in the benthos. It was mentioned that wind-farm deployment should not be limited by benthos or fish concerns. However, there is a need for a monitoring programme for benthos and fish, so as to support this hypothesis in the future.

In contradiction to this, it was stated that with the proposed installation of thousands of wind farms, the change in the benthos as a nutrient source for other animals would have to be taken into account. Thus, impacts on benthic organisms would probably be followed by impacts on top predators, like fish and seabirds. Therefore cumulative – or rather – direct and indirect effects should not be neglected and impacts on benthic organisms and their habitats from wind farms are an important issue within the assessment.

Habitat changes, e.g. by establishing hard substrate where only soft substrates occurred before, would have a negative effect on the habitat. It is inadmissible to conclude that it is always better if there are more species in the same area, due to the introduction of new but artificial habitat structures. From a nature conservation point of view, the original habitat structure must be retained as the basis for assessment.

## 5 WORKSHOP C: SEA BIRDS AND RESTING BIRDS

**Chair:** Julia Köller, Prof. Dr. Johann Köppel

**Rapporteurs:** Tony Fox, Kerstin Wippel, Julia Köller, Prof. Dr. Johann Köppel

**Participants:** Peter Baum, Karen Christensen, Christian Dahlke, Lorna Deppe, Dr. Volker Dierschke, Antje Finger, Tony Fox, Bernd Hälterlein, Thomas Merck, Steffen Nielsen, Ib Krag Petersen, Werner Piper, Anne Grethe Ragborg, Dr. Manfred Rolke, Ines Schreiber, Phillip Schwemmer, Roland van de Heuvel

### 5.1 Introduction

The workshop on Marine and Resting Birds was subdivided into two sections. The first section was dominated by an open discussion; the discussion of the second section was structured as follows:

- main impact correlation
- impact prognosis
- assessment (of state of marine biota and impacts)
- cumulative impacts.

### 5.2 First Section

The chair referred to the presentations from the previous day on seabirds and offshore wind farms (Volker Dierschke), planning and decision-making procedures in Germany (Christian Dahlke) and a case study from the UK on assessing impacts on birds (Allan Drewitt). These showed different ways of assessing the impacts of offshore wind farms, and how different threshold levels can be taken into account in the decision-making process.

The discussion started with the question: What are the reasons for using threshold levels, and which levels can be used for the approval procedure? The following discussion showed the problems of the authorisation of wind farms in general. On the one hand, decision-makers need an approach and also assessment criteria for their evaluation. On the other, knowledge about marine and resting bird populations, population dynamics etc., is not reliable enough to permit the determination and application of such criteria at that stage. The main agreement on this issue was that any generalisation of standards should be avoided. First, it is necessary to increase scientific knowledge, which will also make it necessary to keep assessment procedures, handling of thresholds and decision-making processes flexible.

However, the participants agreed that while a common consensus at the national level might be possible, an international approach would be better. To initiate a process for establishing guidelines in European and national institutions, NGOs and scientists should work together much more intensively. Finally, it was stated that international standards must be defined by the EU Commission.

### 5.3 Second Section

#### 5.3.1 Main Impact Correlations

The main adverse effects on sea and resting birds due to offshore wind farms are characterised by the following potential impact correlations:

- Permanent loss of habitat due to displacement
- Collision risks (bird strike)
- Barrier effect (e.g. fragmentation effects on units of the ecological network, such as resting or feeding areas).

The workshop focused on “permanent loss of habitat due to displacement,” i.a. due to the fact that the notification for authorisation from the German Federal Maritime Hydrographic Agency for offshore wind farms consider “habitat loss” as highly relevant for the evaluation. Additionally, it was mentioned that the magnitude of habitat loss is calculable, and therefore should be the focus of the discussion.

### 5.3.2 Indicators for Impact Prognosis

The following indicators and parameters are necessary to *investigate or measure* the extent of adverse impacts:

- pressure intensity (e.g. size, location and configuration of the wind farm, height of the wind turbines and rotor diameter, lighting of the wind farm)
- specific sensitivities of sea birds and resting birds (e.g. avoidance behaviour)
- occurrence (density of sea birds and resting birds and species composition)
- functional importance of the habitat (e.g. areas especially suited for feeding or moulting, specific winter areas)
- habitat requirements (e.g. minimum size of habitat)
- natural population dynamics and population ecology (factors that limit the population size and the development of the population).

The pressure intensity also depends on traffic noise, noise during the construction phase (pile-driving), and noise during the operational phase. The discussion showed that only general information about specific sensitivities of resting birds exists. The experts pointed out that variations in the sensitivity of birds in relation to certain other parameters exist. For example, the variation between daytime and night-time, as well as functional significance of the affected area, influence the avoidance behaviour of bird species and describe their specific sensitivity.

The workshop also focused on the question of which bird densities should be considered for the investigation of impacts. Is it appropriate to count the average number of birds using a site for a certain period, or would it be better to consider the maximum number of individuals, because otherwise the importance of an area might be underestimated? The participants discussed this very intensively, but did not reach overall agreement. The competent German authority for licensing offshore wind farms normally uses with the average number of individuals as the indicator for the importance of a certain area. In some cases it distinguishes between different areas and species. If a mobile species is known to use a large area as its habitat, it would seem legitimate to use the average number of individuals as the appropriate indicator. If a species occurs in a more limited and smaller habitat, the maximum number of individuals in a certain month should be taken as the basis for the decision-making process. However, seasonal aspects of varying maximum individual numbers must be considered in any case. The treatment of the criteria functional significance, habitat requirements and natural population dynamics is very problematic in the impact assessment process. For example, there is still not enough knowledge about the specific function of areas, or knowledge about death rates due to different types of construction of wind farm facilities. Thus, no comprehensive and reliable conclusions can yet be drawn for the decision-making process.

### 5.3.3 Assessment of Expected Impacts – Parameters and Criteria

In the previous section, the parameters and indicators for the prediction of impacts were discussed. This section set out to pinpoint how to assess the predicted impacts, and how to consider different impact intensities. Different stages of impact assessment should be considered for the assessment procedure: firstly, the present state of a marine biota (status 0) must be appraised. Secondly, the intensity of impacts should be calculated. For example, such criteria as habitat loss, the proportion (number) of displaced individuals, or the proportion of individuals lost, do play a significant role. Criteria such as conservation value, national responsibility or statutory importance also need to be considered within the impact assessment.

The main question discussed in the workshop was: which population size of sea birds and resting birds should be used as a reference or evaluation scale for impact assessment? Examples for such reference scales include:

- bio-geographic populations
- national populations
- national North Sea/Baltic Sea populations
- regional natural landscape units.

The topic was discussed very controversially, and different opinions were stated by the participants. Some argued for the use of the bio-geographic population, others saw national population size as the appropriate reference size for evaluation. Furthermore, it was mentioned that in case of SPAs, the area of the site or the bird population within the site should be taken as the reference. However, it is important to recognise that the choice of the size of the reference population affects the result and the decision-making process. Due to the complexity of the population dynamics of some species, the bio-geographic population does not seem to be an appropriate reference size. In conclusion, there was no agreement as to which reference size should be considered for the determination of impact intensity of offshore wind farms.

### 5.3.4 Assessment of Expected Impacts – Assessment Procedure

Which change of state of the marine biota should be assessed and what point of departures exists for an assessment? The following four possibilities were initially presented by the chair:

- 1: Change of the number of resting birds/seabirds (change from a high density to a low density)
- 2: Quantification of the loss of habitat (loss of size of habitat in hectares or square kilometres), and proportion of predicted habitat loss in relation to overall habitat size for the population
- 3: Increased mortality rate (increase of up to x%)
- 4: Reduction in population size (decrease of total population size; decrease by x% of national population size; decrease by x% of bio-geographic population size).

While the change of the number of resting birds (no. 1) is measurable, the long-term effect of a habitat loss on the population size cannot actually be measured. The discussion revealed that a definition of a maximum acceptable increase of the mortality rate (e.g. >5 %) cannot be applied to assess the loss of habitat. On the one hand, the problem is that the mortality rate due to e.g. loss of feeding habitats is not measurable, on the other hand it is very difficult to determine and to distinguish the actual effect of the wind farm from those due to other factors.



In Germany, a so called 1 % threshold value is taken into account in the licensing and permission procedures. This threshold refers to the 1 % value formulated by the Ramsar Convention. The Ramsar Convention points out areas with a concentration of at least 1 % of a population as valuable for nature conservation. This could be interpreted in the way that the loss of habitat in the same order of magnitude (1 % of the population) cannot be assessed as insignificant. It was pleaded for a transfer of this approach to an international discussion.

It seems reasonable to work with that percentage as an assessment value. But if, for instance, this concept is taken in the Danish context, long-tailed ducks are not very numerous in Danish water, so that there could actually be a one percent situation for the Nysted wind farm. But just outside Danish waters, there are at total of 4 million long-tailed ducks. Thus, this issue really has to be considered in the context of the flyway population. Perhaps it is difficult to have the same approach for all the species and in all cases. So the best would be to have species specific values. Nevertheless there is a real need for such an approach in practice.

If the one percent criterion is applied for the gannet in Germany, the level will almost be achieved if fifteen individuals are affected. But the German part of the North Sea is of no importance to the gannet, compared to the whole North Sea, or the North Atlantic population. So working with this approach is more difficult than expected. Another example shows that in the Kiel Bay area, about ten percent of a certain population of a certain bird species drown every year in fishnets, and that this has been widely accepted by all conservation authorities, by the administration as well as by the NGOs because it did not affect the population. Consequently, species-specific levels must be examined, and clear population areas defined, such as the IBA as a unit, in which there are 10,000 divers or 50,000 gulls; here, a one or five percent level, clearly referring to a certain species, would really make sense.

On the other hand, it is not known to what extent increased mortality effects may occur due to displacement. But for some species, it seems that even a one percent displacement may be important. Of course, the type of reference area to be considered might also be discussed. Hence, the presentation of the one percent criterion based on national populations as an assessment approach is of course not the ultimate solution.

## 5.4 Cumulative Impacts

Cumulative impacts can include:

- Combinations of offshore wind-farm impacts added to the background level of existing adverse impacts in the marine environment such as chemical pollution etc.;
- Impacts from other projects/uses (e.g. fishery, sand and gravel quarrying, ship traffic, military activities, etc.);
- Other impacts from the planned project itself (e. g. maintenance traffic).

The workshop stressed that the interpretation of legal requirements as well as a definition of cumulative impacts must be harmonised. The workshop participants also agreed that natural pressures (e.g. naturally poor breeding conditions) should not be confused with pressures caused by human activities. Results of the spatial planning and of the SEA for the spatial planning process in the exclusive economic zone will, it is hoped, include and improve the consideration of cumulative impacts at level of this planning.

## **5.5 Main Conclusions for the Workshop**

**Main adverse effects on sea and resting birds are the permanent loss of habitat, collision risk, and barrier effects.**

**Among pressure intensities, specific sea and resting bird sensitivities, too, should be considered. The experts pointed out that variations in the sensitivity of birds in relation to certain other parameters (e.g. functional significance of the affected area) exist. It was discussed intensively whether to consider the average number of birds or the maximum number of birds using a site. However no overall agreement was achieved. There is still not enough knowledge about the criteria 'functional significance', 'habitat requirements', and 'natural population dynamics'.**

**Some participants pleaded for the use of the bio-geographic population as a reference or evaluation size, others saw national population size as the appropriate reference size. Four points of departures exist for an assessment: 'change of number of birds (change of density)', 'quantification of loss of habitat', 'increased mortality rate', and the 'reduction in population size'. The change of resting birds density is measurable, but long-term effects of habitat loss on the population cannot be predicted. In Germany the so called 1 % threshold is used. It refers to the 1 % value of the Ramsar Convention. It seems reasonable to work with that value, but certain examples were presented which also showed the problem of using the 1 % value. Consequently it would be best to examine species specific levels.**

**The workshop stressed that the interpretation of legal requirements as well as a definition of cumulative impacts must be harmonised. It was also agreed that natural pressures should not be confused with pressures due to human activities. Cumulative impacts should play a prominent role for spatial planning in the EEC.**

**Any generalisation of standards should be avoided at that stage because it is first necessary to increase scientific knowledge. This also means to keep assessment procedures, and the handling of thresholds and decision-making processes flexible. Finally, international standards must be defined by the EU Commission.**

## 6 WORKSHOP D: MIGRATING BIRDS

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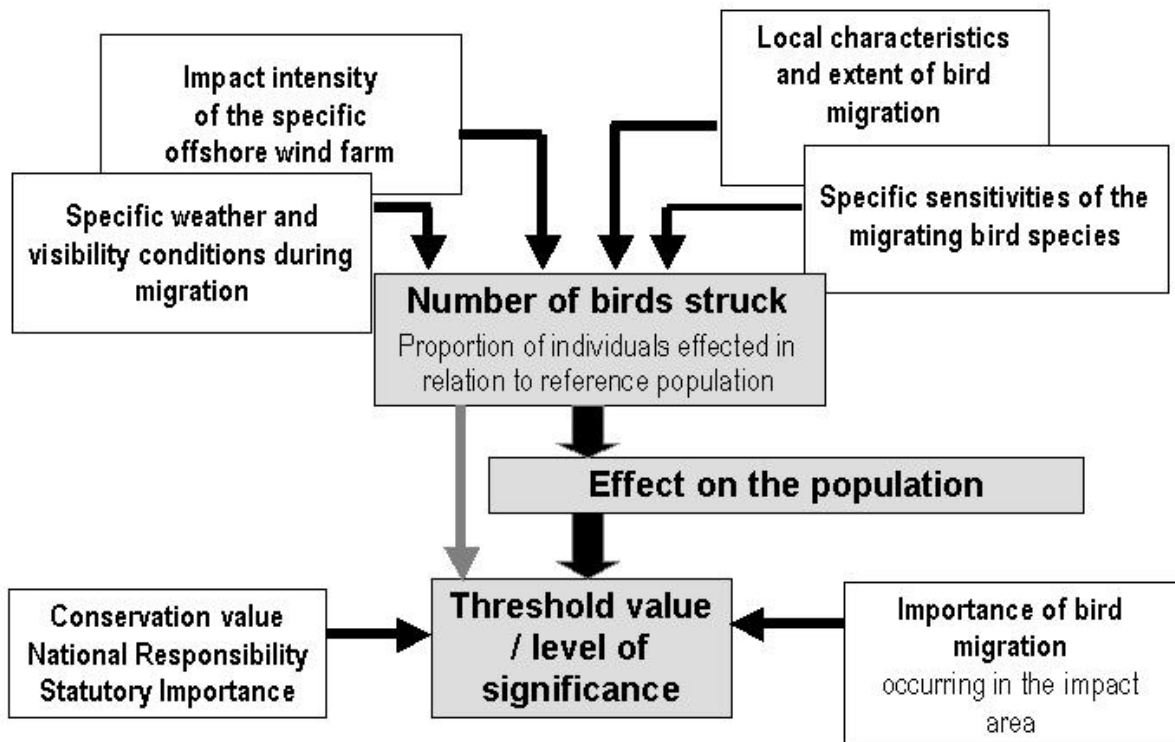
### 6.1 Main Impact Correlations

The main adverse species-specific effects on bird migration due to offshore wind farms are characterised by the following pressures and potential impact correlations:

- a) Collision risks (bird strikes): Increased mortality due to collisions of birds with wind turbines
- b) Disturbance by barrier effect: Increased consumption of energy reserves during migration due to avoidance reactions, possible loss or impairment of orientation

Due to the limited amount of time available the participants decided to focus the discussion on methods and criteria to be applied for the assessment of the collision risk. Therefore, the following results only relate to a). The main headings of the discussion are shown in the schematic diagram (Fig. 1) below:

**Fig. 1 Assessment of the Collision Risk of Migrating Birds at Offshore Wind Farms**



## 6.2 Indicators for Impact Prognosis on Collision Risk

Indicators for an impact prognosis should be characterised by four main influence factors:

- Specific pressure intensity of the wind farm
- Local characteristics and extent of migration
- Specific sensitivities of the migrating bird species
- Specific weather conditions and visibility during migration.

### 6.2.1 Specific Pressure Intensity of a Wind Farm

The participants identified the location of the wind farm as the most essential factor influencing pressure intensity. But the size and configuration of the wind farm and the number of wind turbines, too, were perceived to be important for determining the pressure intensity of a specific wind farm. The height of the wind turbines and their rotor diameter must also be taken into consideration. Other major influence factors discussed are the lighting of the wind turbines (lights will attract most bird species, rather than preventing them from collision, and therefore increase collision risk) and the turbulence created by the turning rotor blades. For example, a case study in Sweden has shown that only one individual was hit by a rotor and three individuals were brought down by turbulence. Another study by Winkelmann concluded that approx. 10 percent of collisions were caused by turbulence and not by direct hits by the rotor. However, only insufficient reliable information is available on this question. Some of the participants mentioned coloration, operating noise and number of rotor blades as possible further influence factors, but their effects are not yet clear. Though these aspects may have an effect, they were not seen as the major factors for determining the specific pressure intensity.

### 6.2.2 Local Characteristics and Extent of Migration

Major factors affecting impact intensity and its significance is the intensity of bird migration in the impact area during daytime and night-time, respectively, the seasonal and altitudinal daytime/ night-time distribution, and the species concerned. Therefore it is important to identify concentration areas by looking at migratory bird routes, species-specific migration behaviour and narrow-band or broad-front migration patterns as well as assessing the species composition. The angle of approach of the migrating birds toward the wind farms seems highly relevant, while the influence of the site-specific weather conditions, such as e.g. frequent fog, has yet to be elucidated (see below).

### 6.2.3 Specific Sensitivities of Migrating Bird Species

To determine the influence of flight altitude and behaviour above the sea, it would be necessary to have knowledge about species-specific and weather-related collision rates, which is still a major problem as very little information exists on the issue and it is hardly possible to collect injured or killed birds, as they fall into the water and disappear. One possibility is to examine previous experiences with bird collisions at sea e.g. with ships, bridges or oil and gas platforms to determine risk factors. Most collisions seem to happen at night, and the time of day during migration seems to be highly relevant when looking at collision risk; generally however, there is not enough knowledge on this topic. Participants agreed that species-specific avoidance and evasion behaviour is the important factor regarding collisions. Also important is the above mentioned attraction to light, and more general aspects, such as manoeuvrability. For determining the ensuing impact on populations, the condition of individuals and the reproduction dynamics of

each species must be taken into account. Therefore, the participants concluded that collision risk must be seen as species-specific and therefore be assessed on a case-by-case basis.

#### 6.2.4 Specific Weather Conditions and Visibility during Migration

Specific weather conditions, such as fog, rain and strong wind which reduce the visibility and/or affect the manoeuvrability of birds during migration can greatly increase collision risk, especially if changes of weather occur during flight. Since it is difficult to determine the probability of bad weather conditions coinciding with bird migration, it has not been possible to make predictions about the frequency and magnitude of such events.

### 6.3 Assessment

#### 6.3.1 Methods for Predicting the Number of Bird Strikes

The participants discussed and assessed which could be *appropriate* methods, i.e. models, for the assessment of the collision risk, and formulated the main questions and issues that need to be addressed as follows:

Avoidance rates: How many birds avoid the wind farm in relation to the proportion flying through, under various conditions (altitude/ time of the day/ weather)?

Collision models: These can be used to estimate collision rates (e.g. Tucker/Winkelman), but may not be very precise as yet. Models are often the best and only existing approach, but avoidance rates have to be included for a realistic outcome. The influence of weather conditions, attraction and avoidance behaviour are currently the weak points in modelling, and need to be considered if the models are to become more realistic. These parameters can be measured and included in models to assess the problem of the collisions. At present, the best available knowledge on avoidance reactions are from the studies of eiders at the wind farm in the Kalmar Sund. Rather limited knowledge is available on other bird species (e.g. passerines) and more research is necessary in this respect. However, using a model now is more satisfactory than waiting another ten years, until a sufficient sample sizes produces more reliable data.

Measurements of collision rates: Infrared cameras are currently used, and can provide information about the magnitude of the problem, but very long time series would be needed to gather sufficient data to calculate more precise collision rates. At present, there is a need to develop the methods for measuring collision rates further. For instance, the combination of various methods, such as radar and infra-red cameras, may be a solution to overcome the difficulty in obtaining data under poor visibility conditions, when collision rates may be higher.

Follow-on effects on the population: Important factors for determining follow-on effects on population are: the effects on natural population dynamics, such as the mortality and reproduction rate and size of a population. The geographic distribution of a population also needs to be taken into account, particularly in terms of such factors as disproportionate effects at the edge of a range of a species. The participants agreed that important factors for making predictions on the development of

a population are e.g. density-dependant effects and adult mortality. Two particular problems noted were that of long-lived species, which need more complex modelling; and the determination of the exact size of a population.

Models on population dynamics – as developed in the UK – can be used to predict when an effect will have an impact at population level. Examples of population models include: models used for hunting in the US, or modelling of Kittiwake populations in relation to oil pollution in the UK.

The experts recommended a ranking of species that are at greater risk from population effects, e.g., a declining population will be more vulnerable to additional mortality.

It was concluded that models on the population dynamics of a species can give an indication of the relative impact on a population, and that they may often be the only tool to determine critical levels (threshold levels) for a population.

### **6.3.2 Criteria and Parameters**

Different criteria for the assessment of impacts on migrating birds by collision were pointed out during the workshop in particular:

- Importance of the bird migration occurring in the impact area (conservation value, national responsibility, statutory importance)
- Reference population (e.g. bio-geographic/ flyway/ national) used to determine proportion of individuals affected by bird strikes (in relation to the reference population).

Due to lack of time, the workshop focused only on the main question of which population should be used as a reference size for impact assessment. For many species, flyway populations are defined, but generally *not* for non-waterfowl species. Therefore, in most cases the bio-geographic population is the better choice, since this also includes the flyway populations. Determination of flyway populations during migration could be approached by counting individuals at breeding / wintering sites in EEZ / coastal areas. Although it will never be possible to precisely determine the total numbers of a population, a rough count should be possible.

In conclusion, the participants agreed that the population referred to when assessing the impacts of offshore wind farms on migrating birds should either be the bio-geographic population, and/or where possible, the flyway population.

Other points raised by the participants include:

- the need to set priorities when assessing the impacts on migrating birds, e.g. there should be a strong emphasis on assessing impacts on protected, threatened and/or declining species;
- the need to apply good practice when choosing wind farm locations, in particular avoiding wind-farm siting within major migratory routes with a concentration of bird migration, e.g. between peninsulas.
- the deployment of offshore wind farm deployment should take a precautionary approach on the basis of what is known about flyway and bio-geographic populations and migration corridors.

## 6.4 Cumulative Impacts

Cumulative impacts can be defined as combinations of offshore wind farm impacts together with the adverse effects of other uses, e.g. bird strikes on other structures. The projects that may be included either already exist or have already progressed very far in the planning process. Furthermore, additional impacts from the project itself, e.g. increased ship traffic, should also be considered.

In the workshop, it was agreed that the reference area and reference population are the most important criteria for assessing cumulative impacts. All activities that effect the defined reference population need to be taken into account when determining cumulative impacts. From an administrative viewpoint, this is often difficult to handle. On the other hand, if each country simply takes one percent of the flyway population as a reference value in the cumulative impact assessment, then the situation may occur in which a flyway, which passes e.g. ten different countries, results in a total of ten percent of the flyway population being affected. Therefore, cumulative effects on bird migration need to be discussed and addressed at the international level and scale, and participants felt that there is a need for regulation at the EU level (e.g. directive/quota system whereby each country is allowed a certain level of impact) to deal with cumulative impacts. But the national authority too is obliged to assess cumulative effects with regard to project applications. Thus, cumulative effects need to be addressed at different levels, and there is a need to define the spatial scale at which cumulative impact assessment should take place.

In this context, it was also pointed out that the Strategic Environmental Assessments (SEA) is an important instrument for addressing cumulative impacts on migrating birds at a regional scale. Furthermore, participants agreed that there is a great need to consider each species by itself, and it is necessary to look at a species-specific level to decide which reference population to select (e.g. sub-population) for the assessment of population effects. Similarly, threshold levels are population-specific and should be determined for each individual species

## 6.5 Main Conclusions for the Workshop

**The participants' main conclusions, which were derived from a brainstorming session with the workshop participants, were briefly discussed, and the following was agreed to.**

**The magnitude of cumulative effects of total wind power plants in Europe is the major problem with regard to impacts on migrating birds.**

- **Therefore, the planning of offshore wind energy use should proceed according to the precautionary principle on the current basis of what is known about flyway and bio-geographic and regional populations and their migration corridors and routes.**
- **Reference populations should be defined on a species-specific level, and be based on either the flyway or bio-geographic population.**
- **Threshold levels need be determined on the regional population level and for each individual species.**
- **Cumulative effects must be addressed, and they must be addressed at an international level (EU). While the proper level must be discussed, there is also a need for more international cooperation.**

## **6.6 Discussion in the Main Plenary**

Creating a collision risk model seems to be of high importance with reference to the impact assessment for migrating birds. It is much easier to establish a collision risk model than to develop a habitat-reduction risk model. That is because it is easier to translate information about collision risks directly into the survival of animals. The problem with habitat loss is the removal of an energy source or a nutrient source, and the fact that birds are forced to concentrate in slightly higher densities. This leads to a reduced possibility of using resources. But to integrate these aspects into a risk model is very difficult. Collision risk offers much more interesting possibilities, with a quite short term delivery on modelling approaches, in a way that habitat loss does not.

Modelling of mechanisms whereby habitat loss is translated into actual mortality is difficult. However, there are shortcuts available for the translation of the implications of a given habitat loss to the resulting reduction in population. While these shortcuts do not permit short term predictions, they at least enable calculation of expected long-term population reduction for a given habitat loss. This could be a reasonable interim approach.



## 7 CONCLUSIVE STATEMENTS (WORKSHOP RESULTS) AND FUTURE PROSPECTS

### 7.1 Conclusive Statements by the Berlin University of Technology

The chair of the main plenary illustrated again that the workshops showed different approaches, criteria and indicators for the assessment of offshore wind farm impacts on the marine environment. The main conclusions are:

- A comprehensive assessment of impacts should consider main impact correlations, indicators for the impact prognosis, assessment criteria and approaches, and finally a clear examination of cumulative impacts.
- For the marine biota harbour porpoise, sea and resting birds and migrating birds it seems to be necessary to determine a clear reference population. Appropriate scales for the assessment of impacts need to be found at national and international level.
- The state of research on impacts on benthos and fish due to offshore wind farms seems not to be sufficient to standardise assessment methods. From a conservation point of view, it is not necessarily an improvement if there are more species in the same area, due to the introduction of new but artificial hard substrate; rather, this depends on the original habitat structure.
- Cumulative impacts cannot just be added up. Combination effects and interrelationships also have to be considered in the assessment process.

Thresholds should also be discussed on a political level, e.g. in the EU. However, the international scientific community should bring forward this discussion. Our thanks to all the participants and those who organised the workshop for their contributions which made conference such a success. Special thanks to:

**Berlin University of Technology:** Johann Köppel, Hanna Baeck, Elke Bruns, Steffen Eißer, Zoë Hagen, Julia Köller, Kathrin Kunzmann, Jana Lippert, Leena Morkel, Wolfgang Peters, Barbara Schnetzer, Ines Steinhauer, Mareike Treblin, Katrin Vogel, Wolfgang Wende, Ilonka Wilk, Kerstin Wippel

**Federal Agency for Nature Conservation:** Antje Finger, Irene Köchling, Thomas Merck, Henning von Nordheim, Catherine Zucco

### 7.2 Conclusive Statements and Future Prospects by the Federal Agency for Nature Conservation

Dr. Henning von Nordheim

Before describing the future prospects of the offshore wind-farm debate, and of how an international exchange might proceed, I would like to take a brief look at its history. In 1999, the first workshop on offshore wind-farm impacts was held on the Isle of Vilm. Since it was the first workshop in Germany on these issues, the very general question was: What technical installations at sea might have a relevant impact on the marine environment? At that time, the pressure in Germany on scientists to provide answers to the question what effects might be expected from offshore wind farms on the marine environment was growing. The Vilm workshop concluded with many unresolved issues (BfN-Skripten No. 29, 2000: "Technische Eingriffe in marine Lebensräume", 182 pp.).

Comparing this present workshop at the Berlin University of Technology in March 2005 to that first workshop in 1999, it is clear that we still have plenty of pending questions,

even though the knowledge about the “offshore situation” has improved considerably in the meantime. Since 1999, many research activities have been carried out, not only in Germany but also in other European countries.

Another workshop was carried out a year and a half later on the Island of Vilm, where once again wind-farm issues and problems were addressed. And still at that time, the scientific discussion was only in its initial phase. Administrative and legal issues were the main topics of this second workshop. And once again, many questions remained unanswered. However, at that time, two very large offshore wind farms had been authorised and installed at Nysted and Horns Rev in Denmark. Data are available from these projects, and those data have provided good indications of how to assess the impacts of offshore wind farms. Ultimately however, the conclusion remained that there was still a lack of knowledge.

Consequently, this workshop at the Berlin Technical University is still somewhere in the middle of the process. At least, a place has been reached where quite a number of details are available, but the question now is in which direction scientific research is to continue. The workshop has created a fairly solid base for further meetings and discussions on the topic of offshore wind-farm impacts. Still, the question of thresholds was not directly addressed at this event. Nonetheless, the scientific community will have to accept the fact that the question of how to assess impacts on the marine environment, and whether and how to establish thresholds is embedded in a legal and administrative decision-making framework. Hence, it will be necessary for the scientific community to try to support decision-makers by giving them the most appropriate assessment tools. These tools must be developed using the best available knowledge, and that means that thresholds will probably also somehow need to be defined in a form of a “scientific consensus on threshold levels”. It is therefore incumbent on the scientific community to discuss these criteria and threshold levels as a next step.

What are the appropriate bodies for initialising this next step? Perhaps the EU Commission. However, it could be a very long time before the EU Commission defines thresholds and guidelines. The answer seems to be that it is up to the scientific community to initialise this discussion on thresholds. If the member countries, and especially scientists in those member countries, start to raise the issue, the EU commission may begin to address it. Nevertheless, it may take some years before all other countries develop their own offshore strategies. It will therefore be up to those countries which already have a special interest in offshore wind energy development to keep the discussion progressing. This workshop has again shown the need to strengthen international co-operation on this aspect.

Future international discourse will hopefully pick up at the point where this Berlin workshop has left off. In such a continuation, it would be advantageous to concentrate more distinctively on the different marine biota. For instance, one workshop could concentrate on marine and resting birds only, and a second separate workshop could concentrate on marine mammals. In particular, the expert discussion on marine mammals and noise is expected to be continued in Germany soon.

Many thanks to all the participants of this Berlin workshop, and to the international marine scientific community. No doubt you are all invited to carry on these discussions in future national and international workshops and symposia, as we collectively begin to understand, and recommend limits upon, the effects of offshore wind farms.

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