Deltares

Monitoring and researching ecological effects of Dutch offshore wind farms

Masterplan

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Summary
Deltares was asked to work out the contents of a master plan for an umbrella monitoring and research programme required to fill in the gaps in information in determining the ecological effect of OWFs. A framework-formulating plan is presented for obtaining information on the ecological effects of OWFs. We have indicated, by means of prioritisation, how this information can be filled in due course. In addition to setting up the content of this master plan, ideas are also provided for data management and international cooperation. This master plan is not a blueprint for monitoring and research in the framework of the OWFs, but it does propose a framework, meaning that it provides the contextual and organisational frameworks as well as prioritisation for monitoring and researching the effects of construction, presence and removal of OWFs in the second and third rounds. Within these frameworks, choices can be made and additional measuring plans and field inventory can be set up on the basis of urgency and progressive insight.

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Disclaimer
Regarding this Masterplan Monitoring and Researching ecological effects of Dutch offshore wind farms it should be stressed that neither about the Masterplan itself, nor about the financing of it, decisions have been taken, so that all content of the Masterplan should be considered provisional.

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1 Introduction

1.1 Background

The cabinet plans to realise a total of 6000 MW of wind energy on the Dutch Continental Shelf (DCS) by 2020 (2009 National Water Plan draft, 2009-2019 North Sea Policy Memo). 228 MW of this was built in 2006 and 2007 in two so-called “first round wind farms” off the Egmond aan Zee coast, *OWEZ* (formerly *NSW*) and *Prinses Amalia* (formerly *Q7*). The “second round” provides for supportive financing, via the so-called SDE subsidy, for construction of 950 MW. Permits for twelve wind farms were issued in 2009. Currently, applications for the subsidy are submitted to the Ministry of Economic Affairs for the wind farms with a final permit. An interdepartmental workgroup is presently working on an approach that should result in realisation of the remaining approx. 5000 MW starting in 2011. This involves allotting space, granting permits and financial support. This workgroup will give its advice to the North Sea Interdepartmental Directors Meeting (NSIDM or IDON in Dutch) in the spring of 2010.

Offshore wind energy is of great importance for reaching the Dutch objective of 20% sustainable energy in 2020. 6000 MW of offshore wind energy can cover 10 to 15% of the Dutch energy needs sustainably. Moreover, there are opportunities and possibilities for the Dutch industry and knowledge institutes. In contrast to wind energy on land, the technology of wind at sea is still in its infancy. In order to accomplish the objective of 6000 MW, it is especially important to reduce the cost price.

On the basis of the experiences with the monitoring and research programmes of the existing first round wind farms (*OWEZ* and *Prinses Amalia*) and the responses to the proposed Monitoring and Evaluation Programmes (MEPs) in the draft permit regulations for the future wind farms in the second round[1], the wish for a larger directive role by the government and an integrated research programming has emerged for both the initiators for offshore wind farms (OWFs) in the North Sea and for the government itself.

On 3 March 2009, a workshop was organised at RWS North Sea for interested parties in the market as well as the government. The role division between market and the government was discussed at this workshop. There was a broad consensus on a stronger directing function by the government. In particular there is a basis for an umbrella research programme and monitoring of relatively generic information as the task of the government, whereby the market could be responsible for supplying location-specific data. Incidentally, no decision has been made as yet on dividing such responsibilities between private and public parties.

Deltares was asked to work out the contents of a master plan for an umbrella monitoring and research programme required to fill in the gaps in information in determining the ecological effect of OWFs. This plan must use existing research programmes for OWFs in the Netherlands and abroad and, if possible, seek connection with other monitoring and research programmes that are not focused on OWFs. On the basis of this, a framework-formulating

[1] In the document below, an overview is given of the Dutch marine wind farms built (first round) and planned (second round). Note that not likely all of the second rouind OWFs will be build, due to financial constrictions: http://www.noordzeeloket.nl/Images/Overzicht%20definitief%20vergunde%20Windparken%2018-12-2009_tcm14-4267.pdf.

plan has been presented for obtaining information on the ecological effects of OWFs. We have indicated, by means of prioritisation, how this information can be filled in due course. In addition to setting up the content of this master plan, ideas are also provided for data management and international cooperation. The environmental effect reports and appropriate assessments made for the OWF in the second round are based on the so-called worst case scenarios, in accordance with the legal obligation. It is of utmost importance to investigate whether such scenarios are correct, or whether additional information would provide a more realistic assessment of the effects, so that decisions are also made on better estimate of effects, and *worst-case* scenarios play a lesser role in this. This master plan is not a blueprint for monitoring and research in the framework of the OWFs, but it does propose a framework, meaning that it provides the contextual and organisational frameworks as well as prioritisation for monitoring and researching the effects of construction, presence and removal of OWFs in the second and third rounds. Within these frameworks, choices can be made and additional measuring plans and field inventory can be set up on the basis of urgency and progressive insight.

This report has been written by several authors from various research institutes in the Netherlands. A.R. Boon is the main author and editor of this report and works at Deltares, Delft. R. ter Hofstede, T.C. Klok and M.F. Leopold all work at the Institute for Marine Research (IMARES), which is located in IJmuiden, Den Helder and at Texel, G. Blacquière works at TNO, The Hague. R.A. Kastelein works at SeaMarco, Harderwijk. M.J.M. Poot works at Bureau Waardenburg, Culemborg. C.J. Camphuysen works at the Royal Netherlands Institute for Sea Research, Texel.

1.2 Legal framework

Currently, the legal framework for the OWFs outside the territorial waters on the Dutch Continental Shelf (DCS) is limited to the Birds and Habitats Directive (BHD) and the Water Act (WA), for which the Ministry of Transport and Public Works is the Competent Authority. The strictest protection regime ensues from the Birds and Habitats Directive, which applies to all European countries. This protection regime is legally laid down in country-specific acts such as the Nature Protection Act (NP Act) and the Flora and Fauna Act (FF Act) in the Netherlands. Area-specific and generic species-specific protection apply respectively on the basis thereof. At this time, the NP Act only applies within the territorial waters. Both the NP Act and the FF Act are expected to go into effect for the entire DCS by the middle of 2011, including for the Dutch EEZ. Article 4 of the Bird Directive states that member countries will strive, outside the protected areas, not to destroy, pollute or cause the quality of habitats of birds (including the species mentioned in Annex I) or of migrating species to deteriorate. Article 6 states explicitly that project and plans - alone or in combination - are not allowed to have "significant" effects on species and habitats protected within SPA's/SAC's. Articles 12 and 13 of the Habitat Directive state that member states are obligated to take adequate measures to maintain a strict protection regime for species and habitats listed in Annex IV of said directive. This implies that wind farms must not have any negative effects on the conservation goals of the species and habitats included in the above-mentioned annexes, either directly or by means of "external effects"[2]. These so-called external effects can also be referred to in the framework of the NP Act. This means that interference outside a Natura

[2] *Check for a description of what is meant by "significant" page page 28, 29 and 34, 35 of the following document: http://ec.europa.eu/environment/nature/natura2000/management/docs/art6/provision_of_art6_en.pdf*

2000 (N2000) area that can cause an effect within this N2000 area in various ways[3] must, by legal obligation, be included in the considerations of whether the relevant interference could cause any significant negative effects on the maintenance objectives of this N2000 area. Currently, several o*ffshore* areas (outside the 12 mile zone) will soon be designated as N2000 areas. The Cleaverbank (for reefs, porpoises and seals) and the Doggerbank (for shallow sandbanks, porpoises and seals) are reported as Habitats Directive areas. The Frisian Front will soon be indicated as Birds Directive area (especially for the guillemot, the great skua, the great and the lesser black-backed gull). Four other *offshore* areas in the DCS are presently still under study, the ecological values connected to these not having been mapped sufficiently as yet: Zealand Banks, Brown Bank, Borkum Reef and Gas Fountains.

The legal obligations of the NP Act may force to take more species of birds into account than just the breeding birds in the current N2000 areas. This may have consequences for placing OWFs, especially due to the external effects. Species such as the porpoise and the seal are already protected due to their status as Annex II species of the Habitats Directive. In addition to the NP Act, the FF Act will also apply to the DCS. This chiefly means that intentional disruption during the breeding period and killing of birds will be prohibited. Marine mammals found in the Netherlands are also listed in table 3 (strictest protection regime) of the FF act. In addition, the Water Act took effect as of 22 December 2009. This Act includes eight water-related acts. The former National Water Management Act is also included in it. Thus the OWFs will be permitted in accordance with the Water Act for round three, and (after the nature legislation takes effect on the EEZ), the Nature Protection Act and the Flora and Fauna Act.

Furthermore, the treaty of Ramsar on protection of water areas is of international significance, especially for water birds (1971), as are the Marpol treaty (1973/1978), the Treaty of Oslo and Paris on protection of the marine environment of the north-eastern Atlantic Ocean (1992; OSPAR treaty), the Biodiversity treaty, (1992; Treaty of Rio), the treaty of Bonn on protection of migrating wild animal species (1979) and the treaty of Bern on preservation of the wild animals and plants in their natural habitats in Europe (1979).

The European Marine Strategy Framework Directive (MSFD) took effect in 2008 and, within the planning period, will also set preconditions for the OWFs on the chemical and ecological quality and the use of the DCS, insofar as these are not dictated by the BHD or the NP Act. Currently, the framework for stipulating the purposes and the desired Good State of the Environment are still in full development. On the basis of this, marine habitats and species found here other than those protected by the BHD and the NP Act can benefit from extra protection. It is probable that frameworks already drawn up under OSPAR (indicators and system) will also serve as the basis for the MSFD in the assessment of the marine environment and nature. These *Ecological Quality Objectives* (*EcoQOs*) have been elaborated for ten different issues: commercial fish, threatened species, marine mammals, sea birds, fish communities, benthic communities, plankton communities, habitats, eutrophication and oxygen consumption (OSPAR 2007). These issues correspond in part with the components for which Good State of the Environment must be achieved by 2020: biodiversity, non-indigenous species, commercial species, food chains, eutrophication, sea

[3] On the one hand there are effects from outside inward, e.g. wind turbines that are positioned close to a N2000 area, but that could have a fright effect on birds within this area. On the other hand, effects from the inside outward are effects caused by turbines outside a N2000 area on birds, for example, that are protected within a N2000 area, but use an area outside the N2000 areas as (essential) feeding grounds or resting area (where the turbines are located), and thus depend on these areas for their sustenance.

bottom integrity, hydrographic properties, polluting substances, polluted consumer products, litter, input energy (underwater noise, mostly).
Standards developed under the MSFD are in principle generic for the North Sea, not area-specific, and can have an influence on the development of the OWFs. Underwater noise due to piling is one of the most significant negative effects mentioned caused by construction of OWFs at this time, and the secondary effect this has on fish larvae, fish and marine mammals is very significant. On the other hand, an OWF can provide a certain added value to certain animal groups due to creation of new habitats.

Presently the extent to which the development of the regulations has an effect on the possibilities for wind farms is not yet clear. It is probable that because of this, the research on and monitoring of the ecological effects of OWFs will also have to be adapted.

1.3 Bookmark

Chapter 2 discusses delineation of the master plan: what the position of this document is in the entirety of monitoring of and research on the effects of wind farms at sea. Chapter 3 presents an overview of the monitoring requirements as these can be formulated with the current state of affairs of information, after which these monitoring requirements will be structured and formulated in chapter 4. Chapters 5 and 6 will discuss the preconditions required for setting up a monitoring plan and having it function properly (data management, synthesis and evaluation of the results and the methods).

An earlier concept version of this report has been reviewed by Dr. E.M.W Stienen of the Institutue for Nature and Forest Research in Brussels, Belgium. The draft final report has been audited by various international peers. The results of these audits, and the response from the authors, have been added as an appendix to this report (Annex B).

2 Delineation

2.1 Introduction

This chapter presents a brief description of the place of this master plan in the larger whole of the research cycle. This master plan is not a blueprint for how the monitoring of the effects of construction, presence and removal of wind farms should take place. There are various criteria that are decisive for which choices are made. The most important ones are financing, seriousness of the effects (social perception and legislative framework), organisation of the work (logistic limitations) and the level of (un)certainty. Different choices can be made on the basis of this, and a more specific monitoring plan must be drawn up.

This master plan creates the framework required in order to arrive at a good monitoring plan: what are the most important questions, what are the gaps in information, what methods can be used, what do they produce and how is the scientific progress organised. The last aspect appears to be outside the customary considerations for research. However, logistics (who is responsible for what) and legal preconditions (openness of data, quality control) are of great importance for the process and success of research.

2.2 Nature of monitoring

Monitoring (and the corresponding evaluation) of the effects of installation, presence and removal of a wind farm is not monitoring in a strict sense. A definition of monitoring is the following (Hellawell 1993 and Brown 2000 in JNCC 2004):

Monitoring is an intermittent (regular or irregular) series of observations in time, carried out to show the extent of compliance with a formulated standard or degree of deviation from an expected norm.

The purpose of monitoring OWFs in not to examine whether a certain norm is being achieved or not, at least not primarily. The purpose of a Monitoring and Evaluation Plan (MEP) of an OWF is actually a study of effects, which eventually can be used to test against permit regulations[4].

Constructing a wind farm can be considered as an intervention in a ecosystem of which the effects are unknown in part. In most respects it can be considered as an analytic experiment, in some respects as a *response-level* experiment. Research is necessary in part in order to sort out how the ecosystem functions, but the response of the system is known to some degree and only the extent of the effect must be studied. As an example of the former, a study of the effects of underwater noise on marine mammals can be used: little is known so far about how a porpoise, for example, responds to underwater noise and to what spectrums and levels. On the basis of research already carried out in the framework of pingers on gill nets, it is known that porpoises are very sensitive to underwater noise, but knowledge on their behavioural reaction to various sound levels and spectrums is rather limited. Fish larvae may

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4. No decisions have been made on the extent to which certain norms must be described in permit regulations for effects of wind farms. Even though including a norm in a permit regulation provides advantages in enforcement, deciding the norm this way may be an obstacle if one wants to adapt this norm. Discussion is also possible on the extent to which stipulations must be included in permit regulations on how, what and when monitoring must take place, as is the case at this time for the first and second round of wind farms at sea.

die as a result of underwater noise, but little is known so far as to at what spectrums and noise levels this occurs.[5].

For the sake of the analytic experiment, it is very important that proper analysis of the status quo of the scientific information in the area of the (response by the) ecosystem to (the construction, etc. of) an OWF is carried out: what can we assume as the basic assumptions for the research; what are the working hypotheses; what definitions do we use for the concepts used; and what data (also methods) are required to test the hypotheses (Ford 2000, Rothchild 2006, among others). The hypotheses are tested (comparison) on the basis of the data, and new hypotheses are formulated and starting points are further substantiated or adapted if necessary. Each study involves such an iterative chain, and making this chain explicit is of great value for every study. The master plan is a link in this chain, namely the link that corresponds to setting up research: the so-called conceptual and the propositional analysis.

2.3 Conceptual propositional analysis

The conceptual propositional analysis is the step required before research can be carried out, and is focused on positioning the research in the field of information of the relevant issue[6].

The purpose of such an analysis is:

1. Defining what is known and what is not known about a research question (axioms or basic assumptions/propositions).
2. Drawing up (work) hypotheses (*postulates*) which can be tested
3. Developing the data question required so that the hypotheses formulated before can be tested, and so that the presuppositions or possible axioms can thus be adapted or reinforced.

Just as in every research project, one starts with matters that are well known, then proceeds with matters that are known in part, then with unknown matters. In order to get a clear idea about this, the analysis is put together in three phases.

<u>Phase 1: What are the most important issues?</u>
In this phase, a first overview is drawn up of the most important basic assumptions, premises and data questions. This allows for quick focusing.

<u>Phase 2: Conceptual analysis</u>
By means of a critical analysis of the concepts as used in the points of departure ("What exactly do we mean by barrier effect?") and by drawing up premises and hypotheses, it can be examined whether there is agreement as to the use of certain ideas and/or concepts in the research.

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[5] *Of course this is a simplification of the actual response. Sublethal effects could also result in reduced fitness of an animal and thus the population; such effects are unknown, but conceiveable, and are probably measurable in a response-level experiment designed for/adapted to this.*

[6] *The terminology used is derived from the broad field of epistemology. Making the different steps of monitoring, analysis and evaluation explicit in dynamic scientific terms is not specifically an objective of this report. Nevertheless, it helps to put the place of the various components in this master plan in the context of the empirical cycle. This can only be given limited space, so that discussion of this component may come across somewhat simplistically, which does not do justice to the complexity of the scientific operation. Incidentally, there is no one fixed method for drawing up such an analysis; the steps could be interchangeable.*

Phase 3: Overview of the entire procedure
By drawing up an overview of the entire procedure and broadening the question again (from small to big), the structure and the context of the research project can be made visible: is the proposed research complete, what is the place of the research in the broader whole, etc.

Setting up and implementing research goes through these stages various times, and in practise the different stages can have a great deal of overlap. Analyses such as mentioned above are often implemented, but mostly implicitly. The advantage of making these components explicit (in any case partially) has the advantage that it structures the entire train of thought and commands focus, but also that it provides others with insight into the process followed.

2.4 Position and tenability of the master plan

The intention of the master plan is to carry out this analysis, but it will necessarily remain at a certain abstract level. After all, as indicated above, a concrete plan can only be developed after certain (policy-related) choices have been made. The master plan is intended to primarily present an overview of the most important research questions, with the main question: "what are the ecological effects of construction, presence and removal of (an) offshore wind farm(s) on the DCS?" to present an overview of the principal monitoring problems by analysis of the results to present. So far, an attempt has chiefly been made to answer this question in various environmental effect studies and suitable assessments. The actual research on ecological effects did not get started until 2004 with the most important precursor the research in the Danish *Horns Rev* and *Nysted* (Baltic Sea) wind farms, which was already started in 1999. Monitoring and research was subsequently started in the Netherlands on the effects of the *OWEZ* and *Prinses Amalia* wind farms. Some of the results from these studies have been published, others not yet.

The research on the effects of *offshore* wind farms comprises a great number of sub questions, which makes the analysis of the research question for this issue quite voluminous and many matters (impact and effect) overlap.

The following structure has been maintained in the master plan at hand. First, an overview is presented of all foreseeable intervention-effect relations as they are known at this time. An example: wind farms can cause birds to loose their habitat for foraging. This is an axiom, a basic assumption that no one has any doubt about any longer. Indeed, it has been demonstrated various times that certain bird species avoid wind farms. Such basic assumptions can be further elaborated on the basis of available and scientifically supported knowledge ("facts"). A presupposition in that case is that the wind farms are avoided by all species completely, so that a testable hypothesis can be drawn up for each species.

Next, we examine what the information questions are. These information questions comprise a categorisation of the intervention-effect relations, and linked to this an inventory of the gaps in information and the relevant data to be collected. Again we use the loss of bird habitat as an example: as a gap in information, it is stated that there are no (location-specific) data on densities of the species being preyed upon in the farms (before and after construction). Such gaps in information suppose premises on the behaviour of birds, the presence of birds that are prey to other animals and the effects of wind turbines that interfere with this. These first two steps are part of the first phase, in accordance with the above-mentioned schedule: narrowing down the most important issues.

In order to go from information questions to gaps in information, an inventory has been made of the state of affairs concerning current and concluded monitoring and research programmes, so that the section on the gaps in information is supported. This way, insight can be obtained at the metalevel in the three above-mentioned purposes comprised by the conceptual propositional analysis.

We also state which methods there are for collecting certain data, what limitations there are and what results they have produced thus far.

The detail level to which these purposes have been elaborated is limited. This master plan does not hold any proposals as to what research questions can be studied precisely with what strategies[7]. This means that there are no links between basic assumptions and gaps in information on the one hand, and the research method still to be elaborated, which are the premises that are required to draw up testable hypotheses on the other hand. Using the example of birds again: what is lacking are explicit hypotheses on the relations between wind farms and the behaviour of birds and their prey. Furthermore, it is unknown how dependent these birds are on the part their prey in the area of the wind farms in order to maintain their fitness on an individual and population level. Such hypotheses serve as a scientifically sound set-up of research on the effect of turbines on the loss in bird habitat. However, it can be shown that such a relation (loss in habitat has a negative effect) can be logically supposed, so that it is included in the research question.

Therefore a number of implicit premises are assumed, also in this report, namely that the disruption that occurs is important to study because possible loss in (individual or population) fitness is caused by the presence of wind farms. As long as it has not been demonstrated (or made very plausible) that such effects do not take place, it makes sense and there is a legal necessity to take this as an assumption (precaution principle). This is a premise that can be confirmed or denied and on the basis of which a testable hypothesis can be drawn up. These premises will not be discussed any further in this master plan, supplementary reports will have to be made to do so.

Finally, as in all research, the results will be surrounded by uncertainty by definition. In addition to the academic uncertainty in the framework of the OWFs, this also will produce uncertainty for the policy makers and those who must make decisions on the basis of these uncertainties.

The purpose of the monitoring and research proposed in this master plan is to limit the scope of these uncertainties. In general, we can assume that setting up a well-thought out plan will lead to this. In scientific terms, this means that research can confirm or reject certain hypotheses and that new hypotheses can be formulated. This will reduce the gaps in information as described here. This is why the validity of this master plan is also limited in time. Due to progressive insight, gaps in information are reduced, but new questions can also be raised. This is one of the characteristics of information: it is never absolute. Tied to this is a different aspect: the recognition of information. The evaluation framework of information obtained, which in theory is value-free, is a social phenomenon. The applicability of information is linked to our recognition of this information. In concrete terms: the fact that birds and marine mammals are given better protection than benthos and plankton has a certain indicator value, in addition to the ease of observation (visually visible without any

[7] *Strategy refers to the entirety of preparation, method, resolution and planninng of a coherent plan for research.*

technically complex instruments), which also has to do with their iconic nature. This recognition is expressed in this master plan in the prioritisation of issues on which monitoring and research should be focused. Should this recognition change, the prioritisation will also change. The crucial point, meaning where the decision is eventually made on how much information is sufficient to answer a certain research question, can only be answered jointly by science and policy: neither of the two has sufficient information to answer this individually.

3 Monitoring and research questions inventory

3.1 Problem description

Installation and presence of *offshore* wind farms (OWFs) potentially cause various, and especially harmful effects on the ecological values present at sea[8]. Effects on birds (victims of collision, loss of habitat by avoidance, barrier effect) are known from studies on land and are also presumed to occur at sea; other effects such as those of underwater noise on fish larvae, fish and marine mammals are presumed on the basis of desk studies, but in practice the result of the effects of underwater noise due to construction and presence of OWFs has thus far been studied to a very limited extent. The potentially positive effects on the organisms living in and on the bottom (benthos) as the consequence of the absence of bottom disturbance by fishing, and the creation of additional habitat and fish (more benthos and thus more food and shelter) may have a positive secondary effect on fish-feeding birds and marine mammals.

Various studies have been carried out over the past few years, in the Netherlands and abroad, which produced important, often location-specific data for baseline data and effect definition. Results of such research are available, such as in the United Kingdom (UK)[9] and in Denmark [10] for the Danish *Horns Rev* (North Sea) and *Nysted* (western Baltic Sea) wind farms. In the Netherlands, research is in progress involving the existing *Egmond aan Zee* and *Prinses Amalia* wind farms. Baseline and effect data have become available for monitoring *OWEZ*[11]. What these entail is presented in the following section.

However, basic information and generic information on the distribution of relevant species and on cause-effect relations of the disturbances caused by wind farms are often lacking, which makes eventual assessment of the effects on large scale levels difficult. In addition, certain disturbances caused by wind farms may have very location-specific effects, for example the intensity and scope of noise distribution due to location-specific variation in depth and sediment properties, or the extent to which the area where a farm is planned overlaps with certain ecological values. Results from research carried out abroad can therefore not just simply be taken over in order to estimate effects in the Dutch situation.

The planned installation (certainly up to 2020) and presence (up to approx. 2040) of 6000 MW (MegaWatt) of OWFs on the DCS and the planning of several dozens of GW (GigaWatt) of OWFs in the North Sea may mean an increase of the effects as they are described in various effect studies (Environmental Effect Reports, EIA and Appropriate Assessments) up

8. The use of the terms "harmful", "advantageous", etc. as qualifications for the effects of OWPs is partially subjective and sometimes tendentious. In an ecosystem, the disadvantage for one species often means an advantage for another species. The terminology used is closely connected to our recognition of the effect or the species. This recognition is often connected to notions such as rarity, biodiversity, iconic effect and "naturalness". However, this recognition is sometimes "antinatural". For example, the breeding population level at which the herring gull and the lesser black-backed gull are protected in the Netherlands is based in part on the high incidence of toss-back by fishing cutters. Reducing this human effect will probably lead to adverse effect on the desired nature objective for these species. The use of the qualifying terms must be seen in this light.

9. http://www.farms.co.offshorewinduk/Pages/COWRIE/

10. http://www.hornsrev.dk/Engelsk/default_ie.html

11. http://www.senternovem.nl/offshorewindenergy/

to several orders of magnitude. The plans for wind farms in other parts of the North Sea and Baltic Sea, such as in Belgium, Great Britain, Germany, Denmark and Sweden must also be taken into consideration in this. Such farms may be on the routes of migrating birds and thus may result in cumulative effects that must be taken into account in measuring the effects of the Dutch wind farms (legal obligation). Furthermore, an inventory will have to be made of the extent to which effects caused by other non-OWF related human activities, plans and projects, both current and planned, may accumulate along with the effects of installation and presence of OWFs.

The information to estimate the effects of such large-scale expansion of OWFs is insufficient at this time, although a great deal of information in this area has recently been bundled and revised (Anonymous 2005, Zucco *et al.* 2006, OSPAR 2006, Michel *et al.* 2007, Elliott 2008). This master plan is a first start in improving this information in a way that tackles the generic and more location-specific problems for the long term.

It is important to note that most monitoring and research programs have not (yet) continued long enough to distinguish between short- and longer- term effects

This chapter maps the gaps in information in a structured manner, the way they can be described given the current state of affairs of our knowledge of the effects of the construction and presence of OWFs, the distribution of species and the cause-effect relations. The next two sections (3.2 and 3.3) will present an overview of the monitoring and evaluation programmes as they have been drawn up and are implemented for the existing wind farms in the Netherlands and abroad. Section 3.4 presents an overview of the cause-effect relations as they have been derived from the various studies: what physical interferences are the result of the construction and presence of OWFs and what is their secondary effect on the ecological values on and in the sea. Next, section 3.5 gives a description of the results as these are known from the various studies in the Netherlands and abroad. This forms the basis of an overview of the ecological problems, and the information questions, information gaps and monitoring questions ensuing from this will be further elaborated (section 3.6). Section 3.7 describes the possible accumulation of effects, after which section 3.8 will, in conclusion, present an overview of possible mitigating measures for the effects of OWFs.

This current need for information forms the input for the subsequent chapter (chapter 4) which will prioritise these specific information questions.

In the figure below, an schematic representation of the structure of this chapter is given.

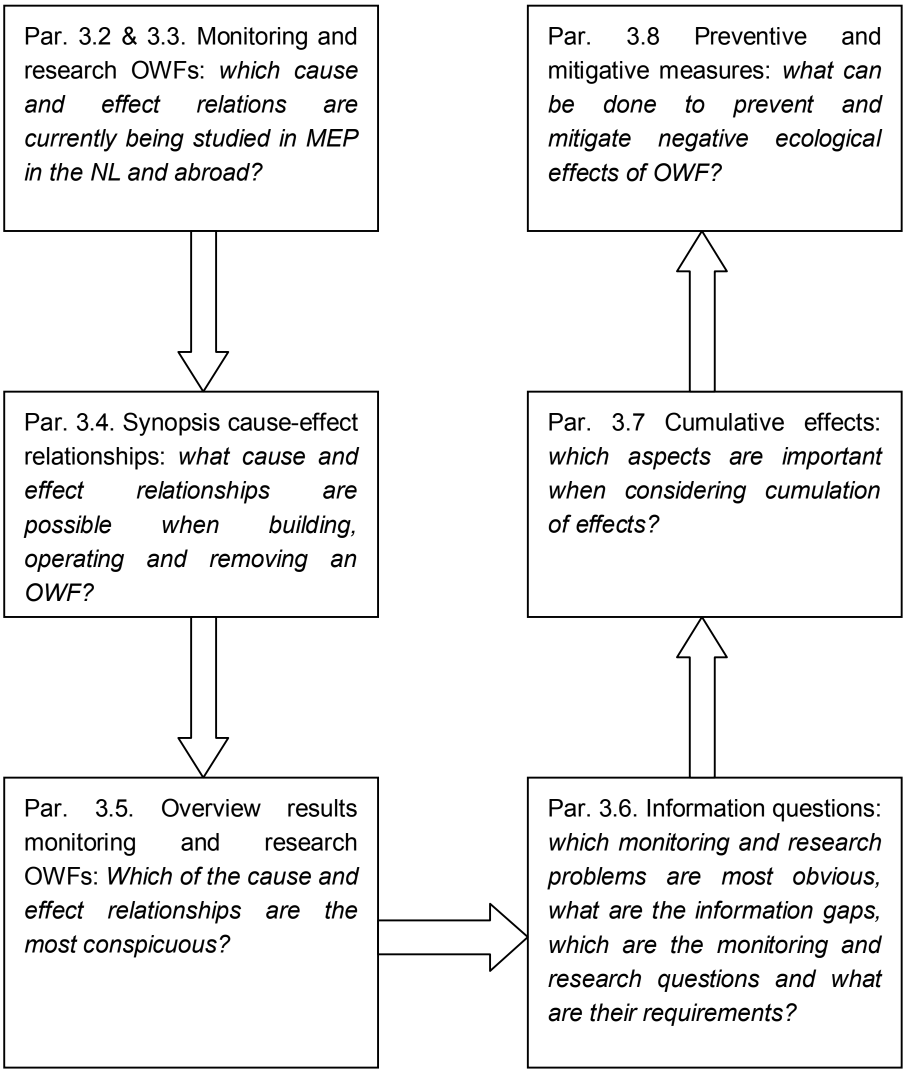

Figure 3.1: Schematic representation of the structure of this chapter

3.2 Monitoring and research programmes for offshore wind farms in the Netherlands

This section presents an overview, in broad outlines, of the set-up and results of the current monitoring programmes in the Netherlands. The same will be done for countries abroad in section 3.3. It presents how the programmes structured and what studies are being carried out.

Effect studies on the potential ecological effects of OWFs were carried out over the past 10 years in the Netherlands as well as in other countries around the North Sea. In many cases this involved desk studies (EIA/MER and AA/PB), but for some scheduled farms, baseline studies were carried out prior to construction, such as for the German and Danish OWFs, or strategic studies were carried out that included field measurements, such as for the British OWFs. In so far as we know, the data of the baseline studies carried out for the German wind farms are not available with respect to property rights and legal procedures. However, the German government did start up studies on the effects of underwater noise on marine mammals, for example. These studies are available to the public[12]. Baseline studies have also been carried out for the two Dutch farms, *Offshore Wind farm Egmond aan Zee (OWEZ*) and *Prinses Amaliafarm*, and effect studies are being carried out. One should realise that these effect studies have only studied a very small part of the fauna, and only a few aspects of the effect per species. Moreover, most studies have not been published in international scientific journals and have not been subjected to the critique of international peers.

In the Netherlands a first desk study (EIA) was done in 2003 on the possible effects of an OWF for the pilot *OWEZ* wind farm (formerly *NSW*). Shortly afterwards it was decided to build a second farm, the *Prinses Amaliafarm* (formerly *Q7*). Permits were granted for both farms, and Monitoring and Evaluation plans (MEP) were drawn up, which are presently being implemented. The results from this are available as far as the T_0 (*baseline*) measurements are concerned, and the first results of the T_1 (effect) measurements are now publicly[13] available (for part of the work). In addition, NWM permits were applied for in 2008 for the follow-up round (second round) of OWFs. Nineteen MERs and AAs were drawn up as part of this. These MERs and AAs include the most recent best available information as far as cause-effect relations of the construction and presence of OWFs on the ecological values present at sea are concerned. The AAs elaborate this information further and relate it to the area-specific nature protected by the Birds and Habitats Directive, which are birds and marine mammals (Arends *et al.* 2008). Deltares has drawn up an assistance document for this purpose (Prins *et al.* 2008). The permits include stipulations for monitoring and evaluation of the effects of these farms. The stipulations were in part produced after extensive consultation with the EIA committee.

Recently, while the master plan was drawn up and as a consequence of one of the workshops, a list was drawn up that prioritises the components of the monitoring and research programme to be implemented (see also chapter 4). The principal components of this list have been accepted by the NSIDM (North Sea Interdepartmental Directors Meeting) as the research to be carried out very soon, and NSIDM has made the means for this available.

3.2.1 Egmond aan Zee Offshore Wind Farm (*OWEZ*)

The Egmond aan Zee Wind Farm (*OWEZ*) was intended as a pilot for research on the technical, ecological, economic and social feasibility of wind farms at sea. An NSW Monitoring and Evaluation programme was set up for the OWEZ in 2001[14], which also includes teaching objectives.

The main questions stated in the MEP-NSW are the following (first set of bullets included literally):

- <u>Birds</u>: Flying patterns, characteristics, intensity, season, day/night with respect to estimate of risks of collision

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[12] At the time this text was written (14 March 2010), an overview of the studies of the Bundesministerium für Umweltschutz was made available by Mr Petrovic (FZ Jülich), but the reports had not yet been received.

[13] More research is and will be done than is publicly available at this time. However, this information cannot be included in the study at hand.

[14] Two categories are included in the MEP-NSW: Nature, the environment and user functions" and "Technology and economy". Only the reports that are part of the "Nature" and "Environment" are mentioned here.

  - Measuring collision chances and numbers and species of victim birds by NSW in view of: 1. reducing risks of future offshore wind farms and 2. the necessity of taking mitigating measures, including closing the farms;
  - Measuring the effects on the population level;
  - Learning for the benefit of offshore wind farms: flying movements, number and species of birds, collision chances and mitigating measures;
  - Adjustments related to environmental effects: flying movements and number of birds.

- Birds: Disturbance of the living and feeding area
  - Measuring the direct and indirect effects of the NSW on the living and foraging area and on the behaviour of birds;
  - Estimating effects of large-scale (offshore) farms;
  - Learning for the benefit of offshore wind farms: number of birds, disruptive factors and disruptive distances for their living and foraging area and the effects of possible mitigating measures;
  - Adjustments related to environmental effects in the area of the number of birds.

- Birds: Barrier effect
  - Measuring the nature and scope of the NSW barrier effect;
  - Estimated effects of large-scale (offshore) farms;
  - Learning for the benefit of effects of the barrier effect of large-scale (offshore) farms and possible mitigating measures;
  - Adjustments related to environmental effects on the area of the number of birds.

- The effect of underwater noise on fish and marine mammals
  - Measuring changes in the level and the nature of underwater noise vibrations (frequency and amplitude) and the response of the organisms to the noise vibrations;
  - Measuring the possible effect of the presence of the NSW on fish and marine mammals;
  - Learning for offshore: 1. deciding whether the effects of underwater noise and the vibrations caused by the turbines are acceptable; 2. effectiveness of mitigating measures during construction.

- The variation and densities of underwater life and the function as a refuge
  - Measuring the variation of underwater life on a small scale in relation to the total population;
  - Measuring the effects on the bottom fauna, epi and endobenthos;
  - Structural changes over the long term, its effects on fishes (demersal and pelagic) and via fish on marine mammals, if applicable;
  - Insight into the effect on distribution of marine mammals;
  - Insight into the function of the wind farm as a refuge;
  - For offshore: is the effect on underwater life acceptable?

The following studies are at this time (March 2010) publicly available as baseline studies (T_0) for the “Nature” and “Environment” components[15]:

- Baseline study on pelagic fish (Grift *et al.* 2004)

[15] *Both the SenterNovem and Noordzeewind websites were searched for this.*

  - Acoustic observations and catches of pelagic fish: densities and distribution in the plan area and two reference areas north and south, April and October 2003
- Baseline study on demersal fish (Tien *et al.* 2004)
  - Catches of demersal fish: densities and distribution in the plan area and three reference areas north (1) and south (2), June/July 2003, January 2004
- Baseline studies on birds (Krijgsveld *et al.* 2005, Leopold *et al.* 2004)
  - Ship countings of birds on and around the NSW plan location (covering plan area **Q7** as well): densities, September and October 2002, April, May, June, August, November 2003, February 2004
  - Radar and human observations of flying birds from the Noordwijk platform: fluxes, flying altitudes, flying directions, from September 2003 to November 2004, two weeks per month
- Baseline study on seals and porpoises (Brasseur *et al.* 2006, resp. Brasseur *et al.* 2004)
  - Observations from ships, and measuring underwater noise with towed hydrophones and T-pods for porpoise in and around the plan area and two reference areas north and south (the **Q7** plan area was also situated within the area), September, October 2002, April, May, June, August, November, December 2003, February, March, May 2004 (observations), June 2003 – May 2004 (T-pods), August 2004 (towed hydrophones)
  - Tagging and following common seals from the Waddenzee (6x) and Delta (6x), 2006.
- Baseline NSW background noise (De Haan *et al.* 2007a)
  - Acoustic observations of background noise at a fixed distance from plan location posts in 2005 and 2006
- Baseline benthos NSW (Jarvis *et al.* 2004)
  - Five Excel files were produced with the data of benthos in Donar data format: box core and surface data May 2003;
  - Benthos densities in the plan area and 2 reference areas to the north and south of the NSW plan area, box core and scraper May 2003.

The following reports are at this time (March 2010 available as T_1 and $T_{construct}$ reports[16]:

- T_1 study on benthos (Bergman *et al.* 2008, Daan & Mulder 2008)
  - Sampling of benthos: densities of infauna (box core) and epifauna (scraper) in NSW area and 6 reference areas (3 to the north and 3 to the south), March 2007.
  - Sampling of and study on recruitment of benthos within the NSW area and in 5 reference areas (2 to the north, 3 to the south). Densities of (juvenile) benthos, October 2007, recruitment experiments, July and August 2007.
- $T_{construct}$ on the effects of construction (pile driving) on birds (Leopold & Camphuysen 2009)
  - Observations on local sea birds during the pile driving period, April and June 2006
- T_1 study on effects of the presence of local birds (Leopold & Camphuysen 2008b)
  - Observations of effects of the presence of a wind farm on local birds from April 2007 to January 2008, 6 surveys
- T_1 study on effects of the presence on flying birds (Krijgsveld *et al.* 2008)

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[16] T_0, T_1 and $T_{construct}$ reports are reports drawn up for the situations for construction, in the first year after installation and during installation, respectively.

- Radar and human observations of flying birds from the meteomast in the wind farm: fluxes, flying altitudes, flying directions, from March 2007 to October 2007
- $T_{construct}$ on effects of construction (pile driving) on marine mammals (Leopold & Camphuysen 2008a)
  - Spatiotemporal analysis of countings of stranded porpoises on the coast near Egmond aan Zee, April - June 2006 (Not an official document in the framework of MEP-NSW)[17].
- $T_{construct}$ of underwater noise during construction (pile driving) (De Haan *et al.* 2007b).
  - Measurements on and analysis of underwater noise during driving of six of the thirty-six piles, April – June 2006.
- T_1 on the effects of the presence of NSW on marine mammals (Brasseur et al 2008, Scheidat *et al.* 2008).
  - Tagging and following of 22 common seals, 6 in the Waddenzee and 6 in the Delta in the spring of 2007, and 6 in the Waddenzee and 4 in the Delta in the fall of 2007.
  - Observations of underwater noise with T-pods inside the wind farm, and in two reference areas north and south, April, June, October and December 2007.
- Study on the hearing sensitivity of the common seal to underwater noise (tones and white noise) (Kastelein *et al.* 2009 a, b).
  - Two pool experiments on the hearing sensitivity of seals to tones and white noise tapes.

3.2.2 Prinses Amalia Wind Farm

The monitoring programme for the Prinses Amalia Wind Farm is not yet publicly available. Samples have also been taken in the baseline studies for NSW/OWEZ at the Q7/Amalia plan location. What is available is a conference paper concerning underwater noise during the construction phase (De Jong & Ainslie 2008). A first interim report for the Prinses Amalia wind farm is expected in the summer of 2010. The occurrence of porpoises in the Prinses Amalia wind farm is followed by means of two C-PODs in the farm and by means of two C-PODS outside the farm, for comparison (M. Leopold).

3.2.3 Second round of wind farms in Dutch waters

Permit applications, with an EIA and AA, for the NWM were submitted for nineteen wind farms on the DCS in 2009. Regulations were drawn up for the farms that were granted a permit, including those for monitoring the effects of the wind farm on the ecological values (Ministry of Transport, Public Works and Water Management 2009a, b).

It is generally required that a Monitoring and Evaluation Plan (MEP) be drawn up (regulation 16), for which certain (minimum) quality requirements are drawn up (text adopted literally):

- Description of existing studies per issue, and how the proposed study links to this.
- Annual production of an independent, readable scientific progress report.
- Underwater noise recording:
  - Collecting data to model the pile driving noise and operational noise.
  - Measuring the effects of underwater noise on fish during pile driving (preventing the presence of fish and causing them to die).
  - Marine mammals:

[17] *This report is not a formal MEP-NSW product, but is mentioned here for the sake of convenience.*

- Determining the avoidance behaviour of porpoises during pile driving.
- Determining the migration behaviour of the common seal and grey seal.

* Birds:
  - Monitoring sea birds to determine their avoidance behaviour due to the wind farm.
  - Fluxing colony breeders and sea birds in and around the wind farm.
  - Quantitative and species-specific avoidance behaviour of birds and colony breeders inside the wind farm (micro-avoidance) and outside the wind farm (macro-avoidance).
  - Spatial distribution of breeding lesser black-backed gulls.

Furthermore, regulations have also been drawn up per component for the method, the time aspects and borders of the area and the desired accuracy. These will not be described any further here.

3.3 Monitoring and research programmes for offshore wind farms abroad

3.3.1 Overview of monitoring activities in European offshore wind farms

Within Europe, England and Denmark have the greatest share of operational offshore wind farms (Figure 3.2). The most extensive monitoring activities, at least those published and available to the public, on the ecological effects of offshore wind farms were carried out in two Danish farms, Horns Rev and Nysted. These are both relatively large wind farms with 80 and 72 turbines, respectively. Monitoring took place here before, during and after construction of the wind farms, usually in accordance with the so-called BACI (Before/After and Control/Impact) set-up. The Danish studies also are the first large public studies on ecological effects of OWFs. For many studies no results are available yet in other countries, or these still only involve the T_0 or plan studies, or non-comparable, very small offshore or onshore wind farms (Vanermen *et al.* 2006, Everaert & Stienen 2007, Vanermen & Stienen 2009), or they are not available to the public (e.g. in Germany), see the observations above. Moreover, in the Danish situation both results of before (T_0), during ($T_{construct}$) and after (T_1, T_2) etc. construction are available. Due to its set-up and scope, the Danish studies have been guiding for many other studies and are frequently cited.

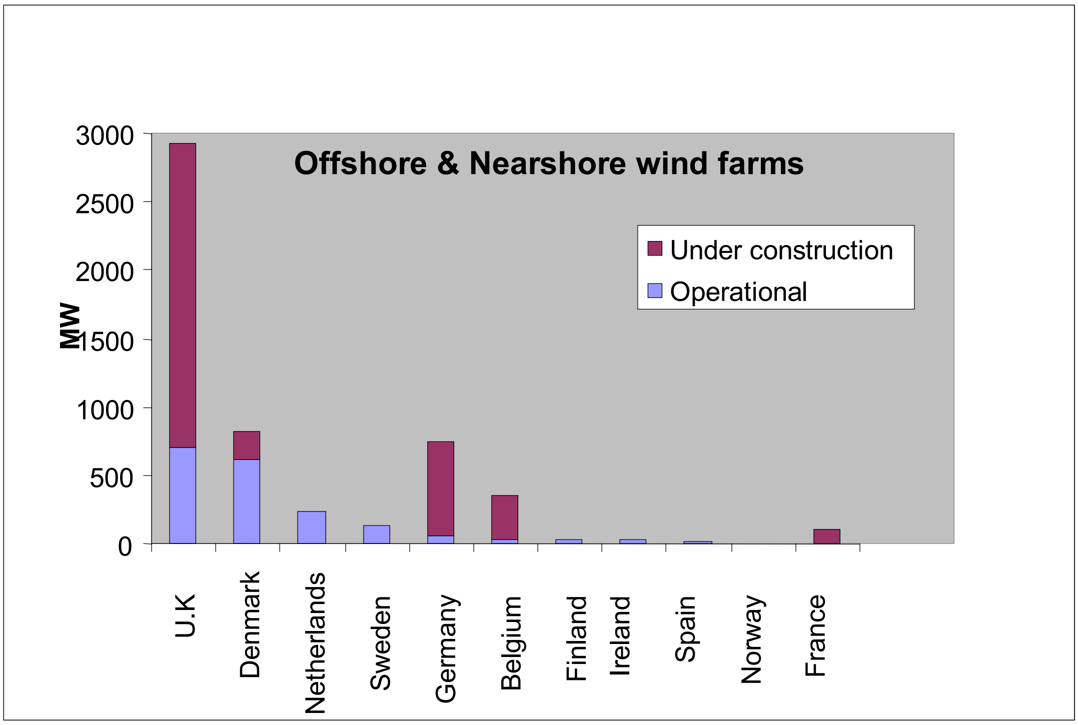

Fig. 3.2. Capacity of offshore and nearshore wind farms in Europe; situation December 2009. Source: Wind Service Holland, http://home.wxs.nl/~windsh/offshoreplans.html

The table below shows the various species and species groups that are monitored in European wind farms.

Table 3.1. Species and species groups mentioned in Monitoring and Evaluation Programmes (MEPs) of European wind farms.

Country	Farm	farm capacity (MW)	migrating birds	local sea birds	bird collisions	mammals in farm	mammals around farm	fish North Sea wide	fish in farm	fish larvae	epibenthos on hard substrate	sand eel	macrobenthos (hard/soft substrate)
Denmark	Horns Rev	160	+	+	+	+	+		+		+	+	+
	Nysted	166	+	+	+	+	+		+		+	+	+
Belgium	Thornton Bank I	30	+	+	+	+	+		+		+		+
	Belwind		+	+	+	+	+		+		+		+
England	North Hoyle, Greater Gabbard, among others		+	+	+	+	+	+					
Germany	Enova, Hooksiel, Alpha Ventus,		+	+	?	+	+				+		+

	among others												
The Nether-lands	OWEZ	108	+	+	+	+	+		+	+	+		+
	Amalia	120	+	+	+	+	+		+	+	+		+

3.3.2 Denmark: *Horns Rev* and *Horns Rev 2*

Horns Rev is the first *offshore* wind farm built by Denmark in the North Sea, in 2002, and is situated off Esbjerg. Another wind farm was installed in Danish waters in the Baltic Sea at the same time, *Nysted*, for which a comparable set-up was used. From the Nysted OWF substantial information has been collected on e.g. barrier effect on migratory birds and on the habitat loss of mainly Long-tailed Duck (Petersen et al. 2007). From that same area an ornithological assessment has been published in relation to the construction of the Nysted 2 OWP (Kahlert et al. 2007).

The following reports are available for the baseline situation of Horns Rev:

- Leonhard (2000): description of benthos and flora at the location of the planned wind farm and the cable trajectory.
- FSM Esbjerg *et al.* (2000): Study on incidence of marine mammals, particularly porpoise and seals, in the plan area and surroundings.
- Skov *et al.* (2002): Study on incidence of porpoises in and around the plan area.
- Hoffmann (2000): Incidence of fish and shellfish and an EIA on the presence of hard substrate on benthos and electromagnetic fields affecting fish and marine mammals.
- Noer *et al.* (2000): Sea bird distribution at the location of the plan area and surroundings, and an EIA.

The effect studies took place from 2002 through 2006. The list with publications is extensive[18] and will not be presented here in detail, only the final reports or the most recent reports involving Horns Rev are mentioned:

- Leonhard & Petersen (2006): Final report on benthos changes before, during and after construction of *Horns Rev*.
- Tougaard *et al.* (2006a): Final report on distribution and behaviour of the porpoise before, during and after construction of *Horns Rev*.
- Tougaard *et al.* (2006b): Final report on distribution and behaviour of the common seal before, during and after construction of *Horns Rev*.
- Hvidt *et al.* (2006): Annual report on acoustic monitoring of fish, including supplementary sampling.
- Petersen *et al.* (2006): Final report of the bird studies at the *Horns Rev* and *Nysted* locations.
- Petersen & Fox (2007): Changes in the use of habitat by birds around *Horns Rev 1*, with emphasis on the common scoter.

Horns Rev 2 was built in 2008 and 2009. Prior to installation of this farms, an MEP was drawn up and implemented, consisting of the following components (Dong Energy *et al.* 2006):

[18] *http://www.ens.dk/en-us/supply/renewable-energy/windpower/offshore-wind-power/environmental-impacts/env.reports_for_specific_projects/sider/forside.aspx*

- Effects on benthos, especially the introduction of hard substrate and a survey of the infauna.
- Distribution of fish around the wind turbines and the rocks dumped, as well as the effects of electromagnetic fields on fish.
- Numbers and distribution of feeding and resting birds by means of an aircraft survey, and the food selected by common scoters.
- Migrating birds, including the collision risks of birds with the turbines.
- The behaviour of marine mammals, porpoise and seals, and their reactions to wind turbines.

This farm is farther away from the coast than the original Horns Rev. Baseline and effects studies were carried out for this farm in 2007 and 2008 on[19]:

- Birds:
  - Piper *et al.* (2008): migratory birds 2007-2008.
  - Skov et al (2008a): food base of the common scoter.
  - Skov *et al.* (2008b): monitoring resting water birds.
  - Skov *et al.* (2009): migratory birds 2008.
- Marine mammals:
  - Skov & Thomsen (2006): monitoring marine mammals
  - Brandt *et al.* (2009): reaction of the porpoise to pile driving.
  - Betke (2008): underwater noise production during pile driving.
- Fish: no monitoring, but an EIA: Jensen *et al.* (2006).
- Benthos: Leonhard (2006): sampling infauna and epifauna, and EIA.

3.3.3 Belgium: Bligh Bank, Thornton Bank[20]

Currently (April 2010) research is being carried out in the Belgian part of the North Sea to assess the ecological effects of the first three Belgian OWFs: *C-Power*, *Belwind* and *ELDEPASCO.* These wind farms are situated respectively on the Thornton Bank, Bligh Bank en the Bank with No Name. OWF *C-Power* is in a pilot stage with six functional turbines and gravity-based foundations. The construction of the first phase of the 55 3 MW turbines for OWF *Belwind* has started end 2009. Piling of its foundations was finished in February. For OWF *ELDEPASCO* research into the T_0 (baseline) situation has started recently. Comparable to studies abroad, monitoring has been set up according to the BACI-design (Before-After, Control-Impact) focusing on the direct impact as well as the indirect, process-related effects. The results of the studies are publicly available (Vanermen & Stienen 2009; Degraer & Brabant 2009[21]). Monitoring and research has been and is being conducted on the following aspects:

- Hydrodynamics and sediment: effects on turbidity, currents, erosion around foundations, erosion on cable trajectories.

- Under and above water sound during the construction, the operation and the removal.

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[19] *see http://www.dongenergy.com/Hornsrev2/EN/about_horns_rev_2/Environment/Pages/Environment.aspx*

[20] *Additional references: **1.** Recommendation by the board to the minister authorised for protection of the marine environment involving: the application for authorisation and permit of the n.v. Belwind for construction and operation of a wind farm at the Bligh Bank in the North Sea. Annex 5: Monitoring. 2007. **2.** Construction and operation of a wind farm at the Thorntonbank in the North Sea. Assessment of the effects on the environment caused by the project, submitted by n.v. C-Power. 2004.*

[21] *http://www.mumm.ac.be/NL/News/item.php?ID=158*

- Benthos: colonisation of hard substrate, with a focus on non-endemic species, effects of the closure of the area for fisheries on infauna, epibenthos and fish, impact of organic enrichment by the hard-substrate epibenthos on the soft-sediment infauna.
- Avifauna: impact on the density of seabirds, the barrier effect of the OWF and research on collisions (by means of counts at sea, radar and collision models).
- Marine mammals: possible changes in the spatial distribution of marine mammals on the Belgian continental shelf (by means of passive acoustic measurements with T-pods and C-Pods, data on strandings and hearing damage (dissection of stranded specimens).
- Electromagnetic field measurements around cables during production phase.

3.3.4 United Kingdom: North Hoyle, Greater Gabbard

In the UK, there are monitoring requirements stipulated by the various licences, notably FEPA (Food & Environmental Protection Act 1985). Research associated with offshore wind farms has been coordinated by both COWRIE and DECC. The COWRIE programme is due to close in 2010 and it is likely that the Crown Estate (landlord of the UK seabed) will assume a more prominent role in research coordination. Under the UK Marine and Coastal Access Act 2009, new marine planning and management structures have been established, the MMO (Marine Management Organisation – 1 – 100 MW installations) and IPC (Infrastructure Planning Commission – installations > 100 MW), so DECC's role as the relevant authority with responsibility for preparation of AAs and consents will be transferred. DECC continues to have a coordinating role in research via its SEA program. See http://www.marinemanagement.org.uk/works/energy/index.htm

The BACI design is utilised in England, whereby a baseline study is made before the installation for a one to two year period during the construction phase, and two to three years in the operational phase. Priority is given to research in order to measure the effect of electromagnetic fields of cables on fish behaviour, the effect of loss of habitat for sea birds due to wind farms, barrier effect on migratory birds and the effect of underwater noise on marine mammals.
To this end, baseline studies are made of the species composition, distribution and density of birds throughout the seasons. The flying altitude (number of individuals in months of the year) of species is also monitored in order to measure the chance of collisions with wind farms. Information on birds is collected by observations from ships and from aircraft. The research is coordinated by COWRIE (but see above)) see website (www.offshore-sea.org.uk). A survey of commercial fish stock in the British waters was recently concluded (Dunstone 2009), which will be used for the spatial planning of wind farms.

3.3.5 Germany: FINO, MINOS

In Germany monitoring activities for offshore wind farms are actually based on the Standards for Environmental Impact Assessment, 2nd update 2007, edited by BSH: http://www.bsh.de/en/Products/Books/Standard/7003eng.pdf

The German standard covers the compartments for which direct effects of offshore wind farms have been considered most probable: benthos and sediment, fish, marine mammals, seabirds, migrating birds and underwater noise. The standard was compiled by scientific groups with expertise in various fields of marine science and supported by representatives of licensing and nature conservation authorities.

The standard describes the spatial and temporal extent of the investigations for the baseline study (EIA) and for monitoring activities during the construction and the operational phase. Methodologies for surveys and data analyses are precisely described according to new developments and scientific results to facilitate the compatibility of data sets collected by various consulting groups. The standard will be updated on demand to fit new requirements and developments.

The baseline studies cover two consecutive years. In cases when the construction phase begins with a delay of more than two years from the end of the baseline study, additional investigations have to be carried out for one year. Moreover, the data of the EIA as well as the monitoring data of the construction and operation phase are quality checked and stored in a common database at BSH. The results (in German) of the baseline study and partly for the construction phase of the first German offshore wind farm „Alpha Ventus“ can be found at:

http://www.bsh.de/de/Meeresnutzung/Wirtschaft/Windfarms/StUK3/index.jsp

More generic information on research programmes on the effects of OWFs in Germany can be found on the (http://offshore-wind.de/) website, which provides information on studies near the BeoFINO1 (2001-2004), BeoFINO 2 (2005-2007) meteomasts, and on studies made as part of MINOS (2002-2004) and MINOS+ (2004-2008). FINO 3 was constructed in 2009. These studies did not take place near (planned) wind farms, but are focused on acquiring generic information on the effect of wind farms on marine organisms. Studies are made near the benthic species community in and around the wind farms in the North and Baltic Seas. In addition, migratory and sea birds are monitored, as well as marine mammals (monitoring focused on the noise effect and loss of habitat), and fish and benthos are monitored to measure the effects of electric cables on marine organisms (effects of electric fields of the cables on Chaetopods, echinoderms and crustaceans). Countings from ships and aircraft are used for monitoring birds and marine mammals. The use of space by porpoises is monitored with T-PODS. A *peer-reviewed* publication has already been published on the latter component (Gilles *et al.* 2009). Various reports in German have also been published. Monitoring in Germany is regulated extensively and strictly, but many data are collected by order of the wind farm owners by agencies and are not available to the public.

3.4 Synopsis of cause-effect relations

The network of wind farms in the North Sea is growing, which this leads to a considerable increase in human disturbance of the marine environment with, undoubtedly, ecological consequences. During the construction of the farms, the bottom will be stirred up and the pile driving work will cause powerful sound waves. During the operational phase, the physical presence of the turbines will create a different habitat, both under and above water; cables will create electromagnetic fields; the turbines in operations will create continuous white noise in the underwater “noise landscape”, and there will be a prohibition on navigation and thus also fishery in the neighbourhood of the turbines, though there will be semi permanent maintenance in the farms, at least when the weather is good.

Marine organisms will in all probability react variously to the construction and presence of wind farms. Changes in the natural “noise landscape” may result in fish, fish larvae and marine mammals suffering temporary loss of hearing or even lethal damage to hearing or other organs when exposed to extreme noises. Less extreme exposures cause disturbances in the natural behaviour of marine organisms, such as communication, reproduction, foraging, predation and dispersion (this effect may be more extensive than the lethal damage because a much larger number of animals will be affected). For example, marine mammals may be disturbed during their migrations, reproduction and nursing, and sea birds may see the wind farms as barriers, leading to reduction of their habitat and change in their migratory routes. On the other hand, wind farms may also have positive effects for some species such as providing perches for cormorants, whereby offshore marine areas will become accessible to these birds, and such as providing a place for bottom organisms that only live on hard substrates to settle, or by functioning as a refuge since no fishing for fish, crustaceans and shellfish is permitted in and around the farms.

The table below presents possible ecological cause-effect relations of construction, presence and removal of the OWFs. The subsequent text describes these possible effects. No assessment is made of the extent of the effect of other (for example legal) preconditions nor whether such an effect should be included in monitoring and evaluation. This assessment is made in chapter 4.

Table 3.2: Overview of possible ecological cause-effect relations of wind farms at sea

Phase	Possible effects	Habitats and species groups						
		Habitats	Plankton	Benthos	Birds	Fish & fish larvae	Marine mammals	Bats
Construction phase								
Construction of foundations	Water quality	X	X	X		X	X	
	Noise / vibrations (under & above water)			X	X	X	X	
Cable installation	Space taken up	X		X		X		
	Water quality		X	X		X	X	
Navigation	Noise / vibrations					X	X	
Operation phase								
Presence wind turbines	Risk of collision				X			X
	Water quality		X					
	Noise / vibrations					X	X	
	Loss of habitat function and/or space	X			X		X	X
	Hard substrate	X	X	X	X	X		
	Scouring, bottom morphology	X		X		X		
Cable presence	EM radiation			X		X	X	
Navigation for	Noise / vibrations					X	X	

Phase	Possible effects	Habitats and species groups						
		Habitats	Plankton	Benthos	Birds	Fish & fish larvae	Marine mammals	Bats
maintenance								
Navigation prohibition	Noise / vibrations					X	X	
	Fishing prohibition			X	X	X	X	
Removal phase								
Removal	Water quality	X	X	X		X	X	
foundations	Noise / vibrations				X	X	X	
Cable removal	Water quality	X	X	X		X	X	
Navigation	Noise / vibrations					X	X	

In the following two figures, the possible cause and effect relationships for the ecological effects of constructing and operating OWFs are given schematically.

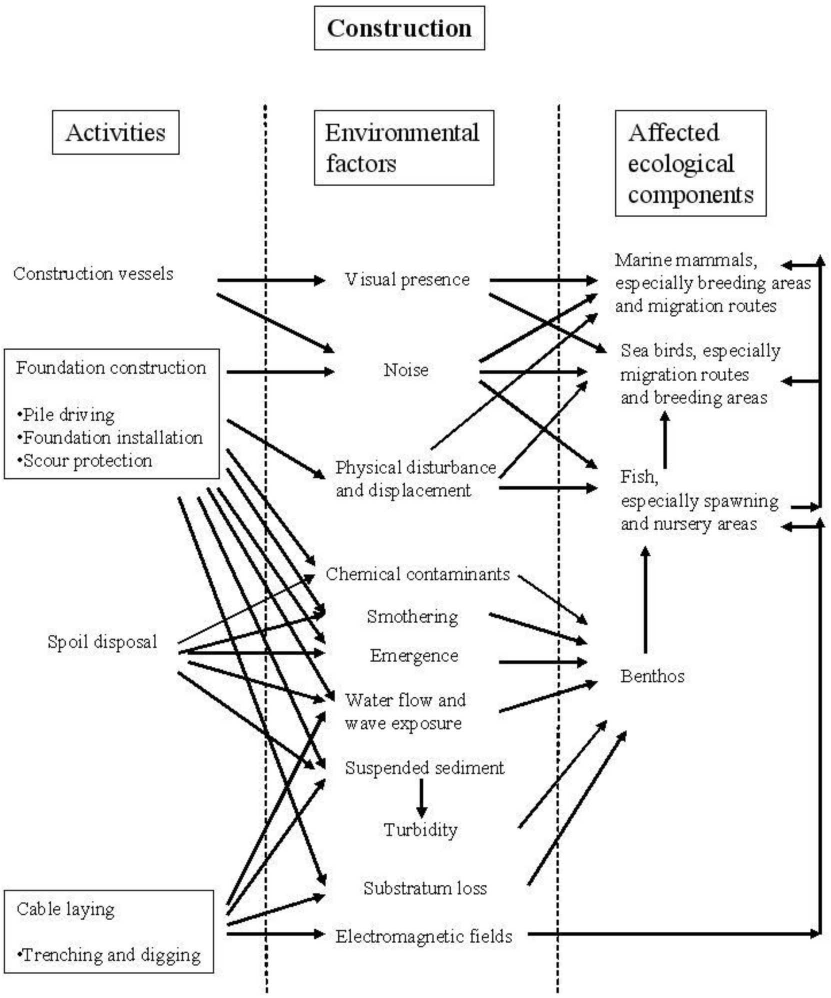

Figure 3.3. Conceptual diagram of the effects of various types of activities, which are related to the construction of wind farms, on environmental conditions and ecology at sea. Based on Hiscock *et al.* (2002), Michel *et al.* (2007).

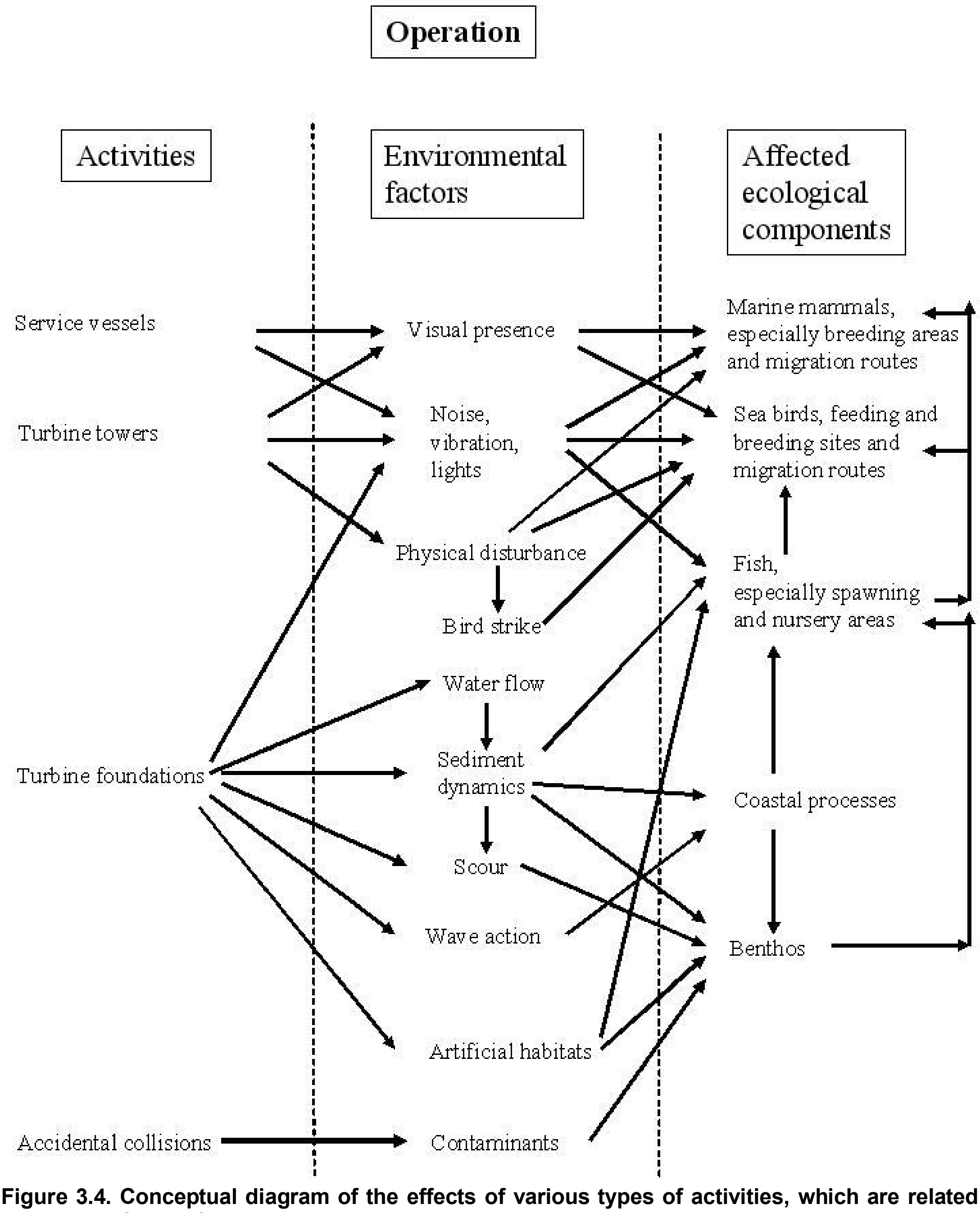

Figure 3.4. Conceptual diagram of the effects of various types of activities, which are related to the operation of wind farms, on environmental conditions and ecology at sea. Based on Hiscock *et al.* (2002), Michel *et al.* (2007).

Point by point, the cause-effect relations can be summarised as follows:

1) Effects on habitats: plankton
   1) Presence of OWF
      a) Introduction of hard substrate -> benthos community, introduction of spawning grounds for fish -> secondary effect on the fish community.
      b) Change in current around the foundation, effects on mixing and turbulence -> phytoplankton composition and production.

   c) Change in habitat around the foundation due to hydromorphological effects -> benthos community.
2) Effects on habitats: benthos
   1) Construction and removal of OWF
      a) Bottom structure disturbance, -> disturbance of chemical processes (redox, nutrient cycles, sludge and organic matter, death of bottom dwellers) -> altered primary productivity, reduced transparency (increased turbidity), release of contaminating substances, changes to benthos community, changes to food web production and composition.
      b) Death of bottom dwellers -> loss in biodiversity, biomass of soft substrate species.
   2) Presence of OWF
      a) Changes to bed morphology -> changes to benthos community and spawning grounds for fish.
      b) Loss of soft substrate -> benthos community, loss of spawning grounds for fish.
      c) Loss of ecological functions (due to the bottom being covered) -> decomposition of detritus, productivity, food function, C storage.
      d) Reduction in disturbance due to bottom fishing and effects on the bottom composition (Corg, nutrients, sludge) -> secondary effects on the benthos community.
      e) Addition of hard substrate -> increase in biomass, biodiversity, C storage, but also introduction of hard substrate species and ways of life[22], *stepping-stone* invasive/plague species, change in recruitment and the endemic species ratio.
      f) Reduction in disturbance by bottom fishing -> less benthos death and disturbance of the benthos community, change in diversity, density and production..
3) Effects on fish
   1) Preliminary study for OWFs: seismic tests
      a) Death of larvae, juveniles and adults due to underwater noise (uwn) -> secondary effect on population dynamics and food function.
      b) Disturbance by uwn -> loss of feeding area, migration options, spawning grounds.
   2) Construction and removal of OWF: pile driving and explosives[23].
      a) Death of larvae, juveniles and adults due to underwater noise (uwn) -> secondary effect on population dynamics and food function.
      b) Disturbance by uwn -> loss of feeding area, migratory options.
   3) Presence of OWF
      a) Loss of feeding and migratory/dispersion options due to uwn.
      b) Change in behaviour around cables due to electromagnetic radiation -> feeding options for elasmobranches (but also other species sensitive?), disturbed migration behaviour.
      c) Reduction / prohibition of fishing -> effects on the fish quantity (local/stock-wide)
      d) Possible effect of uwn on certain fish species in the operational farm (disruption of communication, etc.).
   4) Secondary effects on habitat and benthos
      a) Dead bottom dwellers as food for scavengers (construction).
      b) Absorption of contaminating substances (construction and operational phase).
      c) Change in the type of spawning grounds.
      d) Introduction of refuge function for fish (hiding, resting).

[22]. *This actually involves species that do belong in the larger ecosystem of the North Sea, but not in high densities at this site. Furthermore, the possible change in habitat for endemic species is distinctive, for example benthic juveniles of pelagic adults such as jellyfish living on hard substrate.*

[23] *It seems logical to forbid such techniques in the license. Alternative techniques are available.*

e) Change in feeding options of fish by changes in (Production (P) and Biomass, various) benthos community and pelagic food (P and B, various plankton).

4) Effects on birds and bats
   1) Construction and removal of OWF
      a) Loss of feeding/resting/moulting/migratory options (leading to displacement and avoidance) due to movements of sheers, ships. Especially for birds; for bats only in migration.
      b) Loss as in a) by noise, both above and under water.
      c) Displacement, avoidance due to presence of (de)construction vessels & personnel.
   2) Presence of OWF
      a) Collisions -> death of birds and bats.
      b) Loss of feeding/resting/moulting area (displacement/avoidance/habitat loss) for local sea birds and birds in breeding colonies.
      c) Lighting of turbines for navigation/aviation may affect birds on migration.
      d) An increase in rest options for cormorants also due to new objects, for example making offshore feeding areas accessible for this species; in the future this may even turn into new, offshore breeding facilities.
      e) Loss in migration options for migratory birds and bats (barrier effect).
      f) Prohibition of navigation -> what improvement is made in the disruptions by eliminating navigation.
      g) Displacement, avoidance due to presence of maintenance vessels & personnel.
   3) Secondary effects on habitat, benthos and fish.
      a) Change in transparency of catch success due to changes in silt content, PP.
      b) Change in availability of food due to effects on benthos and fish: see 2.2.a-d, 3.1.a, 3.1.b, 3.2.a, 3.3.a-e.
5) Effects on marine mammals
   1) Preliminary study for OWF: seismic testing
      a) Death due to underwater noise (uwn).
      b) Physical (including hearing) damage.
      c) Loss in feeding/resting area due to uwn.
      d) Loss in migration/dispersion options due to uwn.
      e) Reduction in rest time (makes animals more sensitive to disease).
      f) Stress (makes animals more sensitive to disease).
   2) Construction and removal of OWF: pile driving and explosives
      a) Death due to uwn.
      b) Physical (including hearing) damage.
      c) Loss in feeding/resting area due to uwn from piling.
      d) Loss in migration/dispersion options due to uwn from piling.
      e) Displacement, avoidance due to presence of (de)construction vessels & personnel.
      f) Reduction in rest time (makes animals more sensitive to disease).
      g) Stress (makes animals more sensitive to disease).
   3) Presence and maintenance of OWF
      a) Loss in feeding/resting area due to uwn from turbines.
      b) Loss in migration/dispersion options due to uwn from turbines.
      c) Reduction in communication by masking due to uwn from turbines.
      d) Reduction in rest time (makes animals more sensitive to disease).
      e) Stress (makes animals more sensitive to disease).
      f) Displacement, avoidance due to presence of maintenance vessels & personnel.

4) Secondary effect from benthos and fish
    a) Reduction in availability of food (fish and benthos).

Explanatory notes

Habitats/plankton

The effects of turbine pilings on the local current patterns are poorly known and in general are not regarded as having a significant negative effect. Changes in current patterns may have an effect on processes such as temperature stratification, so nutrients are mixed and algae growth is stimulated. Using current seams could facilitate fish finding food more easily. Phytoplankton communities can also change due to increased turbulence; some algae species are sensitive to this (Elliot *et al.* 2001). Finally, turbulence may change the predator-prey relationships between phytoplankton and zooplankton due to the change in encounter opportunities. Furthermore, some consider it possible that there is a relationship between the introduction of hard substrate and the large increase in jellyfish in coastal seas[24] (Graham 2001, Hoover & Purcell 2009). Such a change in the (zoo)plankton community could be caused by a change in food web relationships in the water column and on the turbine foundations, or due to an increased recruitment of jellyfish on the hard substrate.

Habitat/benthos

Construction, presence and removal of OWF may disrupt and change the bottom habitat locally. The structure is changed by constructing foundations and digging in cables. Dissolved substances, such as nutrients or contaminants, could be released from the bottom in places. Dumping rock around foundations and the foundations themselves changes the nature of the habitat: from a sandy or high-silt nature it becomes a hard substrate with the corresponding changed fauna.

Changes in current around foundations may cause locally increased erosion and sedimentation, whereby the bottom morphology around an OWF changes. At the same time, disruption of the habitat will be reduced by a prohibition on bottom fishing.

The absolute loss of soft substrate by constructing OWF in the North Sea is marginal [25]. The introduction of surface to hard substrate is several factors greater than the loss of surface on soft substrate. Moreover hard substrate is relatively rare in the North Sea: the vast majority of the bottom consists of soft substrate, especially sand and silt. A loss of biomass and types of sand and silt is thus (in a numeric sense) compensated by a gain in biomass and species on hard substrate, although this involves other species and thus a different biodiversity. Loss of soft substrate is moreover compensated (in part) by the elimination of bottom fishing in and in the direct vicinity of wind farms, which may result in an increase in biomass of species that have an affinity for soft substrate.

During construction, the rock dumped as the foundation severely disturbs the bottom at and around the foundation piles, resulting in the death of the bottom fauna with an affinity for local

[24]. See http://www.gulfbase.org/project/view.php?pid=asotrotasjppaop

[25]. When installing 50 GW (very rough estimate internationally in the North Sea), 5 MW per turbine and a surface cover of 2000m^2 (piling including erosion protection) per turbine this amounts to 20 km^2 loss of soft substrate for a total North Sea surface area of 570,000 km^2 (= 0.0035%). In case of exclusive use of gravity-based (50 m base width, extra 25 metres of erosion protection = 100 metres diameter per turbine) this is 0.055%. For the DCS, with a surface area of about 55.000 km^2 this is tenfold, approximately 0.6%.

soft substrate. The dumped rock and the foundation itself provide the opportunity for organisms with an affinity for hard substrate to settle in, and possibly provide the opportunity for invasive species to expand in the North Sea (such structures may function as so-called stepping stones), but on the other hand could be considered as a kind of repair of the hard substrate that disappeared due to fishing (disappearance of stones from the North Sea),

Prohibition of bottom fishing within OWFs could result in a change of the (soft substrate) bottom fauna community. Possible effects are a change in the numbers of certain species or species groups, an increase in biomass and productivity and diversity.

The above-mentioned effects on habitats, phytoplankton, zooplankton and bottom fauna may have a secondary effect on higher trophic levels of the marine ecosystem, specifically fish, marine mammals and birds.

Fish

With respect to the ecological effects of wind farms on the fish community, it is necessary to make a distinction between “fish larvae” (eggs and larvae) and “fish” (juveniles and adults). The distinction is of importance because fish larvae are primarily transported passively by the sea water current (from spawning grounds to nurseries) and thus cannot avoid the wind farm locations, in contrast to the older fish. This means that fish larvae will inevitably be subject to possible effects of the farms, while older fish may have a choice in this.

Fish larvae could die as a result of the pressure waves released by pile driving work on wind farms under construction (see Prins *et al*. 2009, page 4 for a brief overview). Fish larvae and juveniles are transported with the sea water current from spawning grounds to nurseries, and if the pile driving locations are on this transport route, the passively transported larvae may be subject to major effects. The model study by Prins *et al.* (2009) demonstrated that the death of fish larvae that occurs due to underwater noise during pile driving has a secondary effect on the number of juveniles that end up in coastal waters. This could have effects on the availability of food for birds and their young (lesser black-backed gull, terns) in the coastal waters and transition waters. Ground tests are done before an offshore wind farm is constructed. The ground test may consist of geophysical testing (shallow seismics), multi-beam sonar, probes and drilling (BSH 2008). Such measurements, especially the seismic testing may have a disturbing effect on fish, similar to the effects from pile driving.

During the installation of cables and building of foundations, toxic substances can also be released from the sediment, to which fish larvae could be exposed. In addition, the pilings of the turbines are treated with heavy metals such as zinc, aluminium and/or manganese in order to improve the durability of the turbines (sacrificing anodes) and to some extent these substances are released into the seawater during the operational phase, so fish larvae are exposed to them. A model study by Van Dijke (2008) shows that emission of aluminium into the water is relatively limited, and assuming five wind farms, will add a maximum contribution of 1% to the total of sources.

During construction, presence and removal, fish may be subject to various non-lethal effects. Disturbance of the bottom during construction of the foundations and installation of the cables, as well as the presence of foundations may have an attractive effect on fish. Bottom material is stirred up during construction, making bottom dwellers edible to fish available. Once in the operational phase, the foundation of the wind turbines will form an artificial reef landscape which could offer shelter to fish species with an affinity for hard substrate such as gray, bib, cod, Atlantic horse mackerel and sea bass. Current seams and lees may be advantageous for fish to find food or to rest, but also dangerous with respect to an increased chance of predation by sea birds or marine mammals (or big fish). Due to these effects, OWFs could have an aggregating effect on distribution of fish and contribute to their growth. A recent study shows that dumping rock is an effective way to prevent erosion of bottom material around turbine pilings (Whitehouse *et al.* 2008). To present, in the wind farms under study it has not been demonstrated that protective materials themselves had to be replaced or supplemented. It is thereby plausible that the benthic community forming on the hard substrate will not be partially destroyed with some regularity due to repetitive rock dumping.

Fishing activities will also be eliminated in the farms, thus the farms may serve as a refuge for the local fish community. However, so far it is unknown whether fish species are sensitive to the noise produced by the turbines, so the extent to which the fish species can benefit from the farm is uncertain. It is also uncertain as yet how top predators (marine mammals and sea birds) react to wind turbine farms and whether this will increase or decrease the local predation pressure on fish. Finally, electromagnetic fields around the electricity cables may have a disturbing effect on bottom fish sensitive to the fields. Elasmobranches in particular, such as sharks and rays are sensitive to this because the fields of the cables may interfere with the way (electric fields emitted by the fish) these fish find their prey.

Little is known as yet on how OWF will be removed. As indicated in Nedwell & Howell (2004), the options are for cutting monopiles by torch or using explosives. Exploding the concrete is regarded as an option for gravity-based foundations. In the latter case, removal will involve a noise pressure that can certainly be compared with that caused by pile driving during construction. The above-mentioned reference states that dead fish were observed floating on the water surface after explosives were used.

Effects on fish could have secondary effects at a higher trophic level of the marine food web, specifically on birds and marine mammals.

Birds

Birds are expected to be subject to effects particularly while OWFs are present: fatal collisions, loss of feeding area due to the disruptive effect of the turbines and barrier effects are the principal effects. Local disruption can take place during the construction and removal of monopiles due to visual and noise nuisance caused by ships and sheers, but also during the presence of the OWFs due to maintenance vessels and crews. OWF may cause loss of feeding/resting/moulting areas (displacement/avoidance/habitat loss) for seabirds from breeding colonies on land, and during at-sea distribution, including passage migration in spring and autumn, post-natal dispersal of immature/non-breeding birds, moulting aggregations, and non-breeding/wintering distributions.

The possible increased densities of fish and the changes in the bottom fauna may have an attractive effect on certain bird species. Prohibition of fishing in OWF, however, may have a negative effect on birds: gulls in particular benefit from the discards of undersized or commercially less profitable fish. However, the total amount of these discards is not expected to decrease if the fishing remains constant, since fishing is expected to move to other areas nearby. The discards may decrease in the future, which could cause a conspicuous change in the distribution of scavenger birds such as gulls. However, this effect is very minor in the current, very limited no-fishing zone around the OWFs. Cormorants can use wind farms as an operating base to colonise new offshore feeding areas so that their numbers in and around the farms could increase considerably. If birds are attracted, it is in principle also possible that in case of a disturbance, larger numbers of them will fly up and collide with the rotors. The relatively higher numbers of cormorants are conspicuous in both the Danish (Fox *et al.* 2006) and the Dutch wind farms (pers. obs. M. Leopold). The issue of habituation is important. Petersen *et al.* (2007) showed that Long-tailed ducks avoided the Nysted OWP five years after construction. A similar study on the effect on Common Scoter at Horns Rev showed that these birds could indeed accept to forage between the turbines after five years of OWP operation. Therefore, the weighing of attraction by improved foraging conditions with the avoidance effect created by OWP related ships and turbines will be an important issue that will require long-term post-construction monitoring.

Bats

A recent article by Boshamer & Bekker (2008) reports that bats have been found regularly on gas and oil platforms on the DCS. The observations (34 specimens) were made between 1988 and 2007. The most observed species is the *Nathusius pipistrelle* (26 specimens), and the Common Noctule (2x), the Northern bat (1x), the Serotine bat (1x) and the Parti-coloured bat (3x) were also observed.

It is unclear whether and how these specimens found are characteristic for flying movements of bats above the North Sea. In principle, effects on the populations of bats can occur due to collisions and barrier effects. See Winkelman *et al.* (2008) for an overview of effects of wind turbines on land and Ahlén *et al.* (2009) for collisions with offshore wind farms.

Marine mammals

Construction of OWFs with monopiles as foundations causes high pressure levels under water, which may be physically harmful, or up to long distances disruptive to the marine mammals found in the southern North Sea (common seal, gray seal, porpoise, white-beaked dolphin, bottle nose dolphin and several other dolphins and whales (minke whale) which, are found less frequently; Van der Meij & Camphuysen 2006; Madsen *et al.* 2006).

As has already been stated for fish, explosives may be used during removal of the foundations for wind turbines. These cause a very high pressure level that may lead to physical damage (damage to hearing will also result in death after few days because porpoises need to feed continuously) or even immediate death of marine mammals if they are relatively close to the explosion.

During construction resting and feeding areas may also be lost, in addition to death occurring, or migration and dispersion patterns may change. This may cause changes in the natural population dynamics and populations to be affected. If other types of foundations are used rather than monopiles, disturbance due to underwater noise is still possible, but of a lesser order of magnitude; ships are used in the construction of turbines and installation of cables, and dumping rock also results in underwater noise.

While wind farms are present, underwater noise is released, both by turbines and the maintenance ships. Such noise levels can still have disruptive effects on the behaviour of marine mammals, resulting in disturbance of migratory patterns and loss of feeding areas. These wind farm-related noises can also mask communication sounds due to which the marine mammals could have more difficulty finding one another or their prey.

The possibly increased densities of fish near OWFs may act as an attraction to marine mammals.

3.5 Overview results of monitoring and research in the Netherlands and Europe

This section presents an overview of the set-up and methods of monitoring and research on the effects of OWFs and a brief description of the ecological effects of wind farms at sea as has come to the fore from the various studies in the Netherlands and Europe. Considering the scope of the cause-effect relations, the complexity of the marine ecosystem and the multitude of different conditions in the studies, this cannot be any more than a succinct summary in which many details have intentionally been left out[26].

3.5.1 Birds

In the research on offshore wind farms, birds receive a relatively large amount of attention. This involves the birds that are found at the wind farm location (local sea birds), migratory birds that fly across over the location (migratory birds) and birds that breed elsewhere (on land), but feed in and around the farm location (breeding birds).

Local seabirds

In most studies the incidence of sea birds at the location of a wind farm is compared in the situation without a farm (before a farm is built) to that with the farm (once the farm is operational). Allegedly (a lot of information is not available to the public), various German studies involve a strict comparison of the location itself, before and after. In other situations a small buffer zone around the farm is included (UK: North Hoyle, May 2006). Since there are big annual differences in sea bird densities at a certain location, this is a risky approach (Camphuysen *et al.* 2004). For this reason, an ample area around the wind farm locations is studied in more extensive studies. The surroundings of the wind farm serves as the reference area in that case. Such an approach was followed in the Netherlands (OWEZ and Amalia: Leopold *et al.* 2004), Belgium (Thornton bank: Vanermen *et al.* 2006, Vanermen & Stienen 2009), Denmark (Horns Rev: Petersen *et al.* 2006, Nysted: Petersen *et al.* 2007) and Great Britain (Scira wind farm[27]). An interim form is including one or more unconnected reference areas at some distance from the wind farm location (e.g. Tuna Knob, Denmark: Guillemette *et al.* 1998, 1999).

Migratory birds [28]

Migratory birds that fly over the sea may collide with offshore turbines (Desholm & Kahlert 2005), which could kill them. This may be a problem for rare species that migrate (low) across the sea. The same is true for local sea birds which move above the sea over shorter distances, and for breeding birds that reach an offshore wind farm during feeding trips (Arends *et al.* 2009). Species, numbers, flying altitudes and seasonality can be studied visually at the site of a plan location or in a broader sense (Lensink *et al.* 2004; Leopold *et al.*

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[26] *It is important to observe here that the information released from various studies was indeed included by the experts who were involved with the master plan. However, it has been decided to not describe this very detailed information in the master plan.*

[27] http://www.scira.co.uk/downloads/_Environmental%20Statement%20-%20main%20text.pdf

[28] *With respect to the migratory birds, one is often referred to the Danish studies by Horns Rv. However, the ovservation must hereby be made that the situation for migratory birds off the Dutch shore is very different than the one off the Danish shore. Migration is much more driven here, and thus the flux is much higher. Thus the importance of studying this is much higher for the Netherlands than for Denmark.*

2004; Wiersma *et al.* 2005). Since much migration takes place at night and collision perhaps especially occur when vision is poor, visual observations will not be sufficient and thus radar is used (Desholm & Kahlert 2005; Krijgsveld *et al.* 2006, 2008; Petersen *et al.* 2006). Even at night, birds apparently fly around the entire farm ("macro-avoidance") or, if they fly between the turbines, they avoid them ("micro-avoidance"). The extent to which birds succeed in avoiding collisions is decisive for the number of victims, along with the flow of birds that flies through the farm ("the flux"). Actual measurement of the numbers of victims in offshore wind farms has thus far been a very difficult matter. The incidence is low, due to which many observation hours are required; perhaps rare incidents occur of many bird victims in one single night, birds are small in comparison with the rotor surface area and the farm surface area and victims fall into the sea and are lost. In the Netherlands there are systematic searches for birds washed ashore on the beach of Noord-Holland. This programme had been running for several decades and is now being continued with support from Eneco (wind farm *Amalia*). All kinds of measuring techniques have been invented in wind farms at sea (infrared, radar, visual, acoustic), but in the Netherlands these have not yet led to a collision "case". In Denmark, thermal camera's have been able to detect a collision of a small bird or bat with a rotor blade.

Breeding birds
Protected breeding birds may end up in conflict with wind turbines in their feeding area at sea or on their way to the feeding area. This leads to problems with the protection, among other things in (breeding) areas that are protected by Natura 2000. In the Netherlands the focus is on the lesser black-backed gull, the only species that can reach existing and planned wind farms from protected colonies in the Netherlands (Camphuysen *et al.* 2008; Arends *et al.* 2009). Examples of foreign studies are those by Perrow *et al.* (2006) on the little tern in England; van Garthe *et al.* (2008) on cormorants in the German Baltic, and Everaert & Stienen (2007) and van Stienen *et al.* (2008) on common terns in Belgium. Techniques used are visual observations near turbines at sea as well in a broader sense, and telemetry: tagging birds that fly out over the sea to feed. Another conceivable technique is colouring (dying) breeding birds so one can visually determine whether they visit a certain wind farm. The advantage of this is that more birds can be marked with dye than could be equipped with a transmitter or logger due to the costs: the disadvantage is that this does not produce continuous registration and thus that observations have to be actively made in the farm. However, it is of great importance to be certain of the breeding status of the birds: marking birds may also result in observing those that already left the nest and thus demonstrate a different feeding behaviour. This certainty is obtained by transmitters however. Data loggers provided the type with high data resolution and accelerometers are used, provide data on flying behaviour around turbines, flying behaviour to and from food sources (including fishing ships!), so that the collision models can be fed with concrete information.

3.5.2 Mammals

The species of marine mammals that are found regularly at the DCS in large numbers are protected by the Habitats Directive (porpoise, common and gray seal), while the seals also rest and give birth in Natura 2000 areas (Waddenzee, Pre-Delta), so they are covered by the external working regime of the NP Act. These animals are protected by the Habitat Directive, porpoises in a generic sense (Annex 4 HD), while for seals SACs need to be designated (Annex 2 HD). Thus, every initiator that wants to build a wind farm in the North Sea must take these animals into account. Marine mammals are much more difficult to observe at sea than sea birds (due to increased wave action above Beaufort 3 which renders porpoise fins hardly visible), however, although much has been done to catch up with this in the past few years, due in part to the development of offshore wind farms.

Cetaceans

In the meantime a number of techniques have been developed for porpoises, based on transect survey (visual observations: Hammond *et al.* 2002; Scheidat *et al.* 2008), or acoustic (via towed hydrophones: Brasseur *et al.* 2004; Blew *et al.* 2006; Thomsen *et al.* 2006; Scheidat *et al.* in press), or via “acoustic listening stations” on site (T-pods or C-pods: Brasseur *et al.* 2004; Carstensen *et al.* 2006). An unusual Danish study used telemetry by attaching satellite transmitters to porpoises in order to follow their movements (Teilmann *et al.* 2006). Apart from the question of whether capturing porpoises would be permitted for this purpose (or for any purpose whatsoever) in the Netherlands, such studies are limited to small numbers of animals to be monitored[29].
Of all marine mammals studied to present, porpoises have the longest frequency range as far as hearing is concerned (Kastelein *et al.* 2002). It is known that porpoises can hear sound signals in diverse background noise levels (Kastelein *et al.* 2009c). The noise of driving piles consists of short pulses, which porpoises hear less well than longer-lasting noise (Kastelein *et al.* 2010). Audibility of detonation noise (similar to pile driving noise) and the effect on the behaviour on porpoises is presently under study by SEAMARCO.

Seals

These limitations apply to seals to a lesser extent. They can be captured at their lairs (on sand banks in Waddenzee and Delta) in relatively large numbers, and moreover it is easier to attach transmitters to seals than to porpoises. Thus various studies were made using transmitters or GPS loggers on seals in the framework of wind farm studies (Brasseur *et al.* 2004). Seals do not regularly produce sounds under water, so passive acoustics (equivalent of T-pods) cannot be used for these animals. Visual observations (transect survey) of seals can be difficult because they often dive when ships approach. Therefore, this technique is only used rarely (Leopold *et al.* 1997; Gelatt & Siniff 1999; Southwell *et al.* 2004).
Recent research has shown that seals are much more sensitive than previously thought as far as hearing low tones is concerned (Kastelein *et al.*, 2009 a and b). Wind farm related noise has a low frequency and is thus quite audible to this animal species. However, pile driving noise consists of short pulses, and seals can hear those less well than longer-lasting noise (Kastelein *et al.* 2010).

Bats

The case for bats is even more difficult. Little is known as yet about their presence at sea and their interactions with turbines (Limpens *et al.* 2007; Boshamer & Bekker 2008; Goodale & Divoll 2009); these animals are too small to attach satellite transmitters to, they often fly at night which excludes visual observation and they are small and presumably fly in low densities which makes radar observations difficult. However, bats do also fly above the North Sea and appear to be particularly sensitive to wind turbine blades (Baerwald *et al.* 2008). Their own sonar provides opportunities for studies by using bat detectors (Ahlén *et al.* 2009), but these have not been used inside wind farms yet. When on migration, it has been suggested that echolocation is not used, which excludes the use of bat detectors in this case.

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[29] Attaching instruments to porpoises is sexy and sounds useful, but one will only be able to tag a distressingly small number of these animals. More importantly, porpoises are seasonal guests in our country, for which reason the “risk of failure” (for example that the animals will move away immediately after tagging) is very high.

3.5.3 Fish

Research on fish originates from studies on the effects of introduced hard substrate, on the refuge function of wind farms and on the effects of noise (pile driving in particular) on the survival of fish larvae and fish. Furthermore, research is being done on the effects of electromagnetic fields from the high-voltage cables running across the sea bottom from the wind farm to shore on bottom fish.

Fish in the farm and the refuge function

Fishing is prohibited in and in the immediate vicinity (up to 500 m) of wind farms. The effect of this may be that wind farms will serve as refuges for fish species. For example, Wilhelmsson *et al.* (2006) found a higher density of fish species in and in the immediate vicinity of an OWF. There was no difference in abundance of species and diversity. There is currently still a great deal of discussion in the literature of whether, and to what extent, wind farms may be able to act as refuges (Inger *et al.* 2009). In addition to effects of less fishing effort, the introduction of hard substrate may also play a role in the fish composition in and around wind farms. Both aspects, density of fish and species composition in and in the immediate vicinity of wind farms are mentioned in several European monitoring studies.

Fish, fish larvae and external effect

Noise caused by wind farms, and the noise of pile driving in particular, can have a negative effect on fish. A study by Thomson *et al.* (2006) demonstrated that dab and salmon were capable of hearing pile driving noise at a distance of at least 80 kilometres. Adult fish are mobile and can actively avoid the area where OWFs are constructed. Said noise probably causes death of fish larvae because they migrate passively alongside of and through the farms and thus cannot avoid them. Death of fish larvae can have a negative effect in the food supply of sea birds and thus a negative effect, via external action, on the objectives set in the Natura 2000 areas such as the Waddenzee (Arends *et al.* 2009). Research on the death of fish larvae has so far only been presented in Dutch monitoring studies.

Danish studies specifically examined the effects of wind farms on the lesser sandeel. The lesser sandeel was selected as being a good indicator species for changes in the sea bottom habitat, because it was found in high densities in the area where Horns Rev was planned and because it is an important food source for birds and sea mammals. Lesser sandeels were inventoried in Horns Rev before and after construction of the farm. The density of the species appeared to have increased at the wind farm location after construction, thus the conclusion was drawn that the construction of the wind farm does not have a negative effect on the lesser sandeel (Jensen *et al.* 2006).

Avoidance

The predominantly low-frequency underwater noise of an operational wind farm can be heard by cod and herring up to a distance of 4 to 5 kilometres (Wahlberg & Westerberg 2005). Thus the underwater noise must certainly be audible for fish inside a wind farm, and this may have negative effects. However, the question is whether the level of underwater noise in the immediate vicinity of the turbines will be above the tolerance limit (masking of biologically relevant sounds is probably the biggest problem). In October 2004, an experiment was done near the Horns Rev wind farm with the objective of testing a hydroacoustic technique to measure fish density in the wind farm in comparison to the non-affected area (Hvidt *et al.* 2005). The results brought to light that the wind turbines or the hard substrate had little to no effect on the fish density in the wind farm. These results appear to point to the fact that fish do not experience any nuisance from the sound produced by the wind turbines, or that they get used to it. In addition, it may be that the fish are bothered by the noise but that other factors make the wind farm attractive to the fish anyway.

Sharks and rays

In addition to the effect of the physical presence of wind farms, cables in the farm and the high-voltage cables that transport the energy to the shore may play a negative role as to bottom fish. Negative effects (such as loss of habitat) can especially be expected on fish species that use electric impulses to catch their prey, like sharks and rays. These species apparently avoid being near a strong electric field (Gill & Taylor 2001). Most fish can perceive electric and magnetic fields and, in part, orient themselves by this. Sharks and rays are most sensitive to electric and magnetic fields and the species found in the biggest numbers in the North Sea are bottom dwellers. It has been demonstrated that sharks and rays can perceive prey with an electric field of 10^{-8} V/m. Sharks are even attracted by electric fields in the range from 10^{-7} to 10^{-3} V/m (Gradient Corporation 2006). In addition, sharks are very sensitive to magnetic fields. The detection limit for this is approximately 1.2 nT (Gradient Corporation 2006). This means that they can perceive the cables up to a distance of several dozen metres (depending on the depth of the cables and the sheathing, so this observation does not apply in general).

If bottom fish avoid an area where the magnetic field has changed, the electric cable between the wind farm and the shore could form a certain barrier. It is theoretically possible that the orientation and migration of these species are affected by the slight change in the magnetic field. Both (bottom-dwelling) sharks and rays, however, can get away from the bottom and swim over a dug-in cable. Therefore in most Dutch EIAs for new offshore wind farms the reasoning is that the effect of cables is local and does not extend beyond several metres, as a result of which sharks and rays will be able to pass.

Insofar as the authors know, sharks and rays are not specifically included in European monitoring plans (current and planned).

3.5.4 Benthos

Research on the composition of the benthic fauna in and near wind farms is carried out due to the anticipated changes in sediment composition as a result of changes in current patterns (Bech *et al.* 2005). Indirect effects are also expected because of an increase in the density of fish in the wind farm, leading to an increase in predation pressure (Bech *et al.* 2005), to indirect effects of a different species composition due to introduced of hard substrate, and because of the absence of bottom-disturbing fishing. Results of Danish studies show that changes in benthic species composition in the Danish studies are nil (Bech *et al.* 2005). Mussels dominated, so that the increase in biodiversity at the piling foundations was minor, for the time being (Hvidt *et al.* 2006).

Exclusion of bottom-disturbing fishing (refuge)

Bottom-disturbing fishing, as with a beam trawl, can have a major effect on the species composition of the benthos. Species that live on or against the bottom surface and can grow old there (in the absence of frequent bottom-disturbing fishing) have become very rare in the Southern Bight of the North Sea. Because fishing in wind farms is excluded, such species will perhaps get another chance, and can subsequently also start providing spawning from the wind farms to a larger area (Bergman & Hup 1992; Bergman *et al.* 1995; Lavaleye *et al.* 2000; Bergman *et al.* 2005; Lindeboom 2005).

Hard substrate

Hard substrate is introduced with the construction of wind farms. Natural hard substrate is seldom found in the North Sea. In addition to naturally occurring shellfish banks, sunken shipwrecks, oil platforms and dike base reinforcement and fascine mattresses provide

additional hard substrate. Besides changing the species composition, hard substrate can also accelerate the introduction of invasive species.
Studies near Horns Rev (Leonhard & Petersen 2006) show that the growth on piling and dumped rock proceeds in accordance with a certain succession, creating clear vertical zoning. A more or less stable community is estimated to be formed after approximately 5 to 6 years. Storms can prolong the process.

The Japanese oyster *Crassostrea gigas* can be cited as an example of an invasive species that has spread as a result of a change in habitat. This species is increasing spectacularly everywhere along the West European coasts and clearly profits from the increase in construction of artificial hard substrates. In some areas, mussel banks are threatened with a gradual change to oyster banks (Reise 1998), although this does not seem to be the case in Dutch estuaries (Troost 2009).

3.6 More details on information questions

3.6.1 Elaboration of information questions

A summary of required information and the research questions linked to it that are required to make decisions on the anticipated ecological effects of current and still to be built wind farms are shown in table 3.3. for each ecological group. The selected ecological groups are fish larvae, fish (juvenile and adult), marine mammals, sea birds, breeding birds and migratory birds. In so far as plankton are concerned, it is assumed that the negative effects of wind farms on this group are of less importance, or even negligible. Effects on the water column and plankton life are included, however, for the sake of completeness. Although until present benthos has not had a high urgency in the effect measurements, it is not opportune to exclude the possibly “positive” effects on this group. Due to the exclusion of bottom fisheries and the organic enrichment from the hard-substrate organisms, the benthos in the soft substrate may undergo an increase in numbers, biomass and productivity that have a secondary effect on fish and birds. Such effects may have a damping action on the possibly negative effects of wind farms on birds, for example, and are therefore in principle of interest to be included in monitoring.

The classification of table 3.3 serves as a guideline for the order of description of the various gaps in information in section 3.6.2 ff.

The table must be read as follows: the columns of the effects are itemized per ecological group, from left to right, via identification of the requisite information to the formulation of the research question per gap in information.

- *Physical effect:* The ecological effects of wind turbine farms at sea are categorised in accordance with the physical effect that takes place per interference: underwater noise (pile driving, operational phase and removal), change in/loss of habitat (construction, removal, operational phase), barrier effect (operational phase) and electromagnetic fields (operational phase).
- *Information required:* A description, per category, of what information is generally necessary to make decisions on the effect.
- *Information gap:* Description of the gaps for each information type.

- *Information questions:* A formulation of the corresponding research question is given for each information gap.

Table 3.3: Overview of the gaps in information and questions per animal group

Physical effect	Interference category	Ecological problem	Information required	Information gap	Information questions
Plankton					
change in habitat	operational phase	disruption of the water column current	effects of turbine pile on current, processes and on phyto- and zooplankton communities, mutual trophic relations between phyto- and zooplankton	hydrodynamics, relations, laminary/turbulent current on phyto- and zooplankton growth, effect on food web relations between phyto- and zooplankton	how is the current disrupted around the turbine pilings, to what extent are the phyto- and zooplankton communities and their mutual relations disrupted by changes in the current
Benthos					
change in habitat	construction/ removal	disruption of bottom integrity	effects on the structure of organisms, composition of and chemistry in sediment, regeneration capacity	the average is known; local knowledge on structure of organisms, composition and chemistry in the sediment is absent, regeneration capacity only known in a very general sense	what is the structure of the organisms and the composition and chemistry of the sediment on site; how quickly does this structure restore itself
		pollution	sensitivity to toxic substances	threshold values, effects of substances	effects on the benthos by toxic substances released from the bottom during construction/removal of turbines and installation/removal of cables. Bioaccumulation.
	operational phase	change in sediment morphology and composition	changes in seabed topography; mutual relations in physics, chemistry, ecology of sediment	effect topography on benthos relations are practically unknown	mutual relations; what determines the appearance of organisms and what is the interaction with topography, physics and chemistry
		addition of hard substrate	colonisation and succession on hard substrate	reasonably well known, secondary effect on the water column unknown	what is the secondary effect of hard substrate organisms on ecology of the water column and the bottom
			benthos recruitment	recruitment processes	what is the secondary effect of hard substrate organisms on the ecology of the water column and bottom how does the recruitment of benthos proceed without and with hard substrate
		pollution	sensitivity to toxic substances	threshold values, effects of substances	effects on benthos of toxic substances (Al) which are released from anodes on turbine pilings. Bioaccumulation.
Fish larvae					
basic information			density of species	numbers, seasonal rhythms, distribution area	distribution pattern of fish larvae per time unit (month) expressed in percentages of the population
			dispersion patterns	life-history of species	percentage of surface area where the wind farms have an effect on fish larvae in comparison to the surface are of the dispersion area
underwater noise	pile driving	physical damage?, mortality?	sensitivity to frequency/levels	threshold values, noise effects	effects of pile driving noise on physical condition of fish larvae, including limit values

cal effect	Interference category	Ecological problem	Information required	Information gap	Information questions
			radius of damage/mortality to source	threshold values, noise effects	effects of pile driving noise on physical condition of fish larvae, including limit values
	operational phase	physical damage?, mortality?	sensitivity to frequency/levels	threshold values, noise effects	effects of noises of operational wind farms on physical condition of fish larvae, including limit values
			radius of damage/mortality to source	threshold values, noise effects	effects of noises of operational wind farms on physical condition of fish larvae, including limit values
e in habitat	construction / removal	pollution	sensitivity to toxic substances	threshold values, effects of substances	effects on fish larvae of toxic substances released from the bottom during construction/removal of turbines and installation/removal of cables
	operational phase	pollution	sensitivity to toxic substances	threshold values, effects of substances	effects on fish larvae of toxic substances (Al) released from anodes on turbine pilings
vater noise	pile driving	physical damage, disruption	sensitivity to frequency/levels	threshold values, noise effects	effects of pile driving noise on physical condition and behaviour of fish species, including limit values
			radius of damage/disruption to source	threshold values, noise effects	effects of pile driving noise on physical condition and behaviour of fish species, including limit values
	operational phase	physical damage?, disruption, blockage	sensitivity to frequency/levels	threshold values, noise effects	effects of noise of operational wind farms on the physical condition and behaviour of fish species, including limit values
			radius of damage/disruption to source	threshold values, noise effects	effects of noise of operational wind farms on the physical condition and behaviour of fish species, including limit values
e in habitat	construction / removal	disruption, masking	behaviour reaction to disruption	reactive behaviour of species (groups)	effects of work on construction/removal of wind farms on the behaviour of fish species, including range and duration (temporary/permanent)
	operational phase	loss of present habitat, can also be due to avoidance behaviour	density of species	numbers	loss of habitat for (surface) rock avoiding fish species in comparison to the total, including species specification and species densities
		addition of hard substrate	habitat use	life-history of species	habitat use of fish with an affinity for rocks, including species specification and species densities
			density of species	numbers, seasonal rhythms	habitat potency (surface) of fish species with an affinity for rocks in comparison with the total, densities
		refuge - less disruption	change in density of species	numbers, seasonal rhythms	density of fish species in (the vicinity of) the farm in comparison to the surrounding area
		refuge – change in bottom species	change in density of species	numbers, seasonal rhythms	density of fish species in (the vicinity of) the farm in comparison to the surrounding area
		food supply	density of prey species	numbers, seasonal rhythms	density of prey species in (the vicinity of) the farm in comparison to the surrounding area

Physical effect	Interference category	Ecological problem	Information required	Information gap	Information questions
		pollution	sensitivity to toxic substances	threshold values, effects of substances	effects of toxic substances (Al) released from anodes on turbine pilings on fish. Bioaccumulation.
electromagnetic fields	operational phase	disruption, physical damage?	behaviour reaction to disruption, prey detection	reactive behaviour of species (groups)	effects of electromagnetic fields on the behaviour of fish species, including limit values
		avoidance	migration patterns	numbers	percentage of surface area where the wind farms have an effect on fish species in comparison to the surface are of the dispersion area
Marine mammals					
basic information			density of species	population size & distribution (sub) population seasonal rhythms, distribution area	distribution pattern of marine mammals per time unit expressed in percentages of the population
			dispersion patterns	life-history of species importance of habitats for forage, reproduction, etc.	percentage of surface area where the wind farms have an effect on marine mammals in comparison to the surface are of the dispersion area
			basic information on marine mammal hearing	hearing sensitivity parameters such as basis audiogram, critical ratio, directionality of hearing, TTS, and PTS	determine whether wind farm noise can be heard and if so at what distance and at what background noise levels
underwater noise	pile driving	physical damage, disruption	sensitivity of behaviour to frequencies/levels	threshold values, noise effects	effects of pile driving noise on the physical condition and behaviour of marine mammals, including limit values
			radius of damage/disruption to the source	threshold values, noise effects	effects of pile driving noise on the physical condition and behaviour of marine mammals, including limit values
	operational phase	disruption, masking	sensitivity to frequency/levels	threshold values, noise effects, critical ratio, critical bandwidth	effects of noise of operational wind farms on the physical condition and behaviour of marine mammals, including limit values
			radius of damage/mortality to the source	threshold values, noise effects	effects of noise of operational wind farms on the physical condition and behaviour of marine mammals, including limit values
change in habitat	construction / removal	disruption, masking	behaviour reaction to disruption	reactive behaviour of species (groups)	effects of work on construction/removal of wind farms on the behaviour of marine mammals, including range and duration (temporary/permanent)
	operational phase	loss of present habitat	density of species	numbers, distribution	loss of habitat for (surface) farm-avoiding marine mammal species in comparison with the total, including species specification and species densities
		refuge - less disruption	change in density of species	numbers, seasonal rhythms	density of species in (the vicinity of) the farm in comparison to the surrounding area
		food supply	density of prey species	numbers, seasonal rhythms	density of prey species in (the vicinity of) the farm in comparison to the surrounding area
barrier effect	operational phase	avoidance	migration patterns	numbers, distribution	percentage of surface area where the wind farms have an effect on marine mammals in comparison to the surface are of the dispersion area

cal effect	Interference category	Ecological problem	Information required	Information gap	Information questions
e in habitat	construction / removal	disruption	behaviour reaction to disruption	reactive behaviour of species (groups)	effects of work on construction/removal of wind farms on the behaviour of birds, including range and duration (temporary/permanent)
	operational phase	loss of present habitat	density of species	numbers, distribution	loss of habitat for (surface) farm-avoiding bird species in comparison with the total, including species specification and species densities
		food supply	density of prey species	numbers, seasonal rhythms	density of prey species in (the vicinity of) the farm in comparison to the surrounding area; food ecological research in breeding colonies in combination with research on reproductive success in coordination with research on the importance of prey around and in the wind farm
n and barrier	operational phase	collision risks	risk of collision	threshold values	percentage of collision of bird species in the farm, seasons
		gain in habitat: new perches for cormorants	population increase and predation pressure of cormorants on local fish	population development, foraging behaviour and quantities, species of fish eaten	effects of wind farms as stepping stones in population development of cormorants in the North Sea
		food supply	density of prey species	numbers, seasonal rhythms	density of prey species in (the vicinity of) the farm in comparison to the surrounding area, food ecological research in breeding colonies in combination with research on reproductive success
n and barrier	operational phase	collision risks	risk of collision	threshold values	percentage of collision of bird species in the farm, seasons
			density of species	numbers, seasonal rhythms	density of bird species in the farm, seasons population dynamics of colonies (floaters)
		avoidance	migration patterns	numbers, distribution	percentage of surface area where the wind farms have an effect on migratory birds in comparison to the surface are of the dispersion area

3.6.2 Gaps in information

Despite the many indications of effects of wind farms on the marine environment as listed in table 3.3, to present there is still a lack of such information in various areas. Even though a number of gaps of information and uncertainties will already be filled in, and uncertainties clarified, over the next few years by means of effect measurements in Monitoring and Evaluation programmes (MEPs) of offshore wind farms in the Netherlands and abroad, these studies will not be complete, or will only be too local to derive predictions of the most significant effects.

Information on fundamental matters such as sensitivity of marine organisms to noise intensity, the spectrum of the noise, and electromagnetic fields (marine mammals, fish and fish larvae), collision risks (birds) or habitat preference (bottom fish) is necessary in order to estimate the effects of the farms on the marine environment. In addition, information on the spatial distribution and seasonal patterns in the occurrence of the various life stages of the marine organisms is important (since this can vary significantly from year to year). At the same time, little is known concerning technical aspects of the farm and the surroundings, such as the natural background noise and the noise spectrum and noise levels during construction, use, maintenance and removal of the wind farms.

Such insights can be used to determine the extent to which the distribution of animals and that of potential disturbance sources overlap, and how harmful activities could possibly be mitigated.

Below, an overview is given per “effect area” of the gaps in information as given in the former table 3.3. In addition to the above-mentioned “effect areas” habitat – marine mammals, underwater noise has a separate section. A separate workgroup managed by NSIDM is currently mapping the research questions involving underwater noise.

Plankton

Almost nothing is known concerning the effects of turbulence on stratification, nutrient mixing and the secondary effect on plankton communities in the sea, nor what immediate effect turbulence has on the composition of such communities or how this changes the predator-prey relations between phytoplankton and zooplankton. Incidentally, such changes are expected to be local and quantitatively will have presumably negligible effects on the structure and functioning of the local food web.

Benthos

Research concerning the effects on benthos particularly makes sense due to the food web effects on fish (and further up in the web) that can occur. On the one hand, there is marginal loss of soft substrate, but on the other there is presumably an increase in numbers and biomass of soft substrate species due to halting the bottom disturbance caused by trawl fishing (Jennings *et al.* 2001). Production of benthos on hard substrate can also have a secondary effect on fish. Such effects are currently being studied at the Thornton Bank wind farm (Jan Reubens, University of Ghent, Belgium).

In addition to the food web effects on fish, other unknown effects of these changes are the introduction of stepping stones for invasive species or exotics. Low-frequent monitoring of the sessile species on the pilings will enable good tracking of a possible change in species and any secondary effects on the structure of the pelagic food web. The extent to which this is still necessary will depend on what the results are of comparable studies on growth on pilings such as for the FINO platforms in the German Bight and the western Baltic as well as the existing OWEZ offshore wind farm. The growth on pilings in the new wind farms can be expected to be comparable to that on the existing pilings (Kerckhof *et al.* 2009).

Contamination from sediment could accumulate in benthos, but could also result in lowering the fitness of the benthos itself.

Fish larvae

The most significant gaps in information on fish larvae are on the one hand fundamental insight into the spatial and temporal distribution of said larvae, and on the other, the effects of the underwater noise (especially pile driving) on their survival.

Basic information

Some information is available on the distribution of just a few commercial species (herring, mackerel, cod, sole and dab), but there is no information available on rare and non-commercial species (Ter Hofstede *et al.* 2008). Insight into the spatial distribution and seasonal patterns of marine fish larvae can be used to determine the extent to which their distribution overlaps at times with that of the potential sphere of influence of wind farms and how harmful activities can be mitigated.

Underwater noise

The principal presumed effect of wind turbine farms on fish larvae is damage and death as a result of the pressure waves released with the noise of pile driving work during construction of wind farms (Prins *et al.* 2008). A fish larvae model has been developed that can estimate the consequences of death of fish larvae during their passive transport from spawning grounds to nurseries (Prins *et al.* 2009). However, a very important but poorly substantiated premise is the extent of mortality around the pile driving site. Such information is not available.

Change in habitat

The extent to which toxic substances will be released from the sediment during installation of cables and foundations is not clear. It will depend a great deal on the location. When the wind farms in the North Sea are upscaled from several to dozens, the contribution of aluminium released from anodes will also increase. No dose-effect studies are available which show a limit value for the toxicity to marine organisms.

Fish

As the scale diminishes, the information on distribution of fish species decreases, and location-specific data on the fish communities at the level of wind farms are absent. Research on the effects of a wind farm on the fish community will therefore always have to be accompanied by studies in reference areas. As a fish species is rarer or less commercially attractive, the information available decreases significantly.

Underwater noise

Insight into threshold values and the duration of noise levels at which disturbance of the behaviour or damage is caused is not available. Provisional results from research in MEP-OWEZ during the operational phase show that tagged individuals of the cod and sole species are present in the farm during several consecutive months, which suggests that the noise may not have a repelling effect (E. Winter, IMARES, pers. com.). The noise could still have a masking effect, thus having a negative effect on reproduction, for example. Many fish species, including commercially important species such as sole and plaice have no swimbladder and they are thus predominantly sensitive to the particle motion component of sound, rather than the pressure component. There is a large gap in knowledge on a) magnitude and extent of the particle motion fields connected both to pile driving and to operational wind turbines, and b) the effects of intense particle motion (as from pile driving) on fish. There is a very poor understanding of how fish use sound in communication and even poorer understanding of how masking could affect reproductive success.

Change in habitat
The extent to which introduction of hard substrate has an aggregation effect on fish is unknown. Provisional results from research in OWEZ during the operational phase show that tagged individuals of the cod species clearly establish some connections with specific pilings (*homing*) (E. Winter, IMARES, pers. com.). The refuge effect due to the absence of fishing is likewise unknown.
Moreover, fishing activities will continue to be prohibited in wind farms for reasons of safety, so that fish are no longer caught and the bottom remains undisturbed. The extent to which this refuge function for fish exists is unclear.

Just as is the case for fish larvae, contamination from the sediment and foundations can have an effect on fish, also via bioaccumulation in benthos. This information is lacking.

Electromagnetic fields
Electromagnetic fields are created by electrical current through cables (AC or DC) which connect the turbines to one another and to the power plants ashore. Presumably the effect is limited due to the relatively small surface area affected by cables, and because the range of the fields is limited. Various studies on electromagnetic fields and the effect on sharks and rays indicate possible disturbance of the behaviour of these fish, but are in conflict with the effects that may be both negative (avoidance) as well as positive (attraction), and therefore additional research is desirable.

<u>Birds</u>

Basic information
Basic information on distribution of birds at sea is currently incomplete and is indispensable in order to make an estimate of the effects of wind farms on birds during the construction, operational and removal phases. In connection with the spatial distribution of birds on the DCS, information is required concerning the spatial use of foraging areas and migration routes during the various seasons.

Change in habitat
The construction of wind farms has consequences on the use of habitat by birds. Avoidance is farm and location-specific and will have to be studied per site. Specific configurations may produce data whereby avoidance changes noticeably (density, for example, whereby birds will go around the farm more than between the pilings, or whereby they still enter the farm but no longer forage there). Changes in the food supply (fish distribution, discard reduction, changes in benthos) is partially generic, partially farm-specific. The extent to which this has secondary effects on the behaviour and fitness of birds is unknown. There is an almost total absence of information on how diving birds use underwater hearing in their search for prey and orientation and consequently no information on how birds could be affected by underwater noise, both during construction and operation.

Collision risks, barrier effect
The collision risks by and avoidance of farms and turbines are closely connected. Both large-scale avoidance of farms by migratory birds and local avoidance by sea birds or breeding birds are presumably farm-specific (see above). It is possible that there are more generic patterns of avoidance for migratory birds on certain routes. On land, collisions of birds with wind turbines are frequent (e.g. Everaert & Stienen 2007). Direct collisions of birds with OWFs have been observed only in a few cases, in part because of practical and technical

limitations. The newest generation of GPS loggers with onboard accelerometers and with the possibility of extremely high resolution as far as orientation is concerned (one fix per minute or even more frequently) is a very important innovative technology which can show the use of space by active breeding birds in three dimensions (provided properly linked to field work in the colonies from where the logged birds start off). Not only will orientation then be available, but also day/night, weather conditions, flying altitude, flying speed and type of flying behaviour (plus an interpretation of what is happening at sea in a food ecological sense), resting behaviour, and avoidance behaviour if applicable. By using these new data, the collision models can be run again, but now with the correct data, in order to give a better estimate of the effects at (a) population level.

Bats

There is practically no basic or location-specific information concerning bats at sea. It is unclear what bats are doing so far offshore at sea, except for (presumably) migrating. Species, distribution, the use of (migration/habitat) area, avoidance of wind farms and turbines; the information available on all these terrains is only very limited.

Marine mammals

For pile driving it is established that porpoises react to the noise at distances of up to many kilometres. What remains to be established is what the behavioural changes are and what they mean to the animals. It is thus of great importance to establish a link between behavioural changes and fitness of individuals and populations. What does a temporary displacement from the area mean in terms of reduced food intake and reduced ability to nurse calves/pups and how do these changes ultimately affect population parameters (survival and fecundity)? Behavioural effects on other species (seals, dolphins, minke whales) remain to be established. The same applies, although on a much finer spatial scale, to be addressed for turbine noise.

Basic information

No specific migration or foraging areas can be indicated for marine mammals; they may not exist, or they may regularly vary their locations. There is a great need for information on spatial and temporal distribution patterns in the North Sea, the importance of the various parts of the southern North Sea as a foraging, resting and reproduction habitat, and the relative importance of the DCS, especially for the porpoise and white-beaked dolphin, but also for the bottle nose dolphin and the common minke whale. With respect to the porpoise, the large shifts that have been occurring in the past decade are notable. Even though a food-related cause is suspected, it is unclear what the exact cause is and what the effect is on the distribution behaviour of this species throughout the North Sea. Insight into the distribution/migration on a North Sea scale and the use and importance of various parts of it is lacking for the common and gray seals. Perhaps some particular marine mammals can utilise a relatively rich microhabitat (such as monopiles with dumped rock), but it is just as possible that they will have to avoid these potential food hotspots due to noise nuisance.

Underwater noise

In a general sense, relatively little is known concerning the effect of underwater noise (vibrations) on the behaviour of marine mammals. No data are known as yet about any direct harmful effects on the hearing organs of marine mammals of the North Sea. Furthermore, it is not known what type of noise and levels cause changes in behaviour, under different conditions (rest, foraging, pregnancy, migration, size of habitat, etc.). It is unknown how marine mammals respond to these noises over in the short term as well as when chronically exposed to underwater noise. The effects of underwater noise in the operational phase of the wind farm are important with respect to masking of communication between members of the same species, and between predators and their prey. This applies even more during large-scale construction and the presence of wind farms. Changes in behaviour may lead to decreased population fitness.

Change in habitat
The operational phase has a longer term effect than the construction phase, and for safety reasons fishing activities and other navigation traffic are prohibited in wind farms. Whether this has an attractive effect on marine mammals is unknown. The extent to which the change in food supply (fish, benthos) for marine mammals has a secondary effect in a farm on the foraging options of marine mammals is unclear.

Barrier effect
During construction, presence and removal, the OWFs can begin to form a barrier whereby the migration patterns are disrupted. Even though both porpoises and seals were found during the operational phase in the OWEZ farm, the question is to what extent such observation are a reflection of a structural presence of marine mammals in the wind farm. Neither is the extent to which these animals demonstrate customary behaviour in the wind farm clear as yet.

3.6.3 Monitoring and research questions

The section above elaborated the gaps in information per ecological group. The most important research questions linked to these gaps are posed in the current section for each ecological group and effect. The underwater noise has a separate place in this due to the generic role of this information in the effects on fish larvae, fish and marine mammals.

<u>Underwater noise (physical aspects)</u>

The following research questions – derived from the gaps in information – are relevant when deciding on a monitoring regulation for underwater noise in order for answers to be found for solving the ecological problems. The following components are currently of concern for underwater noise:

- What sources are there and how can they be described as source noise/level (*sources*)?
- What supplementary research is required to develop a proper propagation model (*models*)?
- What supplementary data or research is required in view of the hearing characteristics of the effect species (fish, fish larvae and marine mammals) (*effects*).

Sources:
- What variables must be measured: noise pressure or particle velocity, or both?
- Under what conditions must measuring take place (wind force, swell, noise velocity profile, season, day/night, current as a consequence of tides)?

- What supplementary parameters must be measured in addition to the underwater noise (wind force, swell, noise velocity profile, season, day/night, current as a consequence of tides, precipitation, passing ships, etc.).
- How long should measuring take? Continuous, samples, events? One day, a week, a year, 20 years? Such matters should be synchronised internationally.
- What noises must be monitored: only the noise produced by the wind farm, or the natural background noise and noises marine mammals use to communicate as well. In other words: is the concern monitoring the noise of the wind farm, the background noise or monitoring the marine mammals, or is the concern all three of these?
- At what depths must the noise be measured?
- How can an operational wind turbine be characterised as a source?
- How can a pile be characterised as a source?
- Is it necessary to measure at the same point in time at different locations?
- Is it necessary to measure at the same location at different points in time?

Models
- What frequency band is of importance?
- How many measurements are required before the calculation model can be trusted to the extent that measurements still exclusively serve as calibration of the model, but not as validation?
- What noise propagation methods are suitable to use to draw up a map on the basis of the measurements?
- For a frequency analysis: is a division in third octave bands desired, or is a higher frequency resolution required?

Effects
- At what locations in and around a wind farm must the underwater noise be measured?
- The character of pile driving noise at a short distance is pulsating, e.g. 45 pulses per minute. Is this characteristic preserved even at larger distances or will it become a continuous noise? This is important because the impact of pulsating noise on animals is higher than the impact of continuous noise.
- What information must be retrieved from the recorded noises? In other words, what information must be presented on the map? Examples: peak level, noise exposition level (and for how long on average? 24 hours, a year?)
- Should an assessment be made that takes the specific hearing properties of the animal into account (compare with the well-known A assessment for air noise for humans)? And if so, which animals are relevant? Possibilities: common seal (*Phoca vitulina*), grey seal (*Halichoerus grypus*), porpoise (*Phocoena phocoena*), white-beaked dolphin (*Lagenorhynchus albirostris*), certain selected fish species (all age classes).

<u>Plankton</u>

Change in habitat:
- Impact of changes in (turbulence) current due to pilings.
- Effect of turbulent current on species composition and growth of phytoplankton.
- Idem zooplankton.
- Impact of turbulence on phytoplankton and zooplankton predator-prey relations.
- Secondary effect of colonising hard substrate on the water column ecology.

Benthos

Change in habitat:
- Effect of bottom disruption during construction on structure, physics and chemistry of the bottom and on the benthos ecology.
- Impact of the absence of bottom fishing on physics, chemistry of the bottom and on the benthos ecology.
- Development of species and densities of the species on hard substrate.
- Impact of colonising hard substrate on recruitment and density of endemic benthos.
- Impact of hard substrate as “stepping stones” for non-endemic benthos.

Fish larvae (and fish eggs)

Basic information:
- What are the spatial distribution and seasonal patterns in abundance of relevant species of fish larvae, relevant to birds and marine mammals, on the Dutch Continental Shelve?
- Basic information on hearing parameters of all relevant fish species in the North Sea.
- Basic information on behavioural reactions of relevant fish species to various types of noise (spectrums) and levels.

Underwater noise:
- What is the sensitivity (death, physical damage) of fish larvae to underwater noise with respect to noise levels and distance to the source, generated during the construction phase (pile driving), operational phase and the removal phase of wind farms?

Change in habitat:
- What is the sensitivity (death, physical damage) of fish larvae to micro-pollution as a result of release of toxic substances from the sediment when constructing wind farms and the release of heavy metals from the turbines to the surrounding area during the operational phase?

Fish (juveniles and adults)

Underwater noise:
- What is the sensitivity (physical damage) of fish to underwater noise with respect to noise levels and distance to the source, generated during the construction phase (pile driving), the operational phase and the removal phase?

Change in habitat:
- How does the local fish community change as a result of disruption of the habitat during the construction and removal phases of wind farms?
- How does the local fish community change as a result of closing wind farms to fishing during the operational phase?
- How does the local fish community change as a result of changes in the food supply in wind farm during the operational phase?
- What is the sensitivity (death, physical damage) of fish to micro-pollution as a result of release of toxic substances from the sediment when constructing wind farms and the

release of heavy metals from the turbines to the surrounding area during the operational phase?

Electromagnetic fields
- What is the sensitivity of sharks and rays to the electromagnetic fields that are created by the cable network between the turbines, as well as the connection between the wind farm and the power plants ashore?

<u>Marine mammals</u>

Basic information:
- What are the spatial distribution and seasonal patterns in abundance of marine mammals in the North Sea, and what is the variation in migration routes? Much less is known about cetaceans than about seals.
- Are there any sub-populations with behaviour different from the others?
- What are the most important habitats for food, rest and reproduction of the various species of marine mammals to be studied.
- Basic information on hearing parameters of all relevant marine mammals in the North Sea.
- Basic information on behavioural reactions of marine mammals to various types of noise (spectrums) and levels.

Underwater noise:
- What is the sensitivity (PTS, TTS, avoidance, injury) of the various species of marine mammals to underwater noise, with respect to noise levels and distance to the source, generated during the construction phase (pile driving), operational phase and the removal phase of wind farms?

Change in habitat:
- How does the spatial distribution of marine mammal populations change as a result of disruption of the habitat during the construction and removal phases of wind farms?
- How does the spatial distribution of marine mammal populations change during the operational phase of wind farms, and what causes this?

Barrier effect:
- To what extent do wind farms disrupt the migration patterns of marine mammals?

<u>Birds</u>

Basic information:
- What are the spatial distribution and seasonal patterns in abundance of birds in the North Sea?
- What are the most important habitats and food sources of birds at sea and what determines the importance?
- What are the most important migration routes of birds over the North Sea? Is their broad front migration, or are there specific corridors, and what features are used to orientate? Can OWFs play a role in orientation?

Change in habitat:

- How does the spatial distribution of bird populations change as a result of disruption of the habitat, and food supply, during the construction and removal phases of wind farms?
- How does the spatial distribution of bird populations change as a result of changes in the food supply in wind farms during the operational phase?

Barrier effect:

- To what extent do birds fly around OWFs and what are the consequences of this on the fitness of the relevant species?
- To what extent do wind farms disrupt the migration patterns of birds?

Collision risks

- What are the collision risks per bird species of a collision with turbines of wind farms (linked to relevant information on avoidance and barrier effect)?

3.6.4 Monitoring and research requirements

This paragraph describes the requirements and methods for the research questions described above. It should be noted however, that the methods described here are not exclusive or a blueprint for how the research and monitoring should be done. They are derived from experiences by the authors of this report and apply for the circumstances in Dutch near-coastal waters, and thus probably for a limited set of habitats and species. As such, they may not be applicable in environments deviant from those at the Dutch continental shelf.

Plankton

- Species composition, biomass and production of phytoplankton and zooplankton during the operational phase in and outside the farm (impact of pilings on turbulence and pelagic ecology, secondary effect of hard substrate organisms on plankton)
  - Method: sampling of the water column with the plankton net during the day and at night. Food relations to be studied by means of fatty acid analyses/isotopes, DNA barcoding.
- Impact of foundations of turbulence of the water column and mixing nutrients during the operational phase in and outside the farm:
  - Method: setting up a grid with current meters, optic sensors (oxygen, nutrients, temperature), sonar (turbulence).

Benthos

- Effect of bottom disruption during the construction on structure, physics and chemistry of the bottom and on the benthic community
  - Method: Box cores and sledges in and outside the farm (and before and after impact), measurements of depth profile physics, chemistry and benthos
- Impact of absence of bottom fishing on structure, physics and chemistry of the bottom and on the benthic community
  - Method: Box cores and sledges in and outside the farm (and before and after impact), measurements of depth profile physics, chemistry and benthos
- Species development and densities of species on hard substrate
  - Method: Scuba divers (inspection, physical sampling), cameras (inspection); sampling will be necessary for species identification

- Impact of colonisation of hard substrate on recruitment and density of endemic (and non-endemic) benthos
    - Method: colonisation experiments with experimental sediment trays inside and outside the farm.

Underwater noise physics
- Composition, intensity and range of noise produced by wind farms during construction phase, operational phase and removal phase
    - Method: noise must be measured in the field on the basis of which models can be drawn up that can standardise this noise (source noise). There are several possible methods to do so, and synchronisation is necessary with the research plan as presently set up by TNO. Measurements made in the field at standardised distances from turbines (during pile driving and removal as well as in the operational phase) provide information on spectra, noise pressure levels, propagation etc. In addition, mapping the underwater noise in the southern North Sea by means of surveys using hydrophones is also under consideration. The reaction of fish (as well as marine mammals, see below) is largely determined by the background noise.
- Composition, intensity and range of background noise in the (southern) North Sea
    - Method: noise should be measured in the field on the basis of which a noise map of the North Sea can be compiled via interpolation, by means of modelling.

Fish larvae (and fish eggs)

Basic information:
- Spatial distribution and seasonal patterns in abundance of fish larvae on the DCS, whereby the temporal and spatial cover is sufficiently detailed for a reliable assessment of the dynamics of fish larvae.
    - Method: DCS-wide (monthly) ship survey including targeted fishing using plankton nets.

Underwater noise:
- Distance to the source whereby death and physical damage of fish larvae takes place, caused by exposure to noise produced by or similar to that of wind farms during the construction, operational and removal phases.
    - Method: experiments can be carried out in the field as well in laboratory set-ups whereby larvae are exposed to various spectrums and noise (pressure) levels. In the field, little bags with larvae and/or eggs can be suspended at various distances from a pile driving location. In the laboratory, it can be examined whether and how pulsing noises harm larvae and/or eggs. The difficulty with this is that it physically impossible to reproduce realistic pile driving pulses (in terms of frequency-content as well as noise pressure and particle velocity ratio) in pools of limited dimensions: the long wavelengths do not fit in a small pool.

Change in habitat:

- Composition of contaminating substances released from the sediment during the construction phase of wind farms by means of field measurements.
    - Method: water samples can be taken in the field (e.g. rosette samplers) in which the compounds dissolved and absorbed on particles can be analysed. Sediment samples can also be taken, with a box corer to measure the source concentration and calculate the (biological) availability of it via extraction tests. The distribution can be assessed by means of modelling.
- Extent of release of contamination from the turbines into the surroundings during the operational phase.
    - Method: a (model) study has already been carried out for aluminium released by anodes. Comparable studies can be carried out for other substances, depending on what substances may be released by a turbine.
- Dose-effect relations of contaminations released from the sediment during the construction phase of wind farms and from turbines, whereby fish larvae/eggs can be subject to (sub)lethal effects.
    - Method: Such dose-effect relation tests can be carried out in laboratory set-ups (have been informed that research is already being done on this. Source: Cindy van Damme)

Fish (juveniles and adults)

Underwater noise:
- See the statement under fish larvae, but then applied to fish.

Change in habitat:
- Change in the composition of the local fish community due to the construction of a wind farm.
    - Method: by means of monitoring surveys (fishing with nets) before and during construction. The extent to which this technique can be applied and lead to measurable results is still unclear. The heterogeneity in species and numbers is often extensive (both in space and time) and the noise can be so intense that one cannot fish close enough to the wind farm.
- Change in the composition of the local fish community due to closing OWFs to fishing.
    - Method: monitoring surveys during the operational phase inside and outside the wind farm. We do make the observation here that a great deal of thinking must still be done about the fishing technique. No effect was demonstrated in Horns Rev after the first two years, and the fishing method involved standing nets. Innovative methods such as used by OWEZ presently need to be considered (transmitter study).
- Change in the composition of the local fish community due to possible refuge function (= aggregation) of wind farms.
    - Method : as above.
- Change in the composition of the local fish community due to changes in the food supply in wind farms.
    - Method: fish caught as above, including stomach examination.
- For contamination, see the statement under fish larvae, but then for fish.

Electromagnetic fields
- Intensity and distribution of electromagnetic fields produced by the cable network of wind farms during the operational phase.
    - Method: measurements of magnetic fields during the operational phase.

- Threshold values of electromagnetic radiation similar to radiation caused by the cable network of wind farms, whereby behavioural changes occur in sharks and rays (and possibly other fish).
  - Method: behavioural studies using test set-ups in pools.

Marine mammals

Basic information:
- Spatial distribution and movements of marine mammals on the DCS (rather broader to get a better understanding of the ecology of the animals).
  - Method: countings by observers on board aircraft and/or ships (comparison is difficult). High-definition cameras attached to aircraft. Hydrophones behind ships. Each method has its limitations. There is still a great deal of uncertainty, especially involving the use of passive acoustic observation by means of T-Pods (or C-Pods) in order to estimate absolute numbers of porpoises. This has to do with the chance of a detection, the dependency on the precise sensitivity of the T-Pod, the dependency on the prevailing background white noise and the dependency on the classification software. There is currently insufficient information on this. The two methods can thus be said to be orthogonal: surveys monitor densely in space, but intermittently in time; static acoustic monitoring monitors densely in time but intermittently in space.
- Use of habitat by marine mammals: what behaviour do the animals display at which habitat.
  - Method: marine mammals can be fitted with transmitters to record their position and depth. This is already a proven method for seals, although many measurements/long time series are required here in order to obtain quantitative results on distribution. Although this is technically feasible for porpoises, it chiefly depends on whether permits are granted: the current technique is not animal-friendly. Relation to underwater noise generated by pile driving is theoretically possible, but difficult to execute in practice. Marine mammals must in that case be tagged and be near a noise source. Other factors also may play a big role: motivation and background noise.

Underwater noise:
- Threshold values of noise pressure caused by noise (spectrums) similar to those produced by wind farms during the construction phase (pile driving in particular), operational phase and removal phase whereby marine mammals display behaviour related to disruption. This knowledge obtained in the laboratory can be used to determine whether animal species can hear certain noises related to wind farms (all phases) at all, and if so, what their sensitivity is to this (this is frequency-dependent). This can also be used to determine the background noise conditions under which noises are audible. It is advisable to test the hearing in laboratory conditions to decide whether certain field research (many times more expensive) is required.
  - Method: marine mammals can be exposed to noise experiments in pools (however, imitating pile driving pulses is technically difficult to carry out). Supplementary experiments can also be carried out for this, in which “motivation” plays a role. Motivation refers to the various conditions that can have an effect on certain behaviour. Hunger is presumably such a factor, as are pregnancy, condition, territorial behaviour. Such factors can be included in

the measurements by not only examining observable behaviour, but also other physiological parameters, such as heartbeat, food ingestion, etc. After that, the distances at which such levels are present around wind farms can be examined in the field, and the seriousness of the noise can be assessed (if 100 m, no problem (no further study required), if 100 km, big problem (further study required). Questions regarding behavioural effects should thus be conducted as field studies using the real settings, if possible, and alternatively by controlled exposure studies on wild animals in natural habitats.

Change in habitat:

- Change in distribution pattern and behaviour of marine mammals due to construction of a wind farm.
    - Method: by countings (observers), hydrophones (cetaceans) and transmitter studies (especially seals) before, during and after construction in the plan area and amply around it.
- Change in the use of habitat of marine mammals as a consequence of possible fish increase.
    - Method: see above, supplemented with targeted observations in the farm of the behaviour of the animals in it. This can be done by direct observation or by attaching cameras to the legs of the turbines. However, whether this is feasible in turbid waters in unclear.

Barrier effect:

- Changes in migration and dispersion patterns of marine mammals as a consequence of the barrier effect of wind farms.
    - Method: see above. Possible migration and dispersion patterns and the changes in these can be derived by means of a combination of local measurements (in and around the farm) and in the southern North Sea.

Birds

Basic information:

- Spatial distribution and migration of birds on the DCS. This concerns all groups of birds. Differences between the groups must be derived from the data and supplementary measurements (see below).
    - Method: by means of year-around countings on the DCS. Observers on ships and in aircraft are proven techniques, but these have their limitations. Developing and applying innovative techniques such as high-definition cameras in aircraft is recommended[30]. The use of radar is useful for estimating large-scale flying movements, flying altitudes and densities of birds that live on the water, especially on behaviour at night and in bad weather, but also in “normal” conditions. Radar is detrimentally affected by precipitation, especially X-band. Careful thought needs to be given to the best way to deploy radar effectively. Further consideration to the type of radar is necessary. Marine radar and modified marine radar have a limited range which will be a particularly limiting factor for observations over large sea areas. Doppler radar may perform better in relation to wave clutter but is

[30] *For example, there is currently a British company that uses such techniques to count birds and marine mammals at sea, see Hexter (2009).*

more expensive than the basic modified marine radar that has been in use for many wind farm studies. Set-ups on land chiefly provide information on coastal water; set-ups on platforms and recorder posts may produce very valuable information on offshore waters.

- Use of habitat by breeding birds: this concerns flying movements between colonies and the coastal and offshore waters as well as foraging, moulting and resting behaviour at sea of breeding birds as well as (for the latter category) of birds living at sea. Furthermore, the use (and thus the function) of the habitat by breeding birds is expressed by their breeding success.
    1. Method: by means of tagging animals in (relevant) breeding colonies for behaviour from breeding colonies and local behavioural observations for research on foraging and rest behaviour. Using the latest generation of transmitters, as well as high resolution GPS loggers with information on location (very frequent, minimum once per minute), flying height, flying speed, movement rhythm (accelerometer) and temperature, from which the behaviour can be derived is important in this. Tagged birds are meticulously followed in the colony to determine their breeding status (egg laying, chick development, fledging). It is important that the breeding status of tagged birds be known continuously. Unsuccessful breeding birds (a frequently occurring failing) will start behaving very differently, over entirely different distances and in other areas. Observations in breeding colonies on factors that may determine the success of breeding are also required to determine the function (quality) of the habitat. This then concerns ecological food comparisons from which the real meaning of (the surroundings of) a wind farm or a search area could be derived. In other words, a combination of studying diet and breeding success, related to diet specialisations, and information on spatial use.

Change in habitat:

- Change in distribution pattern of certain bird species around wind farms during the construction, operational and removal phases.
    - Method: by means of observers on ships: research on distribution, densities of the swimming as well as birds flying around and in the wind farm. Radar observations to supply information on distribution at night and in bad weather are also advisable here (but see remarks about radar above). Hi-definition aerial surveys also may be useful in assessing changes in distribution and abundance in relation to changes in habitat.
- Change in use of habitat of birds (as foraging, moulting or resting area) during construction, the operational phase and removal.
    - Method: by means of observers on ships or at a central post in the farm, such as a transformation station: the behaviour of birds around and in the wind farm, focused on foraging behaviour, rest behaviour and behaviour during moulting.

Collision:

- Death due to collision with wind turbines
    - Method: is not yet well developed; probably possible in the future via an automated system (cameras with TADS, VARS or WT- bird)[31], which should

[31] Various systems have been and are currently being developed, for birds as well as bats. See, for example, http://www.ecn.nl/docs/library/report/2006/e06028.pdf, http://www.energy.ca.gov/2007publications/CEC-500-2007-004/CEC-500-2007-004.PDF

be mounted on pilings or rotors. Deployment of cameras may be useful for recording collisions of diurnal species, but requires further consideration of deployment, image capture (refinement of motion detection software), and data management. Tracking studies may provide information about the likelihood of collisions.

- Method: Studies of flying behaviour of sea birds in reaction to fishing ships in the immediate vicinity of wind farms, to verify the extent to which ships fishing close to the farm cause risky flying behaviour. For optimum results, such a study must be combined with the studies as described above for use of habitat.

Barrier effect:

- Changes in movements of birds around and in wind farms. A distinction can hereby be made between migratory birds, birds living at sea and breeding birds.
    - Method: large-scale avoidance behaviour around wind farms (macro avoidance) can be studied by radar observations of recorder posts in wind farms. Behaviour in wind farms (micro avoidance) may also be studied in part by means of radar systems, with supplementary observations by observers (to link the behaviour to the species). However, radar systems are currently not advanced enough to filter out such small movements from the clutter caused by the rotor blades. Whether observations at a distance using cameras is a good (and inexpensive) alternative for observers must be studied.

Bats [32]

Basic information:

- Spatial distribution and migration of bats on the DCS.
    - Method: bats can be observed by means of bat detectors (it must be studied whether bat echolocation sounds are masked or not by the ultrasound noise of the turning blades). Application on existing platforms, recorder posts (autoboxes) and ships is possible. Very little is known concerning behaviour (migration, foraging) of bats at sea. In principle radar techniques are also capable of observing bats (Ahlén *et al.* 2007).
- Use of habitat by bats: migration and/or foraging.
    2. Method: the use of radar and bat detectors is also the most obvious method here.

Change in habitat and barrier effect:

- Change in distribution pattern and use of habitat during the construction, operational and removal phases of a wind farm.
    - Method: radar and bat detectors on recorder posts in a wind farm.

[32] *The question is to what extent bats as an animal group must be included in monitoring. There are no indications that these animals suffer from serious harmful effects caused by offshore wind farms. They have been included here for the sake of completeness.*

Collision:

- Death due to collisions with wind turbines
  - Method: via automated system (cameras with TADS, or WT- bird)
- Behaviour of bats with respect to wind turbines by means of radar and behavioural observations.
  - Method: radar and bat detectors on recorder posts and turbines in a wind farm.

3.7 Cumulation of effects

3.7.1 Cumulation of national and foreign OWFs

Belgium, the Netherlands, Great Britain, Germany and Denmark are planning dozens of GW on wind farms in the (southern) North Sea. The plan is to realise this capacity in the next ten years. This means that many effects of wind farms will cumulate, whereby a great deal can be gained if the spatial planning is synchronised on an international scale. In a broad sense, the cumulative effects can be regarded as all effects that occur as a consequence of adding the effects of interference, thus both positive and negative, to the socio-economical as well as the environmental effects (Williams 2005). Since this document is only concerned with the ecological effects of OWFs, this section will also only discuss the cumulative ecological effects of wind farms. This does not concern the cumulative effects of OWFs for user functions such as navigation and fishing (see Berkenhagen *et al.* 2010, for example).

The legal necessity for measuring cumulative effects on ecological values has been laid down in European Directives. These are the Habitats Directive[33], the SEA Directive[34] and the EIA Directive[35].

In article 6(3), the Habitats Directive states: "*Any plan or project not directly connected with or necessary to the management of the site but likely to have a significant effect thereon, either individually or **in combination** with other plans or projects, shall be subject to appropriate assessment of its implications for the site in view of the site's conservation objectives*". Article 7 is expanded in article 6 so the conditions of article 4(4) of the Birds Directive (79/409/EC) are also met.

In its annexes the SEA Directive explicitly states that: measuring the effects must also comprise "*secondary, **cumulative**, synergistic, short, medium and long-term permanent and temporary, positive and negative*…".
The EIA Directive mentions cumulation of effects in article 4(3) and article 5(1). Article 4(3) states "… *requires the use of 'criteria' for assessment of defined projects and Annex III defines these criteria including the significance of their effect in '**cumulation**' with other projects".* Article 5(1) provides details with respect to the mandatory information in the environmental reports in annex IV: "*description of the likely significant effects*", as described in footnote 1: "*direct effects and any indirect, secondary, **cumulative**, short, medium and long-term, permanent and temporary, positive and negative effects of the project*".

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[33] *The conservation of natural habitats and of wild fauna and flora Council Directive 92/43/EEC of 21 May 1992*

[34] *SEA: Strategic Environmental Assessment (The assessment of the effects of certain plans and programs on the environment. Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001)*

[35] *EIA: Environmental Impact Assessment (The assessment of the effects of certain public and private projects on the environment. Council Directive 97/11/EC of 3 March 1997 amending Directive 85/337/EEC).*

Even though the directives above all mention cumulative effects, stating explicitly that these are multisectoral (thus concern not only wind farms), they do not indicate how time and space aspects must be interpreted or for what species cumulation should be calculated.

Current practice shows that Cumulative Impact Assessments (CIA) vary considerably in the methods used, that they result in conclusion with a high degree of uncertainty due to their qualitative nature (King *et al.* 2009). It is clear that CIAs must give a decision on activities at the population level (Habitats Directive), but it is unclear what activities must be included and on what time scale this must take place (current projects, planned projects, anticipated projects) and what spatial scale must be taken into consideration (local population, regional population, entire migration population of the species).

The section below will list the most important issues per organism group.

<u>Plankton, benthos</u>
The effects of wind farms on plankton and benthos is generally assumed to be very limited. Plankton has not been a topic of study anywhere, and for benthos the concern is always about a reduction of the disruption by bottom fishing, which will enable the diversity and biomass to increase. Growth on the foundations and dumped rock may be regarded as an improvement (better biodiversity), but it is not “endemic” substrate in many cases. The negative effects of the OWFs have not been studied anywhere since they are regarded as negligible, but in the case of valuable habitat, such negative effects might not be negligible.. This concerns the above-described effects of the foundations on turbulence, phytoplankton and zooplankton, and of the growth of the (endemic but also non-endemic) benthos on the hard substrate. The question is whether the composition of the plankton in a wind farm is noticeably altered by the changes in turbulence and hard substrate organisms, and whether this cumulation can result in actual changes in the pelagic ecosystem. Some hard substrate organisms may thereby have an effect on the recruitment of benthos. The effects will be most pronounced during the growing season of the plankton, from early spring to early summer. Distribution of unwanted species (invasive species) may be accelerated via a network of OWFs and thus one species (Japanese oyster) may threaten another one (edible oyster) or block its reintroduction.

Effects of a singe OWF on non-endemic species is likely to be negligible. However, if tens of OWFs are built in the (southern) North Sea, such OWFs may seriously act as stepping stones, thereby facilitating the invasion of non-endemic species in other habitats as well. At such a large scale, OWFs may influence water circulation as well (Broström 2008), thereby impacting plankton growth to a more than negligible extent. However, in shallower, mixed areas where no stratification occurs, upwelling or downwelling is likely to have no conspicuous effect on PP.

Leaching of contaminated substances from the sacrificing anodes for wind farms is very limited if a single wind farm is involved. If dozens of wind farms are constructed, this effect must be examined in more detail, especially the intake of contaminating substances by plankton and benthos and the further bioaccumulation in the food chain.

<u>Fish</u>
The cumulative effects on fish larvae caused by pile driving are very opportune and could potentially result in strong effects on the availability of important staple food species for birds and marine mammals such as herring, sprat and sandeel, but also flounders such as dab and sole in the coastal waters. Such changes are directly related to the method of construction:

pile driving. If piles are to be driven in different farms every year, fish larvae may be subject to a cumulation of effects, very dependent on the locations where the piles are driven. Modelling of the effects caused by driving piles on the fish larvae flow to the coastal water has roughly demonstrated that the effects are stronger as the pile driving location is closer to a coastal area or closer to a spawning area. Much can be gained by both spatial and temporal planning as far as the effects of pile driving on fish larvae are concerned. If other techniques are developed for the foundation of a wind turbine (less pile driving noise), these effects will no longer occur or will occur to a lesser degree.

The effects of driving piles on juvenile and adult fish are also little known, and could potentially probably have non-negligible effects on the survival of fish. These effects are expected to remain relatively limited because most specimens can swim away. To present, however this has not been demonstrated.

Birds
Cumulation of collisions, disruption and barrier effects will occur for birds. The cumulation of disruption (loss of habitat) and collision can hereby be expected to nearly add up proportionately for local sea birds, since there is little interaction between birds of the separate wind farms. When farm distance decreases, interaction is possible, so that one population of birds might “visit” multiple OWFs. If the farm density increases, cumulation with navigation will also occur, since ships and helicopters must avoid wind farms and will increasingly sail or fly in greater concentrations elsewhere. Non-wind farm areas will be navigated to an increasing extent because of this, and this will also increasingly disrupt the sea birds outside the wind farms. This could mean a serious impact on the quality of the habitat for sea birds in maritime areas with many (planned) farms, a great deal of shipping and many sea birds such as the southern DCS in winter, considered over a much larger area than the cumulated surface area of the OWFs alone. These effects will presumably also add up proportionately for breeding birds.

The effects for migratory birds may add up less than proportionately, because they swerve away from wind farms at a great distance. If wind farms are built in clusters, they have to fly less far out of their way to avoid a cluster than the sum of the distance to swerve away from the separate farms if they are not in clusters. How much this saves in limiting the loss of time, and thus loss of energy, is unclear. However, it is certain that in cumulation serious effects on the loss of habitat and barrier effects may arise for certain species. If collisions actually take place as modelled (see Arends *et al.* 2009, among others), installing the planned number of wind farms will run up against serious cumulative ecological effects. A well-thought out and internationally synchronised spatial planning, meaning taking the migration routes of birds, position of breeding colonies and concentrations of local sea birds into consideration, will be able to mitigate some of the effects.

Marine mammals
The postulations for birds also apply to marine mammals. Construction by means of driving piles (and the eventual removal using explosives) will cause long-term disruption of the under water habitat by noise. If the noise is audible over long distances and causes changes in the behaviour of seals, porpoises and dolphins as is assumed now, strong effects on the populations may be possible in cumulation. The quality of resting, foraging, nursing and nursery areas will deteriorate considerably if planning for construction of wind farms is not properly synchronised, especially internationally.
In addition to construction, wind farms in place can also cause a loss of habitat and migration zones. Even though the noise levels of operational wind farms are lower than those of farms

under construction, the duration of this phase, and thus the duration of any effects is much longer. At the same time it can be argued that the effects of construction, which are often currently characterised as temporary, will no longer be temporary if piles are to be driven for construction of farms over the next ten years.

In conclusion, it can be stated that cumulative effects of wind farms at sea cause upscaling of ecological effects, usually proportionate. The duration of the construction ensures that there are no longer any temporary effects. Minor effects can also cumulate to become effects that can no longer be neglected. It is of great importance that the planning of OWFs in space and time be synchronised on an international level so that the negative effects can be mitigated.

3.7.2 Cumulation/Interaction with other activities, plans and projects

In addition to cumulation of the effects of construction, use and removal of OWFs, the effects can also cumulate with other current and planned activities and developments at sea. The most significant activities and/or interventions that have an effect on species and ecological processes in the North Sea as well as where the principal effects take place are listed below.

- Existing use
    - Disturbance caused by navigation and recreation: underwater noise, disturbance above water
    - Sand extraction and supplementation: disruption of the bottom habitat, benthos, fish spawning sites, disruption of food web relations, secondary effect on coastal birds, marine mammals
    - Defence - sonar: see above
    - Fishing: disturbance of the bottom habitat, death of benthos and fish, also take into account a shift in fishing patterns due to closing OWFs to fishing
    - Damage to habitats on land (also abroad): disruption of habitats of breeding birds and marine mammals (in this case, land also means Waddenzee, Delta, Wash)
    - Pollution and eutrophication: increase in primary production, disruption of food web relations, input of organic matter, reduction in fitness (especially marine mammals and birds) due to bioaccumulation of contamination
- Future plans and projects
    - Airports and other islands at sea: locally very far-reaching, damage to the bottom habitat, benthos, spawning areas for fish, disruption of primary production, disruption of food web relations, disruption of bird habitat, disruption of migration routes of birds, marine mammal habitat
    - Sand engine or megasupplementations: as above
    - Civil engineering work: such as sand supplementations above
    - Tidal power plants: negative effects on fish survival
    - Reorganisation of the south-western Delta: improvement of estuary functions of the coastal area, improvement of the fish nurseries, foraging opportunities for coastal birds
    - Nature protection Act, Natura 2000 areas: potential for improvement for bird habitat, but unclear how
    - Flora and Fauna Act, Marine Strategy Framework Directive: potential for generic improvements of environment and North Sea habitat, but still unclear how
- Autonomous development (non-adjustable changes)
    - Climate changes: shift in species, change in food web relations (*match-mismatch*), disruption of recruitment (temperature)

Describing all possible interactions and cumulations with these interventions in this document would be going to far. However, it is important to at least properly describe and include the possible cumulative effects for the existing use in the concrete planning of OWFs. Separate documents are being drawn up for several large scale interventions with respect to the future plans and projects, such as megasupplementations, islands in the sea and reorganisation of the Delta, in which such cumulation due to the construction of OWFs must be described. It is of great importance that proper bookkeeping of potential and actually occurring effects is kept as far as the effects on nature are concerned. This must be done to prevent an effect called *shifting baseline syndrome* (Pauly 1995) from occurring. If a situation subject to an effect repeatedly functions as a baseline, the bar for conservation objectives is also lowered each time.

Our knowledge of impacts associated with the listed other activities varies from reasonably comprehensive to poor or non-existent and there is difficulty in attributing causation.

3.8 Preventive and mitigating measures

3.8.1 Measures in the planning phase

Measures that result in a different spatial or temporal planning or change the implementation technique of the OWF in advance are in a strict sense not mitigating measures. Mitigating measures are adaptations to an existing situation in order to extenuate the effect of the original version. Thus measures taken in the planning phase cannot be placed in this category. Nevertheless, it is good to briefly discuss the possible measures at a strategic or implementation level, which we do below.

Prior to implementation of an OWF, one must reflect on the spatial planning of wind farms, as well as on other use of the sea by humans. Conflict situations and cumulation of effects must be avoided to as great an extent possible. Apart from this, there are possibilities in the spatial planning of OWFs to take the ecologically sensitive area into account. Thus far this has not been taken into account in the Netherlands in the first and second round of OWFs. In the next (third) round, this is currently being given more consideration, but due to the great amount of activity in the Dutch coastal waters (shipping, fishing), the unfamiliarity with the extent of ecological effects and the costs of laying cable to the land, planning OWFs in ecologically favourable areas is a difficult affair. After all, since costs increase as one operates further offshore, building as close to the coast as possible is desirable. The uncertainty of this, combined with the strict protection of species (Birds and Habitats Directives, Nature Protection Act), compels one to prudence and thus to a preference of placing OWFs at relatively long distance from the coast. In fact, this is already happening because wind farms will continue to be prohibited within the 12-mile zone due to other interests (unobstructed view of the horizon, as laid down in the 2009-2015 North Sea Policy Memo).

Certain effects that are the focus of a great deal of social interest, particularly the collision hazard for birds and the disturbance of the habitat for birds and marine mammals may be reduced by solutions in the technical realm and the configuration of the farms. Gravity-based foundations normally do not require pile driving, and thus can be constructed with production of much less noise than the monopiles. This will increase the costs, and it is not certain whether such techniques can be applied on the DCS on a broad scale. Presently, there are six turbines on the Belgian CS (Thornton Bank) with such foundations, and the future will tell to what extent these foundations are technically durable in considerably dynamic bottoms.

In addition to adaptations in the foundation technique, one can also examine whether the configuration of wind farms could result in advantages to the ecology at sea. For example, it was observed that the behaviour of birds in wind farms set up somewhat more spaciously (OWEZ) differs from that of birds in wind farms set up more densely (Q7) (M. Leopold, pers. obs.). If the turbines are positioned farther apart, the birds have a tendency to fly or swim more between the turbines. It is true that a denser set up wind farm takes less room than a wind farm built more spaciously. Because of this, the actual surface area is a lost habitat for birds that are dependent on the total farm surface area as well as the turbine density of this surface area. What the eventual effect of this is on the collision risk and loss of habitat is unclear, but studying this further is important. This may also apply to marine mammals, and this reasoning can also be applied on the barrier effect of (clusters of) OWFs.

3.8.2 Measures during construction and presence of OWFs

As stated above, one of the most effective measures for limiting risks in the planning phase is to avoid protected areas for birds and mammals and migratory routes of birds. In addition, a number of measures can be taken during construction and the presence of the wind farm.

Birds

Construction period

A great number of the disruptions can be prevented by choosing the right time to implement work. This involves the customary mitigating measures that, in principle, are applied to all spatial developments. Disturbance of breeding birds on land is prevented by working outside the breeding season. Disturbance of seasonal coastal birds is prevented by working in the late summer and fall before these species arrive in the area. Should it be impossible to conclude the work outside these periods, it should be done as much as possible at one relatively small place, at one time, so that the area to be disturbed is kept as small as possible. Additionally, it could be effective to set time restrictions on construction and maintenance traffic.

Increasing the chance of detection

A number of technical adaptations can be made to a wind turbine in order to minimise the risk to birds. On the one hand, this involves increasing the options to make birds notice turbines (see them or hear them, the chance of detection), allowing birds flying on the route to deviate. This is positive for birds passing by. For birds that would like to use the area as resting or foraging area, this could work out negatively due to the possibly more seriously disrupting effect caused by such adapted wind turbines. However, so far it is still unknown what adapting factors may be involved in the disrupting effect of wind turbines. Assuming that increasing the chance of detection of turbines contributes to minimising the effects on birds, a number of points of attention can be mentioned.

Painting the wind turbines a colour that is especially conspicuous in dark situations increases their visibility. More detailed data on colour types and possible effects are barely available. It is not impossible that the lighting on the wind masts attracts the birds so that the light should be turned off when large numbers of bird fly by (during migration). A new type of lighting (Poot *et al.* 2008) could prevent birds from being distracted in their migration across the North Sea. After some studies, the Netherlands Oil Company (NAM) discovered that the solution to the problem involved the colour of the lighting on drilling platforms. Birds are distracted by the red sections in the colour spectrum, and less so by blue or green.

Painting the structure with reflective coating does not appear to make sense thus far. Wind turbines are easy to spot in sunny conditions. The reflecting materials probably have no effect in dark or misty conditions, when the risks are the highest. A light and conspicuous colour probably makes more sense in those situations. Lighting on the blades could actually help the birds perceive the rotating rotors.

If wind turbines are audible to birds, the chance of detection in dark nights is probably better that that of low-noise turbines. For this reason it is recommended that the audibility not be limited too much. No proper data are available about optimum noise levels and noise intensities, nor about the impact of this on birds in the field (chance of detection).

Another possibility may be to make the turbines audible by having them transmit noise. Positive experience has been gained at several places on land using ultrasound noise to scare off birds. However, this would have to be properly studied for application to offshore wind turbines (and other offshore installations). An important question is whether this also works at longer distances (birds must be warned in a timely way, not when they are already close to the turbine). A test set-up and behavioural measurement of birds are necessary. Possible negative side effects of a large number of ultrasound noise sources (e.g. for marine mammals) should also be examined closely.

Still little is known about how best to increase detection of wind turbines by birds. Knowledge of bird vision indicates that many species are unable to see wind turbines when they are in flight because their vision is trained downwards, for example when undertaking foraging flights (G. Martin pers. comm., University of Birmingham, UK). Additionally, there is a need to consider how birds view wind turbines, rather than applying human vision perspectives. Alteration of lighting during peak migration may be unacceptable in terms of requirements for navigation and aviation. There is a pressing need for experimental testing of different methods, initially this would be easier to undertake on land, rather than offshore, although clearly responses may be different on land, but this would be a useful starting point.

Reducing the chance of collision

The size of the rotor also makes a difference in the number of collision victims, as shown by studies on land (Tucker 1996, Schekkerman 2006). Calculations also show: the larger the rotor, the fewer victims per square meter of rotor surface area and also per quantity of energy generated (Haskoning 2009). For this reason, installing fewer wind turbines with a large rotor surface area is preferable to installing more wind turbines with a small rotor surface area (if the macro-deviation is equal). In addition to increasing the chances of collision, the disrupting effect is also expected to increase more as more wind turbines are constructed. If there is an option to vary the number of wind turbines, the reasons above make it preferable to use fewer (and thus bigger) wind turbines.

In addition, chances of collision can be reduced by temporarily taking the wind turbines out of operation during periods when extreme situations occur for birds, for example the seasonal migration of certain species, when large numbers of birds pass the wind farm, and situations when there are stormy winds. Birds fly lower when the wind blows hard, so the chance of collision can be relatively large. A national bird migration warning system like the ones being used to increase flight safety may be used. If it could be based on real-time large scale radars and the weather forecast and during the very few nights where lots of birds take off on migration and are met by a front-system with rain or fog, the turbines can be stopped during the hours of high collision risk.

Underwater life

The effects of the wind farm on underwater life can be positive as well as negative. The positive effects can be reinforced by supplementary measures. The negative ones can be limited by taking mitigating measures.

Noise and vibrations

It has been concluded that driving monopiles of wind turbines with a diesel block causes the highest and potentially most damaging noise pressure levels. The options of reducing these noise levels or preventing their effects are chiefly the following:

<u>Bell curtains</u>
By using a so-called bell curtain around the site where piles are driven, reductions of the total broadband noise levels by 3 to 5 dB is allegedly feasible (Würsig *et al.* 2000). Some studies have shown significant effects of bubble curtains (up to 25 dB reduction), but it remains to be demonstrated that such high levels of attenuation can be achieved repeatedly in deeper waters under influence from currents and winds. Other authors (Nedwell & Howell 2004), on the contrary, report a very minor effect.

<u>Noise screen</u>
Schultz-von Glahn *et al.* (2006) describe the results of a study on the noise reduction of a noise screen/casing in the water around the piling while it is being driven. Depending on the frequency, reductions from 5 to 25 dB were hereby accomplished. The study was carried out while driving a piling with a 2.2 metre diameter.

<u>Vibratory pile driving</u>
It is generally assumed that vibratory pile driving generates lower noise pressure levels than impact pile driving. Numbers on this, in the form of source intensities calculated on the basis of noise measurements, are not found in the literature, however. Nedwell *et al.* (2003), reports a measurement at a distance of approximately 420 metres, whereby the signal did not rise above the background level of 120 dB re 1 μPa when vibratory pile driving was used. Gerasch *et al.* (2005) estimates that vibratory pile driving of monopiles will result in noise pressure levels up to 30 dB lower than pile driving. Besides that, the frequency normative for the noise is also even more significantly lower than for pile driving. This lower frequency will be below the cut-off frequency in shallow water. However, depending on the bottom condition in particular, it may be necessary to still proceed to drive a pile for the last part. In that case, the effect of vibratory pile driving is partially cancelled again, but the cumulative exposure to the noise of pile driving is reduced considerably if the number of strokes is reduced due to vibratory pile driving. The sensitivity of marine mammals increases when repeatedly exposed to pile driving pulses.

Good design
Noise emission is determined, among other things, by the energy used to drive piles. In order to prevent superfluous energy from being used to drive the monopiles, the diesel block to be used must be properly geared to the monopiles and to the bottom composition. In addition, Elmer *et al.* (2007) estimates a possible reduction of 9 dB of the peak noise pressure levels by extending the duration of impact by a factor 2 while the stroke energy remains the same. Extending the pulse duration makes pile driving less effective so that the process will probably take longer. Moreover, the materials used to extend the peak are very sensitive to wear.

Operational
Due to a so-called soft start, whereby pile driving is started at a low capacity which is gradually increased, some think that the fish and marine mammals have the opportunity to leave the area before harmful noise levels are reached (Bailey *et al.* 2010).In terms of protocols for minimising impact of marine mammals, it has been shown through modelling that even with the current practice of deployment of acoustic deterrent devices (seals scarers and pingers), followed by a ramp-up procedure there is still a significant risk that seals and porpoises are exposed to levels sufficient to elicit TTS (Gordon et al. 2009). In addition, acoustic scare-off devices can be used to scare marine mammals off from the immediate vicinity of the building location. Pingers, underwater warning systems that emit a certain noise intended to scare off marine mammals before pile driving commences were used during the construction of Horns Rev and OWEZ. However, at this time it is not clear whether such a measure makes any sense. It is even possible that the animals, made curious by the pinger noise, come to investigate and thus come closer. This has been reported for seals foraging around aquaculture enclosures (dinner-bell effect) (Underwater Sound Forum Conference, February 2010 at IMAREST, London UK). This should however never be used as an argument to mitigate possible effects; it could be very dependant on local circumstances or (groups of) animals (“culture”). The effectiveness of devices is currently being tested by SEAMARCO for seals and porpoises under orders of COWRIE in the UK.

4 Prioritising monitoring and research questions

4.1 Prioritisation criteria

Monitoring and research of various types of information must be targeted and prioritised, since it is important that measuring be done effectively and in accordance with the preferences imposed by policy and regulations. Criteria have been set up to this end in order to sort and prioritise the various monitoring components. The thought behind the use of these criteria is that an overview can be drawn up of how the most urgent information questions can be tackled effectively in the short term, i.e. in the first term of the monitoring period. The knowledge generated by this will enable a first leap forward, so the effect predictions can be improved considerably. Long-term monitoring surveys and research programmes will also have to be started at the same time in order to tackle the more difficult gaps in information such as population dynamics, food web effects, long-term effects, complex dose-effect relations or cumulative effects of the OWFs.
The prioritisation presented here does not imply that certain research should be excluded. It simply enables us to focus on the most important issues at this very moment. Questions that have not been addressed here are currently not perceived as the most pressing. However, when results show that some effects are stronger or milder than previously thought, the prioritisation needs to be reconsidered. Such cases however can not be foreseen at this moment.

Furthermore, questions for which there are currently no perfectly feasible methods are included; information demand will help to drive the development of technologies and methods to address some of the high priority but challenging questions.

In order to prioritise the monitoring and research questions, the following criteria were considered:

1. Necessity
   - nature and extent of (expected) effects
   - legal obligations (chiefly Birds and Habitats Directives)
   - ecological importance of the plan area in the context of the ampler ecosystem
   - consequences of cumulation of effects

2. Effectiveness
   - scope of information requirements
   - feasibility of surveys and research
   - connection to current research (dictated by current permit obligations, among other things)

3. Cost efficiency
   - affordability
   - flexibility
   - bundling
   - international cooperation

These criteria were devised during the first phases of setting up the master plan. When applying these criteria, it appeared that it was not simple to apply all criteria to an equal extent. Some criteria are excluding criteria (such as legal obligations); others have a relatively strong effect due to current permit obligations (connection with current monitoring and research); and still other criteria actually had little effect because their importance was not yet clear when they were written, such as bundling programmes and international cooperation. Criteria can also interact. For example, affordability has turned out to be a supplementary and interacting criterion. Not that costs do not matter, but sometimes certain measurements or studies are both necessary and costly. On the basis of another criterion (expected strong effects, for example), these criteria (still) have high priority.

In the end, the list of priorities is of course not an absolute list that can no longer be adapted. Sometimes techniques are developed that allow a measurement to be cheaper, or it appears that a combination of research and surveys is possible so it makes sense to include a lower prioritised point in a study that is higher on the list. This has resulted in prioritisation that is chiefly based on a collection of some of the above-mentioned criteria[36].

The priorities are distributed over three categories as follows:

1. <u>Highest</u> priority; it is important to start with this as soon as possible:
   - focused on a legally protected group of organisms,
   - involve the principal and strongest effects,
   - meet the most significant information demands,
   - the projects are perfectly feasible,
   - fit well with current projects and
   - can be combined with current or other planned monitoring projects.
2. <u>Medium</u> priority; it is important to begin with this within one to several years:
   - focused on a legally protected group of organisms,
   - the projects are perfectly feasible,
   - but do not involve the most important or biggest effects, and/or
   - do not meet the most significant information demands, and/or
   - fit with current projects less well, and/or
   - are more difficult to combine with current projects.
3. <u>Lowest</u> priority; these studies are not directly necessary, but could be carried out to a limited extent in some farms of very modest size.
   - The projects score relatively poorly on several of the above-mentioned criteria, and
   - no exclusion criteria such as legal obligation apply to them.

Note that “strongest” or “important” effects mean that the effect is relatively large with relation to the population effect, or that it is rather extended. Mortality of benthos when a turbine is piled is strong for the individual benthic organism, but at a population or community level the effect is negligible. The effect of under water sound from piling on porpoises on the other hand, extends far and can in principle reduce fitness of a relatively large part of a population or a pod.

The highest priority is given to those studies and surveys that can currently be considered “need to know”. They are essential for bringing our knowledge of ecological impacts an important step further. Medium priority considers studies that are a mixture of “need to know” elements with “nice to know”, and lowest priority consists of studies that are mostly “nice to know”. However, this discrimination between “need” and “nice” is based on the current

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[36] The reason why the numbered bullets were included in the report is the fact that certain criteria that could not be applied yet may be useful in a later stage of assessment.

knowledge and on the assumption that we first need to make an important further step in our impact knowledge. This does not disqualify the studies under medium and low priority. When our information and methodological demands develop further, these studies (and likely other ones we can not presume at this moment) become quite important to further advance our knowledge of the ecosystem's reactions to construction and operation of OWFs, especially when considering the cumulative effects.

Next, the monitoring and research projects are subdivided into different types of information. This subdivision is relevant in order to group them properly and thus possibly combine them with other types of research. This will chiefly concern the types of monitoring and research that are in the basic information and generic information categories.
The information collected by means of the monitoring projects or monitoring plans is subdivided as follows:

- Basic information: North Sea-wide information that is not directly related to the effects of wind farms, such as distribution and dynamics and hearing sensitivity of marine mammals, and distribution of birds in the southern North Sea
- Generic information: information related to the effects of wind farms that can be applied to several wind farms, such as the effects of driving piles on relevant animal species.
- Location-specific information: information related to the local (or regional) situation of wind farms, such as migration routes of birds.

Finally, projects have been subdivided according to the terms during which results can be expected to become available and to be useable in order to better assess the effects of wind farms.

- Short term: projects run relatively short term, and already produce results after 1 to 1.5 years, such as the ship survey for fish larvae.
- Medium length term: projects take two or three years or require additional analysis steps so that information is only useful after 2 to 3 years.
- Long term: projects are multi-annual, logistically or technically complex and the methods have not been properly finalised or are innovative. An example is the equipment for detection of collisions of birds with wind turbines.

The formulation of the prioritised projects and plans was created in several workshops with specialists in certain disciplines, and in consultation with the principal.

4.2 Results of prioritisation and subdivision

This section describes the monitoring and research projects and plans for each component, in the order of prioritisation The results are presented in a summary table at the end of each section. Note that aspects of possible importance in cumulation of effects has not been a separate criterion. This asks for a next step in setting up the monitoring and research plans. Cumulation of effects has been addressed in paragraph 3.7.

4.2.1 Underwater noise (physics)

Priority 1

1. (International) consultation must be started as soon as possible, working on standardisation of methods to measure underwater noise at sea. Assessment of the noise, which will be animal species specific (comparable to the dB(A) assessment for atmospheric noise for humans) will have to be discussed in more detail on an international level. Without this synchronisation, the usefulness (= comparability) of the measurements is limited. In that case, it may turn out that national measurements cannot be used internationally, and vice versa. **1 Year, basic information, short term.**

2. An important initial step is the so-called source research. Proper description and validation of the noise sources is necessary. This means that measurements must be taken and models must be made of various sources, primarily the noise of driving piles (of turbine foundations) and of manoeuvring ships. Such measurements are possible in the short term, when the piles are driven for the Belgian wind farm, for example, or when measuring masts are installed on the DCS. The result is a calculation model for the prognosis of underwater noise as a consequence of the various activities. **2 Years, generic information, short term**.

Priority 2

1. There are models that describe the noise propagation in water and on the bottom, but these are insufficiently validated. After validation on the basis of OWEZ and Q7 data, we will find out if the models available suffice or whether further refinement is required. Planning: the first results can be expected in the fall of 2010. It will depend on the validation whether the final result is sufficient or not. **2 Years, location-specific information, medium length term**.
2. Currently, the regulation is in effect that no piles may be driven for half a year due to the risk of death of fish larvae. This regulation could be better substantiated. A review of mitigating measures, resulting in “best practices” is under discussion. In this study, the question can also be answered of what the net effect of pingers is, or under what conditions the use of pingers is an effective mitigating measure. **Generic information, short term.**
3. In addition, the background noise plays a role. A North Sea-wide noise survey can result in an underwater noise map for the North Sea, which can serve as a future basis for more detailed effect measurements. Measurements of the background noise underwater are taken by means of buoys to which hydrophones are attached (autonomous measuring stations). Measuring from a ship is also an option, but ship noise can play an interfering role in this. Moreover, these measurements must be taken for years in order to also calculate the temporal variation. **Basic and generic information, long term.**

Priority 3

1. The eventual goal is to arrive at a risk analysis tool, a software package that combines and integrates all information and models concerning underwater noise, the various sources, the propagation, exposure, exposure-effect relations, mitigating measures, etc. Once such an instrument has been realised, construction plans can be calculated in advance and an assessment can be made of the risk of the proposed activities for the marine environment. Note that the target group here is the project developer (for the EIA) as well as the government (enforcement). This also means that the number of underwater measurements can presumably be reduced. **Generic information, long term**.

4.2.2 Plankton

Priority 3

1. Studies on the effect of pilings on mixing of the water column, nutrients (by means of models and validation in the field) and primary production (as a derivative of standing stock measurements done by remote sensing, modelling and additionally some growth and mortality measurements *in situ*). Alternatively, phytoplankton could be monitored by continuous recordings of fluorescence (a useful and operational proxy for phytoplankton biomass but not for species composition) by long term deployment of automatic sensors. **Generic and location-specific information, short term**.

2. Studies on the phytoplankton and zooplankton community for field sampling, twice per year. **Generic and location-specific information, short to medium length term**.

4.2.3 Benthos

Priority 3

1. Inventory of soft substrate benthos species (infauna and epifauna), once per year, by means of box core and benthic scraper, in and outside the wind farm. **Per farm for 5 years, meaning 2 years T_0 and T_1, T_2 and T_3. Location-specific information, medium length term;**
2. Inventory of hard substrate species on foundations and rock deposits, once per year, by means of scuba or remote cameras. **Per year at T_1, T_3 and T_5. Location-specific information, medium length term**.

4.2.4 Fish and fish larvae

Priority 1

1. Data on lethal and sub-lethal effects on fish and fish larvae as a direct consequence of driving piles of foundations for wind farms are required for better assessment of effects. Experimental studies in the field are necessary for this. If the first wind farm in Belgium is constructed (including pile driving), this will be the first option to measure the direct effects. This may be linked to the pile driving activities for the measuring masts, which, as we understand it, will be done this year. Of course it is relevant in that case to know if these pile driving activities are comparable to those for foundations of wind turbines. Concrete plans for driving piles of wind farms abroad can also be examined (including the Baltic). **One-time, generic information, short term**.

2. Distribution of fish larvae on the DCS. Where the larvae are when is currently only known to a limited extent for a few commercially interesting fish larvae. This is unknown for other fish larvae. For the sake of possibly mitigating measures and improvement of the models used for the dynamics of fish larvae distribution, it is important to study whether there are locations where and time periods when piles can be driven that are more favourable for fish larvae than the periods that are currently mentioned in the permit regulations for the second round of wind farms. **1 Year, generic information, short to medium length term**.

Priority 2

1. Expansion of the hydrological component of the fish larvae model. Supplementary research on the effects of underwater noise in the field will be required for fish larvae and fish. Validation of the distribution models used in the Appropriate Evaluations is necessary, as is expansion to cover species other than the three currently included in the Imares and Deltares fish larvae model. An expansion of the hydrological model for the waters north of the Wadden islands is also required for the benefit of the cumulation of effects with the German farms in particular. Autecology of (a broader selection of) fish larvae is necessary, especially of those species that are eaten by birds and marine mammals in large numbers. Behaviour of fish in different noise conditions will have to be studied both in the lab and the field, also chiefly due to the secondary effect on birds and marine mammals. **One-time via PhD project, component ZKO North Sea noise project, basic information (autecology) and generic information (model), medium length to long term.**

Priority 3

1. Changes in the habitat (water column and substrate) may have a food web effect on the fish in the area (and possibly fish larvae in the area, although this effect is probably negligibly small and practically immeasurable), and cause aggregation and possibly surplus production of fish. This demands research on food relations between fish and benthos, yield from benthos, behaviour of fish around structures and possible spill-over effects, etc., and can link closely to comparable studies on effects of platforms, shipwrecks and (artificial) reefs. The functioning of wind farms as (part of) protected areas (MPA) fits into a broader framework of management of the North Sea (EBM: *ecosystem-based management*). **Generic information, long term**.
2. Electromagnetic fields of cables dug in may have a disrupting effect on the foraging behaviour of elasmobranches, but also on that of other fish. Even though laboratory tests are relatively easy to carry out, various experiments have already been done and these have yielded inconsistent results. The seriousness of the effect appears to be relatively limited so far, but targeted studies might be able to clear up a significant uncertainty. An improved experimental set-up will presumably have to be found for this. **One-time, generic information, long term.**
3. In addition to underwater noise, the possible effects of the release of contaminating substances on fish larvae when the bottom is stirred up may also play a role. It has been indicated that sublethal effects (C. van Damme, pers. med.) have been found, caused by contamination. However, this effect is not assessed as serious, although it is simple to include the concentrations of contaminating substances at the site of a planned wind farm and their release during a bottom disturbance in a measuring programme. **One-time, basic and generic information, long term.**

4.2.5 Birds

Priority 1

1. For breeding birds, and especially the lesser black-backed gull[37], data on population dynamics are chiefly required for better assessment of the effects on protected breeding colonies. This primarily concerns data on survival (ringing and counting back), the share of floaters (study of breeding colonies) and patterns of flying away from the colony tagging breeding specimens; see the observations on the selection of transmitter types above). Such data should be linked to data of the fish larvae, commercial fishing activity and the position of natural food areas, so that a connection can be established between survival at the population level and the food situation in the coastal and offshore waters. Such studies also produce the requisite information on loss of foraging area, barrier effects and change in foraging behaviour for breeding birds. In addition, tags could supply important information on migration pathways and behaviour when the breeding season is over. Also, non-breeding birds could be tagged to this end. **Colony studies, and tagging, 4 years**, **basic information, short to medium length term.**
2. Large-scale offshore distribution data are required for avoidance and/or barrier effects (local sea birds and migrating birds), while smaller scale data are required at the site of the plan locations (including changes in foraging behaviour) for OWFs. Aircraft surveys are especially suitable for the larger scale countings of sea birds; ship surveys are required for location-specific countings combined with behavioural observations and

[37] *Even though the sandwich tern has thus far not been included as a breeding bird that forages at OWFs, this cannnot be excluded in the future, since this bird can also forage well outside the 12-mile zone and will chiefly target herring, sprat and sandeel there.*

measuring flying altitudes. **Aircraft survey (one survey per month), for 5 years. Ship survey; for 5 years**, **basic information, short and long term**.
3. Radar observations for fluxes, flying altitudes, etc. of migratory birds possibly on measuring masts (to be installed soon) or platforms. **5 Years, generic information, medium length term**.

Priority 2
1. Indirect observations of collision victims are made by means of an existing monitoring programme for sea bird strandings (see http://home.planet.nl/~camphuys/NZGNSO.html), a detail study of which has for years been focused on possible collision victims in the farms offshore Egmond of the Noord-Holland region (strandings are expected there; birds are collected for internal examination). This is a cheap and extremely "cost effective" existing programme. Costs are chiefly a four-wheel drive car with petrol for a number of years, to be managed by the volunteer who brings in the data (no salary expenses). Expansion to other regions with OWFs relatively close to the coast may be meaningful. **Location-specific information, long term.**
2. Collision victims are difficult to be measured currently. Observations are as good as impossible: the chance of seeing a collision is negligibly small. Equipment is being developed at this time, the process of using the equipment (WT-Bird) developed by ECN must be facilitated. *If this equipment can be used, measuring collision victims must be given high priority.* **Location-specific information, long term.**

Priority 3
1. Desk study on information on ring data of birds to gain knowledge about large-scale migratory behaviour of birds. **Basic information, short term.**
2. A supplementary ring project for migratory birds to collect additional data on large-scale migration behaviour of birds, only feasible in cooperation with researchers abroad. Notable is that ringing will only deliver information on origins and destination, not about migration routes. Tagging seems to be a better option here (see priority 1). **Basic information, long term**.
3. It is important to study the function of the habitat of coastal breeding birds and birds living at sea in order to assess the seriousness of the population's loss of habitat. For example, the Brown Bank[38] is considered important for razorbills and guillemot due to higher biomass of certain fish/benthos, but the centre of distribution of these species is on the south east side. Targeted studies on the importance of certain areas for birds is therefore meaningful for those species that are characterised as most sensitive to disruption. **Basic and generic information, medium length term.**
4. A thus far still underexposed issue is the effect of pile driving noise on foraging birds under water. In addition to the disruption caused by the work during construction of the farm, it is not inconceivable that the underwater noise causes a harmful effect on diving birds at a longer distance, especially divers and ducks (because of the depth). No data are known about this. **Generic and location-specific information, short to medium length term.**

4.2.6 Bats

There are only very limited data on the flying movements of the bat animal group over the open sea. The seriousness of the effect of OWFs is unknown, but data on land indicate death due to wind turbine as potentially worth mentioning. In all probability, the flux of bats above the sea is most intense during bat migratory season. An important basic study entails carrying

[38] The area around the Brown Bank is a potentially interesting plan area for wind farms (NWP 2009).

out detection programmes along the coast and in offshore waters, as well as the behaviour of bats near turbines by means of TADS, for example.

Priority 3
1. Observations using bat detectors along the coast and from drilling platforms. **Basic information, medium length term.**
2. Requesting data of bats captured on drilling platforms, setting up cooperation of platforms for collecting bats. **Basic information, medium length to long term**.
3. Studying the behaviour of bats around wind turbines on land and at sea. **Basic information, short to medium length term**.

4.2.7 Marine mammals
Porpoise

Priority 1
1. Experiments are required to measure the noise level that causes temporary hearing damage in porpoises, TTS (*Temporary Threshold Shift*). The hearing of porpoises is essential for foraging, and a deterioration in the function of hearing will certainly result in the death of an animal. This level must be therefore prevented from being reached and can be used as a criterion for porpoises. Such experiments can be carried out in pools (Note: experiments to determine changes in behaviour are required as the follow-up step, see priority 2). **3 Years, generic information, short to medium length term.**
2. Basic data are required on the dynamics of the porpoise populations, and dolphin populations if applicable, in space and time in the (southern) North Sea. How porpoises migrate through the southern North Sea is practically unknown, for example whether there different populations and (sub)migrations, etc. A regular survey by aircraft appears to be the most appropriate method for this. Such DCS-wide flights are currently taking place (under orders of the Ministry of Agriculture, Nature Management and Fisheries); continuation of this survey is important for arriving at a proper T_0. **For 5 years, basic information, short term.**

Priority 2
1. Year round data on the presence (and communication) of porpoises (and dolphins, if applicable) at the sites of planned wind farms are required for the T_0 of the wind farms to be constructed. Observations from ships, fixed platforms in the farms and/or the use of buoys with hydrophones or PODs[39] at the site of the planned wind farms or for larger areas appear to be the most appropriate methods for this. Buoys with hydrophones for porpoises could be combined with hydrophones for underwater noise. However, sufficient information is lacking on translating the measured noise into absolute numbers of porpoises passing by. **2 Years, generic and location-specific information, short to medium length term.**
2. Behaviour of porpoises during pile driving of foundations for wind turbines can also be monitored by means of a grid of hydrophones around the plan sites of wind farms (Belgium) or recorder posts (DCS). **Generic information, medium length term.**
3. Other hearing parameters of porpoises, to be measured in pools, such as:
   a. Critical band width. What tones of underwater noise have an effect on what part of the hearing. This can be used to determine whether wind farm-related noises have an

[39] *A point of discussion is what noise recording equipment is most suitable for obtaining quantitative data on porpoises. This chiefly involves T-pods or C-pods, and the quantitative interpretation of the results.*

effect on the detection of biologically relevant sounds produced by members of the same species, prey or predators.
   b. Equal-loudness curves (how loud does a porpoise experience different frequency/noise level combinations). An increase in noise level is not experienced equally loud for all frequencies (A or C assessment is used to set up OH&S noise standards for humans, for example).
   c. Noise source localisation capacity (if porpoises have the capacity to find out where noises originate, they can swim away from them and thus reduce the noise level they experience).

   1 Year, generic information, medium length term.
4. Threshold values at which wind farm-related noise starts having an effect on the behaviour of porpoises. Such experiments can be carried out in pools. **Per type of noise. (e.g. the noise of pile driving, maintenance ships, rotating turbines).**

Seals

Priority 1
1. Comparable to the porpoise, the TTS can also be an important limit value for the foraging options of common seals. **Generic information, short term.**
2. Study on the hearing range of grey seals (audiogram). **Generic information, short term.**
3. Critical ratio of the common seal. These data can be used to calculate the distance at which underwater noise is audible for seals under various background conditions (*sea states*). If the background noise increases (usually positively related to wind force), the hearing detection threshold for noise increases (possibly up to the point they are no longer perceived). The critical ratio defines the increase of the hearing threshold affected by the background level. **Generic information, medium length term.**

Priority 2
1. Distribution of seals at sea. More insight should be provided into the food sources of seals and in the relation to their habitat: why do they go to a certain location (e.g. Borkumse Stenen) and when does an increase in disturbance have a possible effect on the population level (including exchange with populations abroad). Seals at sea are relatively difficult to observe from aircraft or from ships. Expanding working with transmitters to other locations (especially the central parts of the Waddenzee and the Delta Coast) is preferable, both for the common and grey seal, in order to model the information on the habitat preference of the animals and the (seasonal and location-specific) variation in this. Perhaps this study can be expanded to an international level. **Per species /2 locations, for 3 years, basic information, medium length term.**
2. These data are required in order to quantify the effects of noise on the migration and foraging behaviour of seals. **Generic information, short term.**
3. Seal countings should be continued. The countings of the south-western Delta should be synchronised to the international Waddenzee countings. **For the Delta area: basic information, medium length to long term.**
4. Other hearing parameters of seals, such as:
   a. The directionality of the hearing (if they turn their head away from the noise, the intensity of the noise as they hear it is reduced).
   b. Critical bandwidth. What tones of the underwater noise have an effect on what part of the hearing. This can be used to determine whether wind farm-related noises have an effect on the detection of biologically relevant sounds produced by members of the same species, prey or predators
   c. Equal-loudness curves (how loud does a seal experience different frequency/noise level combinations). An increase in noise level is not experienced equally loud for all

frequencies (A or C assessment is used to set up OH&S noise standards for humans, for example).

d. Noise source localisation capacity (if seals have the capacity to find out where noises originate, they can swim away from them and thus reduce the noise level they experience.

Per parameter, 1 year, generic information, medium length term.

5. Threshold values at which wind farm-related noise starts having an effect on the behaviour of seals. Such experiments can be carried out in pools. **Per type of noise. (e.g. the noise of pile driving, maintenance ships, rotating turbines)**.

Porpoises and Seals

Priority 3

For porpoises in particular (and some dolphins), it is important to gain more insight into their distribution in the North Sea, their migration movements, the importance of certain areas in their life cycle and their behaviour to noise sources other than those of pile driving. Porpoises are generally assumed to require constant foraging, especially when juvenile. What effect existing wind farms have on the foraging behaviour and food intake of porpoises is unknown. If large wind farm surface areas are situated on migration routes and/or foraging areas that are important to porpoises, their fitness may be reduced because for some of the time they cannot forage optimally. Although a survey by observers produces valuable information, it is not clear if this will also produce data on the migration and population structure of this animal group. One thinks that porpoises in particular do not form a homogeneous population, but rather consist of several (sub)populations[40]. Evans & Hammond (2004) describe the advantages and disadvantages of various monitoring techniques. Studies on foraging behaviour and food intake could produce valuable information in various field situations (with underwater noise) on the limitation of food intake due to the construction and presence of wind farms. Studies such as these should be set up internationally.

In addition to the direct effects (TTS, PTS), it is important to study the indirect effect of underwater noise and the change in behaviour specifically for marine mammals, first in the laboratory (pool or harbour) and after that possibly in the field, depending on the outcome.

It is currently still a point of discussion what technique is most suitable for this purpose, especially for porpoises and dolphins. Carrying out experiments on seals in a large closed off harbour where the noise conditions are good appears to be a realistic option. Thus far it has not turned out to be possible to study behaviour on a small scale in the field, since the tags used only function if the seal comes to the surface to breathe. It may be possible to use the so-called d-tags. These tags, developed by Woods Hole, offer the option to store all kinds of data on noise under water. The tags can be collected after they fall off. Such versions of the tag, adapted to porpoises, have been tried out in Denmark (DeRuiter *et al.* 2009)[41]. The extent to which this is also practically feasible should be further examined. For various reasons, tagging is not so easy to use for small cetaceans (porpoises and dolphins) as for larger species (Hooker & Baird 2001). Thus there is relatively little experience with tagging small cetaceans. Capturing species such as the bottle nose dolphin is relatively easy because they like to surf on the bow wave of a ship (Klatsky *et al.* 2007). As far as porpoises are concerned, one could use rehabilitated stranded porpoises. Follow-up study is first required on the effect of behaviour of tags on this small toothed whale species. The experience of

[40] http://www.cms.int/reports/small_cetaceans/data/P_phocoena/p_phocoena.htm

[41] http://mit.whoi.edu/page.do?pid=35555&tid=1423&cid=52528

SEAMARCO in 2002 was, however, that the swimming behaviour of animals with tags was conspicuously different from that of animals without tags, due to the resistance of the tag (the tag even caused a strong increase in food consumption).

1. Study on a small scale but with high resolution on migration, use of habitat and foraging behaviour of porpoises in the (southern) North Sea, whether or not in combination with underwater noise recordings. **Basic and generic information, long term.**
2. Study on a small scale but with high resolution on the use of habitat of seals in the southern North Sea. **Basic and generic information, long term.**
3. Study on a small scale but with high resolution on changes in behaviour of porpoises and seals around and in wind farms. **Generic and location-specific information, long term.**

The table below presents an overview of the above-mentioned priorities for the various components.

Monitoring components	**Priority**			**Term**			**Type of information**			**Duration (y)**
	1	2	3	ST	MT	LT	B	G	LS	
Underwater noise										
- Int. consultation	■			■			■			1
- Sources	■			■				■		2
- Propagation model		■			■				■	2
- Mitigation review		■			■			■		1
- Underwater noise map			■			■	■	■		1+
- Risk analysis tool		■				■		■		2
Plankton										
- Mixing, PP			■	■				■	■	?
- Plankton composition			■	■	■			■	■	?
Benthos										
- Soft substrate species			■		■				■	5
- Hard substrate species			■		■				■	3
Fish (larvae)										
- Effect of pile driving	■			■				■		1
- Larvae survey	■			■	■			■		1
- Expansion of the model, validation of death, autecology of larvae		■			■	■	■	■		4
- Food web effect			■			■		■		?
- Effect EM			■			■		■		1
- Effect of contaminations			■			■	■	■		1
Birds										
- Pop. dynamics, tagging lbbg	■			■	■		■			4
- Survey at sea (avoidance of sea birds)	■			■			■			5
- Radar observations	■				■			■		5
- Sea bird strandings related to collisions		■				■			■	5
- Collision measurements		■				■			■	?

Monitoring components	Priority 1	Priority 2	Priority 3	Term ST	Term MT	Term LT	Type of information B	Type of information G	Type of information LS	Duration (y)
- Ring counting desk			X	X			X			?
- Ring counting field			X			X	X			?
- Use of habitat by sea birds			X		X		X	X		?
Bats										
- Bat detection coast & sea			X							?
- Data of catches at sea			X							?
- Behaviour at wind farms			X							?
Marine mammals										
- TTS por	X			X	X			X		3
- Other hearing parameters por		X		X			X			
- Threshold values por		X		X			X			
- North Sea survey por	X			X			X			5
- Wind farm survey por		X		X	X			X	X	2
- Behaviour por as a result of pile driving		X			X			X		?
- TTS com sl	X			X				X		1
- Audiogram gr sl	X			X				X		1
- Critical ratio com sl	X				X			X		1
- Other hearing parameters sl		X			X		X			
- Threshold values sl		X			X		X			
- Distribution of sl at sea		X			X		X			3
- Analysis of the noise effects		X		X				X		1
- Countings		X			X	X	X			5
- Use of habitat por			X			X	X	X		?
- Use of habitat sl			X			X	X	X		?
- Behaviour of por & sl at OWF			X			X		X	X	?

lbbg = lesser black-backed gull, com sl = common seal, gr sl = grey seal, por = porpoise

4.3 International aspects

The cumulative (potential) effects of international expansion of offshore wind farms prompt further expansion of the MEP. As indicated above, not only the Netherlands has big plans to upscale OWFs in the North Sea. Altogether, the Netherlands, Belgium, Great Britain, Germany and Denmark want to realise dozens of GW of OWFs in the (southern) North Sea. Large farms are also planned for the western Baltic and the northern North Sea. Since many fish, birds and marine mammals often use the southern North Sea or an even much larger area (as far as Western Siberia for some birds) as their habitat, the effects must also be taken seriously on that scale. A MEP that focuses on international cooperation is required for this purpose. The previous section already presented a number of monitoring plans with a clear international component, such as distribution and migration of animals (birds, marine mammals) over (the southern part of) the North Sea.

Despite the relatively large effort in monitoring of and research on ecological effects, it can be stated that the information stemming from this has so far not been used in the spatial planning for OWFs. Until now, monitoring and research has chiefly been used to keep a finger on the pulse, *i.e.* to find out if there are any serious unforeseen effects on ecological aspects. This strategy is per definition more location-specific than generic and may need to be adapted to gain insight into effects due to upscaling (increase in the number of wind farms) and in assessing cumulative effects.

At the moment it is highly important to set up an international program focused at harmonisation and maybe even standardisation of research, monitoring and data exchange collected during the construction and operation of OWFs. It should cover co-ordination and co-operation of the field work, methods of assessing effects (statistics, modelling), and data format/access. Moreover, it should include setting up guidelines on how cumulative effects should be assessed, and what other activities, plans of projects should be considered to be included in the assessment. Such a program would need to be set up as soon as possible.

With respect to monitoring cumulative effects, and thus to the international approach to monitoring and research, it is notable that the differences in monitoring activities between the various countries is primarily expressed in the selection of the species and ecological communities to be monitored. Furthermore, the countries differ in the scope and set up of studies, e.g. whether measruments are done only in the farm or also outside it, if a a reference area is included in the study or not, etc. Less attention is paid to the number of repetitions, the duration of monitoring activities (the number of consecutive years). These are important issues because objects of study in monitoring (e.g. the distribution of birds) may produce very variable results. Subjects with great variation in distribution and behaviour demand a larger number of measurement repetitions in order to bring to light any statistical differences between the baseline or reference and the disrupted situation. In addition, the comparisons with undisrupted situations (baseline T_0 or proper references) is important. For example, a study on the effect of land-based wind farms on bird populations showed that there may be effects, however they turned out to be non-statistically significant. Due to a relatively low number of repetitions and the lack of reference studies, it cannot be excluded that there is an effect or that this effect cannot be verified as a consequence of the number of repetitions (Stewart *et al.* 2007). In addition to the above-mentioned aspects, monitoring frequency also plays a role. For example, this has an effect on the likelihood of observing migrating birds during a survey. Various countries are reflecting on repetitions and duration of monitoring activities, for example with respect to birds in Belgium. English studies also show that they are aware that monitoring certain aspects (bird density) may not be intensive enough to have sufficient statistical power to bring the effects of turbines to light if they are not extremely severe (50-100% effect) (Maclean *et al.* 2007).
Maclean *et al.* (2007) state that effects on birds must be interpreted on the population level, which is in keeping with the Birds Directive. They propose using population models to pass on a decrease in survival (e.g. as a consequence of collisions) through the calculation of the population.

Standardisation of measurements, counting methods is another important aspect, especially in view of international cooperation and cumulation of effects. Currently there appears to be a great deal of variation in measuring methods. Standardisation has been sought for certain monitoring activities, such as for bird observation (Camphuysen *et al.* 2004).

Another point is that some wind farms have been planned on national borders. This is true for both the Belgian and German farms and the effect of those farms may be extended into the Netherlands. The development on the Belgian/Dutch border particularly may be of quite some relevance in light of the large flow of migratory birds along the coast.

Designing future international cooperation

In light of the above-mentioned, it is important to link the master plan to research and monitoring activities that are being carried out internationally with respect to wind energy at sea. The Minister for Economic Affairs is about to submit a formal request to join the so-called Joint Declaration that has been agreed upon by Germany, Denmark, Sweden and Norway.

The intention of this Joint Declaration is to formulate joint research requirements, which subsequently offer the option of carrying out concrete (among others) ecological research projects within each others EEZ and/or wind farms. Cooperation takes place on mutual terms, i.e. no financial transactions will take place between countries and/or institutes. International cooperation offers the opportunity to expand the findings, to learn from each others methods and to use research tools more effectively. Foremost, this Joint Declaration can be the framework within which the (potential) cumulative aspects of the wind at sea policy of the countries around the North Sea can be monitored and possible agreements can be made on mitigating measures. Issues that deserve the attention for the Netherlands in the area of conservation and the environment involving wind at sea, and which can be introduced for possible cooperation are, at this time, primarily in the area of physics of underwater noise and the effects of underwater noise on marine mammals.

4.4 Set up of a monitoring and research plan

An aspect of a monitoring and research plan that is often not well developed *a priori*, is the statistical set up of the monitoring or research. Without going into detail, several points need to be developed thoroughly before exercising the field work.

As stated before, building an OWF is much like an large-scale experiment. The experimental set up thus is very important for what can be expected from the measurements. Roughly, two types of set up are possible. The most common set up is the BACI design. It is a design that focuses at changes in a local environment due to some impact, and compares it to the situation before the impact (before-after - BA) and to a comparable environment without impact (Control-Impact, CI). Depending on the heterogeneity of the parameters to be measured, more or less control and effect areas need to be chosen. An example of this is the effect of an OWF on the benthic community within the farm. Another design is applicable when effects are expected to be not local, point wise, but more in a gradient. Measurements can that be done in a grid, where the effect is to be expected (e.g. from a model). An example is the effect of a silt plume, caused by sand extraction, on benthic life. Near the extraction site the effect will be strongest, further downstream it will be less. Effects can then expected to be gradient-like and be related to the degree of impact. Other designs are possible, mostly variations on these themes.
With each design comes a statistical model, such as (*e.g.*) Multiple Analysis of Variance (MANOVA) in the case of BACI, and GLIM (Generalised Linear Modelling) in the case of gradient analysis.

Another important aspect is dealing with uncertainty. Field data are prone to all types of errors. A good set up of the experiment and performance of the field work helps reducing most common errors. However, filtering the effect from the static (natural variability) asks for a thorough statistical analysis and if necessary, a flexible experimental procedure. Usually, a T_0 power analysis is needed to get an estimate of the variability in the samples, and gives support to what size of error (both type-I and type-II) can be expected with a fixed number of samples. Doing several consecutive T_0 helps getting a view on the interannual variability.

Some effects can be long-term (5 to 10 years), and sometimes animals habituate. This may ask for long-term monitoring programs.

All these issues tend to prolong a monitoring and research plan, and consume excessive amounts of money. It is therefore of the utmost importance to have a thoughtful set up: it save a lot of time and money. Nevertheless, for the management of the research (and for policy-making), it is important to realise that some level of uncertainty needs to be dealt with (see also par. 4.3). The error level of lab experiments (Type-I error of 1% or less) is usually not feasible in the field. Somewhere between 5 or 10% is more realistic, but in many cases even this is difficult to realise.

Measuring some local effects, such as benthos diversity changes, has probably a good chance of being detected with a sound set up. However, the important goal of impact assessment is finding the right level at which an effect needs to be addressed. Commonly, this is the population or the community level. Legal constraints for instance often focus at a breeding population (colony) of birds within a protected area, with still seems a feasible level when it comes to assessing effects. However, when birds leave a colony the effect may be “diluted” due to mixing with other specimens when the breeding colony is established the next year. It is therefore important to assess the effect at a “higher” population level. Such assessments are not very easily made and ask for research programs that extend outside the study area. Nevertheless, ecologically, assessing the population fitness (and in the end its power to survive as a species) is the most (if not the only) relevant assessment level.

Thus, it is highly unlikely that within the coming ten years, all desired effects of building and operating OWFs will be known with this certainty. Population effects of under water sound on porpoises for example are not likely to be able to be measured as such. Modelling will be an important part of the work, with important steps trying to get data calibrated and validated. Development of measuring equipment is a prerequisite for getting a grip on collision effects and barrier effects on birds. International co-operation, harmonisation, and reviewing (data methods) will be important catalysts in getting this work done properly.

5 Data management

5.1 Introduction

For the effectiveness of monitoring, it is of great importance that the data and information sources be stored, managed and made available in a clear and accessible way. Quality assurance of the data products is also closely related to the manner in which data are managed.
Since this master plan involves broad multidisciplinary monitoring carried out by a large number of parties, proper data management is not something that goes without saying. With that fact in mind, the section below discusses the general objectives of data management and the roles and responsibilities of the parties involved. In conclusion, several technical solutions are proposed as examples in order to accomplish these objectives and organise the responsibilities.

5.2 User requirements and objectives

The requirements imposed on data management involving OWFs are

- unambiguity & documentation of data sources
- continuity & expandability of the storage system
- completeness & bundling in the system
- quality assurance & quality optimisation
- direct & controlled access to data
- accessibility through connection to other (existing) data infrastructure

Unambiguity & documentation The principal objective of data management is to univocally record the accumulated and historically present information for the benefit of monitoring. Unambiguity relates, among other things, to the topicality of the information available. It is also important for example that the version of certain data on which certain conclusions or decisions are based is also recorded and documented. In order to guarantee unambiguity, it is advisable that the system handle the version management of the data automatically and that it is made accessible at a central location. In addition to a version number, it is very desirable that the data of other meta-information be provided so that the various parties with an interest have insight into the origin and quality of the data and know how the data can be used in combination with other data.

Continuity & expandability Especially for project-exceeding monitoring, it is important that a clear, progressing archive be accumulated that makes it possible to safeguard all relevant data on offshore wind farm management over the course of time. The archive should preferably have a backup function, so that the data will not be lost in case of failures or errors. The archive must also be seamlessly expanded after every new measuring set (in time or place).

Completeness & bundling The archive must be complete in the sense that it, at minimum, includes all data collected as part of the OWF monitoring, thus unique data. In addition, the archive can refer to supporting data that were obtained in other frameworks. Finally, the archive can also include derived data products (statistics, combinations or aggregates of data, reports).

In the specific case of a large group of parties involved and very diverse data types, it is often important for the sake of analysis that data can be seen in their mutual context. The fragmentally obtained data available must in that case thus be made accessible as a bundle.

Quality assurance and quality optimation The above-mentioned metadata and version management make it possible to safeguard the quality of the data. The creation of the data or the data product is recorded in the metadata, including references to measuring protocols, calibration data and reliability information. Not only can the combination of version management and metadata safeguard the quality, but also, if desired, optimise the quality, for example as a result of progressive insight (such as after recalibration of sensors).

Direct & controlled access In addition to storage and filing, it is important to make data available to different users. Besides the above-mentioned actualisation, unambiguity and bundling of fragmented information (traceability), fast availability also plays a role in this. The traceability is improved by publication of the meta-information in accordance with fixed conventions and protocols.
The data are preferably retrievable at any random moment and also directly accessible. Confidential data (or some of it) may only be available to agencies or individuals authorised for this purpose.

Connection to other data infrastructure It is desirable to link the OWF-specific data to the general data-infrastructure of the managing governments in the course of time in view of utilising the investments and efforts made to the benefit of social propagation of information and knowledge. This knowledge can be anchored as such, also outside the context of monitoring wind farms.

5.3 Roles and responsibilities

Various parties with different roles and responsibilities are involved in monitoring OWFs. The competent authority must have an up-to-date overview of the information required for enforcement or for issuing permits. Developers and OWF owners probably do not only want to have location-specific information for the facility, but also current data during operation. NGOs and other parties with an interest will want to keep a strict eye on the progress and possible interim results of monitoring. Finally, a number of parties will be in charge of taking and analysing the measurements. These parties must supply interim and final data and data products, provided with the requisite metadata.
For the continuity of data management, the question of whether a party can be appointed which can be put in charge of making data and data products available and managing them for an indefinite period is central. All above-mentioned parties may, after all, lose their involvement in North Sea-wide monitoring of OWFs (e.g. due to transfer of management of an area, in the case of development of a new area, due to implementation of measurements being granted otherwise) over the course of time. In addition, it is perhaps also politically desirable that management of and providing access to the data and data products be handled by an independent party.

5.4 Technical interpretation

Principally, there are two different technical elaborations possible to meet the above-mentioned requirements as well as to configure the roles and responsibilities of the parties involved:

- central storage with central access provision,
- peripheral storage with central access provision.

Providing access is central in both cases in order to safeguard the desired bundling and completeness. A central or distributed approach may be opted for to handle actual storage, management and maintenance of the stored information. A hybrid implementation is possible in practice. The organisation of the two options is presented in the diagrams below.

Regardless of the choice for a central or distributed variant, the possibility of storing all unique data in a repository is central. A repository is an electronic archive that can be accessed via the Internet. A repository has a back-up function, version management and, if so desired, access secured by a password. A repository can be accessed via one or more web portals, whereby different options can be provided via a user interface to search data and download them, or possibly even visualise them directly. If central storage is opted for, the repository will be accommodated and managed centrally. In that case, the various parties must regularly supply their data to the central repository and also manage the versions there. Access (blocked from the public) is also available for this, linked to version management. This version management usually runs via Subversion software. Figure 5.1 below illustrates a specific central OWF repository next to a generally existing repository where data relevant for OWFs may also be stored.

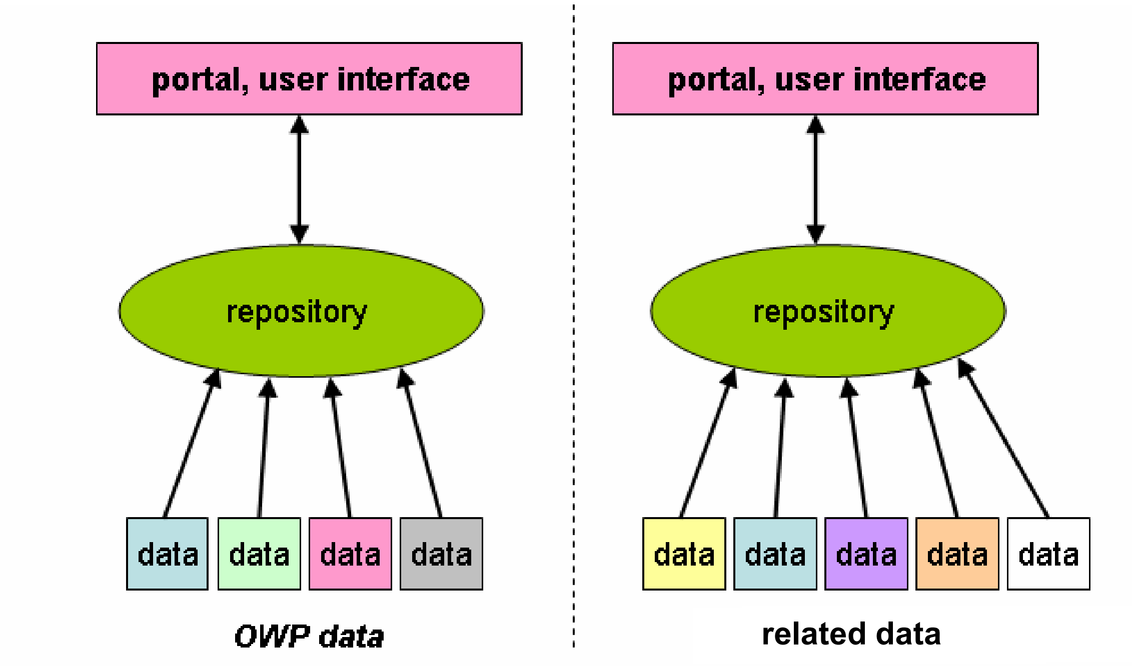

Figure 5.1 Diagram of a central repository for specific OWF data (left) next to one of the other possible repositories (right) for data related to OWF that are not retrieved and are made available exclusively for OWFs.

An alternative to a central repository for OWF-specific data as presented in the part on the left of figure 5.1 above is a network of distributed repositories that is accessed via a central portal. Bundling can take place because of the central portal, but specific parties are in charge of management of the various partial collection of data. These may be the parties gathering data, which also already manage the same or very comparable data for different purposes, or they could be a few appointed managers that manage certain types of data.

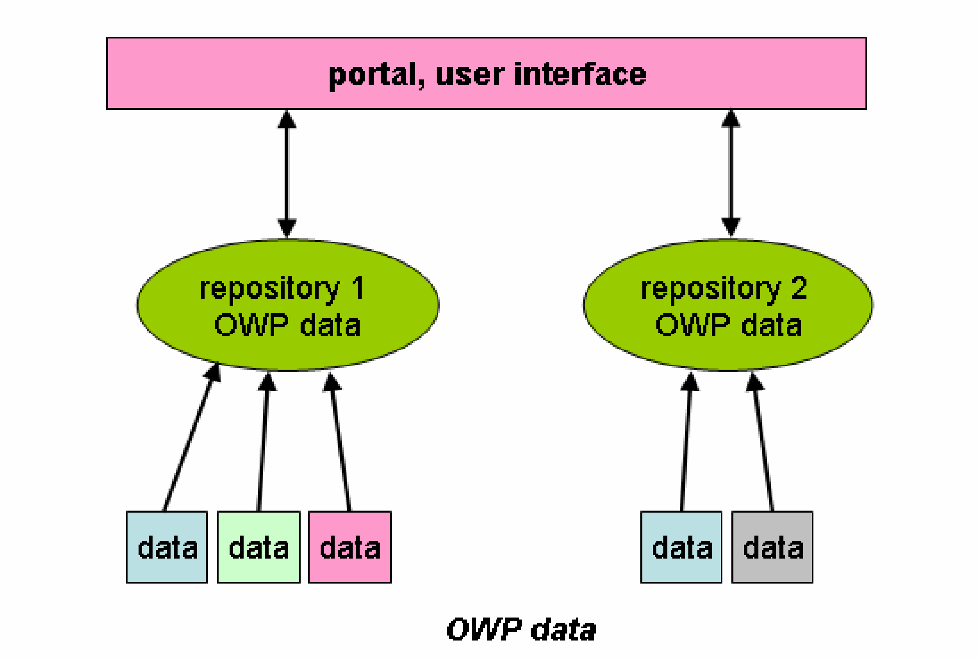

Figure 5.2 Diagram of a peripheral repository for the specific OWF data to which a central portal provides access. The user cannot see whether the data originate from one or more repositories. This is only important for management and maintenance of the data (content) and repository servers (infrastructure). In this scenario, this figure would replace the left hand side of figure 5.1 in the total data overview.

Finally, it is also possible to integrate OWF-specific data immediately or eventually with an already existing repository with related data (right hand part of figure 5.1). This is illustrated in figure 5.3.

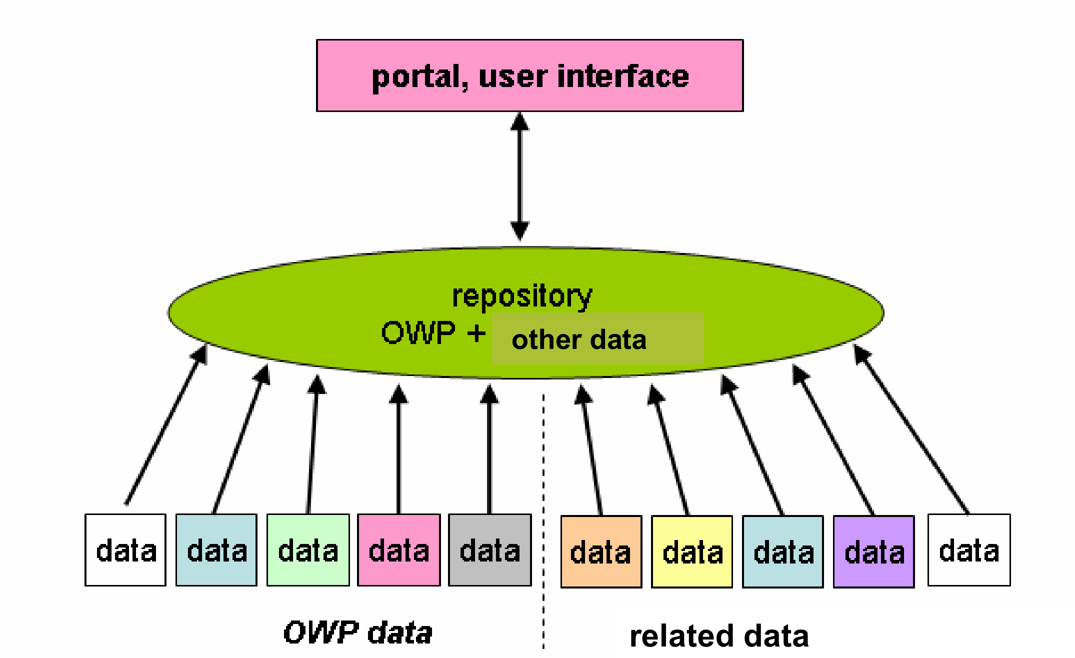

Figure 5.3 Diagram of an integrated repository for specific OWF data (left) as well as other data related to OWF that are not collected exclusively for OWFs (right).

5.5 International context

Since trans-border effects and processes are involved in the development and monitoring of OWFs, it is desirable to dovetail with the operating procedure of the countries around us. These countries have also opted for making data available centrally, as illustrated below:

- The COWRIE (*Collaborative Offshore Windfarm Research Into the Environment*, http://www.offshorewindfarms.co.uk) foundation has been established in Great Britain, directed by Crown-appointed members, the *Department for Energy and Climate Change* (DECC), and the *British Wind Energy Association* (BWEA). COWRIE is the central entrance to all relevant data and information generated during the second round of permits for offshore wind energy generation in British waters.

- In Germany, a *coastal observatory* has been set up, including the three FINO measuring stations, among others. Management of the platforms is subcontracted to a private party there (*Germanischer Lloyd AG*), but data management and dissemination has been given to BSH (*Bundesamt für Seeschifffahrt und Hydrographie*) of the federal government. For the time being, it cannot be said with certainty whether all data are stored centrally or peripherally here.

To make data accessible, it is desirable to be in keeping with international conventions and protocols for documentation, storage and providing access. Within Europe, conventions for nomenclature have been developed in the framework of SeaDataNet, among others, to make data and data products traceable and comparable. The Netherlands has contributed to this via the Dutch Oceanographic Data Commission (NODC), in which RWS DiD and RWS Waterdienst, among others, are represented. The development of conventions is continuing in European context at this time.

6 Synthesis and evaluation of research and monitoring

This chapter gives some recommendations for the quality assurance for the (iterative) process of results for answering the monitoring and research questions. It indicates the preconditions within which this synthesis (integral approach of the results) and evaluation (reconsideration of the basic assumptions) of monitoring should take place. The basis for this is the basic assumption that the process of monitoring and management should be transparent and adaptive. Transparent means that it is clear to everyone which basic assumptions and strategy are to be used, what steps are part of this process and what steps are to be taken, and what role may be expected from the various parties. Adaptive means that the monitoring techniques as well as monitoring strategy and management are sufficiently flexible to enable adaptations (in technique, strategy and management) if progressive insight necessitates this.

Both the synthesis and evaluation are components of the (iterative) empirical cycle, part of which is described in chapter 2. In places where the description of the information questions and monitoring questions are part of the deductive process (from general information to specific research), the synthesis and evaluation are important components of the inductive process (from specific results to general information)[42].

Synthesis and evaluation of the monitoring are processes in which both the information cycle and the policy cycle are of great importance. Synchronisation of these cycles is very important if the professional expertise is to be given a proper place in the policy cycle, and is regarded as a structural component of ecosystem-based and adaptive management (Barkenbus 1998, Ruckelshaus *et al.* 2008). A great deal of literature is available on application of information in policy decisions. A comparable cycle was/is used in the framework of drawing up the EcoQOs for the North Sea, among other things.

Synthesis takes place by arranging the` results of the various studies and monitoring projects next to one another and connecting them. This integrative step is necessary in order to be able to answer the original information questions better. Evaluation in a broader sense means, in this context, the regular interim calibration of the status of information and methodology (in the information cycle) on the one hand, and strategy and management (in the policy cycle) on the other. The first component is chiefly focused on the how, when and where questions of monitoring: is the methodology used adequate for answering the information questions. The second component primarily comprises the what and why questions of monitoring: are the priorities set down in the monitoring programme the right ones. These two have an effect on one another and thus cannot be regarded separately from each other[43]. This effect on each other is evaluation in a more restricted sense: what do the results produce for the “what and why” of monitoring; basic assumptions and priorities can be adjusted so that the “how, when and where” of monitoring can be adapted.

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[42] *see also the footnote in section 2.3.*

[43] *The separation between the “objective” and the “normative” is always artificial, but is separated this way as a process: the moment when the normative nature of monitoring is discussed is evident.*

6.1 Synthesis

As stated above, the synthesis chiefly comprises the integration of the separate results. Synthesis can also be regarded as part of the scientific evaluation of strategies and methods.

Prior to the synthesis, analysis of the data obtained takes place for each research or monitoring component. After statistical or model analysis, these are converted into an answer to the individual information questions. An example is the foraging distance of breeding birds from colonies by means of tagging. Modelling the individual movements of birds results in a certain average idea of the distances, frequencies and directions of birds from a colony to forage. Furthermore, the various components of an information question must be connected to one another in the synthesis. As an example, we can take the question with respect to the collision risk of coastal breeding birds. To this end, insight must be obtained into the flying altitudes, foraging distances and foraging directions, avoidance behaviour and collisions.

This inductive step is required in order to arrive at the evaluation of information and methodology in the information cycle. In other words: what was the quality of the deduction and the conceptual-propositional analysis as carried out prior to monitoring and the research itself with respect to the information question “what is the effect of the presence of wind farms on the breeding colony/colonies of bird X”. In addition to the numerical analysis and testing of the quality of data, testing the previously drawn up hypothesis and possible adaptation of presuppositions will have to provide an answer to this. Furthermore, the cluster of hypotheses for a certain information question will have to be joined and compared in order to support or undermine the basic assumption that “wind farms have a negative effect on breeding colonies of sea birds on the coast”. Incidentally, this is also the time to include results of other, possibly foreign studies in the synthesis.

The quality of this analysis and synthesis is in turn of great importance for evaluation in the policy cycle: are the right questions asked and the right priorities set down. Of course these questions depend on social preferences and political decisions, but are directed to a large extent by the results of monitoring and research. Recognising these processes is essential, as is formalising the synthesis and evaluation steps in and in between the information and policy cycles.

6.2 Evaluation

As stated in the previous section, various evaluation moments can be named: the evaluation moments in the information cycle and the policy cycle, and those of the two cycles together.

Evaluation of the information cycle is the logical consequence of the synthesis (integration: placing the results in the context of the prior deduction of research and monitoring components from the information questions) and comprises recalibration of the basic assumptions and premises of the information questions, after which a new iteration round of the deduction and elaboration of new hypotheses can take place. Evaluation of the policy cycle comprises developing (or not developing) new priorities and making decisions on this on the basis of the progressive insight obtained by research. Such priorities can be developed in the area of the monitoring or research components (should we continue with the same method or in the same direction or use another method or go in a different direction) or between information questions (develop more information for effects on seals, and less for birds). In addition to progressive insight into the information cycle, such priorities can also be caused by changes in social developments or political preferences. The joint evaluation is the time at which the individual evaluations are communicated back and forth. Others, for example private parties with an interest in planning and implementing monitoring can also be involved in this evaluation.

In practice, this process of individual and joint evaluations will take a few rounds, after which the cycles will go their own way again. The frequency at which such evaluations should be made depends a great deal on how quickly the results are generated and the socio-political changes take place, and also do not necessarily have the same frequency.

It is of great importance that time is made available and scheduled into the organisation of a monitoring plan for synthesis and evaluation.

6.3 Audit

Finally, an audit of quality, coherence and continuity of the monitoring and research should have a place in these cycles. Due to the interdependency of research and policy with the interests of the individual parties, appointing an audit committee is important. Such a committee preferably consists of people who have no stake in monitoring the wind farms, or in the wind farms themselves. Considering the international nature of the construction of wind farms and their effects, it goes without saying that foreign researchers, policy makers and people from the industry should be part of this audit committee.

An audit committee can be a touchstone for the various parties involved in the monitoring plan on a regular basis.

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Annex A: List of abbreviations

Abbreviation	Explanation
AA	Appropriate Assessment
BACI	Before-After Control-Impact
BHD	Bird and Habitat Directive
BSH	Bundesamt für Seeschifffahrt und Hydrographie (D)
BWEA	British Wind Energy Association (UK)
CIA	Cumulative Impact Assessments
COWRIE	Collaborative Offshore Wind Research Into the Environment
DCS	Dutch Continental Shelf
DECC	Department of Energy and Climate Change (UK)
DiD	Data- en Informatiedienst (Data and Information Service)
EcoQO	Ecological Quality Objective
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
FEPA	Food and Environmental Protection Act (UK)
FF Act	Flora and Fauna Act
FINO	Forschungsplattformen in Nord- und Ostsee (D)
GPS	Geographic Positioning System
GW	Gigawatt
IDON	Interdepartementaal Directeuren Overleg Noordzee
IPC	Infrastructure Planning Commission (UK)
MEP	Monitoring and Evaluation Program
MINOS	Marine Warmblüter in Nord- und Ostsee (D)
MMO	Marine Monitoring Organisation (UK)
MSFD	Marine Strategy Framework Directive
MW	Megawatt
N2000	Natura 2000
NODC	Nederlandse Oceanografische Data Commissie (Dutch Oceanic Data Commission)
NP Act	Nature Protection Act
NSIDM	North Sea Interdepartmental Directors Meeting
NSW	Near Shore Wind farm
OH&S	Occupational Health and Safety
OWEZ	Offshore Wind farm Egmond aan Zee
OWF	Offshore Wind Farm
PTS	Permanent Threshold Shift
RWS	Rijkswaterstaat
SAC	Special Area of Conservation
SEA	Strategic Environmental Assessment (UK)
SPA	Special Protected Area
TADS	Thermal Animal Detection System
TTS	Temporary Threshold Shift
UK	United Kingdom
WA	Water Act (NL)
ZKO	Zee- en Kustonderzoek (Coastal and offshore research)

Annex B: International audits and the authors' responses

Audit NERI, Denmark

1 Introduction

The master plan initially defines the background for the plan (a "*plan for a measuring programme required to fill in the gaps in information in determining the ecological effects of OWPs*") and the legal framework. In chapter 2 it is stated that "*this master plan creates the framework required in order to arrive at a good monitoring plan: what are the most important questions, what are the gaps in information, what methods can be used, what do they produce and how is the scientific progress organised?*" and "*the master plan is intended to primarily present an overview of the most important research questions, with the main question: "what are the ecological effects of construction, presence and demolition of (an) offshore wind park(s) on the DCS?*". This has been the focus of the present audit.

Chapter 3 summarises monitoring and research programmes for existing offshore wind parks in the Netherlands, Denmark, Belgium, the UK and Germany. The review of activities in these countries (sections 3.1-3.5) is only very briefly commented while our audit concentrates on section 3.6 onwards.

Chapter 2 of this audit represents general comments to the master plan, the suggested monitoring approach and the principles of prioritizing activities, and chapter 3 contains specific comments on the monitoring issues.

2 General comments

The text of the master plan is characterised by numerous abbreviations.
1 A single complete list of all abbreviations will make the document much easier to read.

Several monitoring issues are listed and discussed with reference to existing wind parks and associated monitoring programs. The master plan acknowledges the need for prioritising the monitoring questions. Prioritising the monitoring questions is necessary considering the intrinsic limitations of monitoring programs in terms of economic resources and time schedules. However, it is strongly recommended that comparability and harmonisation of each individual study with existing studies (e.g.
2 cited literature or ongoing monitoring) is explicitly prioritised and included among the criteria listed in 4.1. This is of particular relevance as each monitoring program will refer to one among several projected parks within the North Sea area and since the assessment of possible/expected cumulated or regional effect of several parks obviously depend on comparable data sets. It is further recommended to refer to and
3 prioritise among existing guidelines for the individual parameters (e.g. OSPAR procedures).

4 A general list ranking the priority of the several monitoring questions raised may be inadequate and of little operational value considering the different physical, chemical and biological properties of the potential
5 construction sites within the whole area.

It is recommended that the priority of the monitoring questions should be based on the spatial scales of the expected changes/effects in addition to the criteria already mentioned in the master plan. Spatial scales of expected effects could for example be divided into 1) the near-field of the individual wind turbine in the scale of 1-100 m, 2) local effects within the individual park (1-10 km scale) and 3) regional effects or cumulated effects which arises from the several parks in the Dutch part of the North Sea or the entire North Sea (10 -1000 km) (e.g. review by Petersen and Malm 2008) For the benthic community near-field questions could be the colonisation of hard bottom fauna directly on the submerged part of the wind turbines which would alter the benthic community completely within 1-100 m from the turbine. In the 1-10 km scale no direct effects on the bottom fauna are expected from the constructions. However, exclusion of fishing activities could alter the benthic community due to increased fish predation and reduced disturbance from commercial fishing activities in the 10 km scale. Finally, examples of impacts at the regional scale concerns for example the introduction of hard substrates on several sites due to multiple wind farms that could act as "stepping stones" for invasion of new/alien species or alter the distribution of epifauna due to
6 changes in the connectivity between habitats. The different spatial scales of the questions concerning the benthic fauna will require different monitoring approaches. In the near-field, direct measurements of the colonisation would be relevant with emphasis on target species while locally the fauna should be monitored in relation to abundances of predators and physical disturbance. The regional effect should be evaluated in

terms of how the individual park will contribute to the overall distribution of hard substrate and if the OWP can act as a "stepping stone". Correspondingly, plankton could also be affected over several scales from the near-field enhanced filtrations of bivalves attached to the submerged
7 mill foundations to local upwelling due to changes in the wind stress (Broström 2008).

It is believed that such a framework will help to adopt the priority among parameters in the monitoring programs to the overall to framework of projected parks.

While several of the suggested activities address specific relevant research questions (e.g. effects of underwater noise on marine mammals) the master plan would benefit from a more obvious statistical consideration of the appropriate approach to the monitoring. To use the example of marine mammals and underwater noise, an avoidance of underwater noise by marine mammals may explain observed patterns of different distributions of animals but what method is to be used to examine and validate these differences in distributions? Is the monitoring set-up according to the BACI (Before/After – Control/Impact) approach? For some ecological groups (e.g. benthos) it is specified that effects are determined by comparison of samples taken within the OWP with samples taken outside. This is a control/impact approach which requires that unaffected areas identical to the ones covered by OWPs are available as
8 controls. Unless baseline studies on conditions prior to construction of the OWP are available it will be difficult to justify selection of control areas. It is therefore recommended to include on-site before/after studies.

As the number of offshore wind farms in the North Sea is expected to increase dramatically over the coming years the question of cumulative effects is central for long term planning. The report mentions various cumulative effects but lacks a common framework for assessing these. This could be done in terms of effects on fundamental population parameters, such as age specific mortality and fecundity of marine mammals, which would allow a direct evaluation of combined effects at population level. As most types of impact from single turbines or individual wind farms are likely to be too small to be directly measurable as changes to populations the link to population level parameters must be established indirectly through assessment of factors such as increased metabolic cost of migration, decreased food intake rate, decreased time for nursing of pups/calves etc. and from these factors the net population effect should be extrapolated. This change of focus means that effort should be put in the direction of establishing these relationships. Thus, questions such as "what are the metabolic consequences (and ultimately decrease in fitness) associated with effects such as displacement from the wind farm
9 area and increased migration distances?" should be addressed.

Changing the focus to population level effects not only makes it possible to add effects from several wind farms and effects from other activities, it also allows for a more general approach to mitigation. Thus, if a wind farm is expected to have certain effects on the population of a particular species of concern, then mitigating the effect could as well occur by
10 means of reducing impact from other activities, such as fishery, shipping and oil/gas extraction activities. This will allow further development of offshore wind energy, even if there are significant detrimental effects, by

balancing these effects with removal of other human activities impacting the environment.

An aim of the master plan is to specify the roles of the authorities and the
developers. More emphasis could be put on a description of how admin-
istrative obligations and industry obligations can mutually improve in-
11 sight into effects from OWPs and facilitate improved site selections and
through that reduce environmental impacts.

Obtaining maximal experience from already existing OWPs is of outmost
importance. Therefore administrators should make sure that once an EIA
has been approved and an OWP has been constructed, emphasis should
be made on maintaining long-term monitoring of actual effects from the
structures. Here the definition of the roles of the administration and the
constructors will be important, i.e. that permissions could be granted on
12 the conditions that the actual effect will be monitored during a long-term
post-construction program.

3 Specific comments

Section 2.4, p. 8: Translating the effect of habitat loss of a highly mobile species into an effect on a population level is challenging. A reduction in numbers of e.g. birds utilising a wind farm area may not have an effect of the population or subpopulation. Density dependence may reduce individual bird conditions or alter predation risk. This is an issue that has hitherto been addressed only marginally. Agent-based or individual-based modelling could be one option to address this in more detail. Almost certainly such models will be challenged by lack of basic information on population dynamics and ethological aspects. An agent-based modelling approach may with time also make it possible to address the
13 issue of cumulative effects much more professionally than has been the case up till now.

Section 3.3.2, p.18, Horns Rev and Horns Rev 2: The first set of bullets, with reference to DONG Energy 2006, only refers to Horns Rev 2 and not Horns Rev 1. From the Nysted OWP substantial information has been collected on e.g barrier effect on migratory birds and on the habitat loss of mainly Long-tailed Duck (Petersen et al. 2007). From that same area an
14 ornithological assessment has been published in relation to the construction of the Nysted 2 OWP (Kahlert et al. 2007)

Section 3.3.4, p. 20: There are several reports from the Kentish Flat OWP in the Thames Estuary. In the UK huge strategic areas were defined at an early stage, such as for instance the Irish Sea, the Thames Estuary and The Wash. In Round 3 of the UK development many more strategic areas have been defined. In each of these strategic areas basic monitoring pro-
15 grams have been developed, with the aim to improve the knowledge upon which OWP concessions can be issued.

Section 3.4, "Effects on habitats: plankton", p. 22: The benthic commu-
16 nity has been included as c) – it should be moved to "Effects on habitats: benthos".

Table 3.2: Why are barrier effects on birds, bats and migrating sea mam-
17 mals not included?

Section 3.4, Birds, p. 26: The issue of habituation is important. Petersen et al. (2007) showed that Long-tailed ducks avoided the Nysted OWP five years after construction. A similar study on the effect on Common Scoter at Horns Rev showed that these birds could indeed accept to forage between the turbines after five years of OWP operation. Therefore the weighing of attraction by improved foraging conditions with the avoidance effect created by OWP related ships and turbines will be an
18 important issue that will require long-term post-construction monitoring.

Table 3.3 provides an overview of gaps in information and questions that are elaborated further in section 3.6.2. Under plankton the only change in habit mentioned is disruption of the water column current due to turbine pilling. Attention should be drawn to the possible effects of

OWPs on upwelling and downwelling (Broström 2008). Introduction of an upwelling field during the operational phase may enhance primary production and change plankton composition with possible effects on higher trophic levels (e.g. fish larvae). During the construc-
19 tion/demolition short term effects on plankton due to changes in turbidity are expected.

Table 3.3, Birds: Under "change in habitat", "operational phase" the ecological problem is defined as "loss of present habitat". It must be emphasised that it is actually loss of access to present habitat, since there is no
20 physical loss of habitat but a behaviour-response induced loss of habitat.

Section 3.5.1, Local seabirds, p. 28: When referring to situations where
21 large buffer zones have been used to provide reference areas the Nysted study can be included (Petersen et al. 2007).

Section 3.5.1, Migratory birds, p. 28: When describing local bird movements Desholm & Kahlert (2005) are referred to but that paper is about
22 migrating birds passing the study area twice a year.

Section 3.5.1, Migratory birds, p. 29: It is stated that infrared, radar, visual and acoustic techniques at sea have led to nothing. This is a very general statement which might be true in the Netherlands but in Den-
23 mark the combination of radar, thermal cameras and modelling has successfully been used for estimating the number of bird collisions.

Section 3.6.2 "Gaps in information", Fish p. 39: Many fish species, including commercially important species such as sole and plaice have no swimbladder and they are thus predominantly sensitive to the particle motion component of sound, rather than the pressure component. There is a very large gap in knowledge on a) magnitude and extent of the particle motion fields connected both to pile driving and to operational wind turbines, and b) the effects of intense particle motion (as from pile
24 driving) on fish. There is a very poor understanding of how fish use sound in communication and even poorer understanding of how masking could affect reproductive success.

25 **Section 3.6.2 "Gaps in information", Birds, Collision risks, barrier effect p. 40:** It is stated that collisions between birds and OWPs have never been observed as yet. In Denmark a colliding passerine/bat has been observed with the TADS and in Sweden eiders colliding with offshore wind turbines during daytime have been observed visually (Jan Pettersson, pers. com.). Later in that paragraph the ease by with the collision risk can by assessed at population level using new techniques seems rather optimistic

Section 3.6.2 "Gaps in information", Birds p. 40: There is an almost total absence of information on how diving birds may use underwater hearing in their search for prey and orientation and consequently no informa-
26 tion on how birds could be affected by underwater noise, both during construction and operation.

Section 3.6.2 "Gaps in information", Marine mammals p. 41: For pile driving it is established that porpoises react to the noise at distances of up to many kilometres. What remains to be established is what the be-

havioural changes are and what they mean to the animals. It is thus of
great importance to establish a link between behavioural changes and
fitness of individuals and populations. What does a temporary dis-
placement from the area mean in terms of reduced food intake and re-
duced ability to nurse calves/pups and how do these changes ultimately
affect population parameters (survival and fecundity)? Behavioural ef-
fects on other species (seals, dolphins, minke whales) remain to be estab-
27 lished. The same applies, although on a much finer spatial scale, to be
addressed for turbine noise.

28 **Section 3.6.4 "Monitoring and measuring requirements"**: As it stands
the descriptions of methods in this section are inadequate. The methods
should be elaborated, and in some cases corrected, to provide a compre-
hensive picture of the suggested monitoring. A few examples will be
given in the following.

Section 3.6.4, p. 45: Phytoplankton and zooplankton species composi-
tion, biomass and production are suggested to be analysed by "sampling
of the water column with the plankton net during the day and at night.
Food relations to be studied by means of fatty acid analyses/isotopes,
29 DNA barcoding". There is no rationale behind the day and night sam-
pling, phytoplankton will not be quantified or correctly sampled using a
net and in general the suggested approach is very different from stan-
dard monitoring procedures. As stated previously, one of the main pri-
orities should be to use standard procedures that allow comparison with
30 data obtained through other monitoring programmes and in other coun-
tries.

Section 3.6.4, Birds, p. 45: It should be identified who is responsible for
the individual sections. For instance "basic information" would belong
to a strategic platform assessed by the authorities whereas the second
section "change in habitat" would be the responsibility of the OWP con-
31 structors and will require long-term post-construction monitoring
schemes.

Section 3.6.4, p. 46: "Effect of bottom disruption during the construction
on structure, physics and chemistry of the bottom and on the benthos
ecology" should be examined. The method description is inadequate and
while characterisation of benthos from box core samples can provide in-
32 formation on the benthic community composition it will not describe
"benthos ecology".

Section 3.6.4, Birds, p. 49: High-resolution images are mentioned under
"Method". These are not limited to video systems. High-resolution cam-
eras may also provide high quality information on bird distributions.
The still image approach has the benefit of providing an option for com-
puter automated extraction of birds from the images (e.g Groom et al.
2007, Groom et al. 2010a, Groom et al. 2010b). The high resolution image
method is not limited to the "basic information" section, and may be
even more appropriate as a source of information about bird distribu-
tions in the OWP area with the aim to assess habitat utilisation changes
before and after construction of an OWP. Such an approach could
33 strengthen the ability to detect bird habitat utilisation effects from
OWPs.

Section 3.6.4, p. 52: No single method can provide all required information for all species of marine mammals and a range of methods must be used. Visual surveys are often treated as the standard to which other methods should be compared. However, visual surveys do have a large number of inherent problems, of which some relate to the uncertainty of the final result, others to the applicability of the method in general. The latter refers to the fact that visual surveys are not well suited for low-density areas and cannot be conducted at night and during poor weather. This means, for example, that the current best estimate of porpoise distribution in the North Sea (SCANS II) is only representative for part of the year (July), part of the time (daylight hours) and under certain weather conditions (Beaufort sea state 2 or below). While the total abundance estimate is not affected by this bias, it means that very limited information is available about spatial distribution of porpoises outside summer, at night and under weather conditions more typical of the North Sea. Stationary acoustic monitoring of porpoises comes in as a very valuable supplement to surveys. Even though this method has its own methodological problems, it can provide information on some of the questions that cannot be addressed by surveys. The two methods can thus be said to be orthogonal: surveys monitor densely in space, but in-
34 termittently in time; static acoustic monitoring monitors densely in time but intermittently in space.

Section 3.6.4, p. 53: Effects of noise on marine mammals. Obtaining relevant information to assess effects of underwater noise requires a combination of experiments made on animals in captivity and field studies. Fundamental auditory physiology (audiograms, critical bandwidth etc) and auditory effects of noise (masking, temporary threshold shift (TTS) etc.) should be addressed on captive animals, whereas the behavioural effects must be conducted in the field. Not only is it technically very difficult to recreate realistic sound fields in a tank, but more importantly the recreation of the balance between disturbing/annoying noise and resources the animal wants to obtain (food, mating opportunity etc.) cannot be recreated in a closed confinement. Questions regarding behavioural effects should thus be conducted as field studies using the real set-
35 tings, if possible, and alternatively by controlled exposure studies on wild animals in natural habitats.

Section 3.7.1, Birds, p. 54: It is stated that "there is little interaction between birds of the separate wind parks". This is not the case in Denmark where Horns Rev 1 and Horns Rev 2 as well as Nysted 1 and Nysted 2, respectively, are only few kilometres apart. The point about increased
36 maintenance ship and potentially also helicopter traffic is highly relevant.

Section 3.8.1, Mitigation, p.56: Mitigation is the reduction of an undesired effect of an already established construction. Thus, the description
37 of approaches to reducing effects by informed planning ought to be moved to another section.

Section 3.8.2, Mitigation, p. 56: The three-step hierarchy for risk management should be used here. First you need to try and avoid the conflicts (described as good planning). Second, you can mitigate as described. And finally you can compensate. If mortality of a given species

38 is elevated at one site you may e.g. increase survival of the same species somewhere else.

Section 3.8.2, Mitigation, p. 57: Restrictions on construction and/or maintenance traffic would be another mitigation option. This could be
39 done by spatial or temporal restrictions, restrictions in the type of traffic (ship/helicopter) or by speed limitations to ship traffic.

40 **Section 3.8.2, Mitigation– pile driving noise, p. 58**: A reduction in overall noise level by 3-5 dB must also be considered a very minor effect. Some studies have shown significant effects of bubble curtains (up to 25 dB reduction), but it remains to be demonstrated that such high levels of attenuation can be achieved repeatedly in deeper waters under influence from currents and winds. In terms of protocols for minimising impact of marine mammals, it has been shown through modelling that even with the current practice of deployment of acoustic deterrent devices (seals scarers and pingers), followed by a ramp-up procedure there is still a
41 significant risk that seals and porpoises are exposed to levels sufficient to elicit TTS (Gordon et al. 2009).

Section 3.8.2, Birds, p. 58: Birds often fly at high altitudes in strong tail winds. A national bird migration warning system like the ones being used to increase flight safety may be used. If it could be based on real-time large scale radars and the weather forecast and during the very few nights where lots of birds take off on migration and are met by a front-
42 system with rain or fog, the turbines can be stopped during the hours of high collision risk.

Section 4.2: This section contains a somewhat strange combination of non-specific overall descriptions of activities coupled, in most cases, with specific costs. While we are not able to evaluate the specified costs we do, however, question the relation between costs of some of the activities. As an example the cost of "proper description and validation of the noise sources" including measurements and models to be made is set at 400 kEUR (section 4.2.1, priority 1-2, p. 62) while validation of models based on existing data costs 600 kEUR (section 4.2.1, priority 2-1, p. 62).
43 A more detailed description of activities is needed in order to evaluate costs.

Section 4.2.2: It is suggested to evaluate primary production through remote sensing. At best remote sensing can provide an estimate of chlorophyll concentrations (to be used as a proxy of phytoplankton biomass) given that the OWP is positioned in sufficiently deep water to avoid in-
44 terference from the bottom which is generally a problem in shallow areas. Due to the large seasonal and inter-annual fluctuations in the biomass of phytoplankton, data should be collected over several years (me-
45 dium length term or more likely long term) and not short term as stated. Furthermore, the suggested sampling of phytoplankton and zooplankton for studies on community compositions is insufficient. A sampling frequency of twice per year is in accordance with the minimum requirements of the Water Framework Directive but far too scarce to provide useful information on the composition of the planktonic communities. The rapid seasonal succession and fluctuations in biomass of phytoplankton demands high frequency sampling to provide useful results. Monthly sampling will be a minimum during the growth season. Alter-

natively, phytoplankton could be monitored by continuous recordings of fluorescens (a useful and operational proxy for phytoplankton biomass
46 but not for species composition) by long term deployment of automatic sensors.

Section 4.2.5, p. 65: Observations of collisions are not impossible. How-
47 ever, if the collision risk is very small a lot of systems like WT_bird or TADS are needed. Thus, it is possible but very expensive.

Section 4.2.5, p. 65: In this section the issue of cumulative effects is not
48 visible. Evaluations of cumulative effects will be important for administrative decision making. Therefore the issue ought to be mentioned under "Priority 1".

Benthos: Investigations of effect of wind parks on the benthic communities is described in general terms and very few details are given in terms of methods, sampling design in relation to expected pressures and
49 physical heterogeneity in the potential target areas. Even though the present master plan is aiming at providing general guidelines specific examples of methods would improve the text. Criteria for choosing reference areas should be described explicitly as this is of particular relevance for statistical sound detections of impacts related to the parks. In general benthic fauna is given low priority among the monitoring questions while the motivation for this is described in vague terms. Regional effects in terms of possible changes of the overall distribution of epifauna due to introduction of hard substrates should be described. Relevant methods could involve modelling of current patterns relevant for the dispersal of benthic fauna with pelagic larvae. Also the possible effect of
50 changes in the sedimentation patterns due to local changes in the hydrography especially in areas with strong influence from tides.

Marine mammals: Dynamics of porpoise populations. It is mentioned that visual surveys is a useful tool for obtaining this information. However, porpoise densities are very low in summer in the Dutch North Sea, where survey conditions are best and even in winter densities are comparably low. Stationary acoustic monitoring should be considered as a valuable supplement to surveys, as this method has already demonstrated its usefulness in relation to annual distribution patterns and mi-
51 gration in another low-density area, the German Baltic Sea (Verfuss et al. 2007).

As for abundance inside wind farms, static acoustic monitoring has already proved its usefulness (e.g. Carstensen et al. 2006), whereas the other types of monitoring suggested (visual observers, hydrophone deployment) are unproven methods. Passive acoustic monitoring is not without problems, but this only calls for effort devoted to overcoming these, such as in the direction of standardization of sensitivity and establishing relationship between click recordings and animal densities.

Section 4.3, International aspects, p. 72: Availability of results and baseline data is a critical issue. In order to obtain the best possible basis for planning of future activities (not only offshore wind parks) it is of central importance that all relevant results are available, preferably in the form of peer reviewed publications in international journals. Furthermore the data collected during baseline and impact monitoring should also, in ac-

cordance with the Aarhus Convention of the EU (ECE/CEP/43: http://ec.europa.eu/environment/eia/full-legal-text/aarhus_en.pdf) and the Convention on Biodiversity (http://www.cbd.int/doc/legal
52 /cbd-un-en.pdf) be made available to other subsequent assessments.

Reaction main author on audit NERI

The numbers in the reaction correspond to the numbers in the margin of the NERI audit

General comments

1. OK

2. It is indeed quite relevant to keep track of comparability with other studies performed or being performed. To some extent this is incorporated in the last bullet of the priorities ("can be combined..."). We added a remark about this in the text, but not made it a separate criterion. In the next step (setting up the concrete monitoring programs) it will be a very important issue: harmonising with existing studies.

3. No, this is not a useful criterion. If no existing guidelines exist, this does not mean that the issue is not important, e.g. under water sound. It is something worth looking at though when setting up the monitoring program, since comparability in methods is very useful.

4. Interestingly, this is one of the elements in the criterion that describes the extent of the effect. Whether an effect is local or shows at a larger scale is of course very important. We will add this refinement in our description of the criterion, although its application is currently of a more qualitative nature.

5. At this level, such a list is still quite useful, since the variation in habitat properties is implicitly incorporated in the specific studies proposed. It might be useful to add this as a general comment to the list.

6. I agree with what is said here. I think it is good to emphasise this issue more in the final version. Most of it is placed under the topic "cumulative effects".

7. Again, agreement on this topic. Is mentioned more specifically under "cumulative effects".

8. I fully agree. I have added a paragraph on the set up of monitoring and research plans in chapter 2.

9. This is a very good point and has not received much attention yet in the report. I am aware of the troubles most monitoring studies have when it comes to assessing the effects. In the aforementioned paragraph in chapter 2, this issue is shortly discussed. Within the time frame until delivering the final report, this was the best possible option.

10. Yes, but not an issue in this Masterplan.

11. Currently, a separate chapter (probably an annex) is being written on roles and responsibilities of the various actors.

12. This is a main reason for setting up this masterplan: co-ordination of research, harmonisation of procedures and effectivity and efficiency of evidence-based management. See par. 3.8 (cum eff) and 4.3 (international aspects).

Specific comments

13. The birds have been used only as an example in this section. The way in which individual effects on birds will be assessed at a population level is indeed challenging, but in this report we decided not to go into too much detail on how such calculations will need to be done. It is outside the scope of a masterplan.

14. Has been changed and added.

15. Quite right. The English reviewer has commented likewise. Has been changed.

16. Has been moved

17. It is under "space taken up", we will add this specific issue (and change "space taken up" in "Habitat loss").

18. Habituation is a tricky subject. It may or may not happen, depending on specific species and circumstances. This specific text has been added to the text.

19. Interesting. I did not read yet about this phenomenon. The text has been added to paragraph 3.7.1. However, in shallower parts where no stratification occurs, upwelling or downwelling is likely to have no conspicuous effect on PP.

20. It should be loss of function, since indeed no actual loss of habitat occurs. Has been changed accordingly.

21. Has been added.

22. Reference has been moved to the first sentence.

23. We added the Danish example. The text is about an real collision example. I don't know how you can actually say you have successfully estimated the number of bird collisions if there is no actual "body count".

24. Has been added.

25. The first part of the comment will be added, The optimism comes from the models that have been used earlier in Appropriate Assessments, but of course it is only about an improvement, although probably a considerable one. The text has been changed.

26. Has been added.

27. This text is a good introduction to the more specific questions in our text. it has been used as intro.

28. We added some text in the beginning of the paragraph that explains its non-prescriptive nature. It should not be perceived this way. We went through it and checked the methods and improved where needed.

29. Zooplankton specifically shows a dual migration, affected by day-night rhythms. Sampling should take this into account.

30. Indeed, for phytoplankton sampling normally is carried out using rosette samplers of pumps. Has been changed accordingly.

31. Yes, but that is a matter of organisation, and not of "content". Will likely be addressed in the annex treating this subject.

32. You are right. It should be limited to describing the benthic community when it comes to box coring. And even then boxes will miss out benthic megafauna quantitatively. Has been changed.

33. Has been added.

34. This is more or less a repetition of what is said under "basic information". The last sentence has been added under method/basic information.

35. Comparable to the former note: repetition in other wording. Again, the last sentence has been added.

36. Has been changed.

37. This is actually explained in the first sentence of this paragraph. Makes more sense to change the heading. Is changed in "Preventive and mitigative measures"

38. This is commonly used when writing a EIA and AA for an plan or project. However, we did not go into the possibility of compensation. The masterplan is not the place to deal with what could be effective compensation for the loss of organisms, habitat or functional areas, or for disturbed ecological processes.

39. Has been added.

40. Well, in case of a far-field effect (avoidance behaviour), this could mean a considerable reduction of the effect zone.

41. The effectiveness of pingers will be addressed in field tests, as mentioned in the text. Your remark on the modelling has been added to the first sentence.

42. Interesting suggestion. Is such a system installed anywhere? Have added some text.

43. This section describes the results of the prioritisation. The assessment of costs is done roughly, by experts. This is stressed again in the text.

44. Yes, biomass is explained as standing stock. That is somewhat better explained. (Biomass is result of production and death/consumption).
Benthic PP at the DCP is only an issue at the Dogger Bank.

45. "Short-term" refers to the time it takes for results to become available, not the measurements themselves. Remote sensing can be done quite often, and the sampling is meant to validate biomass estimates for remote sensing. Although I understand the importance of the species composition in pelagic ecology, it is estimated less important in the effect studies for OWP.

46. Has been added.

47. Has been changed.

48. Cumulation of effects is not a monitoring or research issue as such. Addressing the possible cumulative effects is very important. This has been addressed in 3.7.

49. We added a paragraph in chapter 2 on this issue, although treated in general.

50. Scouring effects will get a relatively high priority but as a safety issue, not for ecological effects.

51. For OWFs, such measurements are indeed suggested under priority 2. We added the possibility to do the same for larger areas.

52. It is the objective of the Dutch government to strive for maximum accessibility of the (reworked) data. An extended report, including a peer review would be preferred. Journal papers are often limited in scope, although the quality of the work should of course be of sufficient level to permit publication.

Audit BSH, Germany
Reaction main author included in document (highlighted yellow)

BSH welcomes the Dutch activity to develop a plan for monitoring and researching ecological effects of offshore-wind farms in Dutch waters. In general, BSH is offering to share experiences and co-operate closer on this very important issue.

The document covers a large variety of aspects dealing with monitoring and research on ecological effects of offshore wind farms from legal framework to prioritisation of monitoring activities, cumulative effects, transboundary interactions and data management. A lot of valuable literature information is given.

1. Let me please first describe the German approach, as in the document under 3.3.5 the monitoring and research activities in Germany are shortly described. The main tool for the monitoring activities for offshore wind farms is still missing.

In Germany monitoring activities for offshore wind farms are actually based on the Standards for Environmental Impact Assessment, 2nd update 2007, edited by BSH: http://www.bsh.de/en/Products/Books/Standard/7003eng.pdf

The German standard covers the compartments, for which direct effects of offshore wind farms have been considered most probable: benthos and sediment, fish, marine mammals, seabirds, migrating birds and underwater noise. The standard was compiled by scientific groups with expertise in various fields of marine science and supported by representatives of licensing and nature conservation authorities.

The standard describes the spatial and temporal extend of the investigations for the baseline study (EIA) and for monitoring activities during the construction and the operational phase. Methodologies for surveys and data analyses are precisely described according to new developments and scientific results to facilitate the compatibility of data sets collected by various consulting groups. The standard will be updated on demand to fit new requirements and developments.

The baseline studies extend over two consecutive years. In cases when the construction phase begins with a delay of more than two years from the end of the baseline study additional investigations have to be carried out for one year.
Moreover the data of the EIA as well as the monitoring data of the construction and operation phase are quality checked and stored in a common database at BSH.

The results of the baseline study and partly for the construction phase of the first German offshore wind farm „alpha ventus“ may be found under following URL (in German):

http://www.bsh.de/de/Meeresnutzung/Wirtschaft/Windparks/StUK3/index.jsp
The grey shaded text (under 1) has been incorporated (with some adaptations) in the description of the German monitoring and research program under 3.3.5
First results of noise measurements during pile driving for „alpha ventus“ were presented by K. Betke, 2010: http://www.bsh.de/de/Das_BSH/Veranstaltungen/Cetacean_Society/Betke.pdf

For the evaluation of the monitoring strategy according to the BSH standard, additional ecological research is carried out at „alpha ventus“. A main task of the research programme is the data harmonisation, quality assurance of the data and the development of a common database. The overall analysis of the effects is than based on the common database. The products of the analyses which are carried out by experts will then be widely available.

2. However as already mentioned under 3.4 there is a need of data exchange in order to evaluate transboundary and cumulative effects. The need of common data evaluation should be accentuated. BSH is offering co-operation as BSH has collected information in the above mentioned common database on the basis of EIAs from several wind farm projects. This is a good step forward. I am aware of some existing initiatives focusing on co-operation with German agencies, but not knowledgeable on all details. The international co-operation on set-up, planning and carrying out the programs will need to be part (in my ideal world at least) of a larger project aiming at harmonization of European (or North Sea) planning, monitoring and research, data exchange and quality control. I added text in 4.3 to strengthen this issue. Hopefully, every country will understand the importance of such a program of co-operation and co-ordination.

3. In Table 3.2 the effects of explosives (removal of piles) are also considered. The use of explosives in works for offshore wind farms is in Germany generally forbidden (specific condition in the licence). Further investigations on this subject are not necessary. A remark about this has been added in a footnote.

4. A main point to consider under 3.5 is the challenge to operate in sometimes completely different habitats with strongly varying biotopes and dominant species. The monitoring concepts have then to be adapted to fit the area-specific conditions. We added text in par. 3.6.4.

5. Considering prioritisation criteria I might mention that this should not lead to the result, that some questions are neglected Correct. It is not stated as such in the text, but in the first paragraph the rationale behind this chapter is explained. The thing is that it is not possible at this moment to go into detail on all research issues. Some steps need to be taken to get a better view on effect relationships in order to develop an efficient and effective research program. But the remark has been added that the prioritization does not a priori exclude any of the earlier mentioned research.

It would be nice to see that this Masterplan will become obsolete within a few years and that we need to rewrite the whole thing due to scientific progress….

In general, because of the interactions in the ecosystem, all effects on the marine environment have to be treated in principle with the same high priority. Well, the priority is not based on the connectance of all ecosystem parts, of course, but a.o. on the (societal) valuation of these parts. Nevertheless, often there is a lack of common methodologies, so that specific aspects can only be treated in research programmes. Monitoring data on the other hand must be comparable and widely compatible so that established investigation methods have to be employed. This is treated in the data management part (ch. 5).

6. Regarding data management the need of well-documented, high-quality data must be accentuated. Long-term data storage has to be assured as well as a co-operation among agencies, authorities and experts, so that transboundary cumulative effects may be evaluated in a common context. Cumulative effects are treated in par 3.7.

Main aspects:

The effects of offshore wind farms may be best assessed by a combination of wind farm specific monitoring investigations based on standard procedures and large-scale, long-term investigations in the framework of national marine monitoring programmes. Agreed, that is actually what we propose in the priority 1 studies: both large-scale DCS-wide surveys combined with local effect studies. We have not yet developed any standards for monitoring, it might in time be interesting to look at what BSH has developed.

We therefore recommend following steps:

- wind farm area- and project-specific monitoring according to standard procedures
- large-scale, long-term marine national monitoring programmes
- research programmes to deal with development of new technology, methodologies and thresholds
- international co-operation and exchange to achieve the evaluation of transboundary and cumulative effects or interactions in a common context We already mentioned the existing initiatives to co-operate internationally.

A project- and area-specific monitoring programme for each offshore wind farm according to standard procedures may include the investigation of effects on sediment, water column, benthos, fish, marine mammals, seabirds and migratory birds and must be documented by regular measurements/surveys. Underwater noise must also be measured and the noise propagation must be modelled. Light effects of the wind farms especially on birds must also be documented.
However, as a lot of different aspects cannot be monitored by standard procedures at the wind farm, it is necessary to conduct research, additionally (for example, the standardisation of noise measurements can be carried out in the framework of research programmes. Or for the recording of the bat distribution offshore, special bat detectors can be adapted and further developed for standard use in the framework of research programmes). The abovementioned investigations have all (but one) been proposed. Lighting has only been discussed as a mitigation measure. We now have added this topic earlier in the report as well.

The data must be quality-proven and long-term stored. Co-operation and common data analysis of the monitoring data at least of neighbour offshore wind farms would help to better evaluate cumulative effects and interactions on a transboundary basis. Data treatment and storage is currently undergoing a strong development (OpenEarth, netCDF). It is not clear where it will end, but there is a strong move towards open source, free data exchange and openness. Another move is to international co-operation and harmonization. We added some text.

Large spatial investigations on the distribution and abundance of seabirds and marine mammals in North Sea regions should also be part of long-term monitoring activities. Such data are of basic importance for the overall evaluation of effects of the wind farms on the marine environment. Common logic would dictate strong co-operation with agencies abroad especially on the topics that are covered under the heading „Basic information“ and „Generic information“. See par. 4.3.

Finally, BSH would like to repeat the willingness to co-operate with Dutch agencies, especially with regard to exchange of information, common work on transboundary and cumulative effects and common data analysis of the monitoring data.

Audit CEFAS, UK
Reaction main author included in document (highlighted yellow)

I have only really looked at the contents page & reference list and there are a number of published reports from the UK & OSPAR that I think may add value and fill some of the gaps to avoid duplication – see the list below. Also, there are some new reports from the UK due for publication that will also be of interest and may change what monitoring is asked for (see below) and some ongoing projects that are investigating some of the effects and data gaps highlighted in the 'master plan'.

· Cefas, Fera & SMRU (2010) Strategic Review of Offshore Wind Farm Monitoring Data Associated with FEPA Licence Conditions. To review the monitoring reports on nine UK offshore wind farms prepared under the Food and Environment Protection Act (FEPA); compare findings against international information sources; report lessons learned; and make recommendations for future monitoring. This project provided an overall picture of the effects of offshore wind farms in preparation for further development. Scheduled for publication in mid-May 2010. This report seems to be of specific interest for the Dutch masterplan. It also gives a description of the status quo and recommendations for monitoring follow-up.

Published Reports:
We are aware of the variety of OSPAR reports with useful information. However, the masterplan was not the place to review the available literature (this is simply too much). We will in the follow-ups look more specifically at the OSPAR guidelines, especially when focusing more on the issue of international standardization. In the masterplan, this topic has not received much attention. However, from all countries working on the audit (UK, B, D, DK) some need for harmonization and standardization has been put forward. In the light of possible cumulative effects (which in the near future will form quite a research "challenge") this will be an important first step. Many of the mentioned papers and reports seem to give additional information on effects.

In many countries and on various topics, research is going on and has been carried out regarding the ecological effects of OWF . The masterplan did not have the specific goal of reviewing the most recent studies, most recent knowledge came from the Dutch experts committed to co-writing this report. However, one can not incorporate all existing knowledge.
The international audit had one important goal: does the knowledge described in the masterplan miss out on important issues, subjects etc. At the moment of finishing the final version of the masterplan we did not have the time to check the literature cited in this document for omissions in the masterplan.

We add these comments in an Annex to the report, so all literature cited here will e mentioned.

In the follow-ups of this masterplan, i.e. the topic-specific monitoring and research plans, it will be advised to review most recent literature.

· OSPAR (2004) Problems and Benefits associated with the Development of Offshore Wind-Farm, Biodiversity Series. OSPAR Commission 2004. Available at www.ospar.org

· OSPAR (2006) An Overview of the Environmental Impact of Non-Wind Renewable Energy Systems in the Marine Environment, Biodiversity Series. OSPAR Commission 2006. Available at www.ospar.org

· OSPAR (2008a) Assessment of the environmental impact of offshore wind-farms. Biodiversity Series. OSPAR Commission 2008. Available at www.ospar.org

· OSPAR (2008b) Background Document on potential problems associated with power cables other than those for oil and gas activities. Biodiversity Series. OSPAR Commission 2008. Available at www.ospar.org

· OSPAR (2009a) Assessment of the environmental impacts of cables, Biodiversity Series. OSPAR Commission 2009. Available at www.ospar.org

· OSPAR (2009b) Overview of the impacts of anthropogenic underwater sound in the marine environment, Biodiversity Series. OSPAR Commission 2009. Available at www.ospar.org

· OSPAR (2009c) Assessment of the environmental impact of underwater noise, Biodiversity Series. OSPAR Commission 2009. Available at www.ospar.org

· OSPAR (2009d) Assessment of construction or placement of artificial reefs, Biodiversity Series. OSPAR Commission 2009. Available at www.ospar.org

· OSPAR (2008) OSPAR Guidance on Environmental Considerations for Offshore Wind Farm Development. Reference number: 2008-3. Available at www.ospar.org

· Cefas (2004) OFFSHORE WIND FARMS: Guidance note for Environmental Impact Assessment In respect of FEPA and CPA requirements Version 2 - June 2004. Currently being reviewed / merged with Statutory Conservation Agency Guidance. Available at www.cefas.co.uk

· Mackinson, S.; Curtis, H.; Brown, R.; McTaggart, K.; Taylor, N. & Rogers, S. (2006) A report on the perceptions of the fishing industry into the potential socio-economic impacts of offshore wind energy developments on their work patterns and income. Contract E1103. Cefas Science Series, Technical report No. 133. Available at www.cefas.co.uk

· Rees, J.; Larcombe, P.; Vivian, C. & Judd, A. (2006) Scroby Sands Offshore Wind Farm – Coastal Processes Monitoring. Final Report. Contract Reference AE0262. Available at www.cefas.co.uk

· Cefas (2005) Assessment of the Significance of Changes to the Inshore Wave regime as a consequence of an Offshore Wind Array. Contract Reference AE1227. Available at www.cefas.co.uk

· Maclean, I.M.D; Skov, H.; Rehfisch, M.M. & Piper, W. (2006) Use of aerial surveys to detect bird displacement by offshore wind farms. COWRIE DISP-03-2006. BTO Research Report No. 446. Available at www.offshorewindfarms.co.uk

· Maclean, I.M.D; Skov, H. & Rehfisch, (2007) Further use of aerial surveys to detect bird displacement by offshore windfarms. COWRIE EXTDISP-06-07. Available at www.offshorewindfarms.co.uk

· Mellor, M.; Craig, T.; Baillie, D. & Woolaghan, P. (2007) Trial High Definition Video Survey of Seabirds. COWRIE HIDEF-05-07. Available at www.offshorewindfarms.co.uk

· Norman, T.; Buisson, R. & Askew, N. (2007) COWRIE workshop on the cumulative impact of offshore windfarms on birds – Peterborough 3rd May 2007. COWRIE CIBIRD-01-2007. Available at www.offshorewindfarms.co.uk

· Oxford Arcaeology (2006) Guidance for Assessment of Cumulative Impacts on the Historic Environment from Offshore Renewable Energy. COWRIE CIARCH-11-2006. Available at www.offshorewindfarms.co.uk

· Gill, A.B.; Huang, Y.; Gloyne-Philips, I.; Metcalfe, J.; Quayle, V.; Spencer, J. & Wearmouth, V. (2009) COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2.0. Final Report. COWRIE-EMF-1-06. Available at www.offshorewindfarms.co.uk

· CMACS (2003) A Baseline Assessment of Electromagnetic Fields Generated by Offshore Windfarm Cables. Final Report. COWRIE-EMF-01-2002. Available at www.offshorewindfarms.co.uk

· Gill, A.B., Gloyne-Philips, I.; Neal, K.J. & Kimber, J.A. (2005) The potential effects of electromagnetic fields generated by sub-sea power cables associated with offshore wind farm developments on electrically and magnetically sensitive marine organisms – a review. COWRIE 1.5. Final Report. COWRIE-EM FIELD 2-06-2004. Available at www.offshorewindfarms.co.uk

· Diederichs, A.; Nehls, G.; Dahne, M; Adler, S; Koschinski, S * Verfuβ (2008) Methodologies for measuring and assessing potential changes in marine mammal behaviour, abundance or distribution arising from the construction, operation and decommissioning of offshore windfarms. COWRIE CHANGE-06-2007. Available at www.offshorewindfarms.co.uk

· Bannister, D.J. (2007) Radar In-fill for the Greater Wash Area Feasibility Study. COWRIE INFILL-02-2007. Available at www.offshorewindfarms.co.uk

· Gordon, J.; Thompson, D.; Gillespie, D.; Lonergan, M.; Calderan, S.; Jaffey, B. & Todd, V. (2007) Assessment of the potential for acoustic deterrents to mitigate the impact on marine mammals of underwater noise arising from the construction of offshore windfarms. COWRIE DETER-01-2007. Available at www.offshorewindfarms.co.uk

· Nehls, G.; Betke, K.; Eckelmann, S. & Ros, M. (2007) Assessment and costs of potential engineering solutions for the mitigation of the impacts of underwater noise arising from the construction of offshore windfarms. COWRIE ENG-01-2007. Available at www.offshorewindfarms.co.uk

· Nedwell, J.R.; Parvin, S.J.; Workman, R.; Brooker, A.G. & Kynoch, J.E. (2007) Measurement and interpretation of underwater noise during construction and operation of offshore windfarms in UK waters. COWRIE NOISE-03-2003. Available at www.offshorewindfarms.co.uk

· DTI (2006) Aerial Surveys of waterbirds in strategic windfarm areas: 2004/05 Final Report. Available at http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/policy/offshore/orrsg/rag_projects/rag_projects.aspx

· BERR (2007) Aerial surveys of waterbirds in strategic wind farm areas: 2005/06 Final Report. Available at http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/policy/offshore/orrsg/rag_projects/rag_projects.aspx

· BERR (2008) Review of cabling techniques and environmental effects applicable to the offshore wind farm industry – Technical Report. Available at http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/policy/offshore/orrsg/rag_projects/rag_projects.aspx

· DTI (2005) Guidance on the assessment of the impact of offshore wind farms: Methodology for assessing the marine navigational safety risks of offshore wind farms. Available at http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/policy/offshore/orrsg/rag_projects/rag_projects.aspx

· BERR (2008) Review of reef effects of offshore wind farm structures and potential for enhancement and mitigation. Available at http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/policy/offshore/orrsg/rag_projects/rag_projects.aspx

· DTI (2005) Guidance on the assessment of the impact of offshore wind farms: Seascape and visual impact report. Available at http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/policy/offshore/orrsg/rag_projects/rag_projects.aspx

· DECC (2008) Review of Round 1 sediment process monitoring data – lessons learnt: A report for the Research Advisory Group. Final Report 2008. Available at http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/policy/offshore/orrsg/rag_projects/rag_projects.aspx

· DECC (2008) Dynamics of scour pits and scour protection – Synthesis report and recommendations (Milestones 2 & 3).A report for Research Advisory Group. Available at http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/policy/offshore/orrsg/rag_projects/rag_projects.aspx

Ongoing Research (see www.offshorewindfarms.co.uk for more information):

· Effects of noise on fish: This project will look at the effect of pile driving noise on the behaviour of marine fish. This project is currently out to tender.

· Remote techniques: Development of revised best practice guidance and technical specifications for the use of remote techniques for observing bird behaviour in relation to offshore windfarms. The project should provide an updated review of radar monitoring undertaken at UK and European sites and look at what has been done, what can be done, what are the limitations and what information can be technically delivered.

· Satellite tagging of whooper swans: This project will examine the location of UK windfarms in relation to migration routes between breeding and wintering grounds using satellite tracking.

· Cumulative impacts workshop: This workshop follows on from the one held last year but will be focused on producing written guidance to assist in the process of ornithological cumulative impact assessment (CIA) for offshore windfarms.

· Data standards guidance for marine benthic data: Following on from a workshop in January 2008 on marine life data standards the Marine Biological Association of the UK have been contracted to produce guidance to describe the management of marine life survey data and recommend best practice.

· Coastal processes modeling for offshore windfarm EIA's: The aim of this project is to update existing best practice guidance on the use of models to predict the impacts from offshore windfarms on coastal processes, covering the diffraction and focusing effects on waves and currents and their effects on longshore drift and erosion.

· Fisheries value: The purpose of the study is to develop one or more spatial information layers on the distribution and economic value of commercial fishing and shellfishing activities in UK waters. The information later will primarily be used to support strategic siting assessments for Round 3 offshore windfarms but will also be of relevance for other marine renewable energy projects

Audit Energinet, Denmark
Reaction main author included in document (highlighted yellow)

Introduction

The present review has been performed by the Danish system operator Energinet.dk. Energinet.dk has been involved in most of the Danish offshore wind farm and has recently (2009-2010) been in charge of the environmental impact assessment for the 400MW Anholt Offshore Wind Farm.

The review focuses on the overall content of the master plan. The review does not include proofreading of the document, although a few comments are made on this. With regard to the monitoring and measuring requirement, the review does not question or take a stand on the correctness of this, simply because it is outside the reviewers' field of work and experiences.

Overall conclusion on the review

The document is generally a very comprehensive work. The listing of existing knowledge and research in topic of interest is extensive and forms a good offset for the research and monitoring programmes to be conducted in relation to coming offshore wind farms in the North Sea.

Chapter 3.7 raises an important question. The methods used to evaluate cumulative effects are indeed varying considerably. This should be targeted on an international level and should therefore be prioritised in the view of the plans for offshore wind farms in the North Sea. The master plan does not give any direction how this situation can be improved. Actually, another review raised the same point (making it priority no. 1). I do agree on this point stressing the need for an internationally set up description on how to proceed with this. However, since it is not a specific research or monitoring topic, it can not be included in the list of priorities. It has been given extra attention in this chapter however, look at par. 3.7.1. en 4.3.

The master plan lists and prioritises a large number of questions. We would like to highlight that it is important to distinguish very clearly between " nice to know" and "need to know" in relation to making a decision on whether or not permission should be granted to a specific wind farm project and on what terms. The discrimination between ”need” and ”nice” has been given someattention in the text as a criterion (actually, it is the legal constraint for ecological effects as laid down currently in the EU Bird and Habitat Directive, in national natural law and in . However, using these priorities as criteria for granting one OWP over the other is outside the scope of the masterplan. This is likely to be different between countries as well, and might also depend on specific local habitat or species characteristics.

The formulation of methods to manage the data collected is interesting. It will, if successfully implemented, help to improve efficiency in research and monitoring programmes. It is however a prerequisite, that access to the data are made easy and open to research in general. The use of international conventions and protocols is more crucial than it appears form the Master Plan (page 77). Yes, but at the moment it is not clear whether an international standardisation is feasible. We stressed the importance of an internationalisation of monitoring and research already.

We very much agree with the need of transparency and adaptability in monitoring and research programmes on offshore wind farms. And that spatial planning in the respective countries is one of the keys to a better planning of offshore wind in most European countries.

Specific comments

No.	Reference	Comment	Proposal
General			
1	General	The report uses a large number of abbreviations. Most are explained at first appearance. It is not consistent throughout the document.	Add a list of abbreviations Has been added.
2	General	Consider changing the names to the names usually used in English. Be consistent with the use of the names throughout the report.	wind mill = wind turbine wind park = wind farm wind mill park = wind farm The translator was unaware of the right jargon in these cases. It has been changed accordingly.
3	General	The English language could be improved several places in the document.	Consider to have an English proofreading made on the document. For proofreading has been no time unfortunately. Text and jargon changed when encountered
Chapter 1			
1	Page 3	The abbreviation BVD is not explained. It seems to be a typing error, it should be BHD? The abbreviation DSC is not explained. It seems to be a typing error, it should be DCS?	Correct error Yes, has been corrected.
Chapter 2			
Chapter 3			
1	3.3.2	The Danish Monitoring Programme should be mentioned more explicit.	The Danish Monitoring Programme on offshore wind farms was carried out from 2000-2005, on Horns Rev I and Nysted. Do you refer to a specific program set up for Horns Rev II and Rodsand II? Does it differ in anyway from what we mention in the document for Horns Rev II? Text added as suggested by NERI. On the later projects: Horns Rev II and Rødsand II, research/monitoring on specific topics have been required in the permits. On both projects this research/monitoring is still going on.
2	Table 3.2	Change wordings.	Exploitation phase = production phase Changed to ”operation”
3	3.8	Mitigation measure will typically be technically problematic and economically	Highlight that mitigation measures should only be required IF significant impacts on the environment are expected (for the evaluation in the EIA for the

		negative for an offshore wind farm project.	specific project) In the context of an EIA this is formally correct. However, the interpretation of the legal extent of an EIA differs from country to country, especially regarding the cumulative impacts. And exactly on this topic it would make sense to prescribe a maximum of mitigative measures in stead of only when a significant effect is expected (and what that is also differs from country to country). It is outside the scope of the masterplan to make remarks on the formal of legal applicability of mitigative measures.
Chapter 4			
Chapter 5			
Chapter 6			
1	6.3	We find that it will be very difficult to avoid interdependency of researchers' etc. on offshore wind - and we find it crucial to the research and evaluation, which might come out of the master plan, that experts are involved from the beginning.	By making sure that the respective authority is in charge, it should be possible to involve people who have a stake in the monitoring. To engage with the experts on the various fields of research will be crucial. Interestingly, this is one of the main reasons why the Dutch govt has decided to take the lead in the further implementation of monitoring and research on the effects of OWF. In a later stage, an organisational plan will be added to the Masterplan that goes in detail into specifically this topic!

Audit MUMM, Belgium (in Dutch)
Reaction main author added in document (highlighted yellow)

Algemene opmerkingen

Algemene opmerking: het commentaar in deze audit is verwerkt in de Engelstalige versie. Hierdoor kunnen evt. verwijzingen naar tabel- of paginanummers afwijken van wat er in de Nederlandstalige versie staat.

Dit masterplan beschrijft in detail de Nederlandse aanpak om de ecologische effecten van offshore windparken (OWP's) te bepalen. Men identificeert een aantal kennisleemtes die dienen te worden ingevuld en stelt specifieke meetprogramma's op met vermelding van prioriteit, duur en vermoedelijk budget. De voorgestelde monitoring houdt rekening met het onderzoek dat elders plaatsvindt, maar is specifiek gericht op de Nederlandse situatie, hoewel er ook een aantal algemene vragen in beschouwing worden genomen.

Wat hier uitgewerkt wordt betreft een inschatting van de effecten van offshore windparken in vergelijking tot andere activiteiten vb. doorheen het masterplan komt het geluid van windparken tijdens de operationele fase regelmatig aan bod (prioriteit 1) terwijl degelijke kennis over het achtergrondgeluid ontbreekt en verwerving van deze kennis veel minder belangrijk wordt geacht (prioriteit 3). De experts maken deze inschatting op basis van het uitgangspunt dat eerst dient te worden gewerkt aan die zaken die geacht worden de meeste info op te leveren op korte termijn voor het daadwerkelijk verbeteren van de effectinschattingen. Op basis van de opmerking van MUMM heeft dit onderdel (achtergrondgeluid) een hogere prioriteit gekregen en staat nu op de lijst met prioriteit 2.

Binnen de Europese Karderrichtlijn Mariene Strategie (KRM) en de Goede Milieu toestand worden de aspecten biodiversiteit en niet-inheemse soorten beschouwd. Bij OWP's in het buitenland (Denemarken, België) is reeds gebleken dat de nieuwe kunstmatige harde substraten snel gekoloniseerd worden door een aantal (o.a. niet-inheemse) soorten die, zeker in gebieden met overwegend zachte substraten,voorheen niet of amper in het gebied voorkwamen. In het kader van de verwachte drastische toename aan kunstmatige substraten en het effect van de geassocieerde aangroei op het lokale voedselweb, lijkt het effect van hard substraat soorten hier vrij summier behandelend (onder 'benthos' – prioriteit 3). Dit potentiële probleem wordt wel genoemd, alleen inderdaad een lage prioriteit gegeven. Dit is op basis van vooral de inschatting dat het effect minder groot/ernstig is dan de effecten op vogels, zeezoogdieren en vislarven. Wettelijke verplichtingen zorgen er vooral ook voor dat vogels en zeezoogdieren en vislarven een hoge prioriteit krijgen. In de tekst zal worden aangegeven dat met name de monitoring van exoten en hun verspreiding op hard en in zacht substraat speciale aandacht verdient. Aangegeven is in 3.7 dat het effect van een enkel OWP op de verspreiding van niet-endemische soorten verwarloosbaar klein wordt geacht, maar dat bij cumulatie dergelijke effecten zeker niet meer verwaarloosbaar kunnen worden geacht.

De opmerkingen over de situatie in het Belgisch deel van de Noordzee zijn enigszins gedateerd. Een aantal suggesties ter aanpassing/aanvulling worden hieronder gegeven: Deze suggesties zijn zoveel mogelijk verwerkt in de relevante tekst.

België: Thornton Bank, Bligh Bank en de Bank Zonder Naam

Op dit moment (april 2010) wordt er in het Belgisch deel van de Noordzee onderzoek gedaan naar de milieueffecten van de eerste drie OWP's: C-Power, Belwind en ELDEPASCO die zich respectievelijk bevinden ter hoogte van de Thornton Bank, de Bligh Bank en de Bank Zonder Naam. C-Power bevindt zich in de pilootfase met zes functionele turbines met gravitaire funderingen. Bij Belwind is de constructie van de eerste fase van 55 3MW turbines in volle gang. De hiervoor benodigde heiwerkzaamheden werden eind februari afgerond. Op de site van ELDEPASCO is men bezig de T_0 situatie te bepalen. Net als in het buitenland werd de monitoring opgezet volgens het BACI-design (Before After Control Impact) met aandacht voor zowel impact als proces-gerichte monitoring. De resultaten van de eerste twee jaar monitoring werden gebundeld en zijn vrij beschikbaar (Vanermen & Stienen 2009; Degraer & Brabant 2009[44]). Monitoring van volgende aspecten is voorzien:

- Hydrodynamica en sediment: effecten van de constructie op turbiditeit, stromingen, erosie rond de funderingen, erosie langs de kabeltrajecten,..
- Onder- en bovenwatergeluid: zowel tijdens de constructiefase als tijdens de exploitatie en afbraakfase
- Benthos: opvolging van de kolonisatie van de nieuwe harde substraten met nadruk op niet-inheemse soorten, effect van de sluiting van het gebied voor visserij op infauna, epibenthos en vis, impact van organische aanrijking door epibenthos van de harde substraten op endobenthos van de zachte substraten…
- Avifauna: impact op de densiteit van zeevogels, barrière effect van de OWP's en onderzoek naar aanvaringen (combinatie van zeevogeltellingen, radar en aanvaringsmodellen)
- Zeezoogdieren: eventuele wijzigingen in ruimtelijke verspreiding van zeezoogdieren op het BCP (passieve akoestische waarnemingen met behulp van T- en C-Pods, strandinggegevens en vliegtuigtellingen) en gehoorschade (dissecties bij gestrande exemplaren).
- Elektromagnetische velden: metingen van de EMV ter hoogte van de kabels tijdens de exploitatiefase

Kleine en taalkundige opmerkingen

Er is besloten om door te werken in de Engelstalige variant. Specifieke Nederlandstalige verbeteringen worden derhalve niet van toepassing geacht (NVT). Wel is gekeken of de Engelse vertaling ervan verbetering behoeft.

Kleine aanpassingen aan de tekst zijn in het rood aangeduid.

Pagina 2 – paragraaf 1: "Naast de inhoudelijke opzet van dit masterplan worden ook ideeën gegeven datamanagement en internationale samenwerking." → "Naast de inhoudelijke opzet van dit masterplan worden ook ideeën gegeven over datamanagement en internationale samenwerking." NVT

Pagina 2 – paragraaf 1:"Het is van groot belang om te onderzoeken of dergelijke scenario's kloppen, of dat additionele informatie een reëlere inschatting van de effecten geeft, zodat

[44] *http://www.mumm.ac.be/NL/News/item.php?ID=158*

besluitvorming ook op een betere inschatting van effecten plaatsvindt, en *worst-case* scenario's een kleinere rol hierin spelen." NVT

Pagina 3 – laatste paragraaf: "Onderwatergeluid bij heien is een van de belangrijkste benoemde negatieve effecten van de aanleg van OWP's op dit moment, waarbij de doorwerking op vislarven, vis, en zeezoogdieren van groot belang is." vs. De situatie bij van 'vibration piling', gravitaire of drijvende funderingen. is in het Engels toegevoegd

Pagina 5 – laatste paragraaf: "het is nog weinig bekend over hoe bijvoorbeeld bruinvis reageert op onderwatergeluid, en op welke spectra en niveaus." Er zijn nochtans al een aantal studies (zie vb Lucke et al., 2007 & 2008; Kastelein et al., 2008). tekst is in de Engelse variant aangepast: *knowledge on their behavioural reaction to various sound levels and spectrums is rather limited.*

Pagina 9: "In concreto: het feit dat vogels en zeezoogdieren een sterkere bescherming genieten dan benthos en ~~fyto~~plankton heeft, naast het gemak van waarneming (visueel zichtbaar zonder technische complexe hulpmiddelen) en zekere indicatorwaarde, ook te maken met hun iconisch karakter." OK

Pagina 10 – derde paragraaf: "Resultaten van onderzoek uitgevoerd voor de Engelse kust kunnen dan ook niet zomaar worden gebruikt om een inschatting van effecten te maken in de Nederlandse situatie." → "Resultaten van onderzoek uitgevoerd in het buitenland kunnen dan ook niet zomaar worden gebruikt om een inschatting van effecten te maken in de Nederlandse situatie." OK; hier werd specifiek gedacht aan onderzoeks waaruit blijkt dat kleine mantelmeeuwen bij de Engelse kust lager vliegen dan op de Nederlandse kust

Pagina 12 - Ook voor de twee Nederlandse parken *Offshore Windpark Egmond aan Zee (OWEZ)* en *Prinses Amaliapark* zijn *baseline* studies uitgevoerd en worden effectstudies verricht .NVT

Pagina 17 – layout tabel aanpassen zodat capaciteit v.d. individuele parken telkens op één lijn kan. + toevoegen macrobenthos bij Thornton Bank I. Is aangepast Daarnaast is het eventueel mogelijk om ter verduidelijking macrobenthos te vervangen door Hard/Zacht substraat epifauna OK, maar benoemd als macrobenthos (zowel infauna als epifauna).. Ook het monitoringsprogramma van Belwind (België) zou best worden toegevoegd (cfr. C-Power). OK is toegevoegd

Pagina 20 – deel 3.3.4. "Prioriteit wordt gegeven aan monitoring om het effect van elektromagnetische velden van kabels op vis gedrag te bepalen, het effect van habitatverlies door windparken op zeevogels, barrièrewerking op trekvogels en effecten van onderwatergeluid op zeezoogdieren." → "Prioriteit wordt gegeven aan onderzoek naar het effect van elektromagnetische velden van kabels op vis gedrag te bepalen, het effect van habitatverlies door windparken op zeevogels, barrièrewerking op trekvogels en effecten van onderwatergeluid op zeezoogdieren." OK, is gewijzigd. In veel gevallen (ook buiten dit rapport) wordt *monitoring* gebruikt terwijl o*onderzoek* wordt bedoeld. We hebben dit in hoofdstuk 2 trachten te verduidelijken, maar het oneigenlijk gebruik van *monitoring* speelde ons hier ook parten .Zeker wat betreft elektromagnetische velden gaat het hier om experimenten eerder dan om monitoring. Het onderzoek naar de effecten van OWP's in het VK wordt nog steeds gecoördineerd door COWRIE (DECC = beleid). Zie tekst; is aangepast

Pagina 24 – deel Habitats/Plankton. "Voorts wordt door sommigen een relatie mogelijk geacht tussen de introductie van hard substraat en de sterke toename van kwallen in kustzeeën." – Eventueel weglaten tenzij een betere referentie gevonden kan worden. Referenties toegevoegd:

- Hoover RA, Purcell JE (2009). Substrate preferences of scyphozoan Aurelia labiata polyps

among common dock-building materials. Hydrobiologia 616: 259-267.
- Graham WM (2001). Numerical increases and distributional shifts of Chrysaora quinquecirrha
(Desor) and Aurelia aurita (Linn´e) (Cnidaria: Scyphozoa) in the northern Gulf of Mexico. Hydrobiol. 451: 97-111.

Pagina 27 – deel Vogels – laatste paragraaf. "De relatief hogere aantallen aalscholvers zijn opvallend bij zowel Deense (Fox *et al.* 2006) als Nederlandse windparken (pers. obs. M. Leopold)." – In hoeverre is dit te wijten aan het feit dat het hier relatief near-shore (en – in Denemarken – ondiepe) parken betreft? Dit speelt zeker een rol, maar verwacht dat het mogelijk is voor aalscholvers om ook om deze constructies te gaan broeden (gevallen op constructies in Duitse Bocht bekend), zodat ook OWP op grotere afstanden vanaf de kust "gekoloniseerd" kunnen worden.

Pagina 3.61. "Alhoewel benthos vooralsnog geen hoge urgentie heeft gekregen in de effectbepalingen, is het niet opportuun de mogelijk vooral positieve effecten op deze groep niet mee te nemen." → positief is een geladen term, misschien is het beter om hier te spreken van organische aanrijking door epibenthos van de harde substraten, naast het positieve effect van de uitsluiting van visserij op het endobenthos van de zachte substraten + Tabel 3.3 – lay-out Het gebruik van de term positief f negatief is natuurlijk richtinggevend ten aanzien van de menselijke waardering, en geen wetenschappelijk correcte terminologie. Suggestie voor aanpassing van de tekst zijn overgenomen.

Pagina 38 – deel benthos – 1e paragraaf. "Productie van benthos op hard substraat kan eveneens doorwerken op vis. Deze veranderingen zijn nog niet onderzocht." → "Productie van benthos op hard substraat kan eveneens doorwerken op vis. Deze veranderingen worden momenteel onderzocht in het Thornton bank windpark (Jan Reubens, Universiteit Gent)." OK. Tekst is in het Engelse rapport toegevoegd.

Pagina 43 – deel Benthos – Habitatverandering. Eventueel nog een bijkomende onderzoeksvraag: kunstmatig hard substraat als stepping-stone voor de verspreiding van niet-inheemse soorten. OK. Tekst is in het Engelse rapport toegevoegd.

Pagina 45 – Onderwatergeluid. "Wat is de gevoeligheid (fysieke schade, TTS, vermijding, verstoring) van de verschillende te onderzoeken soorten zeezoogdieren voor onderwatergeluid met betrekking tot spectra en geluidsniveaus en afstand tot de bron, veroorzaakt tijdens de bouwfase (heien), de operationele fase en de afbraakfase van windparken?" cfr het Engelse PTS, TTS, avoidance and injury. in de Engelse tekst aangepast, zoals aangegeven

Pagina 46. – deel benthos - "Ontwikkeling soorten en dichtheden soorten hard substraat - Methode: Scuba duikers, camera's, fysische bemonstering." Bemonstering in inter- en subtidaal (bv. Van quadranten) zal noodzakelijk zijn voor identificatie van de koloniserende organismen. in de Engelse tekst aangepast, zoals aangegeven.

Pagina 51 – deel aanvaring: "toekomst" ipv "toekomast". NVT

Pagina 53 – 4e paragraaf – "Cumulatieve Impact Assessments (CAI)" → (CIA) - ook in volgende zin. is aangepast

Pagina 60 – Deel over het gebruik van pingers. Het zogenaamde dinner-bell effect waarbij zeezoogdieren aangetrokken worden door het geluid van pingers en seal-scarers beperkt zich tot individuen die gewend zijn te foerageren in zones met aquacultuur, waar de pingers de locatie van de enclosures aanduiden (besproken op de IMAREST, Underwater Sound Forum Conference, februari 2010). Tekst is toegevoegd. Door wie is dit besproken? Is dit alleen habituatie? Zou dit dan niet optreden bij regelmatige aanleg van OWP’s waarbij bijv. vissterfte optreedt en dus ook een *dinner-bell effect* kan optreden?

Audit RSPB, UK
Reaction main author included in document (highlighted yellow)

The report is comprehensive and will provide a useful basis for informing monitoring and research requirements for the development of OWPs, but would benefit from further incorporation of extended side-headings and a hierarchy of numbered sections (e.g. 2.1.1.a.i) to help with navigation around the text.

1. Introduction - provides useful context in terms of The Netherlands and wider EU. OK

2. Delineation
Raises openness of data which is essential to build an improved knowledge base and hence reduce uncertainty. Data openness and more peer-reviewed scientific publications are to be encouraged. Data confidentiality, and hence restricted access, should be reserved for genuine need; environmental data should not be classified as commercial in confidence. OK

2.2 The role of monitoring is to provide comparison with a baseline condition, which may include, but is not necessarily restricted to, permit compliance. Permit regulations require monitoring to be stipulated, but I agree this requirement needs to accommodate a flexible response to improved knowledge, so regular reviews should be incorporated in any monitoring and evaluation plan. OK

2.3 An essential prerequisite to any monitoring and research programme is to identify the questions/hypotheses for testing. This important stage is often poorly prepared, leading to failings in study design and failure to meet expectations. OK. This is why it has been mentioned.

3 Monitoring
Also worth mentioning that various impact studies have not (yet) continued long enough to distinguish short- and longer- term effects. Has been added to the text.

Top page 14, Baseline studies on birds, second bullet point should read flying birds (not fish). You're the only one that noted this! We checked the whole text for more "glitches" in the translation.

Table 3.1 column entitled park capacity (MW) needs further formatting. Has been changed.
3.3.4 In the UK, there are monitoring requirements stipulated by the various licences, notably FEPA (Food & Environmental Protection Act 1985). Research associated with offshore wind farms has been coordinated by both COWRIE and DECC. The COWRIE programme is due to close in 2010 and it is likely that the Crown Estate (landlord of the UK seabed) will assume a more prominent role in research coordination. Under the UK Marine and Coastal Access Act 2009, new marine planning and management structures have been established, the MMO (Marine Management Organisation – 1 – 100 MW installations) and IPC (Infrastructure Planning Commission – installations > 100 MW), so DECC's role as the relevant authority with responsibility for preparation of AAs and consents will be transferred. DECC continues to have a coordinating role in research via its SEA program. See http://www.marinemanagement.org.uk/works/energy/index.htm
This text has been copied into the text in 3.3.4

Table 3.2 Exploitation phase, space taken up – query relevance to bats any more than to birds, although possible alteration of perception of habitat, once there are new structures in the sea. However, the presence of turbines may continue to have an effect on localised benthos if positioned on top of specialist communities. Additionally, presence of turbines may

lead to displacement/avoidance by bird species, effectively loss of habitat, either temporary or longer-term.
It has been changed to “loss of habitat function” which encompasses more than just “space taken up”. A bird may change its behaviour within an OWF, although it still flies through it. The same holds for marine mammals (although they won’t fly usually).

Table 3.2 other potential factors, mostly to complement the subsequent text: Text has been adapted to include main points.

- Construction phase: displacement/avoidance by birds & marine mammals due to presence of construction vessels & personnel.
- Exploitation phase: the presence of vessels & maintenance personnel may lead to displacement/avoidance by birds and marine mammals.
- Exploitation phase: Lighting of turbines for navigation/aviation may affect birds on migration. This is quite a contentious issue that is sometimes dismissed as inconsequential but is considered by some to be a real possibility. Effects will depend on the lighting regime that is used. There are possible mitigation measures (intermittency, minimum levels of illumination necessary for health & safety requirements, lighting outer turbines etc.), and development of suitable protocols will require international cooperation between maritime safety agencies. Text has been added. We mentioned this point in the section on mitigation. Shell/NAM have found out that green light does not attract birds on oil platforms, so that is a serious candidate. Repelling would be even better.
- Removal phase: displacement/avoidance by birds & marine mammals due to presence of (de)construction vessels & personnel.

Table 3.2 could be enhanced by distinguishing +ve or –ve effects instead of just indicating that an effect is likely. This point is also applicable to the accompanying text which also could clarify situations where both positive and negative effects may apply for different sectors of communities. The appropriate context is in terms of the BHD and conservation priorities. For example, introduction of hard substrate may be beneficial for some benthic species, but if that results in damage to priority habitats or species, the net result may be considered detrimental, e.g. 2) Effects on habitats: benthos, 2) Presence of OWP, d. This is a hard nut to crack. I mentioned in chapter 2 that what is detrimental for one species may be profitable of beneficial for others. The possible decrease of offal and discards due to displacements of trawlers may have a negative effect on protected gulls. However, although this is negative in the BHD context, it can be considered positive in the context of biodiversity (less dominance from gulls). For hard substrate the reverse is true (gain in biodiversity, but maybe unacceptable change to BHD priority habitats). I prefer to treat simply “changes” and leave to the context to judge the change as much as possible. Of course, some contexts are quite binding, such as the BHD, but when considering effects that are outside BHD context (MFSD might become another legally binding context), connotations such as “positive” or “negative” are not easy to deal with.

There is useful and relevant material contained in this section but its presentation is overly succinct. For greater clarity, the text would benefit from expansion of the current shorthand, e.g.

2.1.a) Bottom structure disturbance etc. – this list does not indicate what the potential concerns are (report text in bold italics, suggested additions in plain text): ***Bottom structure disturbance,*** triggers ***chemical processes (redox, nutrient cycles, sludge and organic matter, death of bottom dwellers***) **–** leading to increases in primary productivity**,** reduced ***transparency*** (increased turbidity?***),*** release of ***contaminating substances,*** changes to ***benthos community,*** changes to ***food web production – and composition***. ? Well that is the idea, the -> is an arrow, suggesting causality. We added the wording, that makes it clearer.
3.4.e) expand P(lankton?) and B(enthos?). It's Production and Biomass…added to the text.

The hierarchy in this section could be improved for clarity when scrolling down the text, for example first order 1), second order a), third order i). This is not clear to me. You mean 4.a.i in stead of 4.1.a? We left it as it is.

4.1.a), what is "sheers" in this context? (see also page 26, under Birds). Sheers are a form of two-legged lifting device, that is used for tasks such as lifting masts and heavier parts of the rigging on board a ship, but also used in a very large version, for the piles of turbines..

4.2.b) Loss of feeding/resting/moulting areas (displacement/avoidance/habitat loss) for seabirds from breeding colonies on land, and during at-sea distribution, including passage migration in spring and autumn, post-natal dispersal of immature/non-breeding birds, moulting aggregations, and non-breeding/wintering distributions. OK, text has been added (but not all in the bullet)

Also changes in substrate, e.g. changes in erosion/deposition – development of new sandbanks; erosion of existing sandbanks – to what extent is the change contrary to existing trends? Well, locally there usually are some changes to the bed but as far as shows from various studies it is all near-field effects. No erosion or growth of sandbanks as such has ever been recorded. The focus here lies on ecological effects. We added the morphological effects to the lists.

Page 26, Birds: loss of habitat due not only to presence of turbines, but potentially due to increased presence of maintenance vessels and crews – depending on location. Has been added.
Cumulative effects are important, given the proposed scale of offshore wind park development planned in the North Sea, across member states. See paragraph 3.7

Breeding birds, page 29, The Everaert & Stienen (2007) study included common, Sandwich and little terns. Tracking technologies are evolving rapidly now with reductions in size and cost of different types of transmitters such that data loggers can be fitted to more birds, providing high resolution data and, as Bluetooth and other technologies also develop, data retrieval methods have less reliance on recapture of individual birds. In the UK there are several studies about to commence or underway using a combination of tracking devices to provide information on foraging destinations of breeding seabirds from SPA colonies, both to augment information on distributions to identify important foraging areas at sea and to improve our knowledge of overlap, and hence risks associated, with planned and proposed offshore wind parks. Additional information, relevant to transboundary studies, will be generated by these research projects. Comparable studies are being planned in the NL by Cees Camphuysen (NIOZ).

3.5.2 Mammals

Cetaceans, line 4, in press, not in pressure. Again a translation glitch…
Bats, NB one theory is that bats may not use echolocation when on long-distance migration, hence apparent inability to detect turbines and associated collision/barotraumas but, as far as I am aware, this has not yet been verified. However, there may be implications for the use of bat detectors. Relevant text has been added.

Table 3.3
Plankton – effect of turbine piling relates to construction rather than operational phase. Should be turbine pile/foundation. changed accordingly.

Birds, Collision risks, barrier effect, page
To my knowledge, there is just one observation of collision with offshore wind turbines, recorded by Pettersson (2005) in the Kalmarsund: A flock of around 310 eiders, in V-formation, flew past an outer turbine when several individuals in the outer flank, and therefore the rear, of the flock struck the rotating blade on its downward trajectory or were caught in the associated turbulence. Four birds were observed to fall into the water, of which at least two flew out and at least one was killed. According to the Danes (NERI), there has been another observed collision, with a bat or passerine, with automated detection (text added).

Tracking will be an important tool for determining at-sea behaviour in relation to wind turbines. At some sites, deployment of cameras may be useful for recording collisions of diurnal species. Is part of the suggested work (priority 1, is currently being set up)

NB need for some long-term studies at selected sites.
Agree desirability for international protocols, especially for transboundary studies. Agreed. International harmonisation and cumulative effects will be a (if not the) major challenge for the coming years.

Underwater noise, page 42. Need information on background noise as well as noise from wind park (construction/decommissioning and operation) to determine whether the latter adds significantly to background levels. Requirement for both replicate measurements at individual sites at different times and comparative measurements at different sites at the same time. See page 47 (3.6.4. under water noise).

Birds
Basic information, page 45
Also need to identify important locations for birds and environmental determinants of these – how consistent/predictable are the environmental variables and species' distributions? Isn't that covered in the second bullet: What are the most important habitats and food sources of birds at sea and what determines the importance?

Identification of migration routes also requires information on whether there are identifiable "routes" for different species or whether broad front migration. Text was added: Is their broad front migration, or are there specific corridors, and what features are used to orientate? Can OWF's play a role in orientation?

Change in habitat
How does the spatial distribution of bird populations change as a result of disruption of the habitat, and food supply, ***during the construction and demolition phases of wind parks?*** OK, has been added

Underwater noise & fish, page 46 & 47 – see latest COWRIE report which used mesocosm experiments. Unfortunately there has been no time update our text accordingly.

Marine mammals, change in habitat, page 49
Unclear about the proposed method for deployment of cameras "to the legs of windmills" – if underwater cameras, likely to have short operational range, particularly if turbidity is a problem; if above water, also potentially limited range especially to penetrate into the water. Yes, changed the text accordingly

Birds, Basic information, page 49 & Change in habitat, page 50
There are problems using radar to identify birds on the water owing to wave clutter; this is likely to require considerably more attention to develop appropriate algorithms to filter out "noise" but retain birds. Radar is detrimentally affected by precipitation, especially X-band. Careful thought needs to be given to the best way to deploy radar effectively. Further consideration to the type of radar is necessary. Marine radar and modified marine radar in avian laboratories have limited range which will be a particularly limiting factor for observations over large sea areas. Doppler radar may perform better in relation to wave clutter but is more expensive than the basic modified marine radar that has been in use for many wind park studies.Text has been added.

Hi-definition aerial surveys also may be useful in assessing changes in distribution and abundance in relation to changes in habitat. Text has been added.

Collision, page 50 - Deployment of cameras may be useful for recording collisions of diurnal species, but requires further consideration of deployment, image capture (refinement of motion detection software), and data management. Tracking studies may provide information about collisions/likely collisions. Yes, both the direct method (detecting collisions) and the indirect method (tracking birds) will need to be applied. Text has been added

Barrier effect, page 51 – radar may offer limited scope for studying micro-avoidance because of the greater reflectivity of the wind turbines than birds passing close to the turbines. True, only advanced, military-type radars are able to deal with this. Text has been added.

3.7 Cumulation of effects
3.7.1, Plankton & benthos, page 54. In the UK, it is not widely considered that growth on the foundations and dumped rock is necessarily positive – it depends on what is displaced or smothered by the hard substrate and its existing conservation importance. The text was changed to be more neutral.

Birds, page 54. If OWPs act as refugia for fish, this may encourage greater foraging activity within OWPs by some species, therefore countering disruptive effects of increased shipping elsewhere, although any commensurate increase in collisions could cancel out any benefits.
For migratory birds, there have been suggestions of using wind farm layout to provide wider corridors between turbine rows in parallel with the main flight orientation, although this is untested. The RSPB pressed for marine spatial planning as a component of the UK Marine & Coastal Access Act 2009. A logical extension of this, as indicated in this report would be to extend spatial planning throughout the North Sea and to include cumulative assessment of regional populations of birds. To date, cumulative impacts have tended to be poorly

addressed in UK environmental impact assessments, and extending a requirement to transboundary consideration will greatly increase the challenges of producing competent CIAs – this is a significant problem to address. An extra paragraph has been written in the report on especially the cumulative effects (par. 3.7), and the lack of studies incorporating this aspect, especially in transboundary effects. Most reviewers have commented this along the same lines, and it seems that the time is ready for an international step forward.

Mammals, page 55. The second paragraph should be highlighted in bold font although, as stated earlier, if alternative foundations to monopiles are used, there may be substantial reduction in potentially negative impacts. Gravity-based foundations are regularly mentioned as the alternative to piling, but as I understand it is not straightforward to use this technique as a standard (yet).

Cumulative impacts require an internationally agreed definition, for example to include all planned and reasonably foreseen projects. There is a concern that owing to time lag in the manifestation of some impacts, they may be wrongly attributed. However, we have not yet found a satisfactory way in which to address this problem. Yes, indeed a large problem. For birds one might add that also land-born activities should be included. Also wind farms on land could add to the mortality or reduced fitness of e.g. migrating birds.

Our knowledge of impacts associated with the listed other activities varies from reasonably comprehensive to poor or non-existent and there is difficulty in attributing causation. Copied this remark to the end of the text.

3.8 Mitigating measures

3.8.2 Construction, Birds, page 58, still little is known about how best to increase detection of wind mills by birds. Knowledge of bird vision indicate that for many species they are often unable to see wind turbines when they are in flight because their vision is trained downwards, for example when undertaking foraging flights (G. Martin pers. comm., University of Birmingham, UK). Additionally, there is a need to consider how birds view wind turbines, rather than applying human vision perspectives. Alteration of lighting during peak migration may be unacceptable in terms of requirements for navigation and aviation. Copied into text

There is clearly a lot more thought and discussion necessary to increase the detection of wind turbines by birds. There is a pressing need for experimental testing of different methods, initially this would be easier to undertake on land, rather than offshore, although clearly responses may be different on land, but this would be a useful starting point. Also added to the text

4 Prioritising monitoring questions

Priorities, page 61. Questions for which there are currently no perfectly feasible methods need to be included – information demand will help to drive the development of technologies and methods to address some of the high priority but challenging questions – I note there is reference to such projects under the long-term subdivision. A sentence was added.

4.2.5 Birds

Priority 1, page 66. Indications from UK wind parks and experience from the coastal wind park at Zeebrugge in Belgium (Everaert & Stienen 2007) are that Sandwich tern is a high-risk species for collision. Studies by Perrow (unpublished) show foraging ranges well beyond 12 nm for breeding birds and overlap with footprints of proposed OWPs in UK waters. Look at footnote 37, states exactly this.

Priority 2, page 66, Indirect observations of collision, using seabird strandings: how is this information connected to OWPs in The Netherlands? Corpse drift may mean that corpses come from other sea areas. Or is the aim of this work to provide an index of strandings, cause of death/nature of injuries consistent with collision before and after large scale deployment of OWPs? How will these data be analysed? Depends on type on injury. Kees Camphuysen explained that it's possible to get some idea of possible collisions from strandings data. Currently there is a project for near-shore wind farms. I have to admit that for offshore farms this does not seem a likely method.

Priority 3, page 67. Ringing will provide limited information about migration routes. Most information from ringing identifies origins and destinations and may indicate possible routes, but to identify migration routes and the variation in migration routes requires a combination of radar to track migration volume, as indicated under Priority 1, and tracking of individual birds. I added a sentence Tracking is feasible, cost-effective (increasingly so for particular types of tag, although with varying levels of precision and accuracy) and offers levels of information that merit consideration under Priority 1, to determine connectivity between SPA breeding colonies and OWPs, identify important foraging areas, transboundary links, migratory flights. I added tagging migratory birds (from our SPAs) under priority 1.

Priority 3, 3, page 67, habitat association/spatial modelling has a role here. Yes, but how this exactly needs to be done will be described elsewhere (i.e. not in the Masterplan)

5. Data management

The data management role must be independent of industry but also have the ability to secure data from industry to allay industry fears of unfair advantage to competitors or disadvantage to themselves. In the UK, the Crown Estate as landlord of the seabed has authority to require submission of environmental data for a centralised database, which was established under the auspices of COWRIE. There are considerable funding requirements to develop and maintain data, and to produce meta-analysis to increase the knowledge base. Consistent methods also ensure that such meta-analysis is possible. The models proposed here have advantages and disadvantages in terms of acceptability to data suppliers, as well as providing access to users. In an annex, the ideas for the organisation of the monitoring and research, and the role and responsibilities of the various actors is laid down. This has been done after consultation with the industry. It definitely is something that is being looked at!

Annex C: Organisational aspects Masterplan ecological effects OWFs

This annex has been published as a separate document; it has not been included in this document. It can be found at (fill in URL link).