MONITORING AND RESEARCHING ECOLOGICAL EFFECTS OF DUTCH OFFSHORE WINDFARMS, MASTERPLAN 2.0

RIJKSWATERSTAAT ZEE & DELTA

10 August 2015
078752099:A - Final
C03041.002043.0100

ARCADIS

Contents

Management summary ... iii

1 Introduction ... 1
1.1 Motivation ... 1
1.2 Problem description ... 3
1.3 Aim & Project- and report outline ... 4

2 Inventory of knowledge gaps: Long List 2015 ... 7
2.1 Method ... 7
2.2 Expert Interviews ... 8
2.3 Literature & Ongoing research ... 9
2.4 Adaptive management ... 13
2.5 Efficacy of mitigation measures ... 15
2.6 Long List 2015 ... 15
2.7 Synthesis: knowledge gaps in ecosystem perspective ... 22

3 Policy Priority List 2015 ... 25
3.1 Method ... 25
3.2 Results prioritization: Policy Priority List 2015 ... 27

4 Expert Priority List 2015 ... 33
4.1 Method: Workshop for prioritizing knowledge gaps ... 33
4.1.1 Plankton, benthos, fish & marine mammals ... 33
4.1.2 Birds & bats ... 36
4.2 Results of prioritization: Expert Priority List 2015 ... 37
4.2.1 Underwater noise (physics) ... 37
4.2.1.1 Propagation of underwater sound produced by pile driving – model validation 37
4.2.1.2 Standardization of underwater acoustic measurements ... 38
4.2.2 Fish ... 38
4.2.2.1 Effect of pile driving noise on physical condition and behaviour ... 38
4.2.3 Marine mammals ... 39
4.2.3.1 Population dynamic parameters and habitat use ... 39
4.2.3.2 Threshold values for TTS, PTS, and avoidance ... 41
4.2.3.3 Assessment of effect on population level ... 42
4.2.4 Birds ... 43
4.2.4.1 Effects of collision on population level of birds ... 43
4.2.4.2 Habitat loss or change ... 45
4.2.5 Bats ... 47
4.2.5.1 Effects of collision on population level of bats ... 47
4.2.6 General aspects ... 48
4.2.6.1 International collaboration and data and knowledge sharing ... 48

5 Synthesis ... 51
5.1 Synthesis priority lists 2015 ... 51
5.2 Adaptive management ... 52

5.3 Efficacy of mitigation measures 53

References 55

Appendix 1 List of abbreviations 67

Appendix 2 Overview of ongoing monitoring OWFs 69

Monitoring programmes for OWFs in the Netherlands 69

Current programmes 69

Egmond aan zee offshore wind farm (OWEZ) 69

Prinses Amalia wind park (PAWP) 70

OWF Luchterduinen 71

OWF Gemini 72

International monitoring programmes for OWFs 72

Overview of monitoring activities in European offshore windfarms 72

VUM studies (vervolg uitvoering Masterplan) 74

Framework Ecology and Cumulation 75

Environmental impact assessments and the “wind farm site decision” 75

Appendix 3 Long List 2015 – extensive working table 77

Appendix 4 Priority List Studies: basis for MEP 79

Management summary

The development of OWFs on the Dutch Continental Shelf can have adverse effects on the marine ecosystem. In recent years, many studies on this subject have been carried out, which provided highly valuable data and new insights. Still, at present many knowledge gaps exist which makes it difficult to draft a solid cumulative impact assessment for relevant species.

In this study, the Masterplan 1.0 (Deltares, 2010) was updated by assessing which knowledge gaps have been addressed over the last years and by making an inventory of new and remaining knowledge gaps. These knowledge gaps have been prioritized by both policy makers and scientific experts. Knowledge gaps concerning marine mammals, birds and bats are prioritized to be addressed on short term, described in more detail below.

Prioritized knowledge gaps:

Marine mammals

The knowledge gaps that have to be addressed with highest priority for marime mammals are (1) the percentage of surface area where effects on marine mammals occur in comparision to the dispersion area and (2) better threshold quantification in combination with more insight in actual behavioural response in the field during construction for both seals and marine mammals. Studies on these gaps will provide better quantified input parameters for the InterimCPOD model, which will contribute to more reliable impact assessments of construction of OWFs on marine mammals. From policy side it is explicitely noted that insights in the efficacy of mitigation measures should be acquired for the purpose of adaptive management.

Birds

The knowledge gaps that have to be addressed with highest priority for birds are (1) on the loss of habitat for (surface) farm avoiding bird species in relation with the total area, including species specification and abundances. and (2) insight in collision rates of birds in OWFs. Experts mainly focussed in the workshop discussion on the development of a system of collision quantification, where policy makers prioritized specifically the effects OWF configuration to minimize collision and habitat loss. Policy makers specifically prioritized insight in the efficacy of mitigation measures, by studying the effects of corridiors, open or closed configuration, small or large turbines, indirect lights, contrasting colors of rotor blades and foundation, and a cut-in speed at >4 Bft on both collision rate and habitat loss.

Bats

The knowledge gaps that have to be addressed with highest priority for bats are the behavioural characteristics of bats at sea. Knowledge of bats at sea is generally limited and should be acquired with high priority to be able to assess the impacts of OWFs on the bat population.

General

During the workshop, the need for international collaboration and data sharing was emphasized by both scientific experts and policy makers. This is not a knowledge gaps by itself, but needs to be facilitated in order to efficiently address the current existing knowledge gaps. Also, this will help in assess the (cumulative) impacts of OWFs on population level of species, as most species are not restricted to national boundaries.

Adaptive management

Knowledge gained in the coming years is extra valuable if it can be used for adaptive management. In order to get all necessary information in time, high priority studies should start and be executed as soon as possible. Adaptive management can only be applied when knowledge from research can be applied during the process, that is why timing is of utmost importance.

According to the time-schedule, the first construction phase is foreseen at the end of 2018, which implies that approx. 2.5 years are available to define and mature indicators for adaptive management. It is noted that applying adaptive management will be challenging; there will most likely be limited sufficiently accurate indicators available that can express the effects of construction and operational OWFs on population level on a short time scale.

1 Introduction

1.1 MOTIVATION

In September 2013 the Dutch Government adopted the “Energy Agreement for Sustainable Growth” (Social Economic Council (SER) - energy agreement) and agreed on a robust legal framework for more offshore wind energy (Tweede Kamer, year 2012-2013, 30 196, nr. 202). The framework aims to achieve a state in which within four years of obtaining a grant, new offshore windfarms (OWFs) should be operational using the latest technology.

Scaling up renewable energy requires intensive efforts on different sources of renewable energy production, such as offshore wind. Within the Dutch objective of producing 14% renewable energy in 2020, 16% in 2023 and 100% in 2050, one of the key points for large-scale renewable energy production is the upscaling of wind at sea, with an objective of 4450 MW being operational in 2023. The existing and planned OWFs have a combined capacity of 1000 MW. Starting in 2015 this capacity will be gradually increased to 4500 MW: 700 MW (2015, Borsselle), 700 MW (2016, Borsselle), 700 MW (2017, Coast of South Holland), 700 MW (2018, Coast of South Holland) and 700 MW (2019, Coast North Holland) (Tweede Kamerbrief, 26 September 2014). This plan is based on achieving a cost reduction of offshore wind of approximately 40% over the coming years. For efficiency purposes, an offshore grid will be used instead of a direct connection to the national grid. TenneT will be responsible for this (SER Akkoord, 2013).

Current OWFs

In 2006 and 2007 two so-called “first round OWFs” were built, with a combined capacity of 228 MW. These first two OWFs were named “Offshore Windfarm Egmond aan Zee” (OWEZ, formerly NSW) and the “Prinses Amalia Wind Park” (PAWP, formerly Q7). The “second round OWFs” were provided with supportive financing via the so-called SDE subsidy, for the construction of a total capacity of 950 MW. Permits for twelve OWFs were issued in 2009, three received a subsidy; Q10 at ‘Hollandse Kust’ (Eneco Luchterduinen), and two windfarms off the coast of Groningen, North of the Wadden Islands (Buitengaats and ZeeEnergie, together named “Gemini”). The remaining 9 permits were withdrawn by the government following the 26 september 2014 administrative decision of the Wind-at-Sea Act

Future OWFs

In April 2013 the Dutch Ministry of Infrastructure and the Environment and the Ministry of Economic Affairs announced their intention to amend the National Water Plan’s Offshore Wind Energy component by creating a ‘Government Structural Vision Wind Energy at Sea’. Two areas were appointed by this structural vision as potential OWF areas: ‘Hollandse Kust’ (HK) and ‘Ten Noorden van de Waddeneilanden’ (North of the Wadden region, TNW). In the SER energy agreement it has been agreed that the Netherlands intends to co-finance the instalment of a total of 3,450 MW of new offshore wind energy in the period 2015 - 2019. Three areas were designated as building areas: ‘Borssele’ (southern location), ‘IJmuiden Ver’ (northern location) and ‘Hollandse Kust’ (middle location). An overview of the three designated OWF areas and indicative cable routes is shown in Figure 2.

Figure. Note that the development of OWFs does not stop at 2020, but will most likely continue until at least 2023 in the designated area IJmuiden Ver.

gebied	MW	Jaar van tender	gereed
Borssele 1,2	700	2015	2019
Borssele 3,4	700	2016	2020
HK zuid 1,2	700	2017	2021
HK zuid 3,4	700	2018	2022
HK noord 1,2	700	2019	2023

Figure 1 Time-schedule OWFs in Dutch waters.

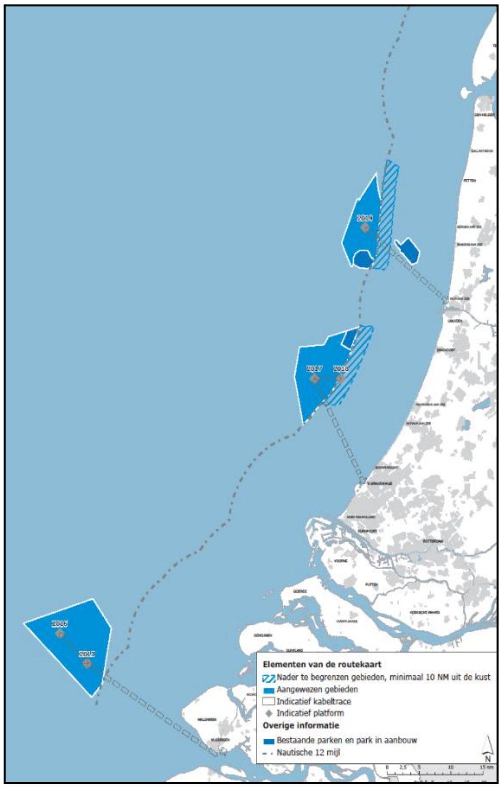


Figure 2 Designated OWF areas in blue and indicative cable routes in grey blocks (SER akkoord).

Masterplan Wind at Sea / Wind op Zee

OWFs can have adverse effects on the ecosystem, however there are knowledge gaps that need to be addressed in order to be able to draft a solid impact assessment of these effects. In 2010, Deltares drafted the first Masterplan, which described the required monitoring and research programme that needed to be conducted to address these knowledge gaps with highest priority. On the basis of existing (inter)national research programmes for OWFs, a framework-formulating plan was presented for obtaining knowledge on the ecological effects of OWFs (Boon *et al.*, 2010). Deltares indicated, by means of prioritisation, how these knowledge gaps could be filled in due course. Research proposals were further prioritized, after funding was obtained for a first series of research projects. The first series of research proposals ("shortlist studies") were effectuated in 2010 and 2011 and the results were published in separate reports.

The shortlist studies and the research carried out in recent years in relation to the two already existing Dutch OWFs, has increased the knowledge with regard to ecological effects substantially (Boon, 2012). After the execution of Masterplan 1.0, VUM (Continued Execution Masterplan) studies were set up to address remaining gaps. As a result of the shortlist and VUM studies, much knowledge on the effects of OWFs on the marine ecosystem has been acquired.

To prioritize currently still existing knowledge gaps, ARCADIS was asked to update the Masterplan 1.0 with the knowledge acquired by (inter)national research conducted over the last years and to prioritize currently existing knowledge gaps. The Masterplan 2.0 contains an inventory of knowledge gaps, process of prioritization and a Priority List 2015 of high-priority research. The Masterplan 2.0 also describes possibilities to apply adaptive management during the construction of OWFs the coming years.

1.2 PROBLEM DESCRIPTION

Installation and operation of OWFs can potentially cause adverse effects on the marine ecosystem. Various (inter)national studies have been carried to collect important, often location-specific data for baseline- and effect definition. In the Netherlands, shortlist and VUM studies have been conducted for the OWFs OWEZ, PAWP, Luchterduinen and Gemini.

Still, basic and generic knowledge on the distribution of relevant species and on cause-effect relations of the disturbances caused by windfarms are often still lacking, which makes it difficult to draft a solid impacts assessment of the (large-scale) effects. In addition, effects can be location-specific, for example underwater noise propagation 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 such as foraging areas or migration routes. Results from research carried out abroad can therefore not always directly be applied for the assessments of effects of Dutch OWFs. It is also important to note that most monitoring and research programmes have not yet been performed over sufficient timespan to distinguish between short- and longer- term effects.

The planned installation of 4500 MW of OWFs on the Dutch Continental Shelf (DCS) and several dozens of GW of OWFs elsewhere in the North Sea, can in cumulation with each others lead to more effects than individually assessed effect studies (Environmental Impact Assessments, EIAs and Appropriate Assessments, AAs). Therefore, the plans for windfarms 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 assessing these effects, as the marine ecosystem is not bound to national borders. The information to estimate the effects of large-scale expansions of OWFs internationally is still insufficient at this time, although much knowledge has been acquired in the many executed studies over the past 4 years.

Update of knowledge gaps

In order to distinguish which studies need to be conducted in the coming years, first an inventory of remaining knowledge needs to be made. Subsequently, this information should be used to update the Masterplan 1.0 (Boon *et al.*, 2010) and to be able to prioritize the remaining knowledge gaps.

Adaptive management
Since the offshore wind industry is rapidly growing and new OWFs are being planned and build at rapid pace, there is a clear need of adaptive management. As soon as new knowledge is acquired and becomes available, it should be used for the assessment and management of (near) future OWFs in order to prevent or minimize adverse effects on the marine ecosystem.

1.3 AIM & PROJECT- AND REPORT OUTLINE

The aim of the project is to update the Masterplan 1.0 by knowledge acquired in studies executed over the last years, make an inventory of remaining knowledge gaps (Long List 2015) and to prioritize the knowledge gaps that need to be addressed in the near future (Priority List 2015). Also, the aim is to identify possibilities to apply adaptive management for the OWFs that will be constructed in the near future.

Figure 3 shows the steps taken to compile the Priority List 2015, which is based on a prioritization by both policy makers and scientific experts. First, an inventory of remaining and new knowledge gaps is made by a literature research and by interviews of ten experts with different expertise related to offshore wind. Also, an inventory of the possibilities to apply adaptive management has been made. Based on the Masterplan 1.0, a Long List 2015 is compiled based on the information gathered. This is described in Chapter 2.

Chapter 3 describes the prioritization of knowledge gaps from the perpective of policy makers. First, the six criteria set by RWS Zee & Delta are described, followed by the prioritization of the Long List 2015. Each knowledge gap is judged on basis of the six criteria, resulting in the Policy Priority List 2015.

Chapter 4 describes the prioritization of the knowledge gaps from the perspective of scientific experts, based on a workshop organized by RWS Zee&Delta. First, general outcomes of the workshop are described, followed by the Expert Priority List 2015.

In the final chapter 5, a syntheses of the prioritizations and an outline of the most important knowledge gaps that need to be addressed in the near future is given. Also, possibilities to apply adaptive management are described. In Appendix 4, short descriptions of the studies that can be conducted to address these knowledge gaps are given.

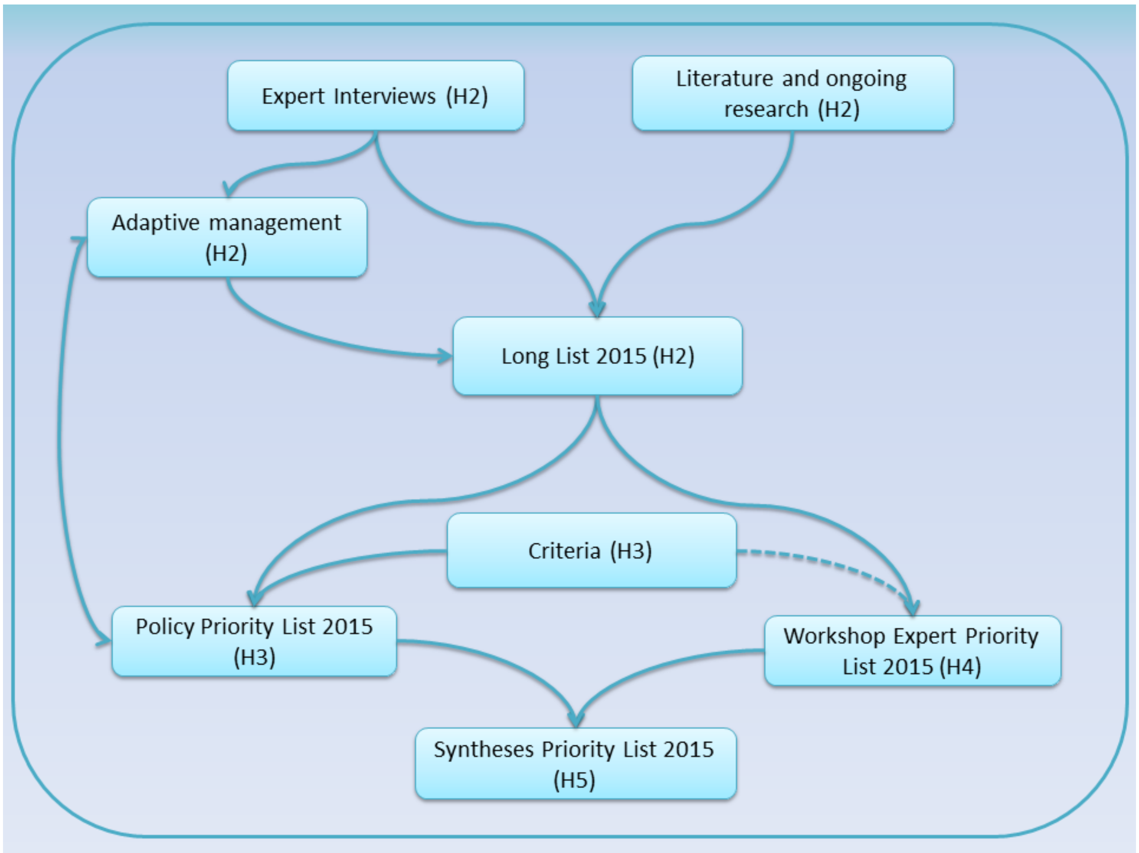


Figure 3: Process of inventory and prioritization of knowledge gaps towards the Priority List 2015 by both policy and scientific experts.

Masterplan 1.0 contained a delineation of monitoring in general and in relation to OWFs (originally Chapter 2). Since this version aims at an update of the knowledge gaps and state of current research, this delineation is not included in this version (for more detail, see Boon *et al.*, 2010). Masterplan 1.0 also included general information on several aspects concerning OWFs. Due to the focus of the update of the Masterplan on the draft of a new Priority List 2015, all general (relevant) information has been moved to the appendices. The extensive working document for the Long List (excel file) is also included in the appendices.

The following appendices are included in this report:

- Appendix 1: List of abbreviations;
- Appendix 2: Overview of ongoing monitoring OWFs;
- Appendix 3: Long List 2015 – extensive working table;
- Appendix 4: Priority List Studies: basis for MEP.

2 Inventory of knowledge gaps: Long List 2015

2.1 METHOD

In 2010, Deltares presented a summary the information and accompanying research questions required to make decisions on the anticipated ecological effects of current and planned windfarms (Masterplan 1.0). This Masterplan 1.0 was taken as a starting point to evaluate the current level of knowledge, by identifying both addressed and new knowledge gaps. In this process of updating Masterplan 1.0 to Masterplan 2.0, many resources have been used to provide input for this. The resources that have been used are illustrated in Figure 4.

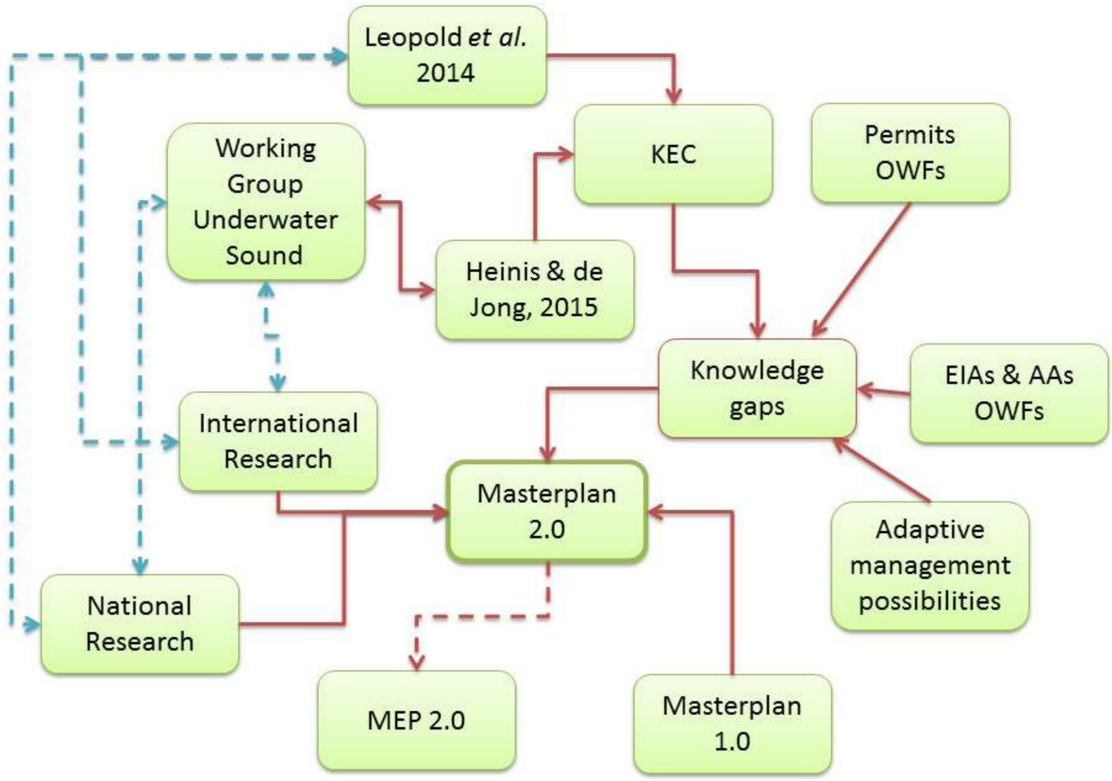


Figure 4 Resources used to update Masterplan 1.0 to Masterplan 2.0

Working document assessment of addressed and remaining knowledge gaps

To compile the Long List 2015, the addressed and remaining knowledge gaps are assessed. A working document was created in which the original Long List of the Masterplan 1.0 was included as a starting point. All information gathered in the different steps described in this chapter, was added to the working document. In this process, insight is gained in which gaps have been addressed by research over the last years and which knowledge gaps are still pending to be addressed. Also new insights and newly identified knowledge gaps over the last years have been included in the working document. For the assessment of the current level of knowledge, the following features were included in the working document:

- Original Long List Masterplan 1.0 as a starting point;
- Recent literature;
- Current Status of the knowledge gap;
- Remaining knowledge gap;
- The feasibility of filling the remaining knowledge gap on the short term (< 5yr);
- The expected outcome on the short term;
- Expert interview feedbacks;
- Value of answering the remaining information gap;
- Adaptive management potential.

The working document can be found in Appendix 4 and has formed the basis of the compiled Long List 2015 as described in this chapter.

2.2 EXPERT INTERVIEWS

In order to gain an up-to-date view of the current available knowledge of OWFs, several expert interviews were taken. The interviewed experts are shown in Table 1.

Table 1: List of experts interviewed to update current knowledge on OWFs.

Expert Name	Expertise	Organisation
Ron Kastelein	Underwater sound and impact on ecology (mainly marine mammals and fish)	SEAMARCO
Floor Heinis	Marine mammals	HWE
Christ de Jong	Underwater sound (focus on acoustics)	TNO
Allix Brenninkmeijer	Birds	Altenburg&Wymenga
Arjen Boon	Marine ecology (focus on benthos and fish)	Deltares
Mardik Leopold	Birds	IMARES
Sophie Brasseur	Marine mammals (focus on seals)	IMARES
Meike Scheidat	Marine mammals (focus on harbour porpoises)	IMARES
Geert Aarts	Marine mammals (focus on seals)	IMARES
Martin Poot	Birds, bats	Bureau Waardenburg
Hans Slabbekoorn	Behaviour (focus on fish)	Leiden University

All experts interviewed gave their professional opinion on the current knowledge gaps that need to be addressed to assess the impacts of OWFs.. New information gathered in the expert interviews was added to the Long List working document, which consisted of information on both conducted research and acquired knowledge and on new knowledge gaps that were identified over the last years.

All experts were asked to provide a top 5 of knowledge gaps which – according to them – need highest priority to be addressed at this point in time. These knowledge gaps are indicated in the Long List 2015 (see paragraph 2.6) with a red exclamation mark. Where possible , methodologies to address these knowledge gaps were given by the experts.

2.3 LITERATURE & ONGOING RESEARCH

This paragraph provides an overview of the found knowledge gaps in recent literature and ongoing research. The literature and research was found online or through expert contacts.

Effects of OWFs on the marine environment are still largely unknown. Although much research has been conducted and several knowledge gaps have been addressed, many questions still remain. Often due to scope and budget, conducted studies cannot fully address the existing knowledge gap, or are e.g. too local to derive sufficiently reliable predictions of the most significant effects for general use. Knowledge on fundamental matters such as sensitivity of marine organisms to noise intensity, noise progagation, and electromagnetic fields (marine mammals, fish and fish larvae), collision risks and habitat avoidance (birds & bats) and habitat preference (bottom fish) is necessary in order to estimate the effects of OWFs on the marine environment. In addition, knowledge on the spatial distribution and seasonal patterns during the various life stages of marine organisms is require, since this can show significant annual variation.

In the past five years, conducted research has provided a lot of information on the topics above, still there are questions remaining which are relevant to assess the impact of OWFs on the marine ecosystem. It is important to note that it is not feasible to fully address most of the currently existing knowledge gaps. For this reason, it is important to group knowledge gaps, express them at the same level of detail and prioritize these gaps following clear criteria. Also, expectations on the level of gained knowledge from the different approaches should be made clear.

The following paragraphs provide an overview of the current knowledge gaps per ecological group as well as general knowledge gaps are described.

General (all species or indifferent of species)

The local sound landscape before any OWF activities take place, during construction and during operation of OWFs covering various sea-and wind-states is subject to monitoring and modelling, though it is essential to validate the currently used models which is partly to be done. Monitoring during decommissioning phase will start in some decades.

Effects of underwater noise on species either due to pile driving or due to noise from other sources (e.g. shipping routes) can have adverse effects on species. Effects of pile-driving alternatives on species and habitats should be addressed as well, in order gain insight in the efficacy on mitigation measures that can be taken to mimize potential effects. Noise effects on invertebrates during the construction, operation and removal phases of an OWF have not been investigated and remains a knowledge gap for know.

Differences in habitats within and outside of OWFs can be detrimental for the marine ecosystem, even though this might not be directly visible. To gain insight in this, habitat characteristics before construction of OWFs need to be mapped. Also, more accurately mapping North Sea species and ecosystems can assist in decisions on location, lay-out and timing construction of OWFs. More knowledge on this will also support the cumulative impact assessment of multiple OWFs on the marine ecosystem.

Also changes in food web relations as a result of OWFs construction or operation can play an important role.

Plankton

In the last five years, little research has been done on the effect of OWFs on phytoplankton and zooplankton communities (only modelling at Alpha Ventus). The effects of turbulence on stratification, nutrient mixing and the secondary effect on plankton communities and species composition are unknown. The same counts for changes in the predator-prey relations between phytoplankton and zooplankton. It is assumed that such changes are local with negligible effects on the structure and functioning of the local food web, though knowledge on this is lacking.

Benthos

The benthos community was studied the past five years (Aguilar de Soto *et al.*, 2013; Bergman *et al.*, 2010; Bergman *et al.*, 2012; Coates *et al.*, 2014; Lindeboom *et al.*, 2011; Lock *et al.*, 2014; Miller *et al.*, 2013; Walls *et al.*, 2013) partly addressing existing knowledge gaps. Remaining knowledge gaps involve specific effects on local communities, recruitment, age, toxicity and electromagnetic fields. Also more generic information such as numbers, densities, distribution and composition of (larval) species and communities is needed to address the earlier mentioned knowledge gaps.

Fish Larvae

In the past five years several studies have been conducted on the effects of OWFs on fish larvae (Bolle e*t al*., 2011; Danish Energy Agency, 2013; Hawkins *et al*., 2014; Popper & Hastings, 2009; Slabbekoorn, pers. com., 2014; Van Damme *et al*., 2011A; Van Damme *et al*., 2011B). In these studies, generic information such as distribution has been collected, as well as more specific information such as effects of pile driving sound on fish larvae. The results of the studies indicate fish larvae appear not to suffer extra mortality from pile driving at ranges further than 100 m and appear not to be particularly sensitive to the construction and operational sound by OWFs in laboratory studies. Relevant field studies are difficult to realize and population effects are hard to establish, they are however being set-up and conducted in new OWFs.

Fish

The effects of OWFs on fish have already been studied extensively, showing a growing database with valuable information to address previous and existing knowledge gaps (Andersson, 2011; Casper *et al*., 2013; Gill *et al*., 2012; Gill & Bartlett, 2010; Haelters *et al*., 2013; Halvorsen *et al*., 2012; Malcolm *et al*., 2013; Merck & Wasserthal, 2009; Mueller, 2007; Mueller-Benkle *et al*., 2010; Nielsen & Carl, 2014; Popper, 2014; Reubens *et al*., 2014; Danish Energy Agency, 2013; Thomsen *et al*., 2012; Van der Molen *et al*., 2014; Van Hal *et al*., 2012; Van Hal, 2013; Van Hal, 2014; Walls *et al*., 2013; Winter *et al*., 2010). Location-specific data on the fish communities at the level of windfarms are still scarce. As stated in the previous Masterplan, research on the effects of a windfarm on the fish community will therefore always have to be accompanied by studies in reference areas. Information becomes even more scarce for less abundant or commercially less attractive a species, despite the fact that these species can have an important role in the marine food web.

Insight in threshold values and duration of noise levels at which disturbance of behaviour or even fysical damage is caused, is now available for a limited amount of species. Specific information for typical Dutch species expected in and around OWFs is however still lacking. At this point in time, there can only be speculated on the exact behavioural and physical responses by fish during the construction and operational phase of OWFs. It is expected that the effects on the population level due to avoidance or individual damage will be difficult to determine, though large-scale tagging studies might provide a solution for the challenges facing.

The extent to which the introduction of hard substrate has an aggregation effect on fish has been (a.o.) studied at the OWF OWEZ and has been shown for species such as cod and bib (Reubens *et al*., 2014; Winter *et al*., 2010; van Hal *et al*., 2012). The refuge effect due to the absence of fishing has been studied for one epi-benthic species (sole) and one semi-pelagic species (cod) in multiple wind farms, though contrasting results are found. Possibly the scale of the OWF in relation to the scale of individual movements plays an important role in this. Fishing activities will continue to be prohibited or limited in OWFs for reasons of safety, implying that fish will no longer be caught and the surface sediment will remain undisturbed in a limited area. The extent to which these areas actually fulfill a refugium function for fish remains unanswered. Research indicates no or small changes in behaviour, however data is limited and comparisons are difficult to establish. Recent Belgian research (Reubens *et al*. 2014) strongly suggests that at least juvenile and sub-adult cod tends to spend summertime in close proximity to both gravity-based and pile-driven foundations of wind turbines while wintering closer inshore or even well up estuarine habitats such as the Wester Scheldt estuary (Platteeuw, pers. com., 2015). For those species that show attraction to these newly created hard substrate habitats, it is still unclear whether this enhances overall population size (productivity) or just redistribution of fish without an increase in population size, as well as food availability and growth.

Contamination from the sediment and foundations can have an effect on fish larvae and adult fish, also via bioaccumulation in benthos. This information, e.g. hazardous substances from the geo-textiles used in the anti-scour protection, is still lacking. Since regulations state that no polluting substances can be used in the building or operation of OWFs in the Dutch North, effects of pollution on fish is expected to be limited.

Limited information is currently available on the effects of electromagnetic fields on fish, although information such as the response of specific native species, threshold values, long-term effects, effects on migration and population effects is still lacking. These knowledge gaps are expected to be difficult to address. Additionaly, at sufficient burial depth effects are expected to be limited as the electromagnetic field will be limited to the sea floor and not reach the water column.

Marine Mammals

Harbour porpoises and harbour- and grey seals are the most common marine mammal species in the Dutch North Sea area. Research during the last five years covers distribution and sensitivity to underwater sound in relation to (the construction of) OWFs (Brasseur *et al*., 2012; Geelhoed *et al*., 2011; Kastelein *et al*., 2008; Kastelein *et al*., 2011; Kastelein *et al*., 2013a & b; Leopold & Camphuysen, 2009; Lindeboom *et al*., 2011; Poot *et al*., 2011B; Danish Energy Agency, 2013; Scheidat *et al*., 2012; Thompson *et al*., 2013; Tougaard *et al*., 2012; Van Polanen Petel *et al*., 2012; Walls *et al*., 2013; Werkgroep Onderwatergeluid, 2014).

Up-to-date basic biological information on all relevant species is still needed, such as density per region, population size & distribution, definition of (sub) populations, spatial and temporal rhythms, population development, life-history of the species (reproduction, etc.), basic audiogram, critical ratio, directionality of hearing, TTS, and PTS. Also knowledge on underlying parameters impacting distribution on a larger scale, e.g. prey availability and climate change, is needed. How to discriminate between effects caused by OWF construction / operation and larger scale ecosystem changes is yet unclear.

Although the interim PCoD model (de Jong & Heinis 2014) has made a first step in investigating how individual reactions (e.g. to noise) of harbour porpoises affect a population, energetic and reproductive studies should be conducted to translate behavioural responses, TTS and PTS effects due to pile driving sound. Growth and reproduction are input parameters used for the interim PCoD model and results will be more reliable with more accurately quantified input parameters. Individual behavioural responses of porpoises needs to be studied to allow the modelling of effects on a larger and potentially cumulative scale.

Also more information is needed on the underwater noise during the operational phase to assess effects on population level. This effect – if present - is likely caused by masking of ecologically important sound for the marine mammals by the sounds of the wind turbines. Internationally, masking is considered to be an important issue for the coming years, as also shipping noise has the potential to mask biologically relevant sounds, and thus increase the distance at which animals can communicate, and detect prey or predators.

For safety reasons, fishing activities and other navigation traffic are (at least for the time being) prohibited in OWFs. If and to what extent this reduction in shipping in OWF areas might have an attractive effect on marine mammals is mostly unknown, although some evidence suggest that this might be the case (Russell *et al.*, 2014). The extent to which the change in potential food supply (fish, benthos) for marine mammals has a secondary effect in a farm on the foraging options of marine mammals is still unclear. An increase in locally dwelling cods around the wind turbines could result in a better food availability to marine mammals, as long as they could constitute prey, but they might also reduce prey availability through their own predation on smaller fish.

During construction, operation and removal, the OWFs can form a barrier whereby migration patterns of marine mammals could potentially be disrupted. Even though both porpoises and seals were found during the operational phase in the OWEZ farm, the question is to what extent such observations are a reflection of a structural presence of marine mammals in OWFs.

Birds

There have been several studies published on the effects of OWFs on birds in the last five years (Brabant *et al.*, 2014; Camphuysen *et al.*, 2011; Canning *et al.*, 2013; Cook *et al.*, 2012; Furness *et al.*, 2013; Gove *et al.*, 2013; Krijgsveld *et al.*, 2011, Krijgsveld *et al.*, 2014, Fijn *et al.*, 2015, Leopold *et al.*, 2010; Leopold *et al.*, 2011; Leopold *et al.*, 2012; Leopold & Camphuysen, 2009; Percival, 2014; Perrow *et al.*, 2011; Poot *et al.*, 2011A; Poot *et al.*, 2011C; Skov *et al.*, 2012; Danish Energy Agency, 2006; Danish Energy Agency, 2013; Verfuss, 2012; Walls *et al.*, 2013; WWF, 2014). New information has become available, although more (specific) information is still needed to fully address the most urgens knowledge gaps.

Basic information on distribution of birds at sea is still limited. In connection with the spatial distribution of birds on the DCS, information is required concerning the spatial use and variability of foraging areas and migration routes during various seasons.

As described in the Masterplan 1.0, the construction of windfarms has consequences on the use of habitat by birds. Avoidance is species-, farm habitus- and location-specific and thus difficult to generalise. Moreover, displacement of certain seabird species by the mere presence of operational windfarms should be better investigated as to which are the factors actually causing the observed displacement and as to which habituation over time might occur. Changes in the food supply (fish distribution, reduction in discards, changes in benthos), both within and outside OWF areas, is partially generic, partially farm-specific. The extent to which these differences might have secondary effects on the behaviour and fitness of birds is still largely unknown. There is still 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.

The collision risks by and avoidance of farms and turbines are closely connected, however conclusive information on this topic is still lacking. By lacking a fully functional monitoring method, it is difficult to collect quantitative data on the amount of birds colliding or avoiding windfarms, establishing risk factors is equally as challenging. Models are being built to estimate collision rates, though validation is necessary. Methods to measure collision have been developed but are only limitedly used.

Bats

There is only very limited basic or location-specific information concerning bats at sea available. Species, distribution, the use of (migration/habitat) area, avoidance of, or attraction to windfarms and turbines is largely unknown. In the update of the Masterplan, knowledge gaps on bats have been added to the Long List 2015.

2.4 ADAPTIVE MANAGEMENT

In this paragraph, a description of the necessity to apply adaptive management is given and some possibilities for this are suggested.

The previous paragraph shows the extensiveness of current knowledge gaps on the effects of OWFs in the marine ecosystem. The time-schedule presented in
Figure 1 shows the (ambitious) planning and development in a short timeframe. The combination of knowledge gaps and a tight time-schedule clearly express the need for adaptive management.

Adaptive management in the framework of offshore wind energy development is a structured, iterative process of robust decision making in the framework of knowledge gaps, with an aim to address knowledge gaps over time via system monitoring. In current AAs, assumptions are made for relevant knowledge gaps in the process of assessing impacts on population level of species. Adaptive management focuses on managing the process of development and operation requirements of actual and future OWFs in such a way that results of research and monitoring addressing knowledge gaps are used to adapt previous criteria. The tight time-schedule of OWF development until 2023, is a limiting factor in acquiring sufficient information to implement adaptive management in the Offshore Wind Dossier of Round 3.

Adaptive management therefore benefits from starting the first-priority studies that might yield concrete results to implement in the planning and construction phase of the upcoming OWFs as soon as possible. Studies of equal importance but not of immediate necessity to address within the construction period will therefore be given a lower priority.

The first set of data (LUD) has been collected in 2014 and 2015 and model validation can take place on short-term (approx. 1 year). The next set (Gemini) will be available at the end of 2015.

Adaptive management therefore basically comes down to clever prioritisation of addressing knowledge gaps in order to include the results yielded in these studies in the planning and development process of OWFs. It is important to ensure the direct link between the results of monitoring and adaptive management. Timely follow-up decisions by tightening the conditions on the development of OWFs should be possible to make.

The possibilities of implementing adaptive management on population effect-monitoring will be very difficult since effects are long-term and difficult to relate solely to windfarm developments. Despite this difficulty, thoughts are given on the possible indicators that can steer adaptive management for OWF development. Indicators should provide (sufficient) information to adjust policy and construction provisions on short term.

The interviewed experts all questioned the applicability of adaptive management to some extent, but provided input on possible indicators. The indicators mentioned are:

Underwater sound:

- It is relatively easy to measure underwater sound produced by (the construction of) OWFs. In Germany, a standard has already been put in place for the allowed level of produced underwater sound. When such a standard has been initiated, a simple noise measurement can give an indication of whether or not the standard is being followed. The efficacy is of course dependent on the efficacy of the (predicted) standard.

Fish:

- Tagging fish using a measurement network during construction may give an indication of avoidance behaviour on short-term, though it will be difficult to translate this on short-term to population effects.

Marine mammals:

- Porpoises & seals: The observations network of stranded porpoises and seals at the coast is reliable. If a peak of strandings in relation to a reference baseline coincides with the construction of a windfarm, this might give an indication of effects due to construction. However, it is difficult to establish a true baseline, as the number of strandings depend on many different factors. An increase in strandings could be linked to other events, such as an increased mortality due to an epidemic or a shift in distribution increasing the local density of animals (and thus the strandings) or a change in environmental conditions (e.g. prevailing winds for a certain direction). To determine a potential effect of construction, the physical effects and causes of death (e.g. ropes, fish nets, ear damage) need to be studied as indicator for strandings before, during and after construction. To determine physical damage caused by acoustic trauma the stranded animals have to be very fresh, which may pose as a challenge. No peaks in porpoise strandings were noticed after the construction OWEZ, PAWP or Luchterduinen.
- Harbour porpoises: a possible indicator could be the density / abundance of harbour porpoises before, during and after construction. This however needs regular surveys on larger scales or a monitoring network to detect effects on local scale and international surveys for the monitoring of population changes.
- Harbour porpoises: In principle it would be possible to use information on individual behaviour in and around windfarms before, during and after the construction to determine effects. This type of study could be done through different methods, such as tagging, monitoring acoustically and visually in a windfarm (including behaviour, e.g. feeding).
- Harbour porpoises: Acoustic monitoring is probably the best method to investigate the long term occurrence of porpoises in a defined area. E.g. listening posts could be deployed inside and outside of windfarms to investigate how porpoises use the area. The indicators to describe their presence could be porpoise active days, hours, minutes as well as the occurrence of feeding behaviour.
- Seals: information on avoidance rates and return behaviour of seals during pile driving can give an indication of effects of OWF. This might be feasible, since there is a good set of tagging data available with information on seal distribution and migration patterns.
- Seals: combination of existing data with affordable transmitters. Tagging a large number of seals with real-time transmission might give an indication on short-term and long-term effects of construction of operation. The indicator would be the behavioural response of seals to the OWFs, mapping avoidance or barrier effects.

Birds:

- Sound effect monitoring studies are essential, with baseline studies longer than 1 year to be able to discriminate indicators for effects on birds.
- Birds: at windfarms close to the shore (for which the BACI approach is necessary to analyse the effect of the OWF);

- Breeding success of potentially affected birds/in nearby colonies; (clutch size, hatching and fledging success, chick growth, parental condition);
- Flight and foraging behaviour of (individual) colonial birds;
- Collision measurement (with e.g. the WT BIRD detection system, ID Stat detection system, TADS or DTBird) and calibration of the collision models in combination with radar survey and bird counts at sea and the tracking of individual birds.

As can be seen from the list of indicators, a monitoring programme before, during and after construction of OWFs might provide information on the short-term effects based on these indicators. Whether these indicators are suitable to apply adaptive management has to be assessed in more detail.

2.5 EFFICACY OF MITIGATION MEASURES

Mitigation measures can be taken to eliminate or minimize possible effects of construction and operation of OWF's and are taken in order to follow the precautionary principle. Preventive measures can already be initiated in the planning phase. Examples are the type of turbine, adaptations in the foundation technique or the spatial planning (including within and in between windfarm corridors) of the entire OWF. Hoewever, the efficacy of these mitigation measures are not always quantified and are therefore considered as a knowledge gap. Addressing these gaps would be valueable in order to take sufficient and effective measures to eliminate of minimize effects of future OWF's. For this reason, the efficacy of mitigation measures as a knowledge gap will be included in the Long List 2015 (see next paragraph).

2.6 LONG LIST 2015

The Long List 2015 (presented in Table 2) based on working document described in paragraph 2.1. The list is split into five columns:

- The first column presents the id-number of each knowledge gap;
- The second column gives the ecological group, the physical effects such as underwater noise or habitat change and the interference category such as operational or construction phase;
- The third column describes the currently existing knowledge gap;
- The fourth column indicates recent papers or experts who provided information for the topic;
- The last column indicates whether an expert has indicated the knowledge gap as high priority.

Knowledge gap of the Long Lost 2015 can be identical to the gap described in the Masterplan 1.0, in case it has not (sufficiently) been addressed over the past four years. The knowledge gap can also be adjusted from the Masterplan 1.0, if for example it has been partly addressed or, according to expert judgement, the knowledge on the subject is still thought to be incomplete or not specific enough. As studies have been conducted, new insights are gained and also new knowledge gaps been inditified. These new knowledge gaps have also been added (delineated in green) to the Long List, which originated from the literature found or from the expert interviews.

Table 2. Long List: Overview of the gaps in knowledge per ecological group, including available literature. Knowledge gaps which are delineated in green are newly identified i.r.t. Masterplan 1.0, all other knowledge gaps are (adapted) from the first Masterplan. An **!** indicates one or more experts mentioning this knowledge gap as having high priority to address.

ID	Ecological group, Physical effect, Interference category	Knowledge gap	Available information on this topic	
1	General	Habitat characteristics before construction of OWFs.	Slabbekoorn, pers. com. 2014.	
2	General	Cumulative effects of OWFs.	Boon, pers. com. 2014.	
3	General	Maps of North Sea species / ecosystems / counting events, etc.	Mentioned in multiple expert interviews.	!
4	General	Effects of pile-driving alternatives on species and habitats.	Graafland, pers. com. 2015.	
5	General	Piling sound source and propagation model (AQUARIUS) validation. Incomplete modelling of seismic airguns. Uncertain modelling of population consequences. Updates Interim PCoD expert elicitation.	De Jong, pers. Com. 2014.	!
6	All species	Cyclic variation such as weather, tides and day-night cycles, in combination with underwater noise effects. Difference between habitats within and outside of OWFs.	Slabbekoorn, pers. com. 2014.	!
7	All species	Other impacts, e.g. contaminants on reproductive success, that can be detrimental even though not as visible. Also: noise from different sources, shipping routes, prey competition, predator relationships.	Scheidat, pers. com. 2014	!
8	Invertebrates	Noise effects on (pelagic) invertebrates such as cephalopods, during the construction, operation and removal phases of an OWF.	-	
Plankton				
9	Plankton, change in habitat , operational phase	Disruption of zoo-and phytoplankton communities, through 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.	Van der Molen *et al*., 2014; ACRB, 2013	
Benthos				
10	Benthos, change in habitat, basic information	Numbers, density, distribution and composition of larval benthic community, as well as information on reproduction, age classes, local and large-scale effects and insights in the cause of changes.	Hans Slabbekoorn, pers. com. 2014; Boon, pers. com. 2014.	!
11	Benthos, change in habitat, construction/removal	Information on the change in benthic assemblage after disruption of bottom integrity as well as chemistry on site and the time in which it recovers.	Lindeboom *et al*., 2011 ; Coates *et al*., 2014; Miller *et al*., 2013	
12	Benthos, change in habitat, construction/removal	Threshold values of effects by and sensitivity to toxic substances released from the bottom during construction/removal of turbines and installation/removal of cables, as well as bioaccumulation.	Aguilar de Soto *et al*., 2013;	
13	Benthos, change in habitat, operational	Changes in seabed topography and sediment morphology, mutual relations; what determines the appearance of	Coates *et al*., 2014; Bergman *et al.*, 2012; Bergman *et al.*,	

ID	Ecological group, Physical effect, Interference category	Knowledge gap	Available information on this topic
	phase	organisms and what is the interaction with topography, physics and chemistry	2010
14	Benthos, change in habitat, operational phase	How does the recruitment of benthos proceed without and with hard substrate	Miller *et al.*, 2013; Lock *et al.*, 2014; Walls *et al.*, 2013
15	Benthos, change in habitat, operational phase	Threshold values, effects and sensitivity of toxic substances (Al) which are released from anodes on turbine pilings. Bioaccumulation.	-
16	Benthos, electromagnetic fields, operational phase	Electric cable within the wind-farm and to shore – increase of temperature in sediments during operation (effect on benthos)	-
Fish larvae			
17	Fish larvae, basic information	Distribution of fish larvae in the windfarm areas has been studied, it is however not yet expressed in percentages of the population.	Van Damme *et al.*, 2011A; Van Damme *et al.*, 2011B; Danish Energy Agency, 2013.
18	Fish larvae, basic information	Distribution of fish larvae in the windfarm areas has been studied, percentage of surface area where the windfarms have an effect on fish larvae in comparison to the surface are of the dispersion area has not all vital basic information.	Van Damme *et al.*, 2011A; Van Damme *et al.*, 2011B; Danish Energy Agency, 2013.
19	Fish larvae, underwater noise, pile driving	Effects of pile driving noise on mortality of fish larvae has been studied on a limited amount of species. Knowledge gaps remain on the sensitivity to frequency levels and threshold values for mortality and other physiological effects of these and other species.	Bolle *et al.*, 2011, 2012 & 2013; Hawkins *et al.*, 2014
20	Fish larvae, underwater noise, pile driving	Effects of pile driving noise on physical condition of fish larvae, including threshold values during pile driving has been researched on a limited amount of species. Knowledge gaps remain on the radius of damage/mortality to the source and threshold values. However, as research indicated no significant mortality in relevant species, this knowledge gap is seen as having low priority. However, Effects of pile driving on fish eggs, embryonal development and hatching rate can be seen as a knowledge gap. There are indications that loud sounds affect these in invertebrate eggs and 'shockwaves' cause damage to fish eggs	Bolle *et al.*, 2011, 2012 & 2013; Winter, pers. com., 2015
21	Fish larvae, underwater noise, operational phase	Effects of noises of operational windfarms on physical condition of fish larvae, including sensitivity to frequency levels and threshold values during the operational phase.	Popper & Hastings, 2009; Popper, 2014.
22	Fish larvae, underwater noise, operational phase	Effects of noises of operational windfarms on physical condition of fish larvae, including radius of damage/mortality to source and threshold values and radius of damage/mortality to source.	Popper & Hastings, 2009
23	Fish larvae, change in habitat, construction / removal	Effects on fish larvae of toxic substances released from the bottom during construction/removal of turbines and installation/removal of cables, including sensitivity and threshold values.	
24	Fish larvae, change in habitat, operational phase	Effects on fish larvae of toxic substances (Al) released from anodes on turbine pilings, including sensitivity and threshold values.	
Fish			

ID	Ecological group, Physical effect, Interference category	Knowledge gap	Available information on this topic	
25	Fish, basic information	Insights into which areas are anthropogenically disturbed and which are not, as well as spawning areas.	Hans Slabbekoorn, pers. com. 2014	!
26	Fish, underwater noise, pile driving	Effects of pile driving noise on physical condition and behaviour of specific native fish species, including sensitivity and threshold values and radius of damage/disruption to source. Some research has been conducted but knowledge gaps still remain.	Casper *et al.*, 2013; Haelters *et al.*, 2013; Popper 2014 ; Mueller, 2007; Halvorsen *et al.*, 2012; Nielsen & Carl, 2014; Debusschere et al. 2014. Slabbekoorn, pers. Com. 2014	!
27	Fish, underwater noise, operational phase	Effects of noise of operational windfarms on the physical condition and behaviour of specific native fish species, including threshold values (sensitivity to frequency/levels and radius of damage/disruption to source). Some research has been conducted but knowledge gaps still remain.	Andersson, 2011; Slabbekoorn, pers. Com. 2014	!
28	Fish, change in habitat, construction / removal	Effects of work on construction/removal of windfarms on the behaviour of fish species, including range and duration (temporary/permanent) and masking effects.	Thomsen *et al.*, 2012 ; Mueller-Blenkle *et al.*, 2010.	
29	Fish, change in habitat, operational phase	Loss of habitat for (surface) rock avoiding fish species in comparison to the total, including species specification and species densities. Research has been conducted but specific numbers are not yet available.	Van Hal *et al.*, 2012; Winter *et al.*, 2010; Van Hal, 2014; Van Hal, 2013	
30	Fish, change in habitat, operational phase	Habitat use of fish with an affinity for rocks, including species specification and species densities.	Van Hal *et al.*, 2012; Winter *et al.*, 2010; Reubens *et al.*, 2014; Nielsen & Carl, 2014	!
31	Fish, change in habitat, operational phase	Habitat potency (surface) of fish species with an affinity for rocks in comparison with the total, densities, numbers and seasonal rhythms. Research has been conducted but a few knowledge gaps remain.	Van Hal *et al.*, 2012; Winter *et al.*, 2010; Danish Energy Agency, 2013	
32	Fish, change in habitat, operational phase	Changes in density of fish species in (the vicinity of) the farm in comparison to the surrounding area, numbers, seasonal rhythms due to less disruption.	Van Hal *et al.*, 2012; Winter *et al.*, 2010; Danish Energy Agency, 2013	
33	Fish, change in habitat, operational phase	Changes in density of fish species in (the vicinity of) the farm in comparison to the surrounding area, numbers, seasonal rhythms due to change in bottom species and more refuge possibilities. Research has been conducted but a few knowledge gaps remain.	Van Hal *et al.*, 2012; Winter *et al.*, 2010; Danish Energy Agency, 2013	
34	Fish, change in habitat, operational phase	Density of prey species in (the vicinity of) the farm in comparison to the surrounding area, seasonal rhythms and numbers are dependent on the predator species, research has been conducted but a few knowledge gaps remain.	Van Hal *et al.*, 2012; Winter *et al.*, 2010; Danish Energy agency, 2013; Van der Molen *et al.*, 2014	
35	Fish, change in habitat, operational phase	Effects of toxic substances (Al) released from anodes on turbine pilings on fish. Bioaccumulation, sensitivity and threshold values.	-	
36	Fish, change in habitat, operational phase	Effect of avoidance on fish species which are bound to certain areas on the reproduction of these species.	Hans Slabbekoorn, pers. com. 2014	!
37	Fish, electromagnetic fields, operational phase	Effects of electromagnetic fields around cables on the behaviour of specific native fish species (e.g. sharks and rays or migratory species that use earth magnetic field such as eel and salmon, including threshold values, prey detection and	Merck & Wasserthal, 2009 ; Mueller, 2007; Gill & Bartlett, 2010; Gill *et al.*, 2012; Nielsen & Carl, 2014; Malcolm *et al.*,	!

ID	Ecological group, Physical effect, Interference category	Knowledge gap	Available information on this topic	
		physical damage).	2013	
38	Fish, electromagnetic fields, operational phase	Percentage of surface area where the windfarms have an effect on fish species in comparison to the surface area of the dispersion area, migration areas. General research has been conducted but specifics remain unknown.	Gill & Bartlett, 2010; Gill *et al.*, 2012; Walls *et al.*, 2013; Malcolm *et al.*, 2013	
Marine mammals				
39	Marine mammals, basic information	Density of species, population size & distribution (sub) population seasonal rhythms, distribution area, distribution patterns per time unit expressed in percentages of the population. Population change, ongoing monitoring is needed.	Poot *et al.*, 2011B; Geelhoed *et al.*, 2011; Brasseur *et al.*, 2012	!
40	Marine mammals, basic information	Percentage of surface area where the windfarms have an effect on marine mammals in comparison to the dispersion area, in combination with the life-history of the species (importance of habitats for forage, reproduction, etc.). The previous knowledge gap should be filled prior to filling this one.	Van Polanen Petel *et al.*, 2012; Brasseur *et al.*, 2012	!
41	Marine mammals, basic information	Validation to determine if hearing data based on one animal, is representative of its species, sex or age group. Hearing sensitivity parameters such as basic audiogram, critical ratio, directionality of hearing, TTS, and PTS for a larger number of animals. Research has been conducted on few animals but information on more subjects is still needed. More information exists on harbour porpoises than for harbour seals.	Kastelein *et al.*, 2011; Kastelein *et al.*, 2008	!
42	Marine mammals, basic information	Harbour porpoises: Knowledge on underlying parameters impacting distribution on a larger scale, e.g. prey availability, climate change. How to separate the effects from windfarm construction / operation from the larger scale changes of the ecosystem	Scheidat (pers. com. 2014)	!
43	Marine mammals, underwater noise	Effects of noise on foraging efficiency in harbour porpoises. This will determine if noise affects the energy budget of marine mammals, and thus their fitness and reproduction (both are PCoD input parameters)	Slabbekoorn, pers. com. 2014, Kastelein pers. Comm. 2014.	!
44	Marine mammals, underwater noise, pile driving	Threshold values of marine mammals for pile driving sounds: TTS growth curves to determine safety criteria (to prevent PTS). Radius of damage. Sensitivity to sound in relation to frequency. Dose-behavioural-response relationship for pile-driving sounds with more subjects, as behavioural responses to sound can vary greatly between individuals. Duration of avoidance/ recovery time after disturbance. Masking effect on communication and (in porpoises) echolocation. Ecological consequences of TTS, PCoD validation. Research has been conducted but more information is still needed (also for harbour seals).	Kastelein *et al.*, 2013a & b; Kastelein *et al.*, 2011; Kastelein *et al.*, 2008; Leopold & Camphuysen, 2009; Thompson *et al.*, 2013; Werkgroep Onderwatergeluid 2014	!
45	Marine mammals, underwater noise, pile driving	Exact threshold values for pile driving effects on marine mammals, TTS growth curcves exact effects. Masking effect on communication.	Kastelein *et al.*, 2013a & b; Brasseur *et al.*, 2012; Danish Energy Agency, 2013	!
46	Marine mammals, underwater noise,	Detailed hearing sensitivity of different species of marine mammals to noise from operational wind farms: threshold	Scheidat *et al.*, 2012; Van Polanen Petel *et al.*, 2012;	!

ID	Ecological group, Physical effect, Interference category	Knowledge gap	Available information on this topic	
	operational phase	values, critical ratio, critical bandwidth. Also, masking effect of amplitude modulated noise such as that produced by operational wind turbines (seals and porpoises).	Brasseur *et al.,* 2012	
47	Marine mammals, change in habitat, construction / removal	Information is needed on the behavioural response of marine mammals to the removal of offshore windfarms, including range and duration.	n.a.	!
48	Marine mammals, change in habitat, operational phase	Loss of habitat for (surface) farm-avoiding marine mammal species in comparison with the total, including species specification and species densities. Note that to answer this knowledge gap, the knowledge gap on basic information on species densities (no. 39 & 40) should be addressed first.	Brasseur *et al.,* 2012; Tougaard *et al.,* 2012; Walls *et al.,* 2013; Danish Energy Agency, 2013	!
49	Marine mammals, change in habitat, operational phase	Change in density of species in (the vicinity of) the farm in comparison to the surrounding area, with focus on a potential use for refuge. Research has been conducted but more information is still needed.	Scheidat *et al.,* 2012; Van Polanen Petel *et al.,* 2012; Brasseur *et al.,* 2012	!
50	Marine mammals, change in habitat, operational phase	Density of prey species in (the vicinity of) the farm in comparison to the surrounding area. This knowledge gap needs to be connected to the relevant prey species.	Lindeboom *et al.,* 2011;	!
51	Marine mammals, change in habitat, operational phase	How dependent are harbour porpoises on habitats with and without OWFs in terms of food, protection, reproduction and population and how does this translate into the population development?	Boon, pers. com. 2014	!
52	Marine mammals, change in habitat, operational phase	Seals: Is there room for changing individual patterns such as haul-out places or foraging places? What are the consequences of breaking the habits of individual seals on the population?	Brasseur, pers. com. 2014	!
53	Marine mammals, barrier effect, operational phase	Percentage of surface area where the windfarms have an effect on marine mammals in comparison to the surface area of the dispersion area specifically in relation to migratory patterns where OWFs can form a barrier. Research has been conducted but more information is still needed on basic migratory behaviour and patterns before this knowledge gap can be filled.	Scheidat *et al.,* 2012; Van Polanen Petel *et al.,* 2012; Brasseur *et al.,* 2012	
Birds				
54	Birds, basic information	Changing baselines, such as effects of climate change on population sizes and distribution patterns, have not yet been addressed and neither have several other factors that might impact at-sea birds numbers, simultaneously with offshore windfarm development.	Leopold *et al.,* 2014	
55	Birds, basic information	Habitat use on the entire North Sea, including prey species such as fish and benthos.	Brenninkmeijer, pers. com. 2014	!
56	Birds, change in habitat, construction / removal	Effects of work on construction/removal of windfarms on the behaviour of birds, including range and duration (temporary/permanent) when timing is unfortunate and no mitigation measures are used.	Leopold & Camphuysen, 2009; Grove *et al.,* 2013; Canning *et al.,* 2013	
57	Birds, change in habitat, operational phase	Loss of habitat for (surface) farm-avoiding bird species in comparison with the total, including species specification and species densities. Needed to fill this gap: detailed information on species specific seasonal distribution, more information on	Leopold *et al.,* 2012; Leopold *et al.,* 2011; Verfuss, 2012; Danish Energy Agency, 2013; WWF, 2014; Camphuysen *et*	!

ID	Ecological group, Physical effect, Interference category	Knowledge gap	Available information on this topic	
		effects further offshore (Doggersbank), assessments of the cumulative impacts of OWFs that will be built in the future, including concentrated shipping in the remaining space.	*al.,* 2011; Walls *et al.,* 2013; Grove *et al.,* 2013; Percival, 2014	
58	Birds, change in habitat, operational phase	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 windfarm, for all relevant species.	Perrow *et al.,* 2011	
59	Birds, collision and barrier effect, operational phase	Percentage of collision of bird species in the farm, seasons: more research is needed at other windfarms. For the Dutch breeding birds, but also for foreign breeding populations, it is only possible to make predictions of population growth at the larger scale.	Poot et al. 2011A; Brabant et al. 2014; Danish Energy Agency, 2006 & 2013; WWF, 2014; Cook *et al.,* 2012; Poot *et al.,* 2011a; Grove *et al.,* 2013; Canning *et al.,* 2013; Furness *et al.,* 2013	!
60	Birds, collision and barrier effect, operational phase	Effects of windfarms as stepping stones in population development of cormorants in the North Sea. Specifics on population development, foraging behaviour and quantities and species of fish still have to be provided	Brabant *et al.,* 2014; Poot *et al.,* 2011A; Leopold *et al.,* 2010; Brabant *et al.,* 2014; Walls *et al.,* 2013; Canning *et al.,* 2013	
61	Birds, collision and barrier effect, operational phase	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 windfarm. More information on basic information on prey species, numbers and seasonal rhythms, as well as on more site-specific information is needed.	Perrow *et al.,* 2011; Grove *et al.,* 2013	
62	Birds, collision and barrier effect, operational phase	Seasonal variation and rhythms of bird populations in the OWF, numbers and densities. Some research has been conducted but more detailed information is needed.	Poot *et al.,* 2011A	
63	Birds, collision and barrier effect, operational phase	Population dynamics of colonies (floaters)	Poot *et al.,* 2011A	
64	Birds, collision and barrier effect, operational phase	Cumulative effects of windfarms on avoidance, migration patterns, numbers and distribution of migratory birds. percentage of surface area where the windfarms have an effect in comparison to the surface are of the dispersion area	Poot *et al.,* 2011A; WWF, 2014; Verfuss, 2012; Skov *et al.,* 2012; Furness *et al.,* 2013; Leopold pers. com. 2014	!
65	Birds, collision and barrier effect, operational phase	The influence of the OWF configuration and type of windmill on the habitat loss and collision risk of bird species. No knowledge of effect of lighted turbines on attraction of (migrating song-) birds	Poot, pers. com. 2014; Leopold pers. com. 2014.	!
66	Birds, collision and barrier effect, operational phase	For migrant birds, the main uncertainties may lay in insufficient knowledge of the relevant catchment areas and the threats facing them elsewhere.	Leopold *et al.,* 2014	!
67	Birds, collision and barrier effect, operational phase	There are no studies that have measured the effects of displacement of seabirds from windfarms, on seabird fitness.	Leopold *et al.,* 2014	

ID	Ecological group, Physical effect, Interference category	Knowledge gap	Available information on this topic	
68	Birds, collision and barrier effect, operational phase	Validation of 10% habitat loss leading to mortality.	Leopold *et al.*, 2014	!
Bats				
69	Bats, basic information	Numbers, densities, trends and species of bats potentially in and around OWFs.	Leopold, pers. com. 2014; Poot, pers. com. 2014.	!
70	Bats, basic information	Behavioural characteristics at sea of bats (e.g. flight and foraging heights, species-specific detection range, to what extent bats use echolocation during migration over sea, echolocation characteristics in relation to the number of fatalities.	Leopold *et al.*, 2014	
71	Bats, basic information	Migration routes of bats across the North Sea.	Leopold *et al.*, 2014	
72	Bats, basic information	A reliable estimate of the sizes of the catchment populations of bats. It is likely to assume that a large proportion of bats originates from countries such as Russia and Belarus. Population estimates from these countries are not available. In addition, there is insufficient knowledge available on the life history characteristics of the Parti-coloured Bat.	Leopold *et al.*, 2014	
73	Bats, collision and barrier effect, operational phase	Reliable estimate of the number of fatalities of bats at sea.	Leopold *et al.*, 2014. Lagerveld, pers. com 2015.	!
74	bats and birds collision and barrier effect, operational phase	Effect of light on turbines and platforms on the behaviour of birds and bats.	Brenninkmeijer, pers. com. 2014.	!
Preventive and mitigating measures				
75	All	Preventive and mitigating measures have been put in place to prevent or minimise effects from OWFs on the marine environment. The efficacy of these measures however is often a knowledge gap.	See information sources on specific relevant topics.	

2.7 SYNTHESIS: KNOWLEDGE GAPS IN ECOSYSTEM PERSPECTIVE

The marine ecosystem is complex and interactions between environment and species take place at all levels. Also, various effects of OWFs can occur at various levels. Figure 5 provides a basis interaction model which puts the inventoried existing knowledge gaps in ecosystem perspective. Each blue box in the model shows the topics at which currently knowledge gaps exists that need to be addressed. As can been seen from this model, all knowledge gaps have a specific position in the interaction model and thereby also in the ecosystem. These positions need to be taken into account in the prioritization of addressing knowledge gaps, as the entire chain (model) needs to be addressed in order to be able to make a solid impact assessment of OWFs.

The essence of knowledge gaps in ecosystem perspective for the purpose of prioritization is illustrated by the example below.

Example knowledge gaps in ecosystem perspective

Knowledge gap 9: 'Plankton, change in habitat, operational phase (disruption of zoo- and phytoplankton communities, through disruption of the water column current: effects of turbine pile on current, processes in 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'.

This knowledge gap is extensive and covers multiple blocks of the interaction model shown in Figure 5. The main component of this knowledge gap concerns the influence of the disruption on the water column current on plankton communities, shown in the block 'Disturbances' as 'habitat alteration'. To determine the actual effects of this habitat alteration on the plankton community, multiple other knowledge gaps also need to be addressed (e.g. basic information of plankton communities, relations between trophic levels). This illustrates that knowledge gaps should be prioritized from an ecosystem perspective and should not be addressed individually.

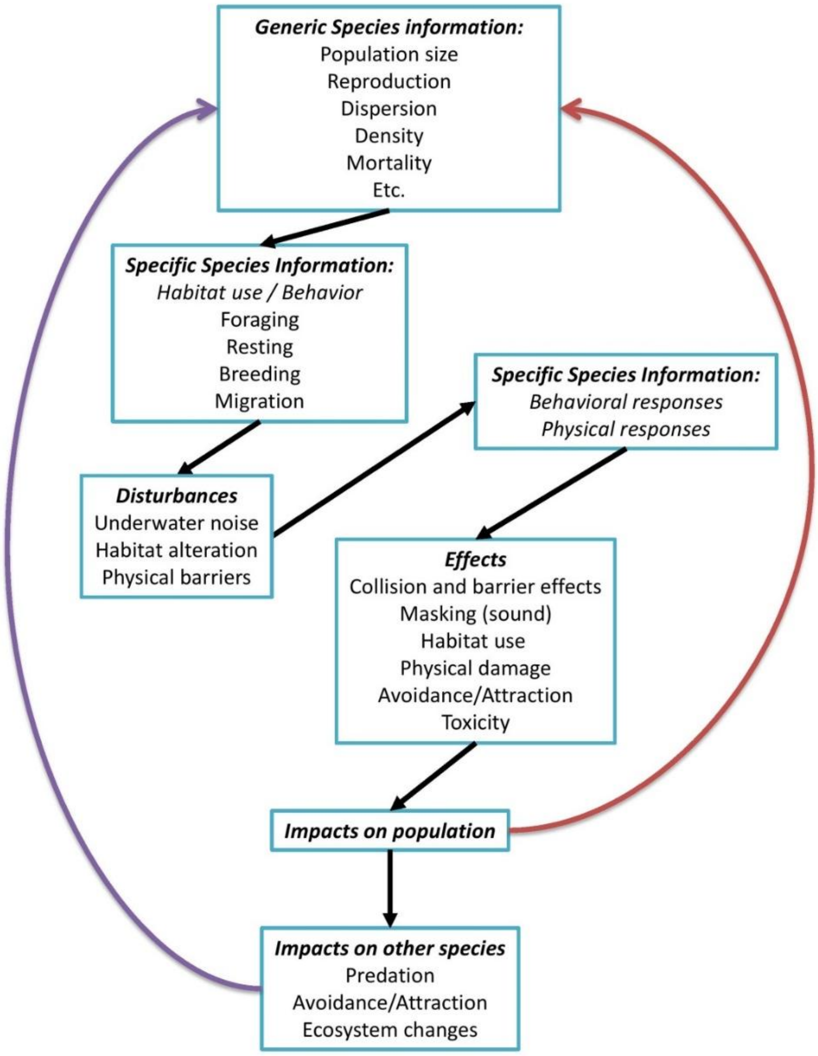


Figure 5: Knowledge gap topics placed into an ecosystem perspective, as an interaction model.

3 Policy Priority List 2015

Chapter 2 presented the Long List of the current knowledge gaps related to OWFs in Dutch marine waters. This list is extensive and cannot be addressed completely on short term. It is therefore necessary to prioritise the Long List by identifying the most urgent knowledge gaps that need to be addressed.

Two steps were separately taken: a prioritization through criteria set up by the Dutch government by policy makers (RWS Zee & Delta) and a prioritization by means of a workshop with Dutch scientific experts on the relevant topics. Both prioritization steps are visualised in Figure 6.

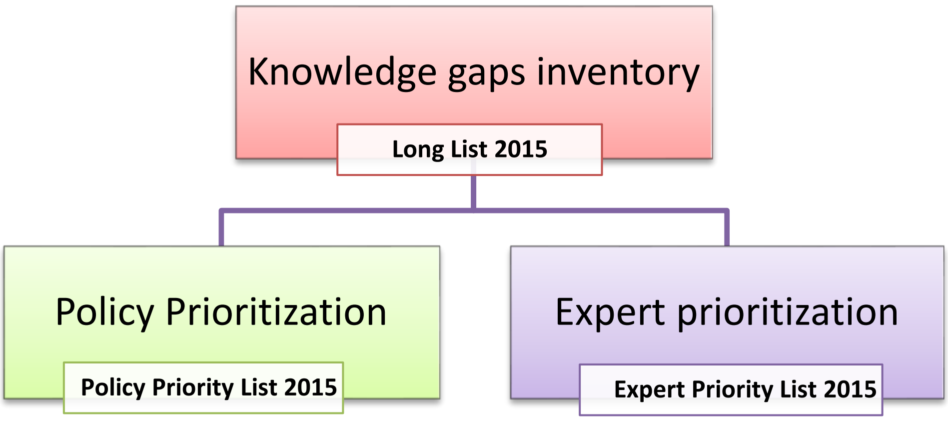


Figure 6: Overview of prioritization steps by policy and scientific experts.

This chapter describes the prioritization of knowledge gaps by policy makers, where chapter 4 will describe the prioritization by scientific experts. In chapter 5, a syntheses of similarities and differences between both prioritizations will be given.

3.1 METHOD

Six prioritizing criteria were developed by Rijkswaterstaat Zee & Delta to prioritize the knowledge gaps assembled in the Long List 2015. The criteria for the prioritization of the knowledge gaps are:

1. ***Studies must contribute to the validation of assumptions about addressed knowledge gaps in the Framework Ecology and Cumulation (KEC).***
   In the KEC for offshore wind, important knowledge gaps - mainly in the context of cumulation of effects - are identified which need to be addressed in order to be able to make a solid cumulative impact assessment of offshore wind.

2. ***Studies must contribute to the validation of assumptions about addressed knowledge gaps in EIAs and AAs***.
   In EIAs / AAs for offshore wind, several knowledge gaps are acknowledged. In case information or knowledge is lacking, usually assumptions are made on which the impact assessment is based. This gives an uncertainty in the assessment of effects, which can be narrowed down by addressing specific knowledge gaps.

3. ***Studies must address knowledge gaps relevant for adaptive management.***
   The construction of ten windfarms with an installed capacity of 3450 MW is planned for the period to 2023. The tight time-schedule makes it necessary to address the most urgent and important knowledge gaps in time to have the possibility to use this knowledge in the process of construction of these windfarms. The key here is to identify the knowledge gaps that are essential to address in the short term (results within one to two years).

4. ***Studies must address the efficacy of mitigating measures.***
   In current AAs, the precautionary principle is leading. If knowledge is insufficient or possible effects cannot be excluded, mitigation and preventive measures can be set to eliminate or minimize effects. Currently mitigation measures are set in place during the permitting procedures before the building phase of an OWF. Examples are the use of slow-starts and ADDs during pile driving or the use of certain colors of light during the night hours. However, these obligations may be costly to operators and the efficacy of these measures is not always proven. It is therefore important to gain insight in the efficacy of these mitigation measures.

5. ***Studies preferentially create opportunities to fill in knowledge gaps by international cooperation and knowledge sharing.***
   The marine ecosystem of the North Sea is not limited by national borders and windfarms are constructed in neighbouring countries as well. This means that effects by windfarms need to be assessed in an international perspective. It is obvious that internationally a large number of studies are conducted to assess these effects, partially covering identical information gaps. It is preferred to address these knowledge gaps by international cooperation and to share data and knowledge gained in the various monitoring studies on effects of windfarms.

6. ***Studies preferentially provide spinoff for other relevant policies (e.g. Harbour Porpoise Protection Plan, Marine Strategy Framework Directive, N2000).***
   There are several other policies in place that can benefit from addressing knowledge gaps for offshore wind, e.g. by addressing more generic knowledge gaps on population size of species. It is preferred to address knowledge gaps that are of value for other policies than solely for offshore wind as well.

Note here that this prioritisation is more general than followed and described in the Masterplan 1.0. Based on that structural prioritisation of knowledge gaps, the monitoring and research programme has been executed in the last years. It is highly unlikely that a completely different focus should be given to the current research due to new insights as a result of addressed knowledge gaps. The proposed criteria therefore aim at the refinement of the research that needs to be conducted. Where in the last years much research has been conducted to develop valuable thorough knowledge on the marine ecosystem, the focus for the coming years should shift towards pragmatic problem-solving research and research on no-regret measures. This is reflected in the described criteria for prioritization.

The prioritisation presented here does not imply that certain research should be excluded. It simply enables a focus on the most important issues at this very moment, from the perspective of policy makers. When results show that some effects are stronger or milder than previously thought, the prioritisation needs to be reconsidered (adaptive management). The highest priority should be given to those studies that are considered as “need to know”, as they are essential for bringing our knowledge of ecological impacts of OWFs an important step further.

All the knowledge gaps in the Long List 2015 were scored using the six criteria presented above. The highest scoring knowledge gaps have been identified to have highest priority to address.

3.2 RESULTS PRIORITIZATION: POLICY PRIORITY LIST 2015

Using the criteria presented in the previous paragraph, no knowledge gaps from the Long List 2015 fulfilled all of the criteria.

Six knowledge gaps fulfilled four of the criteria (40, 55 & 57, 70, 65, 44) and are considered to have highest prirority to address. The main gaps to be addressed for **marime mammals** are the percentage of surface area where effects on marine mammals occur in comparision to the dispersion area and the better threshold quantification in combination with more insight in actual behavioural response in the field during construction for both seals and marine mammals. The main gaps to be addressed for **birds** are on the loss of habitat for (surface) farm avoiding bird species in relation with the total area, including species specification and abundances and insight in the effects of OWF configuration and turbine type on this habitat loss. The main gap to be addressed for **bats** is the behavioural characteristics of bats at sea.

It is noted that the identified gaps which have highest priority are extensive in scope and can should be addressed by a combination of multiple studies that can be executed on mid- and long term.

Seventeen knowledge gaps fulfilled three of the criteria (26, 39, 46, 53, 59, 64, 69, 72, 73, 71, 67, 68, 10, 36, 43, 5, 4). Fifteen knowledge gaps fulfilled two of the criteria (27, 41, 45, 48, 50, 58, 60, 61, 62, 6, 7, 74, 3, 51, 8) and seventeen knowledge gaps fulfilled one of the criteria (11, 27, 28, 29, 30, 34, 35, 37, 38, 47, 49, 63, 72, 54, 66, 25, 42). The full prioritization can be found in Table 3.

Table 3: Policy Prioritization List 2015. Dark green : the criterium is fully met, light green: the criterium is mostly met, orange: the criterium is partly met, red: the criterium has not been met.

		Criterium						
Corresponding Longlist numbers	Knowledge gap	1	2	3	4	5	6	Number of criteria met
40	Percentage of surface area where the wind farms have an effect on marine mammals in comparison to the surface are of the dispersion area.							4
55/57	Loss of habitat for (surface) farm-avoiding bird species in comparison with the total, including species specification and species densities. Needed to fill this gap: detailed information on species specific seasonal distribution, more information on effects further offshore (Doggersbank), assessments of the cumulative impacts of OWFs that will be build in the future, including concentrated shipping in the remaining space, developing a							4

	science-based vulnerability index of birds will enable better policy decissions.							
70	Behavioural characteristics at sea of bats (e.g. flight and foraging heights, species-specific detection range, to what extent bats use echolocation during migration over sea, echolocation characteristics in relation to the number of fatalities.							4
65	The influence of the OWF configuration and type of windmill on the habitat loss of bird species.							4
44	Threshold values of marine mammals for pile driving sounds : TTS growth curves to determine safety criteria (to prevent PTS). Dose-behavioural-response relationship for pile-driving sounds withmore subjects, as behavioural responses to sound can vary greatly between individuals. Duration of avoidance/ recovery time after disturbance. Masking effect on communication and (in porpoises) echolocation. Research has been conducted but more information is still needed (also for harbour seals).							4
26	Effects of pile driving noise on physical condition and behaviour of specific native fish species, including threshold values							3
39	Marine mammals. Density of species, population size & distribution (sub) population seasonal rhythms, distribution area, distribution patterns per time unit expressed in percentages of the population. Population change, ongoing monitoring is needed.							3
46	Detailed sensitivity of different species of marine mammals to frequency levels: threshold values, noise effects, critical ratio, critical bandwidth. radius of damage/mortality to the source, inlfuence of disturbance on feeding and energy use. Also, masking effect of amplitude modulated noise such as that produced by operational wind turbines (seals and porpoises).							3
53	Percentage of surface area where the wind farms have an effect on marine mammals in comparison to the surface area of the dispersion area in relation to migratory patterns.							3
59	Percentage of collision of bird species in the farm, seasons: more research is needed at other wind farms For the Dutch breeding birds, but also for foreign breeding populations, it is only possible to make predictions of population growth at the larger scale.							3
64	Cumulative effects of windfarms on avoidance, migration patterns, numbers and distribution of migratory birds. Percentage of surface area where OWFs have an effect in comparison to the surface are of the dispersion area .							3
69	Numbers, densities, trends and species of bats potentially in and around OWFs.							3
72	A reliable estimate of the sizes of the catchment populations of bats. It is likely to assume that a large proportion of bats originates from countries such as Russia and Belarus. Population estimates from these countries are not available. In addition, there is insufficient knowledge available on the life history characteristics of the Parti-coloured Bat.							3
73	Reliable estimate of the number of fatalities of bats at sea.							3
71	Migration routes of bats across the North Sea							3
67	There are no studies that have measured the effects of displacement of seabirds from wind farms, on seabird fitness.							3
68	Validation of 10% habitat loss leading to mortality.							3
16	Electric cable within the wind-farm and to shore – increase of temperature in sediments during operation (effect on benthos)							3
10	Numbers, density, distribution and composition of larval benthic community, as well as information on reproduction, age classes, local and large-scale effects and insights in the cause of changes.							3
36	Effect of avoidance on fish species which are bound to certain areas on the reproduction of these species.							3
43	Effects of noise on foraging efficiency in harbour porpoises. This will determine if noise							3

	affects the energy budget of marine mammals, and thus their fitness and reproduction (both are PCoD input parameters)	
5	Source Level modelling of seismic airgun arrays, especially directivity of importance for far range propagation. Experimental validation required.	3
5	Validation of Zampolli hybrid model.	3
5	Validation of AQUARIUS model (far range propagation).	3
4	Effects of pile-driving alternatives on species and habitats	3
27	Effects of noise of operational wind farms on the physical condition and behaviour of specific native fish species, including threshold values (sensitivity to frequency/levels)	2
41	Validation to determine if hearing data based on one animal, is representative of its species, sex or age group. Hearing sensitivity parameters such as basic audiogram, critical ratio, directionality of hearing, TTS, and PTS for a larger number of animals. Research has been conducted on few animals but information on more subjects is still needed. More information exists on harbour porpoises than for harbour seals.	2
45	Exact threshold values for pile driving effects on marine mammals, TTS growth curcves exact effects. Masking effect on communication.	2
48	Loss of habitat for (surface) farm-avoiding marine mammal species in comparison with the total, including species specification and species densities	2
50	Density of prey species in (the vicinity of) the farm in comparison to the surrounding area	2
58	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.	2
60	Effects of windfarms as stepping stones in population development of cormorants in the North Sea. Specifics on population development, foraging behaviour and quantities and species of fish still have to be provided	2
61	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, in combination with collision and barrier effects.	2
62	Seasonal variation and rythms of bird populations in the OWF	2
6	Cyclic variation such as weather, tides and day-night cycles, in combination with underwater noise effects. Difference between habitats within and outside of OWFs.	2
7	Other impacts, e.g. contaminants on reproductive success, that can be detrimental even though not as visible. Also: noise from different sources, shipping routes, prey competition, predator relationships.	2
74	Effect of light on turbines and platforms on the behaviour of birds and bats.	2
3	Maps of North Sea species / ecosystems / counting events, etc.	2
51	How dependent are harbour porpoises on habitats with and without OWFs in terms of food, protection, reproduction and population and how does this translate into the population development?	2
8	Noise effects on invertebrates, such as cephalopoda, during the construction, operation and removal phases of an OWF.	2
11	Information on the change in organism composition as well as chemistry on site and the time in which it recovers. Already a lot of information is available on this topic, for this reason it could be seen as less relevant for short term research.	1
27	Effects of noise of operational wind farms on the physical condition and behaviour of specific native fish species, including threshold values (radius of damage/disruption to	1

	source)	
28	Effects of work on construction/removal of wind farms on the behaviour of fish species, including range and duration (temporary/permanent)	1
29	Loss of habitat for (surface) rock avoiding fish species in comparison to the total, including species specification and species densities, numbers.	1
34	Density of prey species in (the vicinity of) the farm in comparison to the surrounding area	1
35	Effects of toxic substances (Al) released from anodes on turbine pilings on fish. Bioaccumulation.	1
37	Effects of electromagnetic fields on the behaviour of specific native fish species, including threshold values.	1
38	Percentage of surface area where the wind farms have an effect on fish species in comparison to the surface area of the dispersion area, migration areas	1
47	Information is needed on the response of marine mammals to the removal of offshore windfarms.	1
49	Change in density of species in (the vicinity of) the farm in comparison to the surrounding area, with focus on a potential use for refuge.	1
63	Population dynamics of colonies (floaters)	1
72	A reliable estimate of the sizes of the catchment populations of bats. It is likely to assume that a large proportion of bats originates from countries such as Russia and Belarus. Population estimates from these countries are not available. In addition, there is insufficient kwowledge available on the life history characteristics of the Parti-coloured Bat.	1
54	Changing baselines, such as effects of climate change on population sizes and distribution patterns, have not yet been addressed and neither have several other factors that might impact at-sea birds numbers, simultaneously with offshore wind farm development.	1
66	For migrant birds, the main uncertainties may lay in insufficient knowledge of the relevant catchment areas and the threats facing them elsewhere.	1
25	Insights into which areas are anthropogenically disturbed and which are not, as well as spawning areas.	1
42	Knowledge on underlying parameters impacting distribution on a larger scale, e.g. prey availability, climate change. How to separate the effects from wind farm construction / operation from the larger scale changes of the ecosystem	1
9	Disruption of zoo-and phytoplankton communities, through 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.	0
12	Threshold values of effects by and sensitivity to toxic substances released from the bottom during construction/removal of turbines and installation/removal of cables, as well as bioaccumulation.	0
13	Changes in seabed topography and sediment morphology, mutual relations; what determines the appearance of organisms and what is the interaction with topography, physics and chemistry	0
14	How does the recruitment of benthos proceed without and with hard substrate	0
15	Threshold values, effects and sensitivity of toxic substances (Al) which are released from anodes on turbine pilings. Bioaccumulation.	0
17	Distribution of fish larvae in the windfarm areas has been studied, it is however not yet expressed in percentages of the population.	0
18	Distribution of fish larvae in the windfarm areas has been studied, percentage of surface	0

	area where the windfarms have an effect on fish larvae in comparison to the surface are of the dispersion area has not all vital basic information.							
19	Effects of pile driving noise on mortality of fish larvae has been studied on a limited amount of species. Knowledge gaps remain on the sensitivity to frequency levels and threshold values for mortality and other physiological effects of these and other species.							0
20	Effects of pile driving noise on physical condition of fish larvae, including threshold values during pile driving has been researched on a limited amount of species. Knowledge gaps remain on the radius of damage/mortality to the source and threshold values. However, as research indicated no significant mortality in relevant species, this knowledge gap is seen as having low priority. However, Effects of pile driving on fish eggs, embryonal development and hatching rate can be seen as a knowledge gap. There are indications that loud sounds affect these in invertebrate eggs and 'shockwaves' cause damage to fish eggs							0
21	Effects of noises of operational windfarms on physical condition of fish larvae, including sensitivity to frequency levels and threshold values during the operational phase.							0
22	Effects of noises of operational windfarms on physical condition of fish larvae, including radius of damage/mortality to source and threshold values and radius of damage/mortality to source.							0
23	Effects on fish larvae of toxic substances released from the bottom during construction/removal of turbines and installation/removal of cables, including sensitivity and threshold values.							0
24	Effects on fish larvae of toxic substances (Al) released from anodes on turbine pilings, including sensitivity and threshold values.							0
31	Habitat potency (surface) of fish species with an affinity for rocks in comparison with the total, densities, numbers and seasonal rhythms. Research has been conducted but a few knowledge gaps remain.							0
32	Changes in density of fish species in (the vicinity of) the farm in comparison to the surrounding area, numbers, seasonal rhythms due to less disruption.							0
33	Changes in density of fish species in (the vicinity of) the farm in comparison to the surrounding area, numbers, seasonal rhythms due to change in bottom species and more refuge possibilities. Research has been conducted but a few knowledge gaps remain.							0
56	Effects of work on construction/removal of windfarms on the behaviour of birds, including range and duration (temporary/permanent) when timing is unfortunate and no mitigation measures are used.							0
1	Habitat characteristics before the building of OWFs.							0
2	Cumulative effects of OWFs.							0
52	Seals: Is there room for changing individual patterns such as haul-out places or foraging places? What are the consequences of breaking the habits of individual seals on the population?							0

4 Expert Priority List 2015

Chapter 2 presented the Long List of the current knowledge gaps related to OWFs in Dutch marine waters and chapter 3 gives the Policy Priority List 2015 based on the six criteria set by RWS Z&D. This chapter describes the prioritization of knowledge gaps (based on the Long List 2015) by scientific experts on the different subjects related to offshore wind (see for overview also Figure 6).

4.1 METHOD: WORKSHOP FOR PRIORITIZING KNOWLEDGE GAPS

The knowledge gaps from the Long List were prioritised during a workshop organised by Rijkswaterstaat Zee & Delta. Approximately 25 experts on various relevant topics from the Netherlands attended the workshop.

During the workshop, knowledge gaps and possible research topics were discussed. The six criteria used for prioritization from policy perspective (see paragraph 3.1) were first presented at the start of the workshop, to give direction and focus to the prioritization. During the workshop, the prioritization was mainly driven by theoretical- and practical expert knowledge and current 'hot-topics' in the scientific field. The presented criteria were hereby not strictly followed, though kept in mind during discussions.

It was decided to discuss the prioritization in two separate groups: birds and bats ('above water') and plankton, benthos, fish and marine mammals ('under water'), as the knowledge gaps for both groups are quite distinctive from each other. It was noted that the ecosystem perspective should not be lost by splitting the discussion in separate groups, as effects can accumulate through the food chain on all levels. Therefore a plenary feedback during the workshop was scheduled.

First a reflection on the discussions in both groups is given to as context and / or as a remark to the Priority List 2015. In the paragraph after that, the Priority List 2015 based on these discussions will be presented.

4.1.1 PLANKTON, BENTHOS, FISH & MARINE MAMMALS

Assessment framework
In the study by TNO & HWE (Heinis & de Jong, 2014), the framework as shown in Figure 7 for the impact assessment was followed. During the workshop, this framework was followed as well to prioritize the most urgent knowledge gaps.

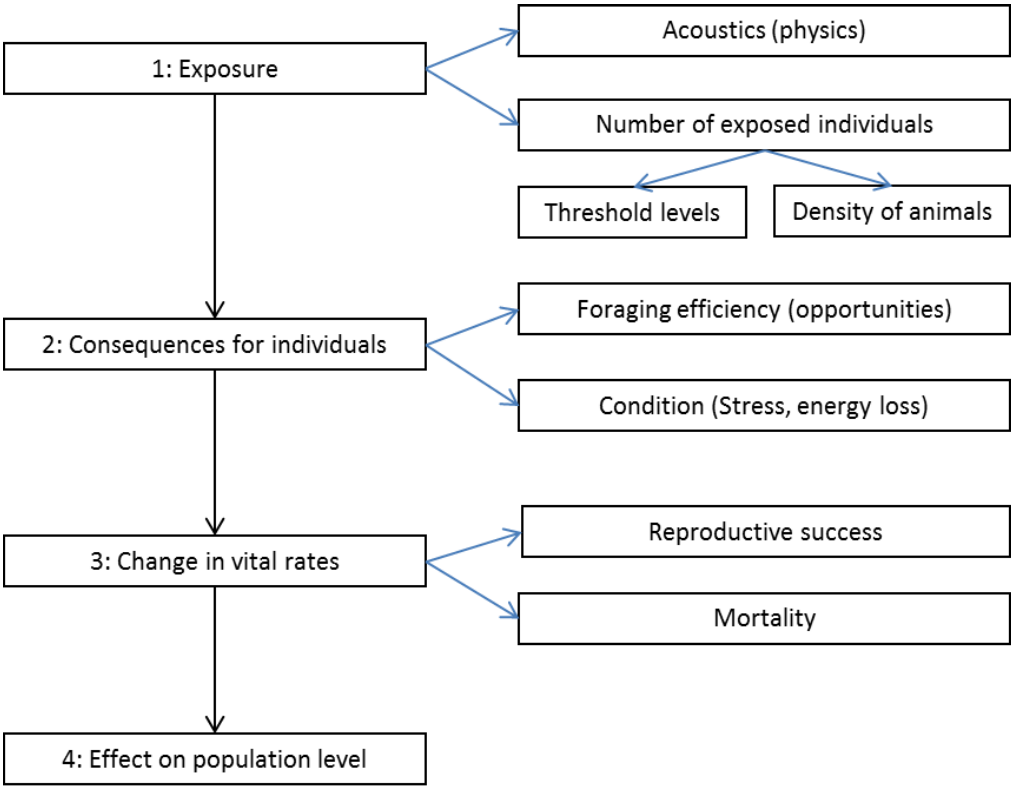


Figure 7 Framework for impact assessment

Workshop discussion

Trends

- The relevance of trend watching in ongoing research in an international context was emphasized. It is expected that experts are aware of the international knowledge level and should be able to detect and signal important trends in research directions.

Effects of underwater noise

- It is expected by the group of experts that the largest effects on the marine ecosystem – mainly on marine mammals and fish - are endured during the construction phase of the windfarms as a result of the production of underwater noise due to pile driving. Nevertheless, effects during the operational phase must be taken into account additional to the effects in the construction phase due to the anticipated life time of a wind farm of at least 35 years.
- Following from this, negative effects on marine mammals are expected to occur mainly as a result of avoidance caused by high noise levels, rather than physical damage to species since the use of acoustic deterrent devices (ADDs) will prevent the latter. Effects on fish are insufficiently studied and the efficacy of ADDs on the prevention of physical damage in fish are largely unknown. Effects of underwater noise in the construction phase on phytoplankton and benthos are at this stage considered of less relevance.
- Based on the recent studies on the effects of underwater noise on fish larvae (Bolle *et al.*, 2011; Bolle *et al.*, 2012; Bolle *et al.*, 2013), it showed that the anticipated mortality on fish larvae has been well below the worst case effects that were taken into consideration when no data was present, and that mortality during pile driving only occurs at short range (< 100 m). Therefore the experts believe the focus should not be on mortality of fish larvae but on (sub)adults. In general it is noted that the change of habitat by the presence of operational windfarms per definition has

effects on the fish population, as the population changes due to displacement and/or altered productivity of prey items. Whether these effects are positive or negative on population level and to what extent is unknown, though due to the local scale of the OWFs in relation to the North Sea effects are expected to be limited.

Marine mammals

- Predominant mammal species in Dutch waters are the harbour porpoise, harbour seal and grey seal. Of these species, the harbour porpoise is considered the most sensitive to underwater noise (based on hearing sensitivity and avoidance studies carried out by Kastelein *et al*. (2012a,b; 2013a,b,c,d,e; 214a,b; 2015a,b) and Diederichs et al. 2014). However, effects on seals are considered equally important to assess. In addition to this, the large dataset of tagged seals that has been collected in recent years offers an important opportunity to address existing knowledge gaps.
- In a recent study by TNO and HWE, the cumulative effects of windfarms on the harbour porpoise and seals are assessed using the Interim PCoD model developed by SMRU. It was noted that this study is an important step forward, nevertheless the followed model and methodology has clear shortcomings based on several knowledge gaps and averaging individual behaviours. Therefore, there is a clear need for a study 'beyond Interim PCoD', which aims at narrowing down the uncertainties where possible and includes a second international expert elicitation process which at this moment forms the basis for the Interim PCoD model (Harwood et al. 2013 ,New *et al*., 2014, http://www.smru.co.uk//pcod).
- The effects on marine mammal populations should be assessed in the North Sea demographic (harbour porpoise) population context, as marine mammal species are mobile and their populations are not bound by national borders.

Modeling

- The use of models to assess and predict effects is valuable, under the condition that the input parameters are solid. Studies should therefore focus on validation of the input parameters, guided by an assessment of the dominant uncertainties in the model predictions, which increases reliability of the outcome of the model studies. It is advised to compare the suitability of different models for the use in impact assessments.

Registration of anthropogenic activities

- An important notice was made in relation to the assessment solely related to offshore windfarms. There is in general limited knowledge on the total range of anthropogenic pressures on the North Sea, which makes it difficult to assess the effects of a specific pressure such as noise related to windfarms. Although most information on anthropogenic pressure is likely registered somewhere, it is advised that this information is collected and centrally stored in a database. It is noted that in context of the MSFD an international impulse register will be implemented in the near future, in which all activities producing impulse noise will be registered. There are also other EU-initiatives (e.g. EMODNET, SEADATANET) that register human activities and can provide valuable information.

Points of attention

During the workshop and process of prioritizing the knowledge gaps, several points of attention were brought up which deserve specific attention and should not be forgotten in future research:

- Electro Magnetic Fields (EMFs) as a result of buried cables to or from windfarms might create a barrier-effect for sensitive species such as rays and sharks and migratory fish that use the earth magnetic field for orientation such as eel and salmon. Effects on the barrier effect but also on avoidance and physical damage are largely unknown, but an EU project has been initiated to study these effects (MaRVEN, results expected in summer 2015).
- Data on all anthropogenic pressures on the North Sea should be collected and combined in a database, so better insights in effects of specific pressures can be gained. At this stage, it is difficult to link tagging data to anthropogenic sources, as it is unknown which other sources might be present in the area.

4.1.2 BIRDS & BATS

The largest effects for both birds and bats are expected in the operational phase of the windfarms. Although disturbances might be present during construction, the range of influence is relatively limited and effects are temporary. The focus for birds and bats should therefore be on the operational phase.

It was noted that the main effects on birds are expected by (1) collisions and (2) loss/change of habitat in the operational phase. The direct effects of collision are considered mainly relevant for migrating species and for species that spend a large proportion of their time flying and are not inclined to avoid windfarms. The indirect effects of habitat loss/change are expected to be mainly relevant for species that reside at sea and make use of the area for e.g. foraging and resting.

Priority in studies with respect to the importance of possible collision victims should be given to certain specific marine or coastal bird species, such as little gull, great black-backed gull, herring gull, lesser black-backed gull, great skua and sandwich tern, mainly because these species do not actively avoid windfarms and have relatively small populations. Moreover, vulnerable species that are expected to regularly pass through wind farms during migration are the Eurasian curlew, red knot, brent goose and bewick's swan.

Another priority to study are the consequences of possible habitat loss as perceived by seabirds that tend to avoid (operational) windfarms (mainly guillemots, razorbills, gannets, red-throated and black-throated divers). Although for the time being (at least until 2023) this does not appear to significantly contribute to cumulative effects, in fact little is known and loss of habitat can be more devastating for carrying capacity and ecosystem quality for seabirds than any other effect. To assess effects of future wind developments after 2023, knowledge on the behavioural responses of windfarm avoiding seabird species in the vicinities of existing and future windfarms should be acquired, to be able to more accurately describe these responses, assess their potential impact on feeding ecology and vital rates, enhanced chances of mortality and/or reproductive success. Crucial here is also the question whether these seabirds get accustomed with to the presence of operational windfarms in their marine habitats and/or whether these windfarms (due to locally less impacts of fisheries, otherwise enriched food resources due to the presence of hard substrates or even merely less human disturbances) may eventually turn out to be actually better as feeding grounds. It is emphasized that it necessary to conduct studies on this topic in an international setting, because it mainly concerns species that breed in or around UK and that outside the breeding season spread out over the entire North Sea area.

A general thought is that research should focus on the effects on population level rather than on effects on individuals.

In contrast to birds, general knowledge on bats is limited and knowledge on the effects of windfarms on bats is extremely limited. Recent measurements (detectors) suggest the presence of bats in offshore windfarms (Lagerveld et al. 2014). Little is known on the population size of the bat species involved and the migratory behaviour of bats between Europe and the UK, which makes it difficult to assess effects on population level. Although it is expected that the bats recorded in the offshore windfarms are migrating individuals, thorough knowledge on migration behaviour is lacking. Effects on bats are expected to occur mainly by collisions and / or the physical damage that can occur due to low pressure or vacuum directly behind the blades (barotrauma).

The effects of loss/change of habitat in the operational phase of the windfarms are considered of lesser relevance for bats, as these typically do not seem to forage or rest at sea.

The priority bat species for studies are the Nathusius's pipistrelle, common noctule and the parti-coloured bat, as these species are identified to be migratory overseas.

It was noted that there are multiple methodologies available to address the knowledge gaps by research on birds and bats. For efficiency purposes, it is advised to combine research for birds and bats in a joint programme where possible.

It is also advised to give special attention to the facilitation of international cooperation and knowledge sharing, as much research on comparable species and effects is done internationally. An international workshop with an extensive knowledge-sharing programme is seen as an important step to discuss and address knowledge gaps and to efficiently conduct the necessary research in future.

4.2 RESULTS OF PRIORITIZATION: EXPERT PRIORITY LIST 2015

In the workshop, the knowledge gaps that needed to be addressed with high priority were identified and these will constitute the Expert Priority List 2015 as presented in the sections below.

4.2.1 UNDERWATER NOISE (PHYSICS)

4.2.1.1 *PROPAGATION OF UNDERWATER SOUND PRODUCED BY PILE DRIVING – MODEL VALIDATION*

This knowledge gap addresses nr. 5 of the Long List as presented in Table 2 in Chapter 2:

> Piling sound source and propagation model (AQUARIUS) validation. Incomplete modelling of seismic airguns
> Uncertain modelling of population consequences. Updates Interim PCoD expert elicitation.

The propagation of sound produced by pile driving is modelled with the Aquarius models by TNO. The Aquarius 1.0 model, based on measurement data from PAWP, has been used for impact assessment studies (including the studies reported in Heinis & de Jong, 2014). In the VUM studies, TNO completed the Aquarius 2.0 model, which includes a detailed source model of the pile. This model was benchmarked against other models for a simple test case in COMPILE – An International Benchmark Study on the Prediction of Offshore Pile Driving Noise (Lippert *et al.*, 2014), organised by TNO and TUHH. Both Aquarius models need further experimental validation. Measurements have been carried out for model validation at short range (up to 5 km), but measurements at larger distances were up till now lacking. During the construction of Eneco Luchterduinen (2014), measurements have been carried out at larger distances with the objective to collect data for model validation. Also during the construction of the Gemini windfarms in 2015, obligations are set to measure the underwater noise at close range and large distances for the same objective of model validation. The validation of the model itself however has not been planned yet.

Based on the gathered information, workshop and expert input, several monitoring and research questions have been formulated.

Monitoring and research questions

- How accurate are sound levels caused by pile driving modelled by the Aquarius models at large distances from the source?

Model validation is currently already covered by existing projects. Therefore no additional short-list studies are formulated in this Masterplan.

4.2.1.2 *STANDARDIZATION OF UNDERWATER ACOUSTIC MEASUREMENTS*

This knowledge gap addresses nr. 5 of the Long List as presented in Table 2 in Chapter 2:

> Piling sound source and propagation model (AQUARIUS) validation. Incomplete modelling of seismic airguns Uncertain modelling of population consequences. Updates Interim PCoD expert elicitation.

Underwater sound measurements are conducted to collect data for e.g. impact assessments or model validation. Underwater sound measurements can be done in various ways. For unambiguous use and interpretation of measured data, it is necessary to implement and follow an internationally standardised methodology for underwater sound measurements. These do not yet exist. In 2011, the International Organization for Standardization (ISO) installed a Subcommittee on underwater acoustics in its technical committee on acoustics (TC43/SC3) under which the first international standards for terminology and measurement methods for underwater sound are being developed. In the perspective of the development of offshore wind, it is necessary to remain actively involved in the process of developing internationally accepted underwater measurement- and modelling standards.

Monitoring and research questions

- What measurement standards have to be followed when conducting underwater sound measurements within the North Sea and Baltic Sea regions?
- What modelling standards have to be followed when modelling sound propagation caused by pile driving concerning the models applied within the North Sea and Baltic Sea regions?

Initiatives for standardization of underwater acoustic measurements are already ongoing. Therefore no additional short-list studies are formulated in this Masterplan.

4.2.2 FISH

4.2.2.1 *EFFECT OF PILE DRIVING NOISE ON PHYSICAL CONDITION AND BEHAVIOUR*

This knowledge gap addresses nr. 26 of the Long List as presented in Table 2 in Chapter 2:

> Effects of pile driving noise on physical condition and behaviour of specific native fish species, including sensitivity and threshold values and radius of damage/disruption to source. Some research has been conducted but knowledge gaps still remain.

There is limited knowledge available on the effects of pile driving on the physical condition and behaviour of adult native fish species. Some studies have been carried out for a limited number of species to determine threshold levels in relation to disturbance, however field data on the actual behavioural response of fish during construction of a windfarm are lacking. Also, thorough knowledge on the occurrence of physical damage as a result of pile driving in the field for native fish species is lacking.

Monitoring and research questions

Underwater noise:

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

Priority list studies to address the knowledge gaps are described in Appendix 4.

4.2.3 MARINE MAMMALS

The marine mammals of prime interest in the environmental impact assessment for offshore windfarms in Dutch waters are the harbour porpoise and the harbour and grey seal. Where relevant a distinction in research for harbour porpoises or seals is made.

4.2.3.1 *POPULATION DYNAMIC PARAMETERS AND HABITAT USE*

This knowledge gap addresses nrs. 3, 39, 40 & 53 of the Long List as presented in Table 2 in Chapter 2:

> Maps of North Sea species / ecosystems / counting events, etc.
>
> Density of species, population size & distribution (sub) population seasonal rhythms, distribution area, distribution patterns per time unit expressed in percentages of the population. Population change, ongoing monitoring is needed.
>
> Percentage of surface area where the windfarms have an effect on marine mammals in comparison to the dispersion area, in combination with the life-history of the species (importance of habitats for forage, reproduction, etc.). The previous knowledge gap should be filled prior to filling this one.
>
> Percentage of surface area where the windfarms have an effect
> on marine mammals in comparison to the surface area of the dispersion area in relation to migratory patterns. Research has been conducted but more information is still needed on basic migratory behaviour and patterns before this knowledge gap can be filled.

Harbour porpoises

The population size of harbour porpoises is estimated based on observations during aerial surveys. The SCANS II survey (2005) and SCANS III survey (2015) provide valuable information on the distribution and abundance of harbour porpoises in the North Sea and adjacent waters (Hammond *et al*., 2013). Also, the aerial surveys that were conducted in various seasons in 2010 and subsequent years on the abundance and distribution of harbour porpoises on the Dutch Continental Shelf (Geelhoed *et al*., 2011; 2013a&b; 2014; Scheidat *et al*., 2012) have provided highly valuable data, used in recent EIAs & AAs for offshore wind and Ecology and Cumulation Framework (KEC) studies.

The SCAN-surveys that have been conducted are valuable but outdated and only provide a snapshot in time and space of the moment of survey. There is insufficient knowledge on the current distribution and migration behaviour of harbour porpoises in the different seasons.

Basic data are required on the dynamics and habitat use of the porpoise populations in space and time in the (southern) North Sea. How porpoises migrate through the southern North Sea is practically unknown, for example whether there are different populations and (sub)migrations, etc. Tagging individuals could be a valuable method to study this.

Year round data on the presence (and communication) of porpoises at the sites of planned windfarms are required for the T0 of the windfarms to be constructed. Observations from ships, fixed platforms in the farms (combined with bird observations) and the use of buoys with hydrophones and CPODs at the site of the planned windfarms and larger areas around them are promising methods. Also surveys by aircraft would be an appropriate method for this.

Seals

A large number of seals have been tagged in Dutch waters in the past years to collect data on the migration and habitat use. These studies have provided valuable insights in the migration and foraging behaviour of seals and gave indications that seals tend to avoid areas in which pile driving occurs.

The tagging of seals has resulted in an extensive and valuable dataset with the potential to address multiple knowledge gaps that need to be addressed for a better impact assessment for offshore wind. However, the valuable dataset has not been analysed to its full extent e.g. to quantify the effects of noise on the migration and foraging behaviour of seals. It should be noted the number of tagged seals will be present in the area of OWFs during pile driving will in practive be limited, which makes it challenging to quantify these effects with sufficient statistical power.

Monitoring and research questions

Basic information:

- What are the spatial distribution and seasonal patterns in the abundance of harbour porpoises, harbour and grey seals in the North Sea, and what is the variation in migration routes? At this point in time more information is available on the distribution of seals than on the distribution of harbour porpoises.
- Are there any sub-populations with behaviour different from the others?
- Are there specific nursery areas with higher densities of mother calf/pup combinations?
- What are the most important habitats for food, rest and reproduction of the various species of marine mammals to be studied?

Change in habitat:

- Does the spatial distribution of marine mammal populations change as a result of disruption of the habitat during the construction and removal phases of windfarms?
- Will new OWFs form an attractive (foraging) habitat for marine mammals?
- Do marine mammals return to previously visited areas although a wind farm might be present in the new situation?
- How soon do marine mammals return in the area after a single piling event?
- Does the migration and (diving) behaviour pattern within a wind farm differ from areas outside?

Barrier effect:

- To what extent do operational windfarms disrupt the migration patterns of marine mammals?

- Do marine mammals avoid areas with higher anthropogenic pressure, such as pile driving or shipping related to offshore wind?

Priority list studies to address the knowledge gaps are described in Appendix 4.

4.2.3.2 THRESHOLD VALUES FOR TTS, PTS, AND AVOIDANCE

This knowledge gap addresses nrs. 44 & 45 of the Long List as presented in Table 2 in Chapter 2:

> Threshold values of marine mammals for pile driving sounds : TTS growth curves to determine safety criteria (to prevent PTS). Dose-behavioural-response relationship for pile-driving sounds with more subjects, as behavioural responses to sound can vary greatly between individuals Masking effect on communication and (in porpoises) echolocation. Research has been conducted but more information is still needed (also for harbour seals).
>
> Ecological consequences of TTS and behavioural responses due to pile driving sound is unknown. Energetic and reproductive studies of which the results which serve as input parameters for the Interim PCoD model are needed. Very little information is available on these subjects (especially for harbour porpoises).

Harbour porpoises

In recent studies by Kastelein *et al*. (2013a,b; 2013d; 2015a,b), TTS (as a means to estimate PTS onset SEL) and avoidance thresholds have been studied in two individual harbour porpoises. These studies provided valuable information for recent (cumulative) impacts assessments for offshore windfarms. Although knowledge gaps on these threshold levels exist, it is not considered highest priority at this stage. The following knowledge gap remain and should be addressed in future:

- TTS growth curves due to pile driving sound for more accurate estimate of PTS onset levels.
- Amplitude modulated masking (operational wind farm sound).

Seals

The knowledge on the threshold levels for the occurrence of , TTS (as a means to estimate PTS onset SEL) and avoidance in seals is currently based on a limited data set with partly indicative results (one seal leaves the water and another seal tolerates disturbance by sound). In the first place, these thresholds levels should be better quantified under laboratory conditions. Since laboratory conditions are not directly representative for field conditions, a comparison of the found threshold levels and actual field data on avoidance should be made for validation, this should be done using data from The Netherlands and bordering countries such as Belgium, Germany and the UK.

Hearing thresholds of seals for underwater sound while swimming at the water surface is currently a knowledge gap. It is assumed that seals swim at the water surface during avoidance of pile driving, however it is unclear if this behaviour actually happens and how this will affect the cumulative Sound Exposure Level (SEL) received by seals during this avoidance.

The frequency dependent directionality of underwater hearing in seals in the horizontal plane is currently a knowledge gap. This is important for seals to determine where pile driving sounds (or the sounds of acoustic mitigation devices) come from and use this ability to swim away from the sound source. Addressing this knowledge gap might provide valuable information for optimal signal frequency selection for seal acoustic deterrent devices.

Monitoring and research questions

Underwater noise:

- What is the sensitivity (PTS, TTS, avoidance, injury) of seals to underwater noise, with respect to noise levels and distance to the source, generated during the construction phase (pile driving)?
- What are the hearing thresholds for seal while swimming at the water surface?
- What is the directionality of underwater hearing in seals in the horizontal pane?
- How does the noise of operating windfarms mask ecologically important sounds for seals ?

Priority list studies to address the knowledge gaps are described in Appendix 4.

4.2.3.3 *ASSESSMENT OF EFFECT ON POPULATION LEVEL*

This knowledge gap addresses nrs. 2, 43, 44, 45 & 46 of the Long List as presented in Table 2 in Chapter 2:

> Cumulative effects of OWFs
>
> Effects of noise on foraging efficiency in harbour porpoises. This will determine if noise affects the energy budget of marine mammals, and thus their fitness and reproduction (both are PCoD input parameters)
>
> Threshold values of marine mammals for pile driving sounds: TTS growth curves to determine safety criteria (to prevent PTS). Radius of damage. Sensitivity to sound in relation to frequency. Dose-behavioural-response relationship for pile-driving sounds with more subjects, as behavioural responses to sound can vary greatly between individuals. Duration of avoidance/ recovery time after disturbance. Masking effect on communication and (in porpoises) echolocation. Ecological consequences of TTS, PCoD validation.
>
> Research has been conducted but more information is still needed (also for harbour seals).
>
> Exact threshold values for pile driving effects on marine mammals, TTS growth curcves exact effects. Masking effect on communication.
>
> Detailed hearing sensitivity of different species of marine mammals to noise from operational wind farms: threshold values, critical ratio, critical bandwidth. Masking effect of amplitude modulated noise such as that produced by operational wind turbines. (seals and porpoises).

The impact assessment of offshore wind construction on population level of both harbour porpoises and the two species of seal is complicated. There is some information on distribution and threshold levels which give an indication of effects, but thorough knowledge on the actual behaviour of marine mammals in the field during pile driving is lacking.

Porpoises are generally assumed to require constant foraging, especially for juveniles. What effect existing windfarms have on the foraging behaviour and food intake of porpoises is unknown. If large windfarm surface areas are situated on migration routes and/or foraging areas that are important for porpoises and the windfarm area is avoided, their fitness may be reduced. 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 windfarms. Studies such as these should be set up internationally.

It is important to study the indirect effect of underwater noise on 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.

In a recent study (Heinis & de Jong, 2014), the cumulative effects of offshore windfarm construction in the North Sea were assessed by making use of both sound propagation modelling and population dynamic modelling using the InterimPCoD model. The Interim PCoD model is based on an expert elicitation, in which the key population dynamic parameters such as reproduction and mortality are estimated by experts. Furthermore, numerous assumptions have been made on other parameters such as behaviour during and after disturbance. Most frequently debated is the assumption of the return time of individuals after the disturbance by piling took place.

To increase the accuracy of the population dynamic modelling and assessment of effects on population level, there is a clear need to address specific knowledge gaps on habitat use and behavioural reaction during and after pile driving for which at this moment assumptions have been made.

Monitoring and research questions
There are many questions relevant for the impact assessment of offshore windfarms on population level for harbour porpoises and seals, e.g.:

- What behavioural reaction will take place after the onset of avoidance?
- Will species avoid the area in a linear pattern away from the source?
- Will they stop foraging during this avoidance reaction?
- Will they swim at a constant speed, until they are outside the avoidance threshold limit?
- How soon after the piling sound stopped do individuals return?
- Will there be any habituation to the noise after a number of strikes?
- To what extent will individual motivation play a role?
- Do mother-calf combinations react differently to disturbance by pile driving?
- Is avoidance behaviour significantly changing vital rates and will this lead to a change in reproductive success or mortality rate? How does avoiding predators compare to this? Is avoidance behaviour not more than changing the swimming course in continued foraging?
- Does avoidance for pile driving affect the energy budget of species?
- Does piling enhance the food availability for marine mammals on return in the area?
- Is communication between individuals actually masked during activities, and if so, will this lead to effects on the population?

The listed questions are certainly not complete, and can also not all be addressed on short or even long term. The list gives an idea of the extensive knowledge gaps that are present in the assessment of effects on population level.

Priority list studies to address the knowledge gaps are described in Appendix 4.

4.2.4 BIRDS

The main knowledge gaps for the impact assessments of operational offshore windfarms on birds in international context are given below, forming the Expert Priority List 2015 of knowledge gaps that need to be addressed with highest priority.

4.2.4.1 *EFFECTS OF COLLISION ON POPULATION LEVEL OF BIRDS*

This knowledge gap addresses nrs. 59, 60, 61, 62 & 64 of the Long List as presented in Table 2 in Chapter 2:

Percentage of collision of bird species in the farm, seasons: more research is needed at other windfarms. For the Dutch breeding birds, but also for foreign breeding populations, it is only possible to make predictions of population growth at the larger scale.

Effects of windfarms as stepping stones in population development of cormorants in the North Sea. Specifics on population development, foraging behaviour and quantities and species of fish still have to be provided

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 windfarm, for all relevant species.

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 windfarm. More information on basic information on prey species, numbers and seasonal rhythms, as well as on more site-specific information is needed.

Seasonal variation and rhythms of bird populations in the OWF, numbers and densities. Some research has been conducted but more detailed information is needed.

Cumulative effects of windfarms on avoidance, migration patterns, numbers and distribution of migratory birds. percentage of surface area where the windfarms have an effect in comparison to the surface are of the dispersion area

Collision of birds with wind farms is often fatal for individuals and can ultimately lead to effects on population level. There is however no knowledge on the actual rate of collisions in offshore wind farms as data collection is difficult. Casualties can be counted relatively easily on land at the turbine locations, but it is difficult to extrapolate these results to an offshore location as different species, different migration routes and different behaviour can be expected at sea. The number of collisions per species of (migrating and local) birds in wind farms is therefore a knowledge gap that needs to be addressed. Since the number of migrating birds can be estimated better, though not precisely per species, the number of collision fatalities is essential to estimate a percentage of fatalities by collision.

Location-specific knowledge on the migration of birds through (planned) windfarms is a key to minimize risk of bird collisions beforehand. Spatial and numerical wind farms variation, course and importance of migration routes should be addressed in an international context.

Knowledge on the barrier effect of OWFs is also largely lacking. How and to what extent will OWFs have an effect on migration patterns and the numbers and distribution of migratory birds, in OWF areas and in comparison with reference areas? Is the contemporary spatial planning of the upcoming windfarms as a north-south strip parallel at 12 nm from the coast favourable for migratory birds? 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 with high definition video are especially suitable for the larger scale surveys of sea birds; ship surveys are required for location-specific surveys combined with behavioural observations and measuring flight altitudes.

Monitoring and research questions

- What are the major species, abundance, flight heights, migration routes etc. for birds potentially at risk from OWFs?

- To what extent do birds proposed avoid OWFs and what are the consequences of this on the fitness of the relevant species?
- What is the barrier effect of OWF's on migratory birds?
- What are the bird fluxes of different species in proposed OWFs?
- 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)?
- Is habituation of (migratory) bird feasible?
- Which demands on windfarm spatial turbine-layout, width and compass orientation of flight (escape) corridors, turbine properties (size, height, rotor-swept area, contrast-colouring, reduction of motion smear), indirect lighting may positively influence the above items?
- What is the effect on above aspects of lay-out of wind farm and lighting of turbines?

Priority list studies to address the knowledge gaps are described in Appendix 4.

4.2.4.2 HABITAT LOSS OR CHANGE

This knowledge gap addresses nrs. 3, 55, 57, 58, 61, 63, 64, 65, 66, & 67 of the Long List as presented in Table 2 in Chapter 2:

> Maps of North Sea species / ecosystems / counting events, etc.
>
> Habitat use on the entire North Sea, including prey species such as fish and benthos.
>
> Loss of habitat for (surface) farm-avoiding bird species in comparison with the total, including species specification and species densities. Needed to fill this gap: detailed information on species specific seasonal distribution, more information on effects further offshore (Doggersbank), assessments of the cumulative impacts of OWFs that will be built in the future, including concentrated shipping in the remaining space.
>
> 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 windfarm. More information on basic information on prey species, numbers and seasonal rhythms, as well as on more site-specific information is needed.
>
> Population dynamics of colonies (floaters).
>
> Cumulative effects of windfarms on avoidance, migration patterns, numbers and distribution of migratory birds. percentage of surface area where the windfarms have an effect in comparison to the surface are of the dispersion area .
>
> The influence of the OWF configuration and type of windmill on the habitat loss and collision risk of bird species. No knowledge of effect of lighted turbines on attraction of (migrating song-) birds.
>
> For migrant birds, the main uncertainties may lay in insufficient knowledge of the relevant catchment areas and the threats facing them elsewhere.
>
> There are no studies that have measured the effects of displacement of seabirds from windfarms, on seabird fitness.

Habitat loss

It is largely unknown to what extent a significant amount of habitat is lost to wind farm-avoiding bird species, in comparison to the areas that remain unchanged. How are species distributed over these areas and how will a change affect the bird population? What are the effects of displacement of seabirds from wind farms? Does the assumed habitat loss of 10% actually lead to mortality of species, and/or should a species-specific percentage be used? Will birds geet accustomed to windfarms to possibly favour from the enhanced food biomass within or close to the unfished perimeter? To answer these questions, detailed information on species-specific seasonal distribution, especially of colonies (floaters) in both windfarms and reference areas is required.

Habitat change

Offshore wind farms change the habitat and this can lead to population effects on birds that use the area. The habitat use of the North Sea area by different (categories of) bird species and their prey is currently an important knowledge gap which makes a solid impact assessment difficult. It is important to study the function of the habitat for the relevant bird species in order to assess the impact of the habitat change on the foraging, moulting and/or resting behaviour of (categories of) species. Targeted studies on the importance of certain areas for birds is most meaningful for those species that are characterised as most sensitive to disruption.

For breeding birds, data on population dynamics are required for better assessment of the effects on protected breeding colonies. This primarily concerns data on survival (ringing and counting back), the proportional number of floaters (study of breeding colonies) and flight patterns of foraging birds by tagging breeding specimens. Such data should be linked to data of the fish abundance, commercial fishing activity and the position of natural food areas, to allow to make a connection between survival at the population level and the food situation in the coastal and offshore waters. Such studies also produce the required information on loss of foraging areas, 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.

Specific knowledge on the density of prey species in (the vicinity of) the farm in comparison to the surrounding area is lacking.

Also unknown is to what extent effects of habitat loss will depend on the wind farm configuration (including flight corridors), type / size of turbine, contrast-colouring, indirect lighting, cut-in windspeed at > 4 Bft (ref. to bats).

Monitoring and research questions

Basic information:

- What are the current 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 (including colony birds breeding in the coastal zone) and what determines the importance and how do they vary in time?
- What are the important migration routes of birds over the North Sea? Do they mainly migrate in a broad front, or are there specific corridors, and what features (e.g. coastline) are used to orientate?

Change in habitat:

- How does the spatial distribution of bird populations change as a result of changes in the food supply in windfarms during the operational phase?
- 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?

- Does habituation occur?

Barrier effect

- To what extent do wind farms disrupt the migration patterns of birds?

Priority list studies to address the knowledge gaps are described in Appendix 4.

4.2.5 BATS

4.2.5.1 *EFFECTS OF COLLISION ON POPULATION LEVEL OF BATS*

This knowledge gap addresses nrs. 69, 70, 71, 72 & 73 of the Long List as presented in Table 2 in Chapter 2:

> Numbers, densities, trends and species of bats potentially in and around OWFs.
>
> Behavioural characteristics at sea of bats (e.g. flight and foraging heights, species-specific detection range, to what extent bats use echolocation during migration over sea, echolocation characteristics in relation to the number of fatalities
>
> Migration routes of bats across the North Sea
>
> A reliable estimate of the sizes of the catchment populations of bats. It is likely to assume that a large proportion of bats originates from countries such as Russia and Belarus. Population estimates from these countries are not available. In addition, there is insufficient knowledge available on the life history characteristics of the Parti-coloured Bat.
>
> A reliable estimate of the number of fatalities of bats at sea, in relation to the wintering populations of the relevant species in the UK which migrate over the North Sea.

There is limited knowledge migratory behaviour of bats offshore and on the population size of those species of bats most likely to be involved. Recent surveys with bat detectors have shown the presence of bats in offshore windfarms and collisions as well as fatalities due to barotrauma are known to occur in onshore windfarms. The effects of offshore windfarms on bats are, however, largely unknown. Tagging studies have shown that bats migrate between the Netherlands and the UK, but the size of the source population, percentage of migratory bats, migration routes and migration intensity in relation to season and weather conditions are largely unknown, as are behavioural responses to the presence of operating wind turbines offshore.

Monitoring and research questions

- What is the migratory population size of the relevant migratory species of bat and how many bat fatalities by windturbines occur as the background reference to assess the impact of turbines?
- What is the spatial distribution of bats on the DCS and thus bat fatality risk distribution as a function of e.g. distance to the coast?
- Are there main migration routes for bats between the Netherlands and the UK and thus enhanced risks of bat fatalities?
- What is the collision rate of bats in OWFs?

Priority list studies to address the knowledge gaps are described in Appendix 4.

4.2.6 GENERAL ASPECTS

4.2.6.1 *INTERNATIONAL COLLABORATION AND DATA AND KNOWLEDGE SHARING*

Although not listed as a knowledge gap in the Long List, there is a general concern expressed among the experts present at the workshop on the international research collaboration and data and knowledge sharing on the effects of offshore windfarms. Species are mobile and migrate over large distances across (administrative) borders. This makes it necessary to assess the effects of windfarms at an international level. There is a large number of internationally ongoing studies, however joint international research and the sharing of data and knowledge is at this moment limited. During the workshop, the need for facilitation of international collaboration was emphasized. It should also be promoted that researchers publish their results in international scientific journals. This way the results will be peer reviewed and available to all researchers and regulators. It would be even better to go a step further in international collaboration and next to the exchange of data set-up monitoring programs on an international scale and do research in collaboration.

The cumulative (potential) effects of international expansion of offshore windfarms requires research and monitoring in an international context. As indicated above, not only the Netherlands have ambitious plans to upscale OWFs in the North Sea. Altogether, the Netherlands, Belgium, Great Britain, Germany, Denmark, Norway and Sweden want to realise dozens of GW of OWFs in the North Sea and Baltic Sea. Since many fish, birds and marine mammals reside in and migrate through those marine areas or an even larger area (as far as Western Siberia for some birds), the effects must also be assessed on the same scale. A monitoring and research programme that focuses on international cooperation is required for this purpose.

Despite the relatively large effort in monitoring of and research on ecological effects, it can be stated that the information from this has so far been of limited use in the spatial and configurative planning of OWFs. Until now, monitoring and research have been used to study whether any severe effects on ecological aspects occur. This strategy is per definition more location-specific than generic, by its limitations lacks power of proof and needs to be adapted to gain insight into effects due to upscaling (increase in the number of windfarms) and in assessing cumulative effects.

At the moment it is highly important to set up an international programme focused on cooperation (sharing of forces),on 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 fieldwork, methods of assessing effects (statistics, modelling), data format/access and data contribution to model development. Moreover, it should include setting up guidelines on how cumulative effects should be assessed, and what other activities, plans or projects should be considered to be included in the assessment. Such a programme would need to be set up as soon as possible.

With respect to the monitoring of cumulative effects, and thus to the international approach to monitoring and research, it is notable how the differences in monitoring activities among 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 measurements are done only in the farm or also outside it, whether a reference area is included in the study or not, etc. Less attention is paid to the number of repetitions or 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 a 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) are important. For example, a study on the effect of land-based windfarms 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.

Standardisation of measurements and/or 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 particular monitoring activities, such as for bird observation (Camphuysen *et al.*, 2004).

In 2014, based on the interviews with experts, the following recommendations for international cooperation are given:

- Use and combine data from neighbouring countries. In particular for marine mammals and the impacts of underwater noise e.g. long-term acoustic monitoring, data could and should be comparable to other comparable projects. An idea to make this more effective and provide better large-scale data is to develop an international, European database for CPOD data. The data could also be analysed in more detail than at the moment required (e.g. looking at "feeding buzzes" to investigate feeding behaviour).
- Central governmental coordination of monitoring and data; avoid differences among countries and work consistently and efficiently, in particular in cooperation with Belgium, Germany, Denmark, UK and Sweden. A lot of data has been collected and researchers noticed from the DEPONS project and the collaboration with SMRU on the Interim PCoD model that international cooperation can allow us to interpret this in a much better way. More attention could be given to coordinate efforts internationally (e.g. timing of surveys, building of international databases).
- Large scale and long term research is required; an international monitoring programme is suggested, for new OWFs and control areas.
- Communication and data sharing should be improved.
- Possibilities for international tagging of marine mammals and birds should be explored. Surrounding countries have a lot of experience in tagging and bird research.
- Expert Elicitation to get insights in different international experiences and results of population effect research.
- Model studies (next level of COMPILE benchmark international with Germany); Which and how many details are required, which measures can be compared and how can models be improved.
- Decisions of new OWFs locations could be based on international research and capacity of the ecosystem and use of space.
- Cumulation studies could be combined with international data; e.g. larger turbines, larger distance between turbines, slow turning speed, etc. The UK project SOSS provides recommendations on methods.

Designing future international cooperation
In light of the above-mentioned, it is important to link the Masterplan to research and monitoring activities that are being carried out internationally with respect to wind energy at sea.

To develop the North Sea 2050 Regional Agenda, North Sea countries discussed new plans and expected developments, with a focus on energy, ecology and shipping. The Marine Spatial Planning directive might require more international cooperation in the planning phase for offshore wind energy and land-sea interactions. Also cooperation on coastal issues like tourism, port connections, energy (grids) and climate is necessary (Rijksstructuurvisie Windenergie op Zee, 2014).

Priority list studies to address the knowledge gaps are described in Appendix 4.

5 Synthesis

The development of OWFs on the Dutch Continental Shelf can have adverse effects on the marine ecosystem. However, at present, many knowledge gaps exist which makes it difficult to draft a solid cumulative impact assessment for all relevant species.

In recent years many studies have been carried out, which provided highly valuable data and new insights on basic information such as density and distribution of species, hearing vulnerability of marine mammals and dose-response relationships for marine mammals. Also more specific information such as the limited effects of pile driving on fish larvae has become available.

In this study, the Masterplan 1.0 (Deltares, 2010) was updated by assessing which knowledge gaps have been addressed in the last years and by making an inventory of new and remaining knowledge gaps. This has resulted in an updated Long List of knowledge gaps.

For the prioritization of the Long List of knowledge gaps, RWS Z&D has set six criteria to comply with in order to to be addressed with high priority. Subsequently, the prioritization was done in two separate steps by (1) policy makers and (2) scientific experts. In the first step, the knowledge gaps have been structurally tested against all six criteria, which resulted in the Policy Priority List 2015. In the second step, the six criteria were acknowledged but not structurally followed and the knowledge gaps have been prioritized based on expert judgement, which resulted in the Expert Priority List 2015.

5.1 SYNTHESIS PRIORITY LISTS 2015

Underwater noise (physics)

The scientific experts prioritized current knowledge gaps on underwater noise (mainly far range model validation), however this was not prioritized by policy makers. The reasoning for this by policy makers is that the current Monitoring and Evaluation Programmes for Luchterduinen and Gemini OWFs already address these knowledge gaps and therefore no additional research on this topic is at this stage necessary.

Fish

The scientific experts prioritized the current knowledge gaps of the effects of construction of OWFs on fish population, both on physical condition and behaviour. This was not considered highest priority of policy makers, though these gaps complied with three of the six criteria (validation of assumptions MER & PB, international cooperation, importance for MSFD and Bruinvisbeschermingsplan).

Marine mammals

Both policy makers and scientific experts identified that the knowledge gaps that have to be addressed with highest priority for marime mammals are (1) the percentage of surface area where effects on marine mammals occur in comparision to the dispersion area and (2) better threshold quantification in combination with more insight in actual behavioural response in the field during construction for both seals and marine mammals. Studies on these gaps will provide better quantified input parameters for b.e. the InterimCPOD model or other population models, which will contribute to more reliable impact assessments of construction of OWFs on marine mammals. From policy side it is explicitely noted that insights in the efficacy of mitigation measures such as ADDs and pile driving mantles should be acquired for the purpose of adaptive management.

Birds

Both policy makers and scientific experts identified that the knowledge gaps that have to be addressed with highest priority for birds are (1) on the loss of habitat for (surface) farm avoiding bird species in relation with the total area, including species specification and abundances. and (2) insight in collision rates of birds in OWFs. Experts mainly focussed in the workshop discussion on the development of a system of collision quantification (e.g. WT-bird), where policy makers prioritized specifically the effects OWF configuration to minimize collision and habitat loss. These are clearly related, since by developing a system to measure collison rates, the effects of configuration can be quantified. Policy makers specifically prioritized insight in the efficacy of mitigation measures, by studying the effects of corridiors, open or closed configuration, small or large turbines, indirect lights, contrasting colors of rotor blades and foundation, and a cut-in speed at >4 Bft on both collision rate and habitat loss.

Bats

Both policy makers and scientific experts identified that the knowledge gaps that have to be addressed with highest priority for bats are the behavioural characteristics of bats at sea. Knowledge of bats at sea is generally limited and should be acquired with high priority to be able to assess the impacts of OWFs on the bat population.

General

During the workshop, the need for international collaboration and data sharing was emphasized by both scientific experts and policy makers. This is not a knowledge gaps by itself, but needs to be facilitated in order to efficiently address the current existing knowledge gaps. Also, this will help in assess the (cumulative) impacts of OWFs on population level of species, as most species are not restricted to national boundaries.

Priority List Studies – basis for MEP

During the workshop, for each of the high priority knowledge that need to be addressed according to the scientific experts, specific studies to address these gaps have been formulated. These studies can form the basis for future Monitoring and Evaluation Programmes and are therefore presented in Appendix 4.

5.2 ADAPTIVE MANAGEMENT

One of the criteria set by RWS for the prioritization of knowledge gaps was the use of this knowledge for adaptive management. In order to get all necessary information in time, studies to address the Priority List 2015 should in general start and be executed as soon as possible. Adaptive management can only be applied when knowledge from research can be applied during the process, that is why timing is of utmost importance.

Following the time-schedule as presented in

Figure 1, the EIAs and AAs for the designated areas Borssele and Hollandse Kust will be drafted in the period 2015 – 2018 and most logically for the area IJmuiden ver somewhere in the period 2019-2020. This implies that not all results from the studies that address the Priority List 2015 (see Appendix 4) can be incorporated in these assessments and that at several aspects the precautionary principle will be followed both in the assessment and the obliged regulations. Nevertheless, it is still useful to start short-, middle- and long term studies all as soon as possible.

The same applies for generic and location specific studies as presented in Appendix 4. Both types of studies need to be executed as soon as possible in order to be able to make a solid impact assessment and use adaptive management during the development of OWFs.

According to the time-schedule, the first construction phase is foreseen at the end of 2018, which implies that approx. 2.5 years are available to define and mature indicators for adaptive management.

Based on various interviews and discussions, it should be note that applying adaptive management will be challenging; there will most likely be limited sufficiently accurate indicators available that can express the effects of construction and operational OWFs on population level on a short time scale. This is necessary to make decisions on policy level on further development of OWFs. More insight on this subject may be gained during the execution of studies that address the Priority List 2015.

5.3 EFFICACY OF MITIGATION MEASURES

Following the precautionary principle, there are several regulatory preventive and mitigation measures set by authorities for the development of OWFs. The efficacy of many of these measures can be logically reasoned, but are often not quantified and therefore unknown. It would be valuable if the studies that address the Priority List 2015 generate knowledge on which measures to take during the development of OWFS. Based on the prioritization, the efficacy of ADDs and pile driving mantles to mitigate effects of underwater noise on marine mammals should be studied. Also, the effects of corridiors, open or closed configuration, small or large turbines, indirect lights, contrasting colors of rotor blades and foundation, and a cut-in speed at >4 Bft on both collision rate and habitat loss should be studied, to be able to take effective measures for the construction of future OWFs.

References

Aarts, G. S. Brasseur, S. Geelhoed, R. van Bemmelen & M. Leopold, 2013. Grey and harbour seal spatiotemporal distribution along the Dutch West coast. IMARES report C103/13: 39p.

ACRB, 2013. Mogelijke morfologische effecten van het Prinses Amalia windpark. ACRB report Q214R1: 24p.

Aguilar de Soto, N., N. Delorme, J. Atkins, S. Howard, J. Williams & M. Johnson, 2013. Anthropogenic noise causes body malformations and delays development in marine larvae. Scientific Reports 3: 5p.

Andersson, M.H., 2011. Offshore windfarms – ecological effects of noise and habitat alteration on fish. Doctoral dissertation Department of Zoology, Stockholm University: 48p.

Arends E, R. Groen, T. De Jager & A.R. Boon (red), 2008. (In Dutch) Appropriate Assessment of windfarm West Rijn. Report for Airtricity Ltd., UK, Pondera Consult BV, Haskoning BV, Bureau Waardenburg BV, Imares, Deltares, Altenburg and Wymenga BV, Arcadis, Heinis Water, Management and Ecology:215p.

Bailey H., B. Senior, D. Simmons, J. Rusin, G. Picken & P.M. Thompson, 2010. Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals. Marine Pollution Bulletin 60: 888-897.

Bailey, H., K.L. Brookes & P.M. Thompson, 2014. Assessing environmental impacts of offshore windfarms: lessons learned and recommendations for the future. Aquatic Biosystems 2014, 10:8: 13p.

Bergman, M, G. Duineveld, P. van 't Hof & E. Wielsma, 2010. Impact of OWEZ Windfarm on bivalve recruitment. NIOZ Report OWEZ_R_262_T1_20100910: 80p.

Bergman, M., G. Duineveld, R. Daan, M. Mulder & S. Ubels, 2012. Impact of OWEZ windfarm on the local macrobenthos community. NIOZ report OWEZ_R_261_T2_20121010: 63p.

Berkenhagen J., R. Döring, M.H.F. Kloppmann, S.A. Pedersen, T. Schulze, 2010. Decision bias in marine spatial planning of offshore windfarms: Problems of singular versus cumulative assessments of economic impacts on fisheries. Marine Policy 34: 733-736.

Blacquière, G., F.P.A. Lam, M.A. Ainslie, C.A.F. de Jong & F.H.A. van den Berg, 2012. TNO Review of IMARES report 'Assessment of the Effects of OWEZ for Harbour Porpoises (comparison T0 and T1)'. TNO report 2012 R10080: 10p.

Bolle, L.J., C.A.F. de Jong, S. Bierman, D. de Haan, T. Huijer, D. Kaptein, M. Lohman, S. Tribuhl, P. van Beek, C.J.G van Damme, F. van den Berg, J. van der Heul, O. van Keeken, P. Wessels & E. Winter, 2011. Shortlist Masterplan Wind Effect of piling noise on the survival of fish larvae (pilot study). TNO & IMARES Report number C092/11: 138p.

Bolle, L.J, de Jong, C.A.F., Bierman, S.M., van Beek, P.J.G., van Keeken, O.A., Wessels, P.W., van Damme, C.J.G., Winter H.V., de Haan D., Dekeling, R.P.A. (2012). Common Sole Larvae Survive High Levels of Pile-Driving Sound in Controlled Exposure Experiments. PLoS ONE 7(3): e33052. doi:10.1371/journal.pone.0033052.

Bolle, L.J., C.A.F. de Jong, S.M. Bierman,·P.J.G. van Beek, P.W. Wessels, E. Blom, C.J.G. van Damme, H.V. Winter & R.P.A. Dekeling, 2013. Effect of pile-driving sounds on the survival of larval fish. 3rd International Conference on the Effects of Noise on Aquatic Life, Budapest, Hungary, 11-16 August, 2013.Identifier: 483523.

Boon, A.R., 2012. Monitoring and Research Shortlist Offshore Wind – Knowledge advancements and follow up. Deltares, Reference 1203488-000-ZKS-0009-: 52p.

Boon, A.R., R. ter Hofstede, C. Klok, M. Leopold, G. Blacquire, M.J.M. Poot, R.A. Kastelein & C.J. Camphuysen, 2010. Monitoring and researching ecological effects of Dutch offshore wind farms – Masterplan. Deltares, Reference 1201176-000: 157p.

Boshamer, J.P.C., & J.P. Bekker 2008. Nathusius' pipistrelles (*Pipistrellus nathusii*) and other species of bats on offshore platforms in the Dutch sector of the North Sea. Lutra 51: 17-36.

Brabant, R., S. Degraer & B. Rumes, 2014. (In Dutch) A closer look at the impacts on the marine environment. Natuur.focus 13(1): 4-10.

Brandt, M., A. Diederichs, K. Betke & G. Nehls, 2011. Responses of harbour porpoises to pile driving at the Horns Rev II offshore windfarm in the Danish North Sea. Marine Ecology Progress Series 421: 205-216.

Brasseur, S., G. aarts, E. Meesters, T. van Polanen Petel, E. Dijkman, J. Cremer & P. Reijnders, 2012. Habitat preferences of harbour seals in the Dutch coastal area: analysis and estimate of effects of offshore windfarms. IMARES Report: OWEZ R 252 T1 20120130, C043-10: 58p.

Broström, G. 2008. On the influence of large windfarms on the upper ocean circulation. J. Mar. Sys. 74: 585-591.

BSH & BMU, 2014. Ecological Research at the Offshore Windfarm Alpha Ventus. Editors: Federal Maritime and Hydrographic Agency, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. Springer, 201p.

BSH, 2014. Ecological research at the offshore wind test site „alpha ventus“. Evaluation of the BSH standards for environmental impact assess-ment (StUKplus) 2009 – 2013 BSH (Federal Maritime and Hydrographic Agency), with manifold involved researchers.

Camphuysen CJ, Fox TJ, Leopold MF, Petersen IK (2004). Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K. - A comparison of ship and aerial sampling methods for marine birds, and their applicability to offshore wind farm assessments. NIOZ Report to Cowrie / The Crown Estate.

Canning, S., G. Lye, L. Givens & C. Pendlebury, 2013. Analysis of Marine Ecology Monitoring Plan Data from the Robin Rigg Offshore Windfarm, Scotland (Operational Year 2). Chapter 5: Birds. Report: 1012206: 85p.

Casper, B.M., M.E. Smith, M.B. Halvorsen, H. Sun, T.J. Carlson & A.N. Popper, 2013. Effects of exposure to pile driving sounds on fish inner ear tissues. Comparative Biochemistry and Physiology, Part A 166: 352–360.

Coates, D.A., Y. Deschutter, M. Vincx & J. Vanaverbeke, 2014. Enrichment and shifts in macrobenthic assemblages in an offshore windfarm area in the Belgian part of the North Sea. Marine Environmental Research 95: 1-12.

Collier, M.P., S. Dirksen & K.L. Krijgsveld, 2012. A review of methods to monitor collisions or micro-avoidance of birds with offshore wind turbines. Bureau Waardenburg B.V. report 10-523: 25p.

Cook, A.S.C.P., A. Johnston, L.J. Wright & N.H.K. Burton, 2012. A review of flight heights and avoidance rates of birds in relation to offshore windfarms. BTO Research Report Number 618, The British Trust for Ornithology, The Nunnery, Thetford, Norfolk: 61p.

Corbetta, G., A. Mbistrova, A. Ho, J. Guillet, I. Pineda & J. Wilkes (EWEA), 2015. The European offshore wind industry - key trends and statistics 2014. EWEA: 25p.

Dähne, M., A. Gilles, K. Lucke, V. Peschko, S. Adler, K. Krügel, J. Sundermeyer & U. Siebert, 2013. Effects of pile-driving on harbour porpoises (Phocoena phocoena) at the first offshore windfarm in Germany. Environmental Research Letters 8: 16p.

Danish Energy Agency, 2013. Danish Offshore Wind. Key Environmental Issues – a Follow-up. The Environmental Group: The Danish Energy Agency, The Danish Nature Agency, DONG Energy and Vattenfall. 101p.

De Jong, C.A.F. & M.A. Ainslie, 2012. Underwater sound due to piling activities for Prinses Amaliawindpark (PA). Update of the TNO report MON-RPT-033-DTS-2007-03388, project nr 033.15620 & 032.31700: 102p.

Diederichs, A., H. Pehlke, G. Nehls, M. Bellmann, P. Gerke, J. Oldeland, C. Grunau, S. Witte & A. Rose, 2014. [In German] Entwicklung und Erprobung des Großen Blasenschleiers zur Minderung der Hydroschallemissionen bei Offshore-Rammarbeiten. BMU Förderkennzeichen 0325309A/B/C, BioConsult SH, Husum.

Dielemans, 2012. [In Dutch] Onderzoek naar radarverstoring door Prinses Amaliawindpark en Offshore Windpark Egmond aan Zee (PA & OWEZ). Radio Holland: 33p.

Debusschere E, De Coensel B, Bajek A, Botteldooren D, Hostens K, et al. (2014) In Situ Mortality Experiments with Juvenile Sea Bass (Dicentrarchus labrax) in Relation to Impulsive Sound Levels Caused by Pile Driving of Windmill Foundations. PLoS ONE 9(10): e109280. doi:10.1371/journal.pone.0109280

Elmer, K.H, W.J. Gerasch, T. Neumann, J. Gabriel, K. Betke & M. Schultz-von Glahn, 2007. Measurement and reduction of offshore wind turbine construction noise. DEWI Magazin 30: 33-38.

Furness *et al*., 2013. Assessing vulnerability of marine bird populations to offshore windfarms. Journal of Environmental Management 119: 56-66.

Geelhoed S, Scheidat M, Aarts G, van Bemmelen R, Janinhoff N, Verdaat H & Witte R, 2011. Shortlist Masterplan Wind – Aerial surveys of harbour porpoises on the Dutch Continental Shelf. Research Report IMARES Wageningen UR - Institute for Marine Resources & Ecosystem Studies, Report No. C103/11.

Geelhoed SCV, Scheidat M, van Bemmelen RSA & Aarts G, 2013a. Abundance of harbour porpoises (Phocoena phocoena) on the Dutch Continental Shelf, aerial surveys in July 2010-March 2011. Lutra 56(1): 45-57.

Geelhoed S, Scheidat M, & van Bemmelen R, 2013b. Marine mammal surveys in Dutch waters in 2012. Research Report IMARES Wageningen UR - Institute for Marine Resources & Ecosystem Studies, Report No. C038/13.

Geelhoed S, Scheidat M, & van Bemmelen RSA, 2014. Marine mammal surveys in Dutch waters in 2013. Research Report IMARES Wageningen UR - Institute for Marine Resources & Ecosystem Studies, Report No. C027/14.

Gerasch, W., K. Elmer, T. Neumann, J. Gabriel, J. Schultz- v. Glahn & K. Betke, K, 2009. (url). Schallimmissionen während des Bauens und des Betriebes von Offshore-Windenergieanlagen. http://erneuerbare-energien.de/files/pdfs/allgemein/application/pdf/gerasch_19.pdf Gordon *et al*., 2009

Gill, A.B. & M. Bartlett, 2010. Literature review on the potential effects of electromagnetic fields and subsea noise from marine renewable energy developments on Atlantic salmon, sea trout and European eel. Scottish Natural Heritage. Commissioned Report No. 401: 43p.

Gill, A.B., M. Bartlett & F. Thomsen, 2012. Potential interactions between diadromous fishes of U.K. conservation importance and the electromagnetic fields and subsea noise from marine renewable energy developments. Journal of Fish Biology 81: 664–695.

Graven, J., 2013. Prinses Amaliawindpark, bathymetric and geophysical survey for morphology studies, survey report 2013. Document P2568-SIS-01-R01: 48p.

Grove, B., R.H.W. Langston, A. McCluskie, J.D. Pullan & I. Scrase, 2013. Windfarms and birds: an updated analysis of the effects of windfarms on birds, and best practice guidance on integrated planning and impact assessment. Convention on the conservation of European wildlife and natural habitats Bern Convention Bureau Meeting: 89p.

Haelters, J., E. Debusschere, D. Botteldooren, V. Dulière, K. Hostens, A. Norro, S. Vandendriessche, L. Vigin, M. Vincx & S. Degraer, 2013. The effects of pile driving on marine mammals and fish in Belgian waters. Chapter 7: 70-77.

Halvorsen, M.B., B.M. Casper, C.M. Woodley, T.J. Carlson & A.N. Popper, 2012. Threshold for Onset of Injury in Chinook Salmon from Exposure to Impulsive Pile Driving Sounds. PLoS ONE 7(6): e38968: 11p.

Hartman, J.C., K.L. Krijgsveld, M.J.M. Poot, R.C. Fijn, M.F. Leopold & S. Dirksen, 2012. Effects on birds of Offshore Windfarm Egmond aan Zee (OWEZ), An overview and integration of insights obtained. NoordzeeWind report nr OWEZ_R_233_T1_20121002, Bureau Waardenburg report nr 12-005: 148p.

Harwood, J., S. King, R. Schick, C. Donovan & C. Booth, 2013. A protocol for implementing the interim population consequences of disturbance (PCOD) approach: quantifying and assessing the effects of UK offshore renewable energy developments on marine mammal populations. Report SMRUL-TCE-2013-014. Scottish Marine and Freshwater Science 5(2): 97p.

Haskoning, 2009. [In Dutch] Offshore windfarm “Den Helder I” - Environmental Impact Assessment part B - The effects, project no. 9S8680.01: 260p.

Hawkins, A.D., A.E. Pembroke & A.N. Popper, 2014. Information gaps in understanding the effects of noise on fishes and invertebrates. Rev Fish Biol Fisheries: 26p.

Heinis, F. & C.A.F. de Jong, 2014. [in Dutch] Cumulatieve effecten van impulsief onderwatergeluid op zeezoogdieren (concept). TNO rapport projectnr. 060.11480, TNO, Den Haag, the Netherlands: 83p.

Hiscock, K., H. Tyler-Walters & H. Jones, 2002. High level environmental screening study for offshore windfarm developments - Marine habitats and species project. Marine Biological Association Report, Plymouth.

Jansen, H.W. & C.A.F de Jong, 2014. Underwater noise measurements in the North Sea in and near the Princess Amalia Windfarm in operation (PA). TNO Project number 052.02582: 55p.

Janßen, H., T. Schöder, M.L. Zettler & F. Pollehne, 2015. Offshore windfarms in the southwestern Baltic Sea: A model study of regional impacts on oxygen conditions. Journal of Sea Research 95: 248–257.

Jarvis, S., J. Allen, N. Proctor, A. Crossfield, O. Dawes, A. Leighton, L. mcNeill & W. Musk, 2004. North Sea Windfarms: Q7, Lot 1 Benthic Fauna. Report ZBB607.1-F-2004, Institute of Estuarine & Coastal Studies, University of Hull: 89p.

Johnston, A., A.S.C.P Cook,. L.J Wright, E.M. Humphreys & N.H.K Burton, 2014. Modelling flight heights of marine birds to more accurately assess collision risk with offshore wind turbines. Journal of Applied Ecology 51: 31–41.

Kastelein, R. A., Gransier, R. Hoek, L, Macleod, A., and Terhune, J.M. (2012a). “Hearing threshold shifts and recovery in harbor seals (Phoca vitulina) after octave-band noise exposure at 4 kHz," J. Acoust. Soc. Am. 132, 2745-2761.

Kastelein, R.A., Gransier, R., Hoek, L. and Olthuis, J. (2012b). “Temporary threshold shifts and recovery in a harbor porpoise (Phocoena phocoena) after octave-band noise at 4 kHz," J. Acoust. Soc. Am. 132, 3525-3537.

Kastelein, R. A., Gransier, R., and Hoek, L. (2013a). “Comparative temporary threshold shifts in a harbor porpoise and harbor seal, and severe shift in a seal (L),” J. Acoust. Soc. Am. 134(1), 13-16. DOI: http://dx.doi.org/10.1121/1.4808078.

Kastelein, R. A., Gransier, R., Hoek, L. and Rambags, M. (2013b). “Hearing frequency thresholds of a harbor porpoise (Phocoena phocoena) temporarily affected by a continuous 1.5 kHz tone,” J. Acoust. Soc. Am. 134, 2286-2292. DOI: http://dx.doi.org/10.1121/1.4816405.

Kastelein, R.A., Hoek, L., Gransier, R., and de Jong, C.A.F. (2013c). “Hearing thresholds of a harbor porpoise (Phocoena phocoena) for playbacks of multiple pile driving strike sounds” J. Acoust. Soc. Am. 134, 2302-2306. DOI: http://dx.doi.org/10.1121/1.4817842.

Kastelein, R.A., Hoek, L., Gransier, R., de Jong, C.A.F., and Jennings , N. (2013d). “Hearing thresholds of two harbor seals (Phoca vitulina) for playbacks of multiple pile driving strike sounds,” J. Acoust. Soc. Am. 134, 2307-2312. DOI: http://dx.doi.org/10.1121/1.4817889.

Kastelein, R. A., van Heerden, D., Gransier, R., and Hoek, L (2013e). “Behavioral responses of a harbor porpoise (*Phocoena phocoena*) to playbacks of broadband pile driving sounds,” Marine Environmental Research **92**, 206-214, DOI: 10.1016/j.marenvres.2013.09.020

Kastelein, R.A., Hoek, L., Gransier, R., Rambags, M., and Claeys, N. (2014a). “Effect of level, duration, and inter-pulse interval of 1-2 kHz sonar signal exposures on harbor porpoise hearing,” J. Acoust. Soc. Am. 136, 412-422. DOI: http://dx.doi.org/10.1121/1.4883596.

Kastelein, R.A., Schop, J., Gransier, R., and Hoek, L. (2014b). “Frequency of greatest temporary hearing threshold shift in harbor porpoises (Phocoena phocoena) depends on the noise level,” J. Acoust. Soc. Am. 136, 1410-1418, DOI: 10.1121/1.4892794

Kastelein, R. A., Gransier, R., Marijt, M. A.T., and Hoek, L. (2015a). “Hearing frequencies of a harbor porpoise (Phocoena phocoena) temporarily affected by played back offshore pile driving sounds,” J. Acoust. Soc. Am. 137, 556–564, DOI: 10.1121/1.4906261.

Kastelein, R. A., Gransier, R., Schop, J., and Hoek, L. (2015b). “Effect of intermittent and continuous 6-7 kHz sonar sweep exposures on harbor porpoise (Phocoena phocoena) hearing,” J. Acoust. Soc. Am. (In press, March 2015).

Kastelein, R.A., Hoek, L., Gransier, R. (2015c) The Cumulative Effects of Exposure to Continuous and Intermittent Sounds on Temporary Hearing Threshold Shifts Induced in a Harbor Porpoise (Phocoena phocoena). (In press, Budapest book. Submitted to editors September 2013).

Kastelein, R.A., & The SEAMARCO Research team, 2011 Temporary hearing threshold shifts and recovery in a harbor porpoise and two harbor seals after exposure to continuous noise and playbacks of pile driving sounds, Part of the Shortlist Masterplan Wind 'Monitoring the Ecological Impact of Offshore Windfarms on the Dutch Continental Shelf'. SEAMARCO Ref: 2011/01: 20p.

Kastelein, R.A., L. Hoek & R. Gransier, 2013b. Hearing thresholds of two harbour seals (Phoca vitulina) for playbacks of multiple pile driving strike sounds. J. Acoust. Soc. Am. 134(3): 2307-2312.

Kastelein, R.A., P.J. Wensveen, L. Hoek, W.C.Verboom, J.M. Terhune & R. Hille Ris Lambers, 2008. Underwater hearing sensitivity of harbour seals for tonal signals and noise bands. IMARES Wageningen UR report C040.08: 32p.

King S., I.M.D. Maclean, T. Norman & A. Prior, 2009. Developing Guidance on Ornithological Cumulative Impact Assessment for Offshore Windfarm Developers. COWRIE.

Kirkwood, R., O. Bos & S. Brasseur, 2014. Seal monitoring and evaluation for the Luchterduinen offshore windfarm 1. T0 - 2013 report. Report number C067/14, IMARES Wageningen UR: 47p.

Koldenhof & de Jong, 2013. [In Dutch] Scheepvaartbewegingen Prinses Amalia windpark, Analyse voor 2009, 2010 en 2011. Rapport nr. 25805.600-1-MSCN-rev.1. MARIN: 28p.

Krijgsveld, K.L., R.C. Fijn, M. Japink, P.W. van Horssen, C. Heunks, M.P. Collier, M.J.M. Poot, D. Beuker & S. Dirksen, 2011. Effect studies Offshore Windfarm Egmond aan Zee, Final report on fluxes, flight altitudes and behaviour of flying birds. NoordzeeWind report nr OWEZ_R_231_T1_20111114_flux&flight, Bureau Waardenburg report nr 10-219: 334p.

Lagerveld, S. Jonge Poerink, B., Haselager, R., Verdaat, H. 2014. Bats in Dutch offshore wind farms in autumn 2012. Lutra 2014 57 (2): 61-69.

Leopold, M. F., E.M. Dijkman, L. Teal & the OWEZ-Team, 2011. Local Birds in and around the Offshore Windfarm Egmond aan Zee (OWEZ) (T-0 & T-1, 2002-2010). IMARES Wageningen UR Report nr. C187/11: 176p.

Leopold, M.F. & C.J. Camphuysen, 2009. Did the pile driving during the construction of the Offshore Windfarm Egmond aan Zee, the Netherlands, impact porpoises? IMARES Wageningen UR Report number C0910-09: 17p.

Leopold, M.F. & R.S.A van Bemmelen, 2011. Local Birds in and around the "Prinses Amaliawindpark" (PAWP) during the T-1 surveys of 2009-2010. Wageningen IMARES: 47p.

Leopold, M.F., M. Booman, M.P. Collier, N. Davaasuren, R.C. Fijn, A. Gyimesi, J. de Jong, R.H. Jongbloed, B. Jonge Poerink, J.C. Kleyheeg-Hartman, K.L. Krijgsveld, Sa. Lagerveld, R. Lensink, M.J.M. Poot, J. Tjalling van der Wal & M. Scholl, 2014. Building blocks for dealing with cumulative effects on birds and bats of offshore windfarms and other human activities in the Southern North Sea. IMARES Wageningen UR Report number C166/14: 183p.

Leopold, M.F., R.S.A. van Bemmelen & A.F. Zuur, 2012. Responses of Local Birds to the Offshore Windfarms PAWP and OWEZ off the Dutch mainland coast. IMARES Wageningen UR Report nr. C151/12:108p.

Lindeboom, H.J., H.J. Kouwenhoven, M.J.N. Bergman, S. Bouma, S. Brasseur, R. Daan, R.C. Fijn, D. de Haan, S. Dirksen, R. van Hal, R. Hille Ris Lambers, R. ter Hofstede, K.L. Krijgsveld, M. Leopold & M. Scheidat, 2011. Short-term ecological effects of an offshore windfarm in the Dutch coastal zone; a compilation. Environmental Research Letters 6: 13p.

Lippert, S., M. Ruhnau, K. Heitmann, T. Lippert, O. von Estorff & M. Nijhof, 2014. COMPILE – An International Benchmark Study on the Prediction of Offshore Pile Driving Noise. Forum Acousticum 2014, 7-12 September, Krakow: 5p.

Lock, K., M. Faasse & T. Vanagt, 2014. Assessment of the soft sediment fauna six years after construction of the Princess Amalia windfarm. Ecoast Marine Research report 2013002: 151p.

Lucke, K., 2013. Telemetry studies in harbour porpoises – An overview of the technical and practical state of the art. IMARES report C043.13.

Lucke, K., Winter, H.V., Lam, F.P., Scowcroft, G., Hawkins, A., Popper, A.N., (2014). Report of the Workshop on International Harmonisation of Approaches to Define Underwater Noise Exposure Criteria (Budapest, Hungary 17th August 2013). IMARES Report C197/13.

Malcolm, F., J. Lancaster & A. Walker, 2013. Analysis of Marine Ecology Monitoring Plan Data from the Robin Rigg Offshore Windfarm, Scotland (Operational Year 2) Chapter 4: Non-migratory Fish and Electrosensitive Fish. Report: 1012206: 46p.

Meesters, E.H., 2014. [In Dutch] Aanvullende analyse van de dataset van de boxcore bemonstering. IMARES Wageningen UR Reference nr 14.IMA0253: 12p.

Merck, T. & R. Wasserthal, 2009. Assessment of the environmental impacts of cables. OSPAR Commission, Biodiversity Series: 19p.

Michel J., H. Dunagan, C. Boring, E. Healy, W. Evans, J.M. Dean, A. McGillis & J. Hain, 2007. Worldwide synthesis and analysis of existing information regarding environmental effects of alternative energy uses on the outer continental shelf. US department of the Interior, Minerals Management Service, Herndon, VA, MMS OCS Report 2007-038: 254 p.

Miller, R.G., Z.L. Hutchison, A.K Macleod, M.T Burrows, E.J. Cook, K.S. Last & B. Wilson, 2013. Marine renewable energy development: assessing the Benthic Footprint at multiple scales. Front Ecol Environ 11(8): 433–440.

Mueller, C., 2007. Behavioural reactions of cod (Gadus morhua) and plaice (Pleuronectes platessa) to sound resembling offshore wind turbine noise. Dissertation Mathematisch-Naturwissenschaftlichen Fakultät der Humboldt-Universität zu Berlin: 214p.

Mueller-Blenkle, C., P.K. McGregor, A.B. Gill, M.H. Andersson, J. Metcalfe, V. Bendall, P. Sigray, Da. Wood & F. Thomsen. Effects of pile-driving noise on the behaviour of marine fish. COWRIE Ref: Fish 06-08 / Cefas Ref: C3371: 62p.

Nedwell .J, A. Turnpenny, J. Langworthy & B. Edwards, 2003. Measurements of underwater noise during piling at the Red Funnel Terminal, Southampton, and observations of its effect on caged fish, Subacoustech Report Reference 558 R 0207, October 2003.

Nedwell J. & D., Howell, 2004. A review of offshore windfarm related underwater noise sources, Subacoustech Report Reference 544R0308, October 2004, To COWRIE, The Crown Estate, 16 Carlton.

Nielsen, B. & J. Carl, 2014. Horns Rev 3 Offshore Windfarm, fish ecology. Orbicon A/S Document no. HR-TR-025: 114p.

Pendleburry, C., R. McGregor & R. Walls, 2012. Integrated ecological monitoring plans (IEMPs) for proposed offshore wind sites. National Wind Coordinating Collaborative, Wind Wildlife Research Meeting IX, 27 - 30 November 2012: 1p.

Percival, S., 2014. Kentish Flats Offshore Windfarm: Diver Surveys 2011-12 and 2012-13. Ecology Consulting: 25p.

Perrow, M.R., J.J. Gilroy, E.R. Skeate & M.L. Tomlinson, 2011. Effects of the construction of Scroby Sands offshore windfarm on the prey base of Little tern Sternula albifrons at its most important UK colony. Marine Pollution Bulletin 62: 1661–1670.

Petersen, I.K. R.D. Nielsen & M.L. Mackenzie, 2014. Post-construction evaluation of bird abundances and distributions in the Horns Rev 2 offshore windfarm area, 2011 and 2012. Report commissioned by DONG Energy. Aarhus University, DCE – Danish Centre for Environment and Energy. 51p.

Poot, H., B.J. Ens, H. de Vries, M.A.H Donners, M.R. Wernand & J.M. Marquenie, 2008. Green Light for Nocturnally Migrating Birds. Ecology and Society 13(2): 47.

Poot, M.J.M., P.W. van Horssen, M.P. Collier, R. Lensink & S. Dirksen, 2011a. Effect studies Offshore Wind Egmond aan Zee: cumulative effects on seabirds, A modelling approach to estimate effects on population levels in seabirds. Bureau Waardenburg bv, report nr: 11-026, OWEZ_R_212_T1_20111118_Cumulative effects: 248p.

Poot, M.J.M., R.C. Fijn, R.J. Jonkvorst, C. Heunks, M.P. Collier, J. de Jong & P.W. van Horssen, 2011b. Aerial surveys of seabirds in the Dutch North Sea May 2010 – April 2011, Seabird distribution in relation to future offshore windfarms. Bureau Waardenburg report no 10-235: 277p.

Popper, A.N & M>C> Hastings, 2009. The effects of anthropogenic sources of sound on fishes. Journal of Fish Biology 75: 455–489.

Popper, A.N., 2014. From Cave Fish to Pile Driving: A Tail of Fish Bioacoustics. A.N. Popper and R.R. Fay (eds.), Perspectives on Auditory Research, Springer, Handbook of Auditory Research 50,Chapter 25: 467-492.

Prins, T.C., F. Twisk, M.J. van den Heuvel-Greve, T.A. Troost & J.K.L. van Beek, 2008. Development of a framework for Appropriate Assessments of Dutch offshore windfarms. Deltares report Z4513: 179p.

Raaijmakers, T., 2013. [In Ducth] Review studie "Mogelijke morfologische effecten van het Prinses Amaliawindpark" door ACRB. Deltares Memo 1208984-000-HYE-0004: 2p.

Rexstad, E. & S. Buckland, 2012. Displacement analysis boat surveys Kentish Flats. Centre for Research into Ecological and Environmental Modelling, University of St. Andrews: 22p.

Rijksstructuurvisie Windenergie op Zee, 2014. Ministerie van Infrastructuur en Milieu, Ministerie van Economische Zaken: 72p.

Rooijmans, P., 2012. [In Dutch] Zichtbaarheid van Prinses Amaliawindpark vanaf de kust bij Ijmuiden. Ecofys Projectnummer: HSENL12282: 42p.

Ruebens, J.T., S. Degraer & M. Vincx, 2014. The ecology of benthopelagic fishes at offshore windfarms: a synthesis of 4 years of research. Hydrobiologia 727:121–136.

Russell, D.J.F., S.M.J.M Brasseur, D. Thompson, G.D. Hastie, V.M. Janik, G. Aarts, B.T McClintock, J. Matthiopoulus, S.E.W. Moss & B. McConnell, 2014. Marine mammals trace anthropogenic structures at sea. Current Biology 24 (14): R638-R639.

Scheidat, M., G. Aarts, A. Bakker, S. Brasseur, J. Carstensen, P.W. van Leeuwen, M. Leopold, T. van Polanen Petel, P. Reijnders, J. Teilmann, J. Tougaard & H. Verdaat, 2012. Assessment of the Effects of the Offshore

Windfarm Egmond aan Zee (OWEZ) for Harbour Porpoise (comparison T0 and T1). IMARES Wageningen UR Report: OWEZ_R_253_T1_20120202, IMARES C012.12: 66p.

Scheidat M, Verdaat H & Aarts G. 2012, Using aerial surveys to estimate density and distribution of harbour porpoises in Dutch waters. Journal of Sea Research 69: 1-7.

Schekkerman H., J. van der Winden, H.A.M. Prinsen & P.W. van Horssen, 2006. [In Dutch] Birds and windenergy developments aong the dikes of the Noordoostpolder. Alterra, Bureau Waardenburg: 99p.

Schultz-von Glahn M., K. Betke & G. Nehls, 2006. Underwater noise reduction of pile driving for offshore wind turbines – Evaluation of several techniques under offshore conditions. UFOPLAN Ref. No. 20553113, final report Umweltbundesamt, Berlin.

Skov, H., S.B. Leonhard, S. Heinänen, R. Zydelis, N. Einar Jensen, J. Durinck, T.W. Johansen, B.P. Jensen, B.L. Hansen, W. Piper & P.N. Grøn, 2012. Horns Rev 2 Offshore Windfarm Bird Monitoring Program 2010-2012, bird migration. Orbicon, DHI, Marine Observers and Biola. Report commissioned by DONG Energy: 134p.

Stewart GB, Pullin AS, Coles CF (2007). Poor evidence-base for assessment of wind farm impacts on birds. Environmental Conservation, 34, 1–11.

Thompson, D, A.J. Hall, M. Lonergan, B. McConnell & S. Northridge, 2013. Current status of knowledge of effects of offshore renewable energy generation devices on marine mammals and research requirements. Edinburgh: Scottish Government: 110p.

Thompson, F., C. Mueller-Blenkle, A. Gill, J. Metcalfe, P.K. McGregor, V. Bendall, M.H. Andersson, P. Sigray & Daniel Wood, 2012. Effects of Pile Driving on the Behaviour of Cod and Sole. A.N. Popper and A. Hawkins (eds.), The Effects of Noise on Aquatic Life: 387p. Advances in Experimental Medicine and Biology: 730p.

Thomsen, F., C. Mueller-Blenkle, A. Gill, J. Metcalfe, P. K. McGregor, V. Bendall, M. H. Andersson, P. Sigray & Daniel Wood, 2012. Effects of Pile Driving on the Behavior of Cod and Sole. A.N. Popper and A. Hawkins (eds.), The Effects of Noise on Aquatic Life, Advances in Experimental Medicine and Biology 730: 387-388.

Tougaard, J. & J. Nabe-Nielsen, 2012. Offshore wind energy and marine mammals - Identified issues and perspectives (PowerPoint presentation). Aarhus University, department of bioscience: 21p.

Tucker, V.A., 1996. A mathematical model of bird collisions with wind turbine rotors. Journal of Solar Energy Engineering 118: 253-262.

Van Damme, C.J.G, R. Hoek, D. Beare, L.J. Bolle, C. Bakker, E. van Barneveld, M. Lohman, E. Os-Koomen, P. Nijssen, I. Pennock & S. Tribuhl, 2011a. Shortlist Masterplan Wind Monitoring fish eggs and larvae in the Southern North Sea: Final report part A. IMARES Wageningen UR Report number C098/11: 56p.

Van Damme, C.J.G, R. Hoek, D. Beare, L.J. Bolle, C. Bakker, E. van Barneveld, M. Lohman, E. Os-Koomen, P. Nijssen, I. Pennock & S. Tribuhl, 2011b. Shortlist Masterplan Wind Monitoring fish eggs and larvae in the Southern North Sea: Final report part B. IMARES Wageningen UR Report number C098/11: 377p.

Van der Molen, J., H.C.M. Smith, P. Lepper, S. Limpenny & J. Rees, 2014. Predicting the large-scale consequences of offshore wind turbine array development on a North Sea ecosystem. Continental Shelf Research 85: 60–72.

Van Hal, R., 2013. Roundfish monitoring Princess Amalia Windfarm. IMARES Wageningen UR Report number C117/13-A: 33p.

Van Hal, R., 2014. Demersal Fish Monitoring Princess Amalia Windfarm. IMARES Wageningen UR Report number: C125/14: 53p.

Van Hal, R., B. Couperus, S. Fassler, S. Gastauer, B. Griffioen, N. Hintzen, L. Teal, O. van Keeken & E. Winter, 2012. Monitoring- and Evaluation Program Near Shore Windfarm (MEP-NSW), Fish community. IMARES Wageningen UR Report C059/12, OWEZ_R_264_T1_20121215_final_report_fish: 161p.

Van Polanen Petel, T., S. Geelhoed & E. Meesters, 2012. Harbour porpoise occurrence in relation to the Prinses Amaliawindpark. IMARES Wageningen UR Report number C177/10: 34p.

Vanagt, T. & M. Faasse, 2014. Development of hard substratum fauna in the Princess Amalia Windfarm, monitoring six years after construction. ECoast report 2013009: 106p.

Vanagt, T., L van de Moortel & M. Faasse, 2013a. Development of hard substratum fauna in the Princess Amalia Windfarm, monitoring three and a half years after construction. ECoast report 2011036: 75p.

Vanagt, T., L. van de Moortel, J. Heusinkveld, M. Faasse, R. Pérez-Domínguez & K. Lock, 2013b. Assessment of the soft sediment fauna five years after construction of the Princess Amalia windfarm. ECoast report 2012011-2: 142p.

Vandendriessche, S., J. Derweduwen & K. Hostens, 2014. Equivocal effects of offshore windfarms in Belgium on soft substrate epibenthos and fish assemblages. Hydrobiologia 2014: 1-17.

Verfuss, U., 2012. Symposium Towards an Environmentally Sound Offshore Wind Energy Deployment. Federal Agency for Nature Conservation: 41p.

Walls, R., C. Pendlebury, J. Lancaster, G. Lye, S. Canning, F. Malcolm, V. Rutherford, L. Givens & A. Walker, 2013. Analysis of Marine Ecology Monitoring Plan Data from the Robin Rigg Offshore Windfarm, Scotland (Operational Year 2) Summary and introduction. Natural Power Consultants, Dalry, Dumfries and Galloway. 14p.

Werkgroep Onderwatergeluid, 2014. Verslag Werkgroep onderwatergeluid 20140516: 6p.

Williams, K., 2005. Guidance on cumulative impacts of offshore windfarms. SNH 2005: 32p.

Winter, H.V., G. Aarts & O.A. van Keeken, 2010. Residence time and behaviour of sole and cod in the Offshore Windfarm Egmond aan Zee (OWEZ). IMARES Wageningen UR Report number OWEZ_R_265_T1_20100916: 50p.

Wright, L.J., V.H. Ross-Smith, G.E. Austin, D. Massimino, D. Dadam, A.S.C.P. Cook, N.A. Calbrade & N.H.K. Burton, 2012. Assessing the risk of offshore windfarm development to migratory birds designated as features of UK Special Protection Areas (and other Annex 1 species). BTO research report no. 592, The British Trust for Ornithology, The Nunnery, Thetford, Norfolk: 211p.

Würsig, B., C.R. Greene & T.A. Jefferson, 2000. Development of an air bubble curtain to reduce underwater noise of percussive piling. Mar. Environ. Res. 49: 79-93.

WWF, 2014. Environmental Impacts of Offshore Wind Power Production in the North Sea, A Literature Overview. WWF-Norway: 25p.

Websites:

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

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

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

http://www.offshorewindfarms.co.uk

www.4offshore.com, 2014.

www.overhead.nl, 2014

Appendix 1 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 Programme
MINOS	Marine Warmblüter in Nord- und Ostsee (D)
MMO	Marine Monitoring Organisation (UK) or Marine Mammal Observer
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 Windfarm
OH&S	Occupational Health and Safety
OWEZ	Offshore Windfarm Egmond aan Zee
OWF	Offshore Windfarm
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)

Appendix 2 Overview of ongoing monitoring OWFs

This chapter presents an overview, in broad outlines, of the current monitoring programmes in OWFs in the Netherlands and other countries in the North Sea area. It presents how the programmes are structured and what studies are being carried out. Also an overview of the current study on the cumulative impacts of OWFs in the Netherlands (Framework Ecology and Cumulation (KEC) is given.

MONITORING PROGRAMMES FOR OWFS IN THE NETHERLANDS

Studies on the potential ecological effects of OWFs were carried out over the past 15 years in the Netherlands as well as in other countries in the North Sea area. In many cases this involved desk studies (EIAs and AAs). The EIAs and AAs included the most recent information on cause-effect relations of the construction and presence of OWFs on the ecological values at sea at that time. The AAs elaborated this information further and relate it to the area-specific nature protected by the Birds and Habitats Directive (Arends *et al.*, 2008). In 2008, Deltares made a support document for this purpose (Prins *et al.*, 2008).

CURRENT PROGRAMMES

In the Netherlands, a first desk study (EIA) was done in 2003 on the possible effects of an OWF for the pilot Offshore Windfarm Egmond aan Zee (OWEZ, formerly NSW). Shortly afterwards it was decided to build a second farm, the Prinses Amalia Wind Park (PAWP, formerly Q7). Currently, the OWFs Luchterduinen and Gemini are constructed. Permits were granted for these farms and included conditions for monitoring and evaluation of the effects of these farms (Monitoring and Evaluation Plans - MEPs). The conditions were in part produced after extensive consultation with the EIA committee.

For each of the windfarms, a short description of the MEPs that have been carried out is given in de the following paragraphs.

EGMOND AAN ZEE OFFSHORE WIND FARM (OWEZ)

OWEZ is located six nautical miles (NM) off the coast of Egmond aan Zee with a generating capacity of 108 MW. It was intended as a pilot for research on the technical, ecological, economic and social feasibility of windfarms at sea. A MEP addressing different topics was set up for OWEZ in 2001, two categories are included in the MEP-NSW: “Nature, the environment and user functions” and “Technology and economy”. A list containing the topics concerning the first category was presented in the first Masterplan and will not be repeated here, please see Masterplan 1.0 for the overview. The second category was created to focus on efficiency and cost reduction of OWFs. Data were collected on the (wind) climate at the site, the power and reliability of wind turbines, the degree to which the generated power can be predicted, manpower requirements for the wind turbines, maintenance aspects and the impact on other local uses such as shipping. This second category is not treated further in this Masterplan. For the first category many studies have already been conducted. The following studies contributed to deal with the (OWEZ) knowledge gaps between 2010 and 2014:

- Residence time and behaviour of sole and cod in the Offshore Windfarm Egmond aan Zee (OWEZ) (Winter et al. 2010).
- Short-term ecological effects of an offshore windfarm in the Dutch coastal zone; a compilation (Lindeboom *et al.*, 2011).

- Bird movements at rotor heights measured continuously with vertical radar at a Dutch offshore wind farm (Fijn *et al.*, 2015).
- Classification trees and radar detection of birds for North Sea wind farms (Meesters *et al*., 2007).
- Note of an additional analysis of the dataset from 2011 boxcore sampling in OWEZ and six reference areas with relevant covariates (Meesters, 2014).
- Assessment of the effects of OWEZ on harbour porpoises (comparison T0 and T1) (Scheidat *et al*., 2012), TNO Review of IMARES report 'Assessment of the Effects of OWEZ for Harbour Porpoises (comparison T0 and T1)' (Blacquière *et al*., 2012).
- Habitat preferences of harbour seals in the Dutch coastal area: analysis and estimate of effects of offshore windfarms (Brasseur *et al*., 2012).
- Effects on birds of OWEZ: An overview and integration of insights obtained (Hartman *et al*., 2012).
- Effect studies OWEZ Final report on fluxes, flight altitudes and behaviour of flying birds (Krijgsveld *et al*., 2011).
- Baseline studies North Sea wind farms: fluxes, flight paths and altitudes of flying birds 2003-2004 (Krijgsveld *et al.*, 2005).
- Nocturnal movements and flight altitudes of Common Scoters *Melanitta nigra*: Research north of Ameland and Terschelling, February 2004, for the baseline study Near Shore Wind farm (Dirksen *et al.*, 2005).
- Local Birds in and around OWEZ (T0 & T1, 2002-2010) (Leopold *et al*., 2011).
- Flight patterns of birds at offshore gas platform K14: Flight intensity, flight altitudes and species composition in comparison to OWEZ (Fijn *et al*., 2012).
- Effect studies OWEZ: cumulative effects on seabirds; A modelling approach to estimate effects on population levels in seabirds (Poot *et al*., 2011).
- Monitoring- and Evaluation Program Near Shore Windfarm (MEP-NSW): Fish community (Van Hal, *et al*., 2012).
- Impact of OWEZ windfarm on the local macrobenthos community (Bergman *et al*., 2012).
- Development of benthic communities on hard substrates of OWEZ (Bouma & Lengkeek 2012).
- Kastelein, R. A., Gransier, R. Hoek, L, Macleod, A., and Terhune, J.M. (2012a). "Hearing threshold shifts and recovery in harbor seals (*Phoca vitulina*) after octave-band noise exposure at 4 kHz," J. Acoust. Soc. Am. 132, 2745-2761.
- Kastelein, R.A., Gransier, R., Hoek, L. and Olthuis, J. (2012b). "Temporary threshold shifts and recovery in a harbor porpoise (*Phocoena phocoena*) after octave-band noise at 4 kHz," J. Acoust. Soc. Am. 132, 3525-3537.
- Kastelein, R.A., Hoek, L., Gransier, R., and de Jong, C.A.F. (2013a). "Hearing thresholds of a harbor porpoise (*Phocoena phocoena*) for playbacks of multiple pile driving strike sounds" J. Acoust. Soc. Am. 134, 2302-2306. DOI: http://dx.doi.org/10.1121/1.4817842.
- Kastelein, R.A., Hoek, L., Gransier, R., de Jong, C.A.F., and Jennings , N. (2013b). "Hearing thresholds of two harbor seals (*Phoca vitulina*) for playbacks of multiple pile driving strike sounds," J. Acoust. Soc. Am. 134, 2307-2312. DOI: http://dx.doi.org/10.1121/1.4817889.
- Kastelein, R. A., van Heerden, D., Gransier, R., and Hoek, L (2013c). "Behavioral responses of a harbor porpoise (*Phocoena phocoena*) to playbacks of broadband pile driving sounds," Marine Environmental Research 92, 206-214, DOI: 10.1016/j.marenvres.2013.09.020

PRINSES AMALIA WIND PARK (PAWP)

PAWP is located 23 km off the coast of IJmuiden and is the world's first windfarm outside the twelve-mile zone. The windfarm has been operational since June 2008 and research was done from 2008 to 2012. Prior to construction (T0), during construction (T1) and during the operational phase (T2), seabird counts in several surveys took place. The observations were conducted according to standard procedures from the

European Seabirds at Sea (ESAS) database, in which all the birds and marine mammals are counted present in an area 300 m wide on both sides of a ship.

To investigate the effect of the windfarm on the (local) morphology of the seabed, measurements took place before and after construction (in 2003, the baseline and in 2013). The researchers found that while changes in the seabed have occurred, they matched the natural, expected seabed changes in this area. There were (other than local scour around foundations) no (undesirable) effects on the seabed morphology by the windfarm (ACRB, 2013; Graven, 2013; Raaijmakers, 2013).

TNO conducted research on underwater noise from the turbine piling in 2007 and from the operating windfarm in 2013. The measured sound levels during pile driving were comparable to those measured in the UK and Germany (De Jong & Ainslie, 2012). The sounds emanating from the turbines did not significantly add to the ambient noises like wind and shipping. It was speculated seals would be able to hear the operating turbines at 100 meters distance while harbour porpoises would not(Jansen & De Jong, 2014).

IMARES investigated during T2 whether there were differenceson the numbers, species and age of round- and flatfish between catches. Catches within and outside of the windfarm differed. The main commercial and non-commercial species of flat fish were analysed in the laboratory. Inside the windfarm the size proportion differed slightly from outside of the farm in the fact that more large fish were found inside. The investigation showed that the absence of (bottom) fisheries may have had a positive effect on some fish species (van Hal, 2013 & 2014).

To determine whether birds are deterred from the area IMARES carried out research on birds after the construction of the windfarm. The research shows that most seabird species commonly found in the area react to the windfarms. Some bird species of bird, including gannets and kittiwakes, were counted less after the construction of the windfarms. Cormorants were clearly attracted by the windfarm (Leopold *et al.*, 2012; Leopold & van Bemmelen, 2011).

Other research included:

- Development of hard substratum fauna in the Princess Amalia Windfarm, monitoring three and a half and six years after construction (Vanagt *et al.*, 2013a; Vanagt & Faasse, 2014).
- North Sea Windfarms: Q7, Lot 1 Benthic Fauna (Jarvis *et al.*, 2004) and assessment of the soft sediment fauna five and six years after construction of the Princess Amalia windfarm (Vanagt *et al.*, 2013b; Lock *et al.*, 2014)
- Shipping movements for the Princess Amalia windfarm (Koldenhof & de Jong, 2013).
- Research on radar disturbance caused by the Princess Amalia windfarm and OWEZ, results from field experiments during calm waters in 2010 (Dielemans, 2012).
- Visibility of the Princess Amalia windfarm from the coast at IJmuiden (Rooijmans, 2012).

OWF LUCHTERDUINEN

In 2014 ENECO started building the OWF Luchterduinen (formerly Q10) planned to finish by the end of 2015. A Monitorinng and Evaluation Programme (MEP) will be conducted, covering the following topics:

- Underwater noise measurements;
  - Far range pile driving measurements;
  - Operational phase measurements: alternative project is formulated.
- Sublethal effects (injury and long-term) of pile driving sound on juvenile sea bass and fish larvae;

- Harbour porpoises in the DEPONS project;
- Bats;
- Harbour seal and grey seal tagging study in southwestern Delta and western Wadden Sea (T0, TC and T1). Reports: Spatio-temporal distribution along the Dutch West coast (Aarts *et al.*, 2013) and seal monitoring and evaluation for the Luchterduinen offshore windfarm 1, T0 - 2013 (Kirkwood *et al.*, 2014);
- Seabird counts, shipbased in and outside LUD, OWEZ and PAWP to study avoidance behaviour (draft report T0 has been submitted);
- Migrating bird counts. ENECO takes part in the ORJIP project, aiming at development of a bird collision and flux quantification system.
- Bat research: in preparation.

OWF GEMINI

The OWF Gemini is planned for construction in 2015. A Monitorinng and Evaluation Programme (MEP) will be conducted, covering the following topics:

- Underwater noise measurements;
  - Far range pile driving measurements;
  - Operational phase measurements.: alternative project is formulated
- Pile driving and fish (alternative MEP project): lab experiments at Seamarco on behavioural reactions of Sea Bass to playbacks of offshore pile driving sounds;
- Harbour seal and grey seal tagging study eastern Wadden Sea(T0, TC and T1).
- Harbour porpoises: Aerial countings of harbour porpoises during pile driving to study avoidance behaviour, in addition with CPOD studies. (T0, TC and T1).
- Seabird counts, shipbased in and outside Gemini OWF to study avoidance behaviour.
- Migrating birds: no project formulated yet.
- Colony breeding birds: no project formulated yet.

INTERNATIONAL MONITORING PROGRAMMES FOR OWFS

Internationally, monitoring and research programmes have also been set up, such as for the German, and Belgian OWFs. Strategic studies were carried out that included field measurements, such as for the British OWFs. As far as we know, the data of the baseline studies carried out for the German windfarms 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 and most of these studies are publically available.

OVERVIEW OF MONITORING ACTIVITIES IN EUROPEAN OFFSHORE WINDFARMS

Within Europe, England and Denmark still have a great share of operational offshore windfarms in 2014. Recent information on OWFs is provided by the UK. Germany is still relatively limited in sharing monitoring data, though several conducted monitoring studies are publically available.

Below an overview of the published international studies after 2010 are given.

Denmark

- Responses of harbour porpoises to pile driving at the Horns Rev II offshore windfarm in the Danish North Sea (Brandt *et al.*, 2011)

- Horns Rev 2 Offshore Windfarm Bird Monitoring Program 2010-2012, bird migration (Skov *et al.*, 2012).
- Offshore wind energy and marine mammals - Identified issues and perspectives (PowerPoint presentation Tougaard & Nabe-Nielsen, 2012).
- Danish Offshore Wind, key environmental issues – a follow up (Danish Energy Agency, 2013).
- Post-construction evaluation of bird abundances and distributions in the Horns Rev 2 offshore windfarm area, 2011 and 2012 (Petersen *et al.*, 2014).
- Offshore windfarms in the southwestern Baltic Sea: A model study of regional impacts on oxygen conditions (Janßen *et al.*, 2015).

Belgium

- The effects of pile driving on marine mammals and fish in Belgian waters (Haelters *et al.*, 2013).
- Windfarms in the Belgian part of the North Sea, the ecological effects examined (Brabant *et al.*, 2014).
- Enrichment and shifts in macrobenthic assemblages in an offshore windfarm area in the Belgian part of the North Sea (Coates *et al.*, 2014).
- The ecology of benthopelagic fishes at offshore windfarms: a synthesis of 4 years of research (Ruebens *et al.*, 2014)
- Equivocal effects of offshore windfarms in Belgium on soft substrate epibenthos and fish assemblages (Vandendriessche *et al.*, 2014).
  In situ mortality of sea bass juveniles due to pile driving: results of *in situ* experiments on wind mill foundations (Debusschere *et al.*, 2014).

United Kingdom

- Literature review on the potential effects of electromagnetic fields and subsea noise from marine renewable energy developments on Atlantic salmon, sea trout and European eel (Gill & Bartlett, 2010).
- Effects of the construction of Scroby Sands offshore windfarm on the prey base of Little tern *Sternula albifrons* at its most important UK colony (Perrow *et al.*, 2011).
- A review of methods to monitor collisions or micro-avoidance of birds with offshore wind turbines (Collier *et al.*, 2012).
- A review of flight heights and avoidance rates of birds in relation to offshore windfarms (Cook *et al.*, 2012).
- Potential interactions between diadromous fishes of U.K. conservation importance and the electromagnetic fields and subsea noise from marine renewable energy developments (Gill *et al.*, 2012).
- Integrated ecological monitoring plans (IEMPs) for proposed offshore wind sites (Pendleburry *et al.*, 2012).
- Displacement analysis boat surveys Kentish Flats (bird displacement) (Rexstad & Buckland, 2012).
- Effects of Pile Driving on the Behaviour of Cod and Sole (Thompson *et al.*, 2012)
- Assessing the risk of offshore windfarm development to migratory birds designated as features of UK Special Protection Areas (and other Annex 1 species) (Wright *et al.*, 2012).
- Assessing vulnerability of marine bird populations to offshore windfarms (Furness *et al.*, 2013).
- Modelling flight heights of marine birds to more accurately assess collision risk with offshore wind turbines (Johnston *et al.*, 2013).
- Marine renewable energy development: assessing the Benthic Footprint at multiple scales (Miller *et al.*, 2013).
- Analysis of Marine Ecology Monitoring Plan Data from the Robin Rigg Offshore Windfarm, Scotland (Operational Year 2) Chapter 4 (Malcolm *et al.*, 2013).
- Current state of knowledge of effects of offshore renewable energy generation devices on marine mammals and research requirements (Thompson *et al.*, 2013).
- Assessing environmental impacts of offshore windfarms: lessons learned and recommendations for the future (Bailey *et al.*, 2014).

- Kentish Flats Offshore Windfarm: Diver Surveys 2011-12 and 2012-1 (Percival, 2014).
- Predicting the large-scale consequences of offshore wind turbine array development on a North Sea ecosystem (Van der Molen *et al.*, 2014).

Germany

- Effects of pile-driving on harbour porpoises (*Phocoena phocoena*) at the first offshore windfarm in Germany (Dähne *et al.*, 2013).
- Ecological research at the offshore wind test site „alpha ventus“. Evaluation of the BSH standards for environmental impact assess-ment (StUKplus) 2009 – 2013 BSH (Federal Maritime and Hydrographic Agency), with manifold involved researchers (BSH, 2014).

VUM STUDIES (VERVOLG UITVOERING MASTERPLAN)

An overview of the results of the VUM (Continued Implementation Masterplan) studies from 2012 to 2015 is published in July 2015.

The research for VUM consisted of 9 sub studies:

- A sound model for piling at sea;
- A classification tool for cumulative effects of underwater sound (SORIANT);
- The effects of offshore piling sound on the hearing of Harbour Seals;
- The effect of piling sound on the survival of fish larvae;
- Swimming speeds of marine mammals in the North Sea;
- Modelling the number of seabird collisions with offshore wind turbines;
- Bat migration at sea;
- The effect of wind parks on seabirds.

Report delivered by the VUM research are:

- Nijhof M.J.J., Binnerts B., Ainslie M.A., de Jong C.A.F. (2015) Integration source model and propagation model, TNO Rapport, TNO 2015 R10186
- von Benda-Beckmann A.M., de Jong C.A.F., Binnerts B., de Krom P., Ainslie M.A., Nijhof M., te Raa L. (2015) SORIANT VUM – final report. TNO Rapport, TNO 2015 R10791
- SEAMARCO (2013) Hearing thresholds of two harbor seals (*Phoca vitulina*) for playbacks of multiple pile driving strike sound, Report no. 2013-02
- SEAMARCO (2015) Effect of pile driving sounds' exposure duration on temporary hearing threshold shift in harbor seals (*Phoca vitulina*), Report no. 2015-03
- Bolle L.J., de Jong C.A.F., Blom E., Wessels P.W., van Damme C.J.G, Winter H.V. (2014) Effect of pile-driving sound on the survival of fish larvae. IMARES, Report no. C182/14
- SEAMARCO (2013) Hearing thresholds of a harbor porpoise (*Phocoena phocoena*) for playbacks of multiple pile driving strike sounds, Report no. 2013-01
- SEAMARCO (2013) Behavioral responses of a harbor porpoise (*Phocoena phocoena*) to playbacks of broadband pile driving sounds, Report no. 2013-04
- SEAMARCO (2014) Hearing frequencies of a harbor porpoise (*Phocoena phocoena*) temporarily affected by played back offshore pile driving sounds, Report no. 2014-05
- SEAMARCO (2015) Effect of pile driving sounds' exposure duration on temporary hearing threshold shift in harbor porpoises (*Phocoena phocoena*), Report no. 2015-09
- SEAMARCO (2015) Hearing thresholds of a harbor porpoise (*Phocoena phocoena*) for narrow-band sweeps (0.125-150 kHz), Report no. 2015-02
- Aarts G.M., Brasseur S.M.J.M., Winter H.V., Kirkwood R.J. (2015) Persistent maximum swim speed of harbour porpoise, harbour seal and grey seal.
- Lagerveld S., Jonge Poerink B., de Vries P. (2015) Bat activity at the Dutch continental shelf in 2014, IMARES Wageningen UR, Den Helder, Report no C094/15

- Lagerveld, S, Aarts, G, Jonge Poerink B, Winter E. (in prep.) Offshore bat activity at the Dutch Continental Shelf in relation to coastal and offshore weather.
- Kleyheeg-Hartman J.C. (2014). Overzicht en korte beschrijving van beschikbare collision rate models. Notitie Bureau Waardenburg, Culemborg.
- Kleyheeg-Hartman J.C., Krijgsveld K.L., Collier M.P, Poot M.J.M., Boon A., Troost T.A., Dirksen S. (2014) Predicting collisions of birds with wind turbines offshore and on land: an overview and comparison of theoretical and empirical collision rate models. Article in preparation Bureau Waardenburg, Culemborg.
- Krijgsveld K.L. (2014). Avoidance behavior of birds around offshore wind farms. Overview of knowledge including effects of configuration. Rapport 13-268, Bureau Waardenburg, Culemborg.
- Leopold M.F., van Bemmelen R.S.A., Zuur A.F. (2013) Responses of local birds to the offshore wind farms PAWP and OWEZ off the Dutch mainland coast. IMARES Report no. C151/12.
- Leopold M.F., Booman M., Collier M.P., Davaasuren N., Fijn R.C., Gyimesi A., de Jong J., Jongbloed R.H., Jonge Poerink B., Kleyheeg-Hartman J., Krijgsveld K.L., Lagerveld s., Lensink R., Poot M.J.M. van der Wal J.T., Scholl M. (2014) Building blocks for dealing with cumulative effects on birds and bats of offshore wind farms and other human activities in the Southern North Sea. IMARES Report no. C166/14.

Within VUM an international Workshop on International Harmonisation of Approaches to Define Underwater Noise Exposure Criteria (Budapest, Hungary 17th August 2013) was organised directly following 'Third International Conference on the Effects of Noise on Aquatic Life' (11-16 Augustus) in Budapest Hongaria. Over 100 international experts (scientists and policy makers) on sound and ecology attended this workshop (white paper on noise regulations by Lucke, Winter & Lam and proceedings of this workshop Lucke *et al*., 2014).

FRAMEWORK ECOLOGY AND CUMULATION

The cumulative effects of all existing and planned windfarms on the DCS, and windfarms in other parts of the southern North Sea together, are according to the Dutch "Commissie MER" insufficiently investigated. However, knowledge of cumulative effects is essential when considering the creation of an overall plan that regulates the issuance of lots, i.e. individual tenders for certain pre-specified locations, taking into account ecological interests.

To gain more insight into the subject of cumulative effects, the Ministry of Economic Affairs has asked Rijkswaterstaat in 2014 to set up a project called 'Assessment framework ecology and cumulation of effects, 3rd Round Offshore Wind' (Dutch: Kader Ecologie en Cumulatie, KEC). This Framework of Ecology and Cumulation supervised two studies on (1) underwater noise and marine mammals and (2) operational OWFs and birds and bats. Reports of both studies are published in 2014 with all recent knowledge and knowledge gaps on the specific topics of birds and bats (Leopold *et al.*, 2014) and underwaternoise; (Heinis & de Jong, 2014). These studies have provided input to the Long List.

The framework is finished in 2015, but will be updated when necesseray.

ENVIRONMENTAL IMPACT ASSESSMENTS AND THE "WIND FARM SITE DECISION"

The focus of Environmental Impact Assessments (EIAs) and Appropriate Assessments (AAs) is on assessing the chance that (among others) significant negative ecological effects occur and on providing guidance on the use of mitigation. These assessments are individually carried out for each OWF. The outcomes of the KEC will be used in future assessments. After the initial assessments a “Wind Farm Site Decision” (Dutch: Kavelbesluit) will indicate where and according to which conditions the OWF can be built and exploited.

Figure 8: Process of environmental effect assessments and measures before the built of an OWF.

Appendix 3 Long List 2015 – extensive working table

Excel table

Appendix 4 Priority List Studies: basis for MEP

Chapter 4 describes the expert priority of knowledge gaps that need to be addressed. During the workshop, for each of these knowledge gaps a study was formulated. These studies are presented in this appendix and can form the basis of future Monitoring and Evaluation Programmes (MEP).

Note that paragraph structure correnspords with the structure of chapter 4 in which the knowledge gaps are described. Also, a summarizing table with the type and term of studies is given after the description of the studies.

Type of studies and accompanying timeframe

There are four different types of Priority List studies.

- *Generic studies that can be conducted without the presence of windfarms (G, WO)*. These studies can start on the short term, are independent of the planning or the construction of windfarms and address relevant knowledge gaps for adaptive management.
- *Generic studies that need to be conducted with the presence of windfarms (G, W)*. These studies can (possibly) start on short term in existing windfarms for effects in the operational phase of a windfarm, but need to be timed with the construction of the planned parks to study the effects of the construction phase of a windfarm.
- *Location specific studies that can be conducted without the presence of windfarms (LS, WO)*. These studies (e.g. reference monitoring, monitoring of migration routes) can start on the short term and are independent of the planning of the construction of windfarms.
- *Location specific studies that need to be conducted with the presence of windfarms (LS, W)*. These studies need to be conducted during the construction and in the operational phase of the planned windfarms and are therefore considered to yield results on long-term.

The following classification on the terms for research is followed:

- Short term (ST): projects run relatively short term, and already produce results after 1 to 2 years.
- Medium length term (MT): projects take two or three years or require additional analysis steps so that information is only available after 2 to 3 years.
- Long term (LT): projects are multi-annual (or can be addressed on the long term only), 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.

Both type and timeframe of research are not included as criteria for prioritization, though this information is essential to have for applying adaptive management. Short term gaps can and need to be addressed first, however this does not imply that long term gaps are of lesser importance or don’t need to be addressed.

Underwater noise (physics)

Propagation of underwater sound produced by pile driving – model validation

Model validation is currently already covered by existing projects. Therefore no additional short-list studies are formulated here.

Standardization of underwater acoustic measurements

Initiatives for standardization of underwater acoustic measurements are already ongoing. Therefore no additional short-list studies are formulated here.

Fish

Effect of pile driving noise on physical condition and behaviour

1. The study to be carried out is the collection of behavioural field data of native fish species by a large-scale tagging study in combination with an assessment of the acoustic exposure, to track the dispersion / migration of fish before, during and after the construction phase in both project and reference areas. A combination of fish caught in nets, following tagged fish and use 'control areas' (e.g. by experimental hard substrate) will give insights in composition, changes and relations.

   Type: Location specific study (but gaining knowledge that is generally applicable), with- and without OWF.

   Term: The study can start on relatively short term, but is expected to yield results on mid-term, approx. 2-3 years

2. The study to be carried out is to investigate the effects of pile driving on native fish species under controlled semi-natural circumstances with adult native fish species held in a floating pen in a harbour in the 'Oosterschelde', to study both behavioural and physical response to pile driving sound. The floating pen facility is already present and can be used for this study. There is a possibility to combine this study with threshold level quantifications in fish under laboratory conditions.

   Type: Generic study, without OWF.

   Term: The study can be carried out on mid-term, 2-3 years.

3. The study to be carried out is use the outcomes of the tagging and floating pen studies as input for population dynamic models, to study the effects of pile driving on the fish population in the North Sea. Existing models currently used for stock assessment can be adapted and used to assess effects on population level.

   Type: Generic study, without OWF.

   Term: The study can be carried out on long-term, 4-5 years, since it can only start after the tagging and floating pen studies are finished.

Marine mammals

Population dynamic parameters and habitat use

4. The study to be carried out is to monitor distribution of harbour porpoises in various seasons by aerial surveys on the Dutch Continental Shelf on two consecutive years. The study should be comparable to the study from 2011 and provide an update of the estimated abundance and distribution of harbour porpoises. The monitoring is preferably internationally coordinated and conducted in cooperation with surrounding countries like Belgium, UK and Germany. Information from SCANS III and Gemini monitoring should be integrated as much as possible. Also, the feasibility of use of high definition video for marine mammal mornitoring should be studied.

   Type: Generic study, without OWF. In case of denser monitoring on OWF areas -> location specific, with and without OWF.

   Term: The study can take place on mid-term (2-3 years), as multiple years of monitoring are proposed.

5. The study to be carried out is to improve the knowledge on habitat use of both seals and harbour porpoises by better and more accurate habitat modelling. Input from the monitoring studies (baseline information and indicators on abundance and distribution which can be used to describe patterns and predict future patterns, study 7 and 10) is necessary to improve the accuracy on the outcome of the modelling. Also comparison studies of different habitats are relevant (comparing quiet areas and busy areas; including change indicators e.g. resistance, less space, different human activities) (interview Scheidat, Brasseur & Aarts, 2015).

   Type: Generic study, without OWF.

   Term: The study can take place on mid-term (2-3 years), as input from the monitoring studies is required.

6. The study to be carried out is a large-scale tagging study for harbour porpoises in the Dutch coastal zone, preferably in close cooperation with the DEPONS project. Tagging studies for harbour porpoises have been conducted in Denmark, and provide valuable information on the behaviour of porpoises. It provides basic information about marine mammal behaviour; knowledge on social behaviour, migratory behaviour, feeding behaviour, independent of the impacts of OWFs. This study should also provide insight on the impacts of prey density, of prey is monitored or modelled in separate / other studies (interview Scheidat, Brasseur & Aarts, 2015).

   Also monitoring with acoustic techniques in 3D over a longer term is an option to consider in this study (interview Scheidat, Brasseur & Aarts, 2015).

   Tagging is believed to provide a tremendous amount of valuable data on e.g. behaviour, distribution and habitat use that can play a crucial role for many of the other proposed Priority List 2015 studies on harbour porpoises. Despite its challenging and costly nature, the tagging of harbour porpoises is considered as highly valuable for the impact assessment of offshore windfarms in both construction and operational phase.

   Type: Generic study, without OWF.

Term: The study is challenging and is considered as long-term (>3 years).

7. The study to be carried out is to analyse tagging data of seals in the Dutch coastal zone that havebeen collected over the past years and to combine this with habitat modelling to gain insight in the habitat use of Dutch marine waters by seals. Field data areare available for circa 500 seals, these could be analysed to determine direct and long term response of seals, differences between males and females, etc. (interview Scheidat, Brasseur & Aarts, 2015).

   Type: Generic study, without OWF.

   Term: The study is considered as mid-term (2-3 years).

Threshold values for TTS, PTS, and avoidance

8. The study to be carried out is to better estimate threshold levels for PTS (by extrapolation of TTS growth curves) and avoidance in seals under laboratory conditions, determine hearing thresholds of seals while swimming at the water surface, and determine the directionality of underwater hearing of seals in the horizontal pane.

   Type: Generic study, without OWF.

   Term: The study can presumably take place on short-term (approx. 1 year) .

9. The study to be carried out is to validate the avoidance based on threshold levels and modelled sound propagation by collecting and analyses of field data. This study will be mainly based on the analyses of tagged seals in combination with an assessment of the acoustic exposure and a change in distribution of avoidance during pile driving activities.

   Type: Location specific, with OWF.

   Term: The study can take place on mid-term (approx. 2-3 year).

Assessment of effect on population level

10. The study to be carried out is getting more accurate insight in the relation between the response of individuals to disturbance by pile driving and the effects on population level. This study is a follow-up on the Interim PCoD modelling study and includes better quantification of key assumptions and improving the accuracy of the modelling output. One important step in this study is to support SMRU in a new expert elicitation process specifically for the species in the North Sea (harbour porpoise and seals), in which population dynamic parameters are more accurately estimated. DEPONS could for harbour porpoises provide, among others, input by calculating energy and population consequences of specific human activities (interview Scheidat, Brasseur & Aarts 2015).

    Type: Generic study, without OWF. International collaboration.

    Term: This study can take place on short term and rapidly show results (approx. 1 year).

11. The study to be carried out is to quantify the energy budget of the harbour porpoise under laboratory conditions, including effects of increased swimming speed, seasonal fluctuations in body weight, respiration rate, blubber thickness, reduction in body mass due to fasting, maximum food intake and weight gain after fasting. This study focuses on the harbour porpoise only, as this species constantly needs to forage for its energy balance and is therefore sensitive to temporary disturbances. The outcomes can be used for model optimization (e.g. InterimPCoD, DEPONS).

    Type: Generic study, without OWF.

    Term: The study can take place on short and mid-term (1-3 years).

12. The study to be carried out is to assess the effects of pile driving on the foraging efficiency of harbour porpoises under laboratory conditions. This study gives insight whether foraging efficiency is actually decreasing during avoidance behaviour.

    Type: Generic study, without OWF.

    Term: The study can take place on mid-term (2-3 years).

Birds

Effects of collision on population level of birds

13. The study to be carried out is the development of a system to actually measure collision of birds, identify the species colliding and to assess and be able to determine the number of collisions at species level. This could be the further roll-out of the WT Bird system including cameras, but there might be other systems available internationally (ORJIP). The specific aim is to develop an operational warning system for avian collisions in offshore wind farms. The results can also be used for the validation of models by which effects on population level are assessed.

    Type: Generic study, with OWF.

    Term: The study is considered to have results on mid-term (2-3 years).

14. The study to be carried out in combination with the avian collision system (item 17). Results are bird flux intensities in current and future windfarms by means of horizontal and vertical radar measurements, thermal imaging cameras and visual panorama view observations by researchers. The results will be used as flux intensity warning system (radar only), for the validation of models by which effects on population level are assessed, use of flight corridors by (species of) birds. Essential for this study is international cooperation and cooperation with ORJIP, as well as knowledge gathered in OWEZ with the WT-Bird set-up and TAD.

    Type: Location specific, with OWF.

    Term: The study is considered to have results on mid-term (2-3 years).

Habitat loss or change

15. The study to be carried out is to assess the seasonal abundance and distribution of specific bird species in both wind farms and reference areas.

    It is proposed to assess this by High-Definition video cameras during aerial surveys. High resolution is required, compared to the current MWTL programmes, in which transects are widely spread and limited in number (interview Poot, 2015). However, a local change to the flight route of the current MWTL programme allows to study a specific site (f.e. a proposed OWF) in more and sufficient detail.

    The use of radar is useful for a continuous quantification of large-scale flying movements and flying altitudes of both local birds and passing migrants, specifically at night and during bad weather conditions, when the viewing conditions for regular observations are limited. Radar is however affected by precipitation, especially X-band, so a 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, that 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 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.

    Also, it is proposed to conduct a tagging study for high priority species such as lesser black-backed gulls and sandwich terns (both colonial breeders). Tagging of birds is a that quickly developing method at the moment. and can provide information in 3D on habitat use and flight heights .of individual birds. Several tagging studies have been executed in the Netherlands, amongst others on lesser black-backed gulls at Texel and sandwich terns in the Voordelta, but it is also possible to use this technique species like gannets and guillemots . Apart from the currently protected colonies threatened by extinction, also surrounding colonies can provide relevant information on wind farm / bird interactions via tagging (interview Leopold, 2015). Furthermore, a clear list of biological parameters, that is consistently used by all involved researchers and stakeholders is relevant for the effect studies on survival, micro- and macro-avoidance (interview Brenninkmeijer, 2015).

    Type: Location specific, with and without OWF.

    Term: The study is considered to have results on long-term, since surveys need to be conducted in multiple years (>4 years). Feasibility study: < 1 year. Mini-radar development: 1 year.

Bats

Effects of collision on population level of bats

16. The study to be carried out is to measure bat occurrence in species composition as well as in numbers over the southern North Sea as a function of distance to the coast, season and weather condition. Also, migration routes of bats across the North Sea should be determined. The bat flux in current and future windfarms should be assessed, by registering species composition and specific abundance by installing bat detectors in the windfarms and analysing the data. Also, if feasible, the number of fatalities should be assessed in relation to the wintering populations of the relevant species in the UK that migrate over the North Sea (not the catchment populations in eastern Europe). Fatalities should be investigated with a thermal-imaging camera, possibly in combination with bird fatality research. For efficiency, the study can be combined with proposed

bird-studies. Bats are likely to be detected by the radar studies as proposed to measure bird fluxes in OWFs, though identification will be challenging.

Type: Location specific, with OWF.

Term: The study is considered to be able to start on short term and quickly yield results, but will take mid-term as a result of multiple years of monitoring (2-3 years).

General aspects

International collaboration and data and knowledge sharing

17. The desk study to be carried out is to identify existing (inter)national collaboration initiatives (both offshore and onshore), whether these fit within the concept of an international knowledge and data management centre, what has to be done (compilation, formats) to enable the sharing of data and to be the basis of which a translation from data to policy can be made. This should be an international effort in which participation from directly neighbouring countries is required (B, UK, D, DK), but also countries outside of this range as part of the ecosystem reach of species involved (N, S, Can, USA to global China, Japan).

    Type: Generic, without OWF.

    Term: The desk study can start on short-term (< 1 year), but has to be implemented on mid- to long-term. (2 - 3 years).

18. The desk study to be carried out is identifying the feasibility of an international conference on migration routes and habitat change for birds and bats), in which all new insights will be shared between countries and where alignment in research and (mitigation) methodologies and programmes can be created and harmonisation of governance explored. It is essential to consider all the ongoing initiatives in conferences and platforms to assess whether additional conference would be additional value.

    Type: Generic, without OWF.

    Term: The study can be conducted on short-term (approx. 1 year).

The table below gives a summary of the Expert Priority List studies described above.

Table 4 Summary of Expert Priority List 2015 studies (G: Generic, LS: Location Specific, W: With OWF presence, WO: Without OWF Presence, ST: Short-Term, MT: Mid-Term, LT: Long-Term).

		G, WO	G, W	LS, WO	LS, W	ST	MT	LT
Fish								
1	Behavioural field data	X	X	X	X		X	
2	Floating pen behavioural studies	X					X	
3	Population dynamic modelling	X						X
Marine Mammals								
4	Monitor distribution porpoises by aerial surveys	X	X	X	X		X	
5	Modelling habitat use porpoises	X					X	
6	Tagging study harbour porpoises	X						X
7	Analyses seal tagging data	X					X	
8	Threshold levels quantification in seals	X				X		
9	Validation of behavioural thresholds with field data				X		X	
10	Response avoidance on population level porpoises and seals	X				X		
11	Energy budget porpoises	X					X	
12	Foraging efficiency porpoises	X					X	
Birds								
13	Development of collision measurement system		X				X	
14	Bird flux measurements				X		X	
15	Bird distribution monitoring			X	X			X
Bats								
16	Bat detection				X		X	
General								
17	International data and knowledge sharing centre	X					X	
18	International workshop	X				X		

APPENDIX 3 BEHORENDE BIJ MASTERPLAN 2015

On this page the table with information gaps from the Masterplan 1.0 has been copied and pasted in red. In green, ARCADIS has made new columns for the update of the original table. The second sheet shows a list of all the found sources and references for the update. At the bottom of this sheet we have incorporated new found information gaps which were not part of the original table. Blue text is taken from interviews which have not yet been confirmed by the expert. The columns "status", "feasibility" and "value of answering the remaining information gap" have been filled in using expert knowledge, this is not "hard" data and open for discussion.

Table 3.3 from the original Masterplan.

Aantal groen | Validatie aannames KEC | Validatie aannames MER en PB | van Belang voor adaptief management | validatie effectiviteit mitigerende maatregelen | kans op internationale samenwerking | tevens van belang voor bruinvisbeschermingsplan of KRM | Aantal groen

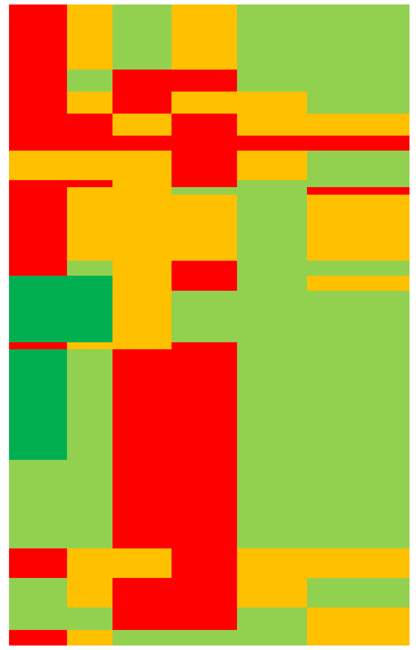
Aantal groen	Report Longlist numbers		A: Physical effect	B: Interference category	C: Ecological problem	D: Information required	E: Information gap	F: Information questions	G: Topic / Title / Information	H: literature	I: Status (+ = solved, ± = partly solved, - = not solved)	J: Remaining information gap	K: Feasibility (high, average, low)	L: Expected outcome for this information gap on the short term (<5yrs) including questions / remarks / highlights for workshop	M: Interview feedbacks	N: Value of answering the remaining information gap, based on the status, feasibility, expected outcome and interview feedbacks (1-10)	O
		2	Plankton														
0	9	3	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	Predicting the large-scale consequences of offshore wind turbine array development on a North Sea ecosystem (Van der Molen et al., 2014): "Because of the different spatial scales of the response of the three models, the combined results suggested a combination of environmental changes within the windturbine array that marine organisms might respond to". ACRB, 2013: Bottom morphology analyses suggest no major changes in bottom morphology due to the Princess Amalia Windfarm. (Due to changing currents, hydrodynamics, etc.)	Van der Molen et al., 2014; ACRB, 2013	-	Disruption of zoo-and phytoplankton communities by offshore windfarms	average, research could be quite extensive	Information on the difference in zoo- and phytoplankton communities in- and outside of windfarms, related to the currents. Gathered from field or lab research. *Note: effects on zoo- and phytoplankton communities from pollution or toxicity from the (placing of) wind turbines would also fall under this knowledge gap.*	Knowledge gap: Uncertainty on population effects of disturbance. (This comment was originally directed at marine mammals from Christ de Jong. It can however be seen as relevant for all different species in and around OWFs, including zoo- and phytoplankton species.)	[illegible]	
		4	Benthos														
1	11	5	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.	The results indicate no short-term effects on the benthos in the sandy area between the generators, while the new hard substratum of the monopiles and the scouring protection led to the establishment of new species and new fauna communities. Bivalve recruitment was not impacted by the OWEZ wind farm. Species composition of recruits in OWEZ and the surrounding reference areas is correlated with mud content of the sediment and water depth irrespective the presence of OWEZ. Recruit abundances in OWEZ were correlated with mud content, most likely to be attributed not to the presence of the farm but to the absence of fisheries. (Short-term ecological effects of an offshore wind farm in the Dutch coastal zone; a compilation). ; Marine renewable energy development: assessing the Benthic Footprint at multiple scales	Lindeboom et al., 2011 ; Coates et al., 2014; Miller et al., 2013	±	Information on the change in organism composition as well as chemistry on site and the time in which it recovers. Already a lot of information is available on this topic, for this reason it could be seen as less relevant for short term research.	low. Information would need to be won before and after the build of an OWF, both in benthos community composition as well as chemistry. Research would be extensive and costly. Furthermore, because information is already available this topic could be seen as having a low priority at this point in time.	Information on change in organism composition and chemistry on site and recovery time, for at least one windfarm.	Arjen Boon: Knowledge gap [illegible]	[illegible]	
0	12	6			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.	Research has shown that noise exposure during larval development in marine invertebrates can caise body malformations.	Aguilar de Soto et al., 2013;	-	effects on the benthos by toxic substances released from the bottom during construction/removal of turbines and installation/removal of cables. Bioaccumulation.	low, this is very site-specific.	Information gathered pm effects on the benthos by toxic substances released from the bottom during construction/removal of turbines and installation/removal of cables and on bioaccumulation, either on site or in the lab.		[illegible]	
0	13	7		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	Enrichment and shifts in macrobenthic assemblages in an offshore wind farm area in the Belgian part of the North Sea. ; Impact of OWEZ wind farm on the local macrobenthos community. ; Impact of OWEZ Wind farm on bivalve recruitment, this paper goes into the environmental variables, species composition and settlement, as well as the length of settlers and correlation between species distribution of bivalves and abiotic variables.	Coates et al., 2014; Bergman et al., 2012; Bergman et al., 2010	±	**mutual relations**; what determines the appearance of organisms and what is the **interaction with topography, physics and chemistry**	low, research on this detailed field will need a large budget and a very long time. The question also needs to be less broad. However, some information is already available.	More information on mutual relations between appearances of organisms, topography, physics and chemistry.		[illegible]	
0	14	8			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	Offshore wind farms in the southwestern Baltic Sea: A model study of regional impacts on oxygen conditions. ; Equivocal effects of offshore wind farms in Belgium on soft substrate epibenthos and fish assemblages. ; Marine renewable energy development: assessing the Benthic Footprint at multiple scales ; Between the turbines: soft substrate epibenthos and fish ; In the Robin Rigg OWF in Scotland, there was no evidence, to date (2012), that the construction and operation of the Robin Rigg Wind Farm has had any significant impact upon the benthic fauna in the immediate or surrounding area.	Janßen et al., 2015; Vandendriessche et al., 2014; Miller et al., 2013; Rutherford & Lancaster, 2013; Bouma & Lengkeek, 2012; Vanagt et al., 2013	+	n.a.	n.a.	n.a.		[illegible]	
0	14	9				benthos recruitment	recruitment processes	how does the recruitment of benthos proceed without and with hard substrate	Marine renewable energy development: assessing the Benthic Footprint at multiple scales ; Biodiversity and abundance of soft sediment benthos vary between different wind farms in the southern bight of the North Sea, yet densities and biomasses within a windfarm are in most cases not consequently different from those in reference areas, which indicates no measurable effects of wind farms on density and biomass of common benthos species. This pattern was confirmed during the present study (Lock et al., 2014). A study on the benthos infauna development before during and after the construction and during the operation of an OWF in Scottish waters concluded the following: "Changes in benthic community were due to dynamic nature of the Solway Firth and cyclical patterns in benthic fauna, rather than the impact of construction and operation. The ES predicted any impacts on the benthos as a result of construction activity would not be significant and where any may occur they would be of a short duration. On this basis of this analysis the ES predictions appear to be correct." (Walls et al., 2013)	Miller et al., 2013; Lock et al., 2014; Walls et al., 2013	±	how does the recruitment of benthos proceed without and with hard substrate	average; this question is quite broad, it needs to be specified first.	As this question is not specified on OWF scale, it is seen as too broad. Also a lot of information on this topic is already available. The expected short term outcome is therefore limited.		[illegible]	
0	15	10			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.	-	-	-	effects on benthos of toxic substances (Al) which are released from anodes on turbine pilings. Bioaccumulation.	average; more information is needed but might be hard to accumulate.	Information on effects on benthos of toxic substances (Al) which are released from anodes on turbine pilings and on bioaccumulation.		[illegible]	
		11	Fish larvae						Fish larvae								
0	17	12	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	Distribution pattern studied but not expressed in percentages of the population. Another study on sandeel at the Horns Rev windfarm didn't show any major effects (Danish Energy Agency, 2013).	Van Damme et al., 2011A; Van Damme et al., 2011B; Danish Energy Agency, 2013.	±	Distribution of fish larvae in the windfarm areas **expressed in percentages of the population**	low, specific population numbers would be needed in and outside of the windarm areas which are hard to obtain.	Information on different species, but not expressed in percentages of the population.	Knowledge gap: Uncertainty on population effects of disturbance and uncertainty on the numbers of effected animals because of uncertain estimates of distribution and numbers. (This comment was originally directed at marine mammals from Christ de Jong. It can however be seen as relevant for all different species in and around OWFs, including benthos species.)	[illegible]	
0	18	13				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 area of the dispersion area	Distribution pattern studied but not expressed in percentages of the population.	Van Damme et al., 2011A; Van Damme et al., 2011B; Danish Energy Agency, 2013.	-	**percentage of surface area** where the wind farms have an **effect** on fish larvae in comparison to the surface are of the dispersion area	low, as it is practically impossible to research the effects of the windfarm on the larvae population.	Possibly a little bit of information on the effect of windfarms on fish larvae but no percentages.		[illegible]	
0	19	14	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	common sole: no evidence found that survival of larvae depends on the different levels of exposure to piling noise. (Bolle et al., 2011); The greater likelihood is that fishes and invertebrates will be injured by high intensity impulsive sounds with rapid rise times, and that some of these injuries could result in fatalities over the short term or over a longer term if animal fitness is compromised (Halvorsen et al. 2011, 2012a, b; Casper et al. 2012a, b, 2013a, b). If an animal is injured it may be more susceptible to infection because of open wounds or a compromised immune system. Even if the animal is not compromised in some way, it is possible that the damage will result in lowered fitness, reducing the animal's ability to find food or making it more subject to predation (Hawkins et al., 2014).	Bolle et al., 2011 ; Hawkins et al., 2014	±	effects of pile driving noise on physical condition of fish larvae, including threshold values on other species during pile driving.	High, research is ongoing for multiple species (executed in VUM)	Information on the effects of pile driving noise on physical condition of fish larvae, including threshold values, on other species than already studied.	Hans Slabbekoorn: [illegible]	[illegible]	
0	20	15				radius of damage/mortality to source	threshold values, noise effects	effects of pile driving noise on physical condition of fish larvae, including limit values	common sole: no evidence found that survival of larvae depends on the different levels of exposure to piling noise.	Bolle et al., 2011	±	effects of pile driving noise on physical condition of fish larvae, including threshold values , other species and radius of damage/mortality to source during pile driving.	average, costly and many candidate species, but feasible to obtain.	The information gathered from the previous knowledge gap is needed to fill this one, for that reason the short term expected outcome is low. Also, information on the radius of damage/mortality to source is very hard to obtain. Knowledge about behaviour on the long term is needed.	Knowledge gap: Uncertainty on disturbance on the extend of disturbance due to uncertain threshold values for relevant behavioural effects. [illegible] (This comment was originally directed at marine mammals from Christ de Jong. It can however be seen as relevant for all different species in and around OWFs, including benthic species.)	[illegible]	
0	21	16		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	no recent information found	Popper & Hastings, 2009	-	effects of noises of operational wind farms on physical condition of fish larvae, including threshold values during the operational phase.	low, research is needed and could be done on this topic. Measuring physical effects on larvae may pose a problem however and effects might only occur after long-term exposure, which would mean extensive research and high costs. At this stage, effects are considered of lesser relevance.	Information on the effects of turbine noises on fish larvae.		[illegible]	
0	22	17				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	no recent information found	Popper & Hastings, 2009	-	effects of noises of operational wind farms on physical condition of fish larvae, including threshold values and radius of damage/mortality to source.	Average, depending on the level of detail and number of species which will be researched. At this stage, effects are considered of lesser relevance	The information gathered from the previous knowledge gap is needed to fill this one, for that reason the short term expected outcome is lower, also information on the radius of damage/mortality to source is very hard to obtain.	Knowledge gap: Uncertainty on disturbance on the extend of disturbance due to uncertain threshold values for relevant behavioural effects. (This comment was originally directed at marine mammals from Christ de Jong. It can however be seen as relevant for all different species in and around OWFs, including benthic species.)	[illegible]	
0	23	18	change 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	no information found		-	effects on fish larvae of toxic substances released from the bottom during construction/removal of turbines and installation/removal of cables	low, research is needed and could be done on this topic. It is however seen as negligible, because of the local characteristics of possible toxic releases and strict regulations regarding toxicity.	Information on the effects on fish larvae of toxic substances released from the bottom during construction/removal of turbines and installation/removal of cables.		[illegible]	
0	24	19		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	no information found		-	effects on fish larvae of toxic substances (Al) released from anodes on turbine pilings	average, research could be done on this topic and might be easy to preferm. It is however seen as negligible, because of the local characteristics of possible toxic releases and strict regulations regarding toxicity.	Information on the effects on fish larvae of toxic substances (Al) released from anodes on turbine pilings.		[illegible]	
		20	Fish						Fish								
3	26	21	underwater noise	pile driving	physical damage, disruption (disturbance)	sensitivity to frequency/levels	threshold values, noise effects	effects of pile driving noise on physical condition and behaviour of fish species, including limit values	Effects of exposure to pile driving sounds on fish inner ear tissues ; The effects of pile driving on marine mammals and fish in Belgian waters ; From cavefish to pile driving: a tail of fish bioacoustics ; The results show that cod and plaice were capable of detecting the sound and that cod showed significant avoidance behaviour to most of the produced sound fields with strongest reactions to sound between 60 Hz and 125 Hz. From the results it would be expected that the sound emitted by offshore wind farms could cause at least temporary changes in distribution of cod and plaice. (Mueller, 2007)	Casper et al., 2013; Haelters et al., 2013; Popper 2014 ; Mueller, 2007	±	effects of pile driving noise on physical condition and behaviour of specific native fish species, including threshold values	high, similar research has already been done, it just needs to be specified more to the Dutch environment and circumstances. Species need to be defined for this research	As a lot of information on this topic is already available, we do not see it as having high priority at this point in time. Research on the short term however could provide information on effects of pile driving noise on physical condition and behaviour of specific native fish species, including threshold values, as well as the effectiveness of ADDs during construction.	**Christ de Jong**, knowledge gap: [illegible] Hans Slabbekoorn: [illegible]	[illegible]	[illegible]
3	26	22				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	Halvorsen et al., 2012: Threshold for Onset of Injury in Chinook Salmon from Exposure to Impulsive Pile Driving Sounds; Nielsen & Carl, 2014: A Study for the third OWF in Danish waters on fish ecology. *"Even though some fish species are very sensitive to noise, no significant permanent effects are expected. However, fish may avoid the areas with high impacts, but return to the area shortly after the noise from the construction is ended."*	Halvorsen et al., 2012; Nielsen & Carl, 2014	±	effects of pile driving noise on physical condition and behaviour of specific native fish species, including threshold values	Average, radius may vary a lot between species and individuals. However, an indication could be given in combination with the research mentioned above.	More information is needed on the physical effects and threshold values for different species before the radius of damage/disruption to source can be studied. The question is quite broad. The expected outcome therefore would be general knowledge but no specifics for all species yet.	Knowledge gap: Uncertainty on disturbance on the extend of disturbance due to uncertain threshold values for relevant behavioural effects. (This comment was originally directed at marine mammals from Christ de Jong. It can however be seen as relevant for all different species in and around OWFs, including benthic species.)	[illegible]	
2	27	23		operational phase	physical damage, disruption(disturbance), 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	Fish lacking a swim bladder (e.g. gobies and flatfish) will only sense the measured particle acceleration at distance of about 10 meters from the foundation (Enger et al., 1993; Horodysky et al., 2009; PAPER V). Further away, most species are limited by either there hearing threshold or the ambient sound masking the wind farm noise. (Andersson, 2011)	Andersson, 2011	±	effects of noise of operational wind farms on the physical condition and behaviour of specific native fish species, including threshold values (sensitivity to frequency/levels)	high, research can be done in laboratory conditions.	Reserach is already on its way on this topic, the expected outcome is specific information for a limited amount of species.		[illegible]	
1	27	24				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	Fish will most likely respond in different ways to various noise sources. The tolerance thresholds are linked to age, sex, condition, season and habitat preferences (Hawkins, 1993; Mitson, 2000; Popper et al., 2004). (Andersson, 2011)	Andersson, 2011	±	effects of noise of operational wind farms on the physical condition and behaviour of specific native fish species, including threshold values (radius of damage/disruption to source)	Average, radius may vary a lot between species and individuals. However, an indication could be given in combination with the research mentioned above.	More information is needed on the physical effects and threshold values for different species before the radius of damage/disruption to source can be studied. The question is quite broad. The expected outcome therefore would be general knowledge but no specifics for all species yet.	Knowledge gap: Uncertainty on disturbance on the extend of disturbance due to uncertain threshold values for relevant behavioural effects. (This comment was originally directed at marine mammals from Christ de Jong. It can however be seen as relevant for all different species in and around OWFs, including benthic species.)	[illegible]	
1	28	25	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 fish species, including range and duration (temporary/permanent)	This study is the first to document the behavioral response of marine fish due to playbacks of piledriving sounds. The results indicate that a range of received sound pressure and particle motion levels will trigger behavioral responses in sole and cod. Our study further implies a relatively large zone of behavioral response to pile-driving sounds in marine fish. Yet the exact nature and extent of the behavioral response needs to be investigated further. Some of our results point toward habituation to the sound. (Thomsen et al., 2012) ; Instead of one threshold for behavioural response, we found a range of received sound pressure levels at which sole and cod react. This has important implications for management as we believe that any assessment proposing only single thresholds (e.g. Nedwell et al. 2007a) should be viewed with caution. We also found a range of reactions with significant differences across the test species indicating that impact assessments providing impacts zones for all marine fish fall short of their objective. (Mueller-Benkle et al., 2010)	Thomsen et al., 2012 ; Mueller-Benkle et al., 2010.	±	effects of work on construction/removal of wind farms on the behaviour of fish species, including range and duration (temporary/permanent)	average, depending on species and scope. The question is too broad and needs to be specified.	There is already information available on this topic, however the question is quite broad and specifics are still missing for specific species. However a general knowledge base has already come in place, therefore we deam it less important to answer this question in the specifics. The expected outcome is more general information.	Hans Slabbekoorn: [illegible]	[illegible]	
1	29	26		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	no specific information on this is available. General information on species distribution is available (Van Hal et al., 2012; Winter et al., 2010); Van Hal et al., 2012, monitoring program OWEZ: *"The surveys monitoring the species on a larger scale in the Dutch coastal zone did not show significant effects of the wind farm on the abundance of fish in the farm compared to the reference areas. This means that the construction of the farm and the exclusion of fisheries in the area did not lead to detectable changes in abundance of the monitored species."* and also: *"On the smaller scale of the wind farm clear differences were observed between the new artificial hard-substrate habitat and the sandy bottom."*; Van Hal, 2013, monitoring Princess Amalia OWF: *"The expectation that larger and older individuals as well as species vulnerable for fisheries would have a better chance to survive and so increase in size and numbers, is not supported nor reject by the data collected. The field work conducted as part of this study is too limited to draw statistically significant conclusions regarding the refugium function of the wind farm for roundfish."* Van Hal, 2014, Princess Amalia OWF: *"The overall impression is that fish species composition is equal inside to outside the wind farm. The expectation that larger and older individuals would have a better chance to survive and so increase in size and numbers, might be supported for the species analysed in this project."* This is in contrast to data found by the Environmental Group in 2013: "A	Van Hal et al., 2012; Winter et al., 2010; Van Hal, 2014; Van Hal, 2013	-	loss of habitat for (surface) rock avoiding fish species in comparison to the total, including species specification and species densities**, numbers.**	average, the question is quite broad and should be specified to species level preferably.	Information is available on the different species inhabiting the OWFs. However, numbers, densities and comparisons are quite difficult to measure or make as basic information is missing on most species. Therefore the expected outcome for this question will be more information on habitat use or avoidance but not on combination with total species specifications or densities.	Knowledge gap according to Hans Slabbekoorn: [illegible] Arjen Boon: [illegible] Effecten op adulte vissen [illegible]	[illegible]	
1	30	27			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	General information on species distribution is available, see previous knowledge gap.	Van Hal et al., 2012; Winter et al., 2010; Reubens et al., 2014; Nielsen & Carl, 2014	+	n.a.	n.a.	There is already a lot of information available on this topic, therefore we see this question as answered for the short term.		[illegible]	
0	31	28				density of species	numbers, seasonal rhythms	habitat potency (surface) of fish species with an affinity for rocks in comparison with the total, densities	general information available, no specifics. General information on species distribution is available, see previous knowledge gap.	Van Hal et al., 2012; Winter et al., 2010; The Environmental Group, 2013	±	habitat potency (surface) of fish species with an affinity for rocks **in comparison with the total, densities**	average, the question is quite broad and should be specified to species level preferably.	Information on total species densities and seasonal rythms is limited. More information on this is needed before this knowledge gap can be filled. On the short term the expected outcome is limited as well for the same reason.	Knowledge gap: Uncertainty on population effects of disturbance and uncertainty on the numbers of effected animals because of uncertain estimates of distribution and numbers. (This comment was originally directed at marine mammals from Christ de Jong. It can however be seen as relevant for all different species in and around OWFs, including fish and fish larvae.)	[illegible]	
0	32	29			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	General information on species distribution is available, see previous knowledge gap.	Van Hal et al., 2012; Winter et al., 2010; The Environmental Group, 2013	-	**changes** in density of fish species in (the vicinity of) the farm in comparison to the surrounding area, **numbers, seasonal rythms**	average, the question is quite broad and should be specified to species level preferably.	General information is available but needs to be specified more to the topic of refuge (less disruption), changes in species density, numbers, seasonal rythms and comparisons to the surrounding area. General information on this can be expected in the short term but might be hard to come by.		[illegible]	

0	33	30			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	General information on species distribution is available, see previous knowledge gap.	Van Hal et al., 2012; Winter et al., 2010; The Environmental Group, 2013	-	**changes** in density of fish species in (the vicinity of) the farm in comparison to the surrounding area, **numbers, seasonal rythms**	[illegible]	General information is available but needs to be specified more to the topic of refuge (change in bottom species), changes in species density, numbers, seasonal rythms and comparisons to the surrounding area. General information on this can be expected in the short term but might be hard to come by.	**Arjen Boon**: Vissen worden elders vandaan getrokken, is dat effect nul of leidt dat tot toename omdat ze worden opgehouden in dat gebied, groter worden? In cumulatief opzicht: is er systeemeffect op vissen? Connectiviteit voor benthos en vis wordt belangrijk; stepping stones, opgroeigebied voor vis met verhoogd niveau van bescherming bij veel windparken. Dat zou best meetbaar kunnen worden. • Hoelang zitten de dieren daar? • Wat eten de dieren? • Zou dat kunnen leiden tot een netto voordeel? Geldt zowel voor benthos als voor vissen. Door middel van metingen en modelleren kun je het aannemelijk maken. Effecten op adulte vissen: zijn er wel maar wordt niet beschouwd als een erg slecht effect. Eerder positieve effecten	6
1	34	31			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	General information on species distribution is available, see previous knowledge gap.	Van Hal et al., 2012; Winter et al., 2010; The Environmental Group, 2013; Van der Molen et al., 2014	±	density of **prey species** in (the vicinity of) the farm in comparison to the surrounding area	Low, this question is too broad.	As this question is formulated in a very broad manner, specific answers are not expected in the short term. This question needs to be specified more on prey items, etc.	Knowledge gap: Uncertainty on population effects of disturbance and uncertainty on the numbers of effected animals because of uncertain estimates of distribution and numbers. (This comment was originally directed at marine mammals from Christ de Jong. It can however be seen as relevant for all different species in and around OWFs, including fish and fish larvae.)	3
1	35	32			pollution	sensitivity to toxic substances	threshold values, effects of substances	effects of toxic substances (Al) released from anodes on turbine pilings on fish. Bioaccumulation.	no information available at this point.	-	-	effects of toxic substances (Al) released from anodes on turbine pilings on fish. Bioaccumulation.	High, initial research could be done on short notice.	This topic has not been researched a lot yet, the expected outcome on the short term therefore is information on the effects of toxic substances (Al) released from anodes on turbine pilings on fish and on bioaccumulation. Because of the local characteristics of possible toxic releases and strict regulations regarding toxicity this knowledge gap could be viewed as having [illegible]		7
1	37	33	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	some general information (<2010). ; Current knowledge suggests that EMFs from subsea cables and cabling orientation may interact with migrating eels (and possibly salmonids) if their migration or movement routes take them over the cables, particularly in shallow waters (<20m). The effect, if any, could be a relatively trivial temporary change in swimming direction, or potentially a more serious avoidance response or delay to migration. Whether this will represent a biologically significant effect cannot yet be determined (Gill & Bartlett, 2010). ; Nielsen & Carl, 2014: "*Studies have demonstrated that the EMF's from AC cables installed in relation to OWF does not exceed natural levels.*" ; Malcolm et al., *2014:* "No significant effect on electrosensitive species has been detected during the monitoring program." *(Robin Rigg OWF, Scotland).* See also comment René Dekeling (interview feedback)	Merck & Wasserthal, 2009 ; Mueller, 2007; Gill & Bartlett, 2010; Gill et al., 2012; Nielsen & Carl, 2014; Malcolm et al., 2013	±	effects of electromagnetic fields on the behaviour of specific native fish species, including threshold values.	Average, the question is quite broad but general information is already available. Research might be possible in lab conditions.	The topic has been studied on a general level. The expected outcome is research on the effects of electromagnetic fields on native species.	**Allix Benninkmeijer** knowledge gap: Gebrek aan kennis over elektromagnetische velden van stroomkabels in de zee. Mogelijk vallen de effecten mee, maar er is weinig over bekend over bijvoorbeeld de effecten op (bodem)vissen (mogelijk verstoring van elektroreceptie in zijlijnsysteem). **René Dekeling:** Regarding the scale and evidence of impact of emf, the ec has funded a project to study the environmental impacts of noise, vibrations and electromagnetic emissions from marine renewable energy devices, the marven project (marine renewables, vibrations, electromagnetics and noise). one goal of the project is to make an in-depth analysis of the current norms and standards and environmental impacts related to emf for marine renewable energy systems as well as performing relevant on-site measurements of emf from cables. the project will report their findings by june 2015. (www.marven.dhigroup.com).	7
1	38	34			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	Current knowledge suggests that EMFs from subsea cables may interact with migrating Anguilla sp. (and possibly other diadromous fishes) if their movement routes take them over the cables, particularly in shallow water (<20 m). The only known effect is a temporary change in swimming direction. Whether this will represent a biologically significant effect, for example delayed migration, cannot yet be determined.(Gill et al., 2012) A study before and during construction and operation in a Scottish OWF concluded "On the electrosensitive fish survey along the cable route elasmobranch abundance was low throughout the duration of the survey with only 43 individuals recorded in 80 trawls and no significant difference detected between survey periods" (Walls et al., 2013). Malcolm *et al*., 2014: "No significant effect on electrosensitive species has been detected during the monitoring program." "*Seasonal migrations occurred throughout the duration of the monitoring program suggesting that this was not affected by the presence of the Robin Rigg Wind Farm.*" (Robin Rigg OWF, Scotland). See also comment René Dekeling (interview feedback)	Gill & Bartlett, 2010; Gill et al., 2012; Walls et al., 2013; Malcolm et al., 2013	±	**percentage of surface area** where the wind farms have an effect on fish species in comparison to the surface are of the dispersion area, **migration areas**	[illegible]	According to Gill et al., 2012: "A number of important knowledge gaps exist, principally whether migratory fish species on the whole respond to the EMF and the sound associated with MRED. Future research should address the principal gaps before assuming that any effect on diadromous species results in a biological effect." In addition to that, more information is needed on migratory patterns and migration areas before this gap can be filled. The short term outcome is expected to be minimal.	**René Dekeling:** Very unlikely that the percentage will be a significant number, effect ranges will be very small. the potential for barriers blocking migration routes should be a clear main priority; check with the marven project for results	5
		35	Marine mammals						Marine mammals							
3	39	36	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	Surveys of harbour porpoises and seals have been conducted.	Poot et al., 2011B; Geelhoed et al., 2011; Brasseur et al., 2012	+	populations change, ongoing monitoring is needed.	High	Monitoring can be conducted on the short term, information is very relevant for further research and should have a high priority.	Knowledge gap: Uncertainty on population effects of disturbance and uncertainty on the numbers of effected animals because of uncertain estimates of distribution and numbers. (This comment was originally directed at marine mammals from Christ de Jong. It can however be seen as relevant for all different species in and around OWFs, including bird species.) Knowledge gaps **Meike Scheidat** (porpoises): Baseline information on abundance and distribution which can be used to describe patterns and also predict patterns into the future. Knowledge gaps **Sophie Brasseur** (seals): Verspreiding van zeehonden en hoe dit reeds gestuurd wordt door menselijke en natuurlijke processen. Dan kan bepaald worden hoeveel individuen precies verstoord worden door bepaalde activiteiten. Grote leemte is wat er nu al gebeurt in de zee. In kaart brengen wat er nu allemaal al gebeurt in de zee, visserij, scheepvaart, bommen & granaten, hoe sturen deze activiteiten de zeezoogdieren. Afhankelijkheid van ruimte en de ruimte om daarvan af te wijken. Ontbreekt aan goede ruimtelijke planning, waarbij ook natuur een element is. Wat zou voor bruinvissen en zeehonden de minst slechte keuze zijn voor locatie van een windpark. Knowledge gaps **Floor Heinis** (seals): Betere kaart voor de dichtheden nodig. Verwerking van nieuwe zendergegevens. **Geert Aarts** knowledge gaps: Aantallen van dieren en waar ze zitten; DEPONS rekent de energetische en populatie consequenties van specifieke menselijke activiteiten door. Als basis is het belangrijk om te weten hoeveel individuen worden beïnvloed en waar ze zich bevinden ten opzichte van de activiteit. Dergelijke basiskennis kan verkregen worden door vliegtuigtellingen	9
4	40	37				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	Harbour Porpoises: A GAMM-model was used to compare the data from CPODs within the wind farm to those in the reference area. This analysis showed no difference between the two areas, indicating no effect of the wind farm on the occurrence of harbour porpoises. The effect of wind farms is not totally clear yet for the distribution of seals.	Van Polanen Petel et al., 2012; Brasseur et al., 2012	±	**percentage** of surface area where the wind farms have an effect on marine mammals in comparison to the surface are of the dispersion area	[illegible]	[illegible]	[illegible]	[illegible]
2	41	38				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	Temporary hearing threshold shifts and recovery in a harbor porpoise and two harbour seals after exposure to continuous noise and playbacks of pile driving sound have been conducted, as well as underwater hearing sensitivity of harbour seals for tonal signals and noise bands.	Kastelein et al., 2011; Kastelein et al., 2008	+	Hearing sensitivity parameters such as: basic audiogram, critical ratio, directionality of hearing, and PTS, for a larger pool of animals and comparisons between lab and field conditions.	[illegible]	[illegible]	[illegible]	[illegible]
2	45	39	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	General information is available on the effects of pile driving on harbour porpoises and seals, as well as on subsequent behaviour (Kastelein et al., 2013; Kastelein et al., 2011; Kastelein et al., 2008; Leopold & Camphuysen, 2009; Thompson et al., 2013). Thresholds and limit values are hard to come by however, especially in the field. Please also refer to the "Werkgroep Onderwatergeluid", for example, reports on meetings, for more information on this knowledge gap.	Kastelein et al., 2013; Kastelein et al., 2011; Kastelein et al., 2008; Leopold & Camphuysen, 2009; Thompson et al., 2013; Werkgroep Onderwatergeluid 2014	±	Exact threshold values for pile driving effects on marine mammals. TTS growth curves exact effects. Masking effect on communication.	[illegible]	[illegible]	[illegible]	[illegible]
3	44	40				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	Kastelein et al., 2013a en b: "*The results suggest pile driving sounds are audible to porpoises at least tens of kilometers from pile driving sites.*" "*The present study suggests pile driving sounds are audible to harbor seals up to hundreds of kilometers from pile driving sites.; Pile driving activities could have influenced the seals distribution*" Brasseur et al., 2012: "*Pile driving for OWEZ and then Prinses Amalia Wind Park took up almost a year. The seals tracked during these constructions did not visit the area, thus effects cannot be excluded. This ranges up to at least 40 km's north of the wind farm, and over 1-00 km south of it.*" Dähne *et al., 2013 state for a German OWF: "Generalized additive modelling of SAM data showed a negative impact of pile-driving on relative porpoise detection rates at eight positions at distances less than 10.8 km. Increased detection rates were found at two positions at 25 and 50 km distance suggesting that porpoises were displaced towards these positions.*" The Environmental Group, 2013: "*This study documents harbour porpoise* [illegible]"	Kastelein et al., 2013a en b; Brasseur et al., 2012; The Environmental Group, 2013	+	Exact threshold values, radius of damage. Threshold-levels after pile driving. Sensitivity to sound in relation to frequency. Ecological consequences of TTS, PCoD validation.	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	46	41		operational phase	disruption, masking	sensitivity to frequency/levels, radius of damage/mortality to the source	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	[illegible]	Scheidat et al., 2012; Van Polanen Petel et al., 2012; Brasseur et al., 2012	±	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	47	42	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)	[illegible]	n.a.	±	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	48	43		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	[illegible]	Brasseur et al., 2012; Tougaard et al., 2012; Walls et al., 2013; The Environmental Group, 2013	±	**loss of habitat** for (surface) farm avoiding marine mammal species **in comparison with the total**, including species specification and species densities	[illegible]	[illegible]	[illegible]	[illegible]

3	59	51	collision and barrier effect	operational phase	collision risks	risk of collision	threshold values	percentage of collision of bird species in the farm, seasons	The analyses in this report have shown that the effects of the multiple offshore wind farm scenarios are far away from the levels above which decreasing trends occur and as such, this might be representative for multiple wind farms in the Dutch North Sea. Results mostly show a highly unlikely effect on population levels. In some cases there is no effect and there may be a positive cummulated effect for cormorants. Brabant et al. 2014: Op basis van de waargenomen vogeldichtheden in de parken en wiskundige modellen wordt geschat dat er jaarlijks ongeveer 1.300 zeevogels in aanvaring zullen komen met een turbine, wanneer alle acht geplande windmolenparken operationeel zullen zijn. Dit zullen voornamelijk grote meeuwen zijn, aangezien zij het vaakst op rotorhoogte vliegen (15-22%) (Vanermen et al. 2013a). The environmetnal group, 2013: "The computer model developed to assess cumulative effects of multiple wind farms on the red-throated diver population suggested there would be very small impacts from the three wind-farm development scenarios considered for Danish waters and the Baltic Sea. Even in the scenario where 15,000 km2 were classified as wind farms, a less than 2% change in the population level was predicted. Further development of the model, and better knowledge on the biology of red-throated divers, are needed to be able to draw conclusions with more certainty." WWF, 2014: "The risk of collision will vary greatly depending on the site, species and season. In order to fully evaluate the biological impact of birds colliding with wind turbines the data must be seen in relation to population size of the specific species and the demographic characteristics of that particular species." The environmetnal group, 2006: "Of 235,000 common eiders passing	Poot et al. 2011A; Brabant et al. 2014; The environmental Group, 2006 & 2013; WWF, 2014; Cook *et al.*, 2012; Poot *et al.*, 2011C; Grove *et al.*, 2013; Canning *et al.*, 2013; Furness *et al.*, 2013	±	**Percentage of collision** of bird species in the farm, seasons: more research is needed at other wind farms For the Dutch breeding birds, but also for foreign breeding populations, it is only possible to make predictions of population growth at the larger scale.	average, more general information is needed on collision and species density around OWFs, as well as on basic species distribution and numbers.	Research is on the way but difficulties do arise. The outcome on the short term includes more general information about species and collision, but no specifics yet.
2	60	52			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	Based on the recorded flight movement with radar and the visual observations it cannot be ruled out that the flight movements will yield collision victims. Based on the calculations done with the Band model the numbers of estimated collision victims are substantial. However, it is clear that the main effect of OWEZ is a positive one and must be regarded as habitat expansion. Without the presence of the metmast and the wind turbines, the distribution of **cormorants** would not be so far out at sea (Leopold et al., 2010). Potentially the collision victims in this respect must be regarded as a side effect of a larger positive effect. Brabant et al. 2014: "Zoals eerder vermeld worden ook bepaalde vogelsoorten aangetrokken door de windmolenparken. Of dit komt door de fysische aanwezigheid van de windmolens, als rustplaats of als referentiepunt in de open omgeving, of doordat ze reeds kunnen profiteren van een hoger voedselaanbod, blijft vooralsnog onbeantwoord. Veel meeuwen worden rustend op de nieuwe structuren waargenomen, maar er zijn ook aanwijzingen dat zeevogels nu al profiteren van een hogere voedsel- beschikbaarheid in het gebied. Zo is het percentage Drieteenmeeu- wen dat actief foerageert in het windmolenpark op de Bligh bank nu al veel hoger in vergelijking met een referentiegebied in de buurt (5,9 % versus 0,3 %). Hoge aantallen Kleine mantelmeeuw werden foerage- rend gezien in de buurt van de C-Power jacket-funderingen. Om deze hypothetische link tussen een verhoogd voorkomen van prooisoorten en hogere densiteiten zeevogels in de parken te ontrafelen, zal in de toekomst veel aandacht worden besteed aan het gedrag van zeevogels in de windmolenparken en aan het voorkomen van pelagisch vissoorten (Vanermen et al. 2013b)."	Brabant *et al.*, 2014; Poot et al., 2011A; Leopold et al., 2010; Brabant et al., 2014; Walls et al., 2013; Canning et al., 2013	±	Specifics on population development, foraging behaviour and quantities and species of fish still have to be provided	high, as the question is already specified to species level. Also, this could be attainable in the short term.	More specific information about comorants and the use of OWFs.
2	61	53			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	Effects of the construction of Scroby Sands offshore wind farm on the prey base of Little tern Sternula albifrons at its most important UK colony, this study was not linked to collision effects. Grove *et al.*, 2013 state: "*Effects on prey abundance and availability may be direct, or mediated via changes in habitats. This may increase or decrease habitat and food availability for some bird species and accordingly reduce or increase the magnitude of a particular risk (e.g. displacement or collision risk).*"	Perrow et al., 2011; Grove *et al.*, 2013	±	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, **for other species than the Little tern on other windfarms than Scroby Sands and in combination with collision and barrier effects**	low, it will first need results from food supply research in general and next it will have to be linked to the collision and barrier effects which would be too broad a question on the short term.	More general and basic information on food ecology, collision and barrier effects.
2	62	54				density of species	numbers, seasonal rhythms	density of bird species in the farm, seasons	This study represents the first attempt to estimate the cumulative effects of multiple offshore wind farms in part of the North Sea on the population levels of a range of species. The analyses in this report have shown that the effects of the multiple offshore wind farm scenarios are far away from the levels above which decreasing trends occur and as such, this might be representative for multiple wind farms in the Dutch North Sea.	Poot et al., 2011A	-	Seasonal variation and rythms of bird populations in the OWF	average, research can be done on existing wind farms in the North Sea area on local species, research might be extensive and costly.	Some general information is already available. On the short term monitoring can be done to fill this knowledge gap.
1	63	55						population dynamics of colonies (floaters)	This conclusion was confirmed by using the Potential Biological Removal approach; a method for estimating the level of sustainable mortality without causing a negative population trend. Emphasis should be placed on the fact that calculations were carried out conservatively and followed precautionary assumptions. Future research related to monitoring the effects around new offshore wind farms in deeper waters would likely yield results to confirm that in this report a worst-case approach has been followed.	Poot et al., 2011A	±	population dynamics of colonies (floaters)	average, the question is quite broad and should be specified to species level preferably.	On the short term more general information on species density and distribution patterns are needed, as well as more information on the food ecology of specific species. On the short term it is expected this knowledge gap will be partly filled.
3	64	56			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	In general, waterbirds reacted to the wind farms at distances of 5 kilometers while deflecting at 3 kilometers. Over 50 percent of the birds avoided passing through the wind farms at a distance of 1 to 2 kilometers203. It has been suggested that the detour caused by wind turbines is insignificant compared to the total length of migration. The observations gathered around OWEZ are not suitable for assessing the consequences of barrier effects at the population level, however, compared to the direct mortality associated with collisions with turbines the consequences of barrier effects are considered to be negligible. Another study in Denmark by Skov *et al.*, (2012) indicated that "for all main species the barrier effect could be judged as partial as no species completely abandoned the wind farms" and also "due to the limited spatial scale of the barrier effect of local seabirds at HR1 and HR2 no cumulative barrier effect exists between the two wind farms." indicating	Poot *et al.*, 2011A; WWF, 2014; Verfuss, 2012; Skov *et al.*, 2012; Furness *et al.*, 2013	±	Cumulative effects of wind farms on migratory birds	average, the question is quite broad and should be specified to species level preferably.	More information on migratory patterns and dispersion is needed before this question can be answered. The expected outcome therefore is limited.

Group	!! NEW !! (based on literature and interviews)
all species	Hans Slabbekoorn: Inzicht in cyclische variatie in combinatie met geluidseffecten: Van het probleem gereedschap maken; monitoring van geluid om het potentiele probleem in kaart te brengen. We weten nog weinig van de cyclische variatie van, weer, getij, tijd en de dag en nacht. Je kunt het opnemen maar het is onbekend wat de cycli voor variatie te weeg brengen en toevoegen van omgevingsgeluiden voor schade aanbrengen. Gaat op voor zeezoogdieren, vissen, kreeftachtige die geluiden maken? Larven van oesters vinden bv substraat door gebruik te maken van geluid. Gebieden met en zonder parken met elkaar vergelijken zodat je voorspellende modellen kunt maken.
all species	Knowledge gap Allix Brenninkmeijer: Gebrek aan kennis over precieze effecten van onderwatergeluid: zowel in aanlegfase tijdens het heien (mitigatie door het gebruik van pingers: is het werkelijke effect hiervan al in het veld onderzocht?) als in operationele fase door het 'gezoem' van de wieken (in welke mate heeft dit effect op zeezoogdieren, duikende zeevogels en vissen?).
all species and habitats	Meike Scheidat (harbor porpoises): Investigating other impacts, e.g. contaminants on reproductive success, that can be detrimental even though not as visible. Also: noise from different sources, shipping routes, prey competition, predator relationships. NOTE: This is relevant for all protected species and habitats!
bats	Mardik Leopold: Onbekend hoeveel vleermuizen er zijn, wel kwetsbaar voor botsingen, luchtdrukverschil is al genoeg voor een vleermuis. Vleermuizen trekken vaak richting windparken, dus er is een vrees dat er meer effect.
	Martin Poot:Voorkomen van vleermuizen; De bevindingen staan in de cumulatiestudie (zie concept document 15/12). Fluxen van trekkende vleermuizen op de Noordzee, zoveel slachtoffers dat het mogelijk doorwerking geeft op de populatie. Het gaat om twee soorten vleermuizen en mogelijk een derde, te weten ruige dwergvleermuis en rosse vleermuis (en mogelijk ook tweekleurige vleermuis) die de Noordzee oversteken. Mogelijke parallel met foeragerende gierzwaluwen.
bats	Missing knowledge gap: over vleermuizen is niet alleen te weinig bekend over het vóórkomen en gedrag op zee (aantallen in ruimte en tijd en in relatie tot het vóórkomen van obstakels als windturbines), maar ook over de omvang, verspreiding en trends van de populaties van de soorten die in potentieel substantiële aantallen over de (Noord)zee vliegen.
bats	The main knowledge gap is a reliable estimate of the number of fatalities of bats at sea.
bats	behavioural characteristics at sea of bats (e.g. flight and foraging heights, species-specific detection range, to what extent bats use echolocation during migration over sea, echolocation characteristics in relation to the number of fatalities.
bats	migration routes of bats across the North Sea
bats	a reliable estimate of the sizes of the catchment populations of bats. It is likely to assume that a large proportion of bats originates from countries such as Russia and Belarus. Population estimates from these countries are not available. In addition, there is insufficient kwowledge available on the life history characteristics of the Parti-coloured Bat.
bats and birds	Knowledge gap Allix Brenninkmeijer: Ook effect van wit licht bij boorplatforms. Misschien in het kader van de cumulatieve effecten kijken of dat een probleem is. Hoe zit het met verlichting bij windturbines en platforms , Voor vogels is wit licht het slechtst (i.v.m. desoriëntatie), rood licht is medium en groen licht is het minst desoriënterend. During the operational phase.
birds	Martin Poot knowledge gap: De invloed van configuratie van windparken op habitatverlies van verschillende soorten zeevogels: tussenafstanden in de range van 300 en 900 meter. We vermoeden dat barrière-werking vooralsnog geen groot issue is, omdat ligging kolonies en ligging windparken niet conflicteren. Doorvertaling naar verhoogde sterfte en effect richting populaties is noodzakelijk. Er is een statistische analyse geweest van huidige beschikbare data, maar veel variëteit van zeevogelvoorkomen speelt hierbij een rol. Ook data van baseline studies kunnen helpen om dit te tackelen. Configuratie speelt wel mee, ook bijvoorbeeld het type molens. Hoe dicht turbines naast elkaar staan is windturbine afhankelijk. Hand aan de kraan is daarom een belangrijk aspect. Ook onderhoud, onderzoek etc. hebben effect op vogels. Kleuren, lichten etc. zijn van ondergeschikt belang.
birds	Changing baselines, such as effects of climate change on population sizes and distribution patterns, have not yet been addressed and neither have several other factors that might impact at-sea birds numbers, simultaneously with offshore wind farm development.
birds	For migrant birds, the main uncertainties may lay in insufficient knowledge of the relevant catchment areas and the threats facing them elsewhere.
birds	There are no studies that have measured the effects of displacement of seabirds from wind farms, on seabird fitness.

3	10	benthos	Kennisleemten bij larven/benthos: • Aantal en soorten benthische larven: Wat is de samenstelling? En hoe belangrijk is dat voor de ontwikkeling van de gemeenschap? Als het gaat om verarming van bodemdieren en soortsamenstelling, dat treedt niet op bij windparken op zee. Je creëert een ander habitat. Heeft zo'n lokaal windpark een lokaal effect aggregatie? • Reproductie • Leeftijdsopbouw van benthos • Verschil tussen lokale en grootschalige effecten bij benthos • Inzicht in oorzaken van de verandering (en achterliggende mechanismen) (o.a. visserij). Hoe verwachten we dat een effect optreedt en hoe zouden we dat moeten meten? • Fysische bodemsamenstelling en de effecten die dat heeft op bodemdieren; relevante relaties om langdurige effecten in beeld te krijgen.
3	30	fish	Hans Slabbekoorn: Effecten op vissen: Vissen kunnen schrikken, weggejaagd worden of blijven in het gebied. Je hebt gebonden vissen en minder gebonden vissen. Ecologische 'val', dieren hebben een bepaald zoekstimuli om een gunstig ecosysteem te vinden. Relatie bij met name kabeljauw en natuurlijke gebieden en rondom windmolenparken, wat heeft dat voor gevolgen voor de reproductie van deze beesten?
1	20	fish	Hans Slabbekoorn: Antropogeen verstoorde gebieden en niet verstoorde gebieden is nog een kennisleemte bij vissen. Met betrekking tot vissen is er ook over paaigebieden nog niet veel duidelijk. - Dit in kaart brengen is wel reëel. Visserij stopt daar, dat is een overrulende factor m.b.t. lawaai en effecten van schepen. Dit dient integraal bekeken te worden.
0	1	general	Hans Slabbekoorn: Effecten van windparken: Systematische monitoring bij diverse parken, ruim voor aanleg en erna, op internationale schaal en samen met controlegebieden; Controlegebieden worden niet onderzocht. Dit onderzoek zou je voor en na aanleg parken moeten doen. Om begrip er uit te krijgen en het naar modellen te kunnen vertalen die voorspelbare waarde hebben. Wetenschappelijke replicatie en controle hanteren.
0	2	general	Arjen Boon: De insteek op cumulatieve effecten is een verandering tov het vorige masterplan, waarin alleen effecten op zichzelf zijn benoemd. (Mentioned bij several experts, incl. Allix Brenninkmeijer)
1		general	Demografische kenmerken: Functionering van organismen in het grotere systeem van de Noordzee. Voorbeeld: effecten van onderwatergeluid op bruinvissen, beschrijven van deze effecten kan met redelijke betrouwbaarheid, maar effecten op populatieniveau kan door middel van modellen maar geeft beperkt inzicht. Bandbreedte van de resultaten van PCOD is bijvoorbeeld nog groot.
2	3	general	Maps of North Sea species / ecosystems / counting events, etc.
		general	Nog kennisleemte van nieuwe methoden? Bv intrillen (Vibrohammer)
1	42	harbour porpoises	Meike Scheidat (harbor porpoises): - Knowledge on underlying parameters impacting distribution on a larger scale, e.g. prey availability, climate change. How to separate the effects from wind farm construction / operation from the larger scale changes of the ecosystem
3	40	harbour porpoises	Hans Slabbekoorn: Geluidseffect vang efficiëntie bruinvissen: De foerageer efficiëntie van bruinvissen kan achteruit gaan. Hierin kan SEAMARCO een rol spelen. Wat is de invloed van het lawaai? Lawaaikaarten samen met TNO kunnen zaken voorspellen.
2	31	harbour porpoises	Arjen Boon: Habitatafhankelijkheid (voedsel, bescherming bruinviskalven, dynamica populatie). Hoe afhankelijk is zo'n bruinvis nou van die windparkplek/habitat en hoe werkt dat nu door op populatieniveau?
4	44	harbour porpoises	De berekende effectafstanden zijn sterk afhankelijk van de gekozen discrete drempelwaarde. Informatie over de dosis-effect relatie voor bruinvissen is beperkt tot een laboratoriumstudie (SEAMARCO) en een aantal Duitse veldstudies. Meer gedetailleerde informatie over de dosis-effect relatie (waarbij het niveau van de gedragsreactie afhangt van het blootstellingsniveau en het achtergrondruisniveau) zou de schatting van het aantal mogelijk verstoorde dieren mogelijk robuuster kunnen maken. Mogelijk komt uit de monitoring rond de GEMINI windparken meer informatie beschikbaar over het effect van heigeluid op de activiteit van bruinvissen. Men kan zich echter afvragen of deze resultaten het inzicht in genoemde dosis-effect relatie op een substantieel hoger plan zullen brengen dan wat op grond van de resultaten rond het Borkum II23 West project nu al bekend is (maar nog niet toegepast in het Interim PCoD model). Het gaat daarbij zowel om informatie over het aandeel van de binnen de verstoringscontour aanwezige bruinvissen dat reageert als de duur van de verstoring (herstel bruinvisactiviteit).
2	8	invertebrates	Noise effects on invertebrates during the construction, operation and removal phases of an OWF.
3	5	model validation	Christ de Jong: Onzekerheid over geluidverspreiding vanwege gebrek aan validatie van bron- en propagatiemodellen heigeluid. Nog incomplete modellering van geluid van seismische airguns. Met name de validatie van bron- en propagatiemodellen heigeluid en de updates van Interim PCOD (samen met SMRU Marine) kunnen op korte termijn opgepakt worden. Directe monitoring, om effecten te vermijden, zoals in Duitsland wordt gedaan.
3	5	model validation	De modellering van de bronsterkte van seismische airgun arrays, en dan met name de afstraling in de richtingen die van belang zijn voor propagatie over grotere afstanden, in AQUARIUS behoeft verdere ontwikkeling en experimentele validatie.
3	5	model validation	Het door TNO ontwikkelde hybride model [Zampolli et al, 2013], waarmee het heigeluid wordt berekend uit gedetailleerde gegevens van heipaal, heihamer en omgeving, zou in principe een nauwkeuriger beschrijving van de geluidverspreiding kunnen geven, maar dit model behoeft nog nadere validatie én het vraagt meer gedetailleerde informatie over de projecten voor aanleg van windparken dan op dit moment voorhanden is.
3	5	model validation	De verspreiding van het geluid is berekend met het AQUARIUS model. Dit model is nog niet experimenteel gevalideerd voor afstanden groter dan 6 km. De verwachting is dat deze kennisleemte in de komende paar jaar (deels) wordt opgevuld. Bij de aanleg van de ENECO Luchterduinen 1 (2014) en GEMINI parken (2015) zijn en worden metingen op grotere afstanden uitgevoerd ten behoeve van de validatie van bron- en propagatiemodellering.
0	32	seals	Sophie Brasseur (seals): Hoeveel (ecologische) ruimte is er om de individuele patronen te veranderen? En hoe vast zijn die patronen van jaar op jaar? In theorie zet je je windpark in gebieden waar grote aantallen zeehonden van afhankelijk zijn (waar de dieren vaak komen). Zeehonden vertonen een zekere mate van plaatstrouwheid zowel w.b.t. ligplaatsen als ook foerageergebieden. Wat is de consequentie van doorbreken van dergelijke plaatstrouwheid als gevolg van verstoring? Zenderdata kan bij het onderzoek hiernaar een rol in spelen, maar weinig dieren zijn jaar op jaar gevolgd. OWEZ analyse 2008 is een goed begin, maar nu is er veel meer nauwkeurigheid en zijn veel meer dieren gevolgd
1		under water noise	De bronsterkte van het heigeluid is tot nu toe steeds geschat op basis van meetdata van Q7, als bovengrens van een range van schattingen met een bandbreedte van 6 dB. Daarbij is geschaald met de geschatte toe te passen hamerenergie. Experimentele validatie van deze schatting is zeer beperkt. Wel zijn vergelijkbare niveaus op afstanden rond 1 km van de paal bij OWEZ en Duitse parken gemeten.
2		under water noise	De nauwkeurigheid van de het aantal geschatte dierverstoringsdagen hangt eveneens af van de nauwkeurigheid van de beschikbare informatie over de ontwikkelingen in seismisch onderzoek op de Noordzee, die minstens zo onzeker is.
3	4	under water noise	Effects of pile-driving alternatives on species and habitats



all species	Tagging is seen as a realistic and wanted way of tracking animals.