DUTCH GOVERNMENTAL OFFSHORE
WIND ECOLOGICAL PROGRAMME

Rijkswaterstaat
Ministry of Infrastructure and the Environment

RWS UNCLASSIFIED

Offshore wind energy ecological programme (Wozep)

Monitoring and research programme 2017-2021

Date	24 november 2016
Status	Final

Colophon

Published by	Rijkswaterstaat
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Edited	Royal HaskoningDHV
Date	24 november 2016
Status	Final
Version number	1.0

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Preface

This document describes the monitoring and research programme Wozep for the period 2017 – 2021. It gives insight into the objectives of Wozep, the knowledge questions and research proposals. The Wozep steering committee (chaired by the Ministry of Economic Affairs) approved the programme on 17 November 2016 and will use it as a basis for the actual execution of the research proposals.
The programme 2017 – 2021 will be evaluated every year based on research results and developments that concern offshore wind farms in a broader sense (political, scientific and technological developments on a national and international scale). Therefore, the programme can be seen as a scope for the coming years, which is updated every year following which an adjusted plan is prepared for the following year. All formal documents from the Wozep project will be published on the website www. noordzeeloket.nl.

1 Introduction

1.1 General introduction

This “Monitoring and Research Programme 2017-2021” describes the overall monitoring and research programme for the Dutch Offshore Wind Ecological Programme (Wozep). Wozep is part of the assignment from the Ministry of Economic Affairs (EZ ED 2020) for Rijkswaterstaat (RWS). In 2015, EZ ED 2020 decided to set up an integrated monitoring and research programme to study gaps in our knowledge relating to the impact of offshore wind farms on the ecosystem of the North Sea. This generic programme was established in response to a recommendation from RWS, that knowledge gaps are primarily generic rather than specific for individual offshore wind farms (OWFs). This conclusion was based on research and monitoring set out for and executed during Round 1 and 2 OWFs. This led to the establishment of Wozep. The scope set out by the Ministry of Economic Affairs to RWS was issued in late 2015 for the period 2016 to 2021.

Wozep is not the first project to investigate the ecological impact of OWFs in the southern North Sea. During the last decade, the government has initiated several research programmes (the Shortlist and Master Plan Offshore Wind Energy (VUM) programmes) to study these ecological impacts, in addition to the mandatory monitoring and evaluation programmes (MEPs) for OWFs for which licences were granted. Both types of projects have provided valuable results. The first MEP of the pilot OWF OWEZ (Egmond aan Zee) (2006-2010), set out the basis of the Master Plan (2010). Additional research programmes and the consecutive MEPs for the OWFs Prinses Amalia (PAWP), Luchterduinen and GEMINI established the backbone of the long term ecological monitoring of offshore wind[1] . The Master Plan was updated in 2014-2015.

In the Monitoring and Research Programme 2017-2021 (MRP 17-21) the outline of the complete research and monitoring programme for the period 2017-2021 is set out. The programme leaves room for flexibility where required. Instances where flexibility may be required include but are not limited to:

- Changes following results from the undertaken research;
- Changes in policy; and
- Changes in priorities going forward.

In light of the above, we see the MRP 17-21 as a 75% outline which will be amended annually. The choices made and priorities given in this MRP 17-21 will be described as transparently as possible to set out the purpose of the research and how the findings will be used. In addition to the MRP 17-21, a separate Plan for 2017 will be developed. This will consist of the research from the MRP 17-21 that will take place during the year.

[1] Masterplan Ecologische effecten Wind op zee, 2010 http://www.noordzeeloket.nl/images/Masterplan%20Ecologische%20Monitoring%20Wind%20op%20Zee_624.pdf

Monitoring and research in Wozep must contribute to the following three objectives:

- Reduce (scientific) uncertainties concerning knowledge gaps and assumptions from the Framework Ecology and Cumulation (KEC), Environmental Impact Assessment (EIA) and Appropriate Assessment (AA).
- Reduce uncertainties concerning knowledge gaps and assumptions regarding long term impacts and upscaling of OWFs (in relation to OWF plans that may follow up on the roll-out of the Energy Agreement[2]).
- Determine effectiveness of mitigation measures (in the context of the 40% cost reduction in the Energy Agreement).

Wozep is part of an adaptive management process surrounding the legislative process for offshore wind in the Netherlands. Adaptive Management is a decision process that promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events are better understood[3]. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Part of adaptive management is the iterative cycle of Plan-Do-Check-Act (PDCA): as information and data are gathered over time, management approaches and decisions can be adapted to better accommodate the ecological process or system being managed, leading to better understanding of the target ecological system and improved management decisions (see Figure 1).

In the offshore wind legislative process this cycle is applied in the following way: in "Planning" EIA, AAs and the KEC are drawn up to determine whether and under what conditions wind farm site decisions could be issued for the selected wind farm sites. In "Doing" the goal is to reduce the scientific uncertainties around the assumptions made in Planning. This is the role of Wozep within the PDCA-cycle. In Wozep, the most important assumptions and associated uncertainties have been identified and linked to proposed research projects (see 1.2 for a description of this process). In "Checking" results from Wozep will be evaluated by checking against the assumptions made in Planning. This can lead to an adjustment in policies ("Act") for the next Planning phase. It can also lead to a direct adjustment of research proposals and priorities within the Wozep monitoring and research programme.

This logically applies to the first two goals of Wozep mentioned above, but also to the third goal of reducing uncertainties around the further upscaling of offshore wind. Therefore, by identifying uncertainties during Planning, attention was also paid to these types of uncertainties, specifically when certain ecological limits will be met.

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[2] Energy Agreement for Sustainable Growth: In September 2013 the Dutch government, together with more than fourty organisations signed the Dutch Energy Agreement (in Dutch: Energieakkoord) which describes the energy ambitions and targets up until 2023. The Energy Agreement reflects the ambitions and strategy for the energy transition from 2013 until 2023 in the Netherlands and includes clear targets and a high level roadmap. The fundamental objective is to strengthen the economic structure hand-in-hand with cleaner energy sources (and lower CO_2 emissions) through heavy investments in renewable energy such as wind and solar. The main goal of the plan is to increase the share of renewable energy as part of the total energy mix to 14% in 2020 and 16% in 2023. Full text available on: www.energieakkoordser.nl

[3] *IEA Wind Task 34 (WREN) Technical Report, December 2016* Adaptive management white paper, full text available on: www.tethys.pnnl.gov/about-wren

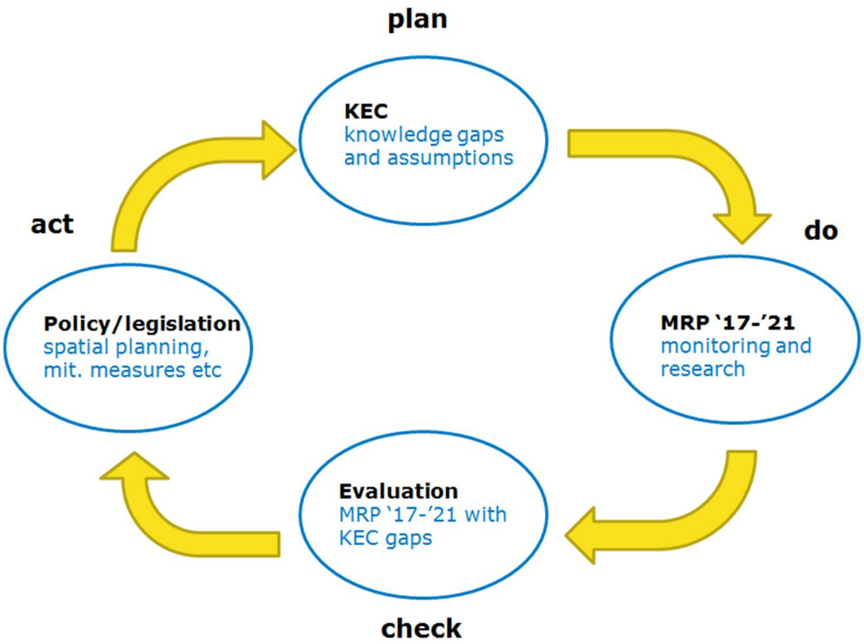

Figure 1 Plan-Do-Check-Act-Cycle

At the beginning of 2016, Wozep started a process of formulating a coherent set of research questions; building on former projects and transparently linking them to the objectives from Wozep (KEC). This process took several months. Parallel short term research projects (feasibility studies, inventory of international data and cooperation, etc.) were started. The results provided input for the MRP 17-21. These activities led to the MRP 17-21, this describes the most important knowledge gaps and the associated research questions for OWFs. The research questions form the input of the research to be carried out by research centres within the framework of Wozep.

1.2 The process so far

The first research projects of Wozep (Warnas, 2016) were started in 2016. These research projects are mostly studies on feasibility or inventories of current methods as preparation and input for the upcoming MRP 17-21 research period. The results of the studies in 2016 will be used as input for the MRP 17-21.
The path towards MRP 17-21 followed an open and transparent thinking process from management objectives and knowledge gaps towards research questions. Stakeholders were identified and involved in workshops or asked for comments on concept documents in order to come to a supported outline. The following paragraph describes the actions taken in the period April – November 2016.

First, the objectives for Wozep were determined and submitted to the Wozep steering committee for approval. Previously, high priority species groups had been defined such as birds, bats and marine mammals, fish and benthos were identified as lower priority species groups. However, it is worth noting that fish and benthos should be considered as they are an important part of the habitat as well as food resources for both birds and marine mammals. A list of all known knowledge gaps concerning these species groups was compiled from previous research and the KEC, EIA and AA for OWFs. During an internal government workshop (28 June 2016) a

selection was made of the knowledge gaps with the highest priority (based on Wozep objectives). These knowledge gaps were formulated into knowledge questions[4]. The outcome was approved by the steering committee Wozep on 15 September 2016.
The next workshop (29 September 2016), attended by Dutch knowledge institutes and Dutch research bureaus, discussed the knowledge questions and reformulated them into more detailed research questions. All parties were publicly invited (TenderNed) and attendants were selected on their relevant knowledge and were compensated for their time. The reports of the five topic specific workshops will be open to the public in order to share all available knowledge. Subsequently, the Wozep team analysed, evaluated and integrated the results into coherent clusters of research questions. Feasibility, costs and international connections were checked and evaluated. The results of this process are presented in the following chapters of this Programme '17-'21.

A draft programme was presented to the Wozep preparation and consultation group. The Wozep preparation group represents several relevant parts of the Dutch government and evaluated the programme on matters concerning logic, reasoning and synergy with connected dossiers. The consultation group represents stakeholders of the wind sector and NGOs who provides comments based on their specific areas of expertise. The Wozep team analysed and evaluated the input from these groups and decided if and where adjustment of the draft MRP17-21 was required.

The MRP 17-21 was approved by the Wozep steering comittee on 17 November 2016.

The prioritised research questions will be worked out to research projects which will be outsourced to knowledge institutes or research bureaus.

1.3 Reader's guide

The aim of the MRP '17-'21 is to provide a general description of the research scope/framework within WOZEP up until 2021. In addition to the MRP, a plan will be set out for each year which describes what research will be undertaken within that year. In this way the research framework is determined within the MRP '17-''21 but is still subject to change following research results and broader developments concerning offshore wind farms (political, scientific and technological developments on a national and international scale).However it is expected that most of the research described in the MRP will be undertaken.

The first chapter describes the background and aim of WOZEP and the process which resulted in the MRP '17-'21. The following chapters 2 through 7 describe the state of knowledge at the start of WOZEP, the research questions, the research started and/or executed in 2016 and the proposed research scope for 2017-2021 for each research topic (birds, bats, marine mammals, benthos and fish). With respect to the three aims for WOZEP the proposed research scope is categorised in priority 1, 2 and 3. If only part of the proposed research can be undertaken, items with priority 3 will be considered less crucial than priority 2 and priority 2 less crucial than priority 1. Research categorised as priority 1 should be executed regardless.

[4] RWS Verslag vraagarticulatieworkshop28 juni (in Dutch), available on www.noordzeeloket.nl

Not all research is directly associated with one specific WOZEP goal but provides information that serves multiple goals. This is also taken into account when prioritising research.

Between the research topics there may be a difference in the level of detail as this is dependent on the amount of knowledge that is currently available on the specific topic. In addition for some of the research that has been proposed multiple methods can be applied. As it would not be beneficial to propose only one method at this stage, several research methods are proposed. Within this document there is also some difference in structure between chapters; within the topics birds and marine mammals the proposed research has been categorised to show the relationship between sub research projects. Every research topic chapter concludes with a schematic diagram which visualizes the different phases of the research in a certain time frame. The diagram sets out the relationship between the different research projects, the WOZEP aims and the research questions and if applicable the relation to other research topics.

Chapter 8 describes the management of data and information within WOZEP, chapter 9 the importance of international collaboration within WOZEP and chapter 10 further describes the prioritisation between research topics taking into account that the use of data and new developments (such as new OWFs) can influence the prioritisation in the future. Finally chapter 11 describes the follow-up process within WOZEP once the MRP has been formally adopted by the steering committee.

2 Birds: displacement from habitat

2.1 State of knowledge at start of Wozep

For some species of offshore living seabirds, it has been observed that they tend to avoid areas where OWFs have been constructed. Many ship based and aerial monitoring surveys have shown that densities of several species of auks, gannets, tubenoses and divers decrease after the installation of wind turbines. Bird densities also decreased in neighbouring areas, where no new infrastructure was constructed. It is not known if this response is temporary (e.g. birds will return following habituation), or if the displacement from habitat is permanent for these species. Based on several studies in OWFs (e.g. the ship based bird surveys of ESAS (European Seabirds At Sea) in the UK, The Netherlands, Belgium, Denmark, Germany) species can be allocated to three categories:

- species that avoid OWFs
- species that are indifferent
- species that are attracted to the OWFs.

The Before-After results of the wind farms studies are reasonably consistent, particularly for the species that avoid OWFs. The research results also show that location, wind turbine characteristics and spatial configuration of the turbines within the wind farms, as well as habituation of the birds to their presence, should be considered as possible explanations for patterns in bird distribution in and around wind farms in species that do not (entirely) avoid them. These aspects require further investigation.

Until further clarification, in impact assessments (such as 'KEC') it has been assumed mainly for modelling purposes that there is a 10% mortality rate for birds that are displaced. Although this is based on the best available knowledge, at this moment very little is actually known about how habitat loss affects populations, or what will happen to species when the total surface area for OWFs continues to increase.

Apart from studying ecological effects of OWFs on behaviour and habitat use of birds and assessing the possible impact of these effects, it will also be necessary to improve our knowledge on other factors that may influence bird ecology. The development of OWFs is a new factor in this field, though birds may already be experiencing negative impacts as a result of other human activities such as disturbance in shipping lanes, oil and gas production platforms, pollution, fisheries etc. It would be useful, particularly for future marine spatial planning, to know how much room for OWFs can be created if other activities are also reassessed.

2.2 Research questions

1. To what extent do numbers / densities of seabirds of different species decrease in and / or in the vicinity of OWFs as a consequence of the presence of (operational) wind turbines? What is the time frame for this impact.
2. To what extent is this (partial) displacement in individual species linked to the spatial configuration of the turbines in the corresponding wind farms? (distance between turbines / density of turbines / size of turbines / value of possible 'flight escape corridors')

3. What is the additional mortality (or reduced fitness) of the displaced birds per species?
4. Up to which point is availability of offshore, out of breeding season feeding habitat in (parts of) the North Sea an ecological bottleneck? What is the threshold at which total area of habitat loss will become an issue?
5. Are 'Individual Based Models' (IBMs) the way forward to adequately model habitat use and food availability in relation to population development for reliable predictions about effects and impacts? Which seabird species have priority as conservation (status) targets, either because of particular sensitivity or vulnerability to habitat loss or because of declining populations. Which population parameters make up the key sensitive input to predict the maximum impact that might influence conservation targets of a (sub)population.
6. Which human factors other than (the development of) OWFs are likely to substantially influence seabird behaviour and / or habitat use to such an extent that impacts on (sub)populations cannot be excluded? Possible adverse effects of OWFs on habitat use by seabirds are unlikely to be the only human-induced adverse impact on bird populations. It would therefore be useful to gain some insight into other factors and their relative contributions to the actual state of conservation of the seabird species concerned. Questions such as: up to which point OWFs may contribute to unfavourable conservation status or whether extra limitations on those other human activities might enhance the possibilities of installing more OWFs are the ones we would want to get to grips with.

2.3 Wozep research 2016

Three preliminary studies were undertaken in 2016, concerning the issue of displacement and habitat loss of seabirds due to the presence of OWFs:

1. **International working conference highlighting displacement in relation to wind farm configuration.** A feasibility study investigating the possibility of organising a workshop for international North Sea seabird specialists, with the aim of establishing the actual state of the extent of displacement of common guillemots (*Uria aalge*) by OWFs in a peer-reviewed paper; in the workshop special attention will be given to differences in the rate of displacement as a function of spatial configuration of the turbines in the OWFs under survey
2. **Numbers and behaviour of guillemots in existing OWFs (OWEZ, PAWP, LUD) from a platform** A pilot study in an existing (Dutch) OWF, attempting to study actual behaviour of seabirds (with special focus on common guillemot) within and outside of the confines of the OWF, thus assessing whether or not this is a promising way of getting to grips with ecological consequences of (partial) habitat loss; this way forward in research of possible consequences of (partial) habitat loss could be of importance to estimate and eventually validate assumptions on additional mortality (or reduced fitness) of (partially) displaced birds
3. **Exploratory study on the survival of seabirds at sea during the year in relation to a selected area** The aim of this study is to provide a better understanding of whether offshore areas (both in- and outside of currently designated OWF areas) can be identified that, independent of local seabird densities, are more sensitive to the impact of OWFs than other areas. In other words, are birds in certain areas subject to more or less pressure than elsewhere, and how does this vulnerability vary with season? Conversely: which

species and which colonies (and in which seasons) are really expected to be affected by OWFs as planned? The results of this study should produce a much clearer picture of the actual relevant populations affected by OWFs as planned up until 2023. In addition, the research provides an understanding of spatial planning with respect to OWFs after the roll-out of the Dutch Energy Agreement. Input for this purpose is being gathered from a number of seabird ringer analysts working at ringing centres, in the Netherlands as well as in other countries (Isle of May, Scotland, and other locations in the UK, Helgoland, and Norway). In 2016 the possibilities afforded by the data up until then will be summarised in a feasibility study. It will then be possible to determine in late 2016 whether it will be meaningful to proceed with the substantive implementation of this study in 2017, possibly including the setting up of promising new field work.

2.4 Proposed research 2017-2021

The following research topics with respect to (partial) displacement, habitat loss and the possible negative (fitness-related) consequences for individual birds and hence for (sub) populations have been identified:

1. Identification of the 10 most vulnerable seabird species with respect to displacement by OWFs, based on both actual distribution data within and around OWFs as well as on available studies on before and after installation of OWFs[5]. Subsequently produce for these species:
   a) A quantification of the degree and time frame of displacement and potential habitat loss for each one the 10 species
   b) A general ecological profile for each of these species in the North Sea context, including the non-breeding habitat use of North Sea seabird (sub)populations of the 10 species (analysis of existing shared databases of North Sea seabird surveys as in e.g. [1]): identification of annual and seasonal fluctuations in non-breeding distribution in relation to environmental factors

   Priority 1: Of utmost priority since the results of this desk study are needed as a baseline for all other investigations proposed. The general knowledge of the ecology of the 10 most vulnerable seabird species for habitat loss and a state of the art insight into the degree of displacement they suffer are the basis for all other research topics. Particularly for the long term goal of Wozep (what are the consequences of the long-term development of offshore wind on the North Sea), it is crucial to gain an understanding of how a much larger total offshore wind footprint may have a negative impact on habitat use by these birds.
2. The (potential) consequences of habitat loss for individual birds involved has to be assessed as quantitatively as possible (in order to be able to extrapolate these to possible threats for (sub) populations). This should include assessments / approximations/ estimates of:

[5] To be based on e.g. findings of V. Dierschke, R.W. Furness & S. Garthe 2016. Seabirds and offshore wind farms in European waters: Avoidance and attraction. Biological Conservation 202: 59-68 and of M.F. Leopold, M. Boonman, 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, S. Lagerveld, R. Lensink, M.J.M. Poot, J.T. van der Wal & M. Scholl 2014. A first approach to deal with cumulative effects on birds and bats of offshore wind farms and other human activities in the Southern North Sea. IMARES Report C166/14.

- Behavioural consequences: do the displaced birds of the species identified in 1 have to expend more energy due to habitat loss and/or are they less able to fulfil their energetic needs: are alternative sites sufficiently easily available (related to carrying capacity and energetic spatio-temporal bottlenecks).
- How does reduced fitness of individual displaced birds affect long-term (sub)population trends, i.e. how could (sub)population trends be influenced by non-breeding habitat loss of individual birds.
- The IBMs habitat use should pay specific attention to the most important other human factors that influence behaviour and habitat use in such a way that individual fitness of the birds concerned may be reduced; these insights are relevant to assess the relative importance of OWF with respect to other human activities in determining the limits of cumulative human impacts that can sustainably be supported by (sub)populations of seabirds.

These questions are virtually impossible to answer by direct measurements in either field or laboratory circumstances. Therefore, the only feasible way to come to terms with these matters is the development of a modelling framework in which the causal relationships between habitat loss and behavioural consequences, between behavioural consequences and reduced individual fitness and, finally, between reduced individual fitness and long-term population trends are identified. Such a framework would provide the basis for individual based habitat use models for the top 5[6] most vulnerable seabird species, in which measurements or (best guess) estimates of the parameters of degree of displacement and resulting habitat loss, habitat suitability (carrying capacity / food availability, see 3), suitability of alternative sites, field data on offshore distribution, reduced individual fitness, possible reduced reproductive output etc. can be fed.
Therefore, it is proposed to:

a) Build an individual based (IBM) habitat use model for each of the top 5 most vulnerable seabird species.
b) Feed this model, as best as possible, with (existing or still to be measured) field data or best educated guess estimates of non-breeding offshore distribution (i.e. existing data as well as new monitoring data as proposed in Chapter 3), the best available data on (known, deduced or presumed) optimal feeding opportunities in time and space and theoretically calculated minimum requirements of yearly energy uptake for all individuals of the relevant (sub)populations[7]. This may involve some iterations over the years with model runs identifying measurable parameters that could ask for extra field measurements.

The use of specifically built habitat use models should at least enable us to explore the bandwidth (model uncertainty analysis) of the possible consequences of habitat loss for both individual birds that are displaced and, when coupled to population models, for populations as a whole. Moreover, it will help to identify the crucial parameters (model sensitivity analysis) that potentially steer the level of the impact and offer options to estimate the

[6] Here it is proposed to address the top 5 most vulnerable species instead of the top 10 for practical reasons.

[7] Minimum required carrying capacity, expressed as the total amount of food necessary to support an entire (sub)population of a seabird, could be quantified for all species with relative ease, based on individual daily energy needs, known data on prey composition, (sub)population size and biometrical data on body mass.

sensitivity of these parameters as well as the need for better ground validation with field data.

Priority 1: It is of high importance to get to grips with the energetic consequences of the displacement / habitat loss the birds are facing as a key factor in the population dynamics with resepect to an inherent decline. This link is crucial to assess the real ecological damage that loss of non-breeding habitat due to OWF footprint could lead to thus stressing the importance of effective mitigation in the future (marine spatial planning). It also validates mitigation measures while spatially planning, developing and operating OWFs in the longer term.

3. Enhancing the understanding of the relationships between (non-breeding) offshore distribution and actual carrying capacity of the North Sea ecosystem for the seabird species concerned. Carrying capacity is more than anything related to food availability for the species, rendering quantitative research into this matter extremely expensive since this would involve exhaustive year-round monitoring programmes for several smaller, non-commercial fish species together with extensive fieldwork to better pinpoint foraging behaviour in time and space. In order to better understand this complicated matter, it is proposed to:
    a) Extend the individual based habitat use models, developed in 2, with a model that allows the introduction of parameters of spatio-temporal variations in species specific food availability.
    b) Feed this extension as best as possible with real data on food availability.
    c) Perform a series of sensitivity analyses with the entire IBMs in order to get to grips with the question as to whether habitat loss, due to the presence of OWF footprint, is or is not likely to result in a reduction of carrying capacity for non-breeding seabird species in the top 5.

    Priority 1: It is considered of the utmost importance to gain a better and more quantitative insight into the relationship between carrying capacity of the marine environment for seabirds and their population trends in order to find out what the hazards of habitat loss can be. Direct investigations at sea on bird behaviour as well as on food availability are extremely difficult and costly, but a model-based survey on the flexibility and vulnerability of the crucial parameters of carrying capacity (e.g. daily energy needs, food availability, foraging habits, population size, distribution patterns etc.) will shed light on the margins as well as on the needs and the possibilities of future in-depth investigations on the most crucial parameters. This insight might even open ways for future effective mitigation of adverse effects.
4. Reliable data-fed population models must become available for the same 5 most vulnerable seabird species for habitat loss due to OWFs, either by adopting existing models or by developing new ones. Good links need to be established between these population models and the individual based habitat use models built in 2, in order to translate effects on habitat use into (potential) impacts on population level. Also, a ‘common currency’ is needed in how to express the amount of (possible) impact of displacement and resulting habitat loss on the level of relevant (sub)populations of the (potentially) vulnerable seabird species. So far, we have used the concept of Potential Biological Removal (PBR) as a measure of the ‘safe’ level of additional disturbance a (sub)population can sustainably support. It is of the utmost importance that the use of PBR is justifiable for all (sub)populations potentially ‘at risk’ for habitat loss (as well as for additional mortality due to collisions and other anthropogenic stressors) and that the parameters used for its calculation

concur with the real population dynamics parameters from the field-fed model(s), regardless of e.g. current population trends. Therefore, validation of parameters used for PBR (PBR = 0.5 *Rmax * Nmin * Rf[8]), and more particularly the recovery factor Rf, should be duly carried out. Such a validation involves the introduction of an additional annual mortality at the level of the calculated PBR value for each of the species concerned into their specific population model, in order to verify whether such an extra mortality can indeed be supported without a subsequent population decrease.

Priority 1: This exercise is necessary to verify whether PBR is indeed the best available method to determine a reliable common currency for assessing the degree of 'acceptable' impact on population levels amongst different species (and possibly even different populations) in a comparable and robust manner. This will allow for both sustainable populations and wise use of the North Sea for OWF development.

5. Since it is likely that the underwater habitat in OWFs will change as the result of the presence of hard structures (providing shelter and settling conditions for different benthic communities and thus possibly other fish communities), local food availability for birds is also likely to undergo changes. It is recommended to link the research on birds as best as possible to the research topics on benthos and fish, also addressed in Wozep, in order to establish any relevant changes in local suitability of OWF locations for seabird species in the top 10 as identified in 1. This also concerns suitability of constructions above water as seems to be the case for cormorants in OWF OWEZ[9].

   Priority 2: Establishing the content link between the Wozep research topics on benthos and fish and the local (at the level of the OWF) carrying capacity issue for birds is important. After establishing the actual ecological energetics of these seabird species at sea in relation to habitat / patch use, one should aspire at trying to understand the possible consequences of local changes in food availability in OWF areas.

6. Investigate the degree of (individual and species-specific) 'habituation' to the presence of OWFs. Do (individuals of) seabird species, that initially tend to be displaced by offshore structures, become accustomed to their presence over time? For the answer to the question we are concerned with ("do the vulnerable species eventually return to OWF sites in original pre-construction densities over the years or not"), it will suffice to repeat seabird surveys within and (immediately) outside OWFs with the same surveying techniques used for T0 to T3 monitoring programmes in later years (e.g. T5 to T10, 5 to 10 years post-construction; see proposed integrated monitoring programme in Chapter 3). Whether habituation on 'species level' is caused by individual habituation or by any other mechanism is not considered to be of interest within the Wozep programme. Last but not least, behavioural differences between birds within and outside OWFs are (in combination with insights in possible OWF-related changes in food availability within the confines of an OWF, see 5) also

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8 R_{max} = maximum recruitment rate, N_{min} = population size, Rf = recovery factor (based on expert judgement). From: Dilligham, PW, D Fletcher 2008. Estimating the ability of birds to sustain additional human-caused mortalities using a simple decision rule and allometric relationship. Biol. Cons. 141: 1738-1792

9 Poot, MJM, PW van Horssen, MP Collier, R Lensink, S Dirksen 2011 Effect studies Offshore Wind Egmond aan Zee: cumulative effects on seabirds. A modelling approach to estimate effects on population levels in seabirds. Report OWEZ_R_212_T1_20111021_Cumulative effects.

important to take into account in assessing the possible impact of OWF on (functional) habitat loss.

Priority 1: First impressions might lead to this research topic seeming to be less important than establishing the potential maximum impact of displacement / habitat loss, which is needed to be able to apply the precautionary principle. However, if habituation can be shown to occur during operation of an OWF (and the birds resume their original (feeding) behaviour), mitigation might, in the long run, be less necessary and therefore cheaper than originally thought. This does render this topic important for the longer term and therefore priority 1 is the most appropriate.

2.5 Phasing of activities for 2017-2021

Crucial to the entire research into the issue of displacement / habitat loss is the development of the species specific habitat use models and their interactions with population dynamics modelling on the one hand, and the field validation on the other hand. As part of the latter, as much empirical data as feasible will be collected on distribution, behaviour and carrying capacity related parameters of offshore seabirds vulnerable to displacement, in order to validate the models.
Based on the mutual relationships of the six proposed research activities for Wozep over the period 2017-2021, a logical phasing of these proposals is presented in figure 2.1.

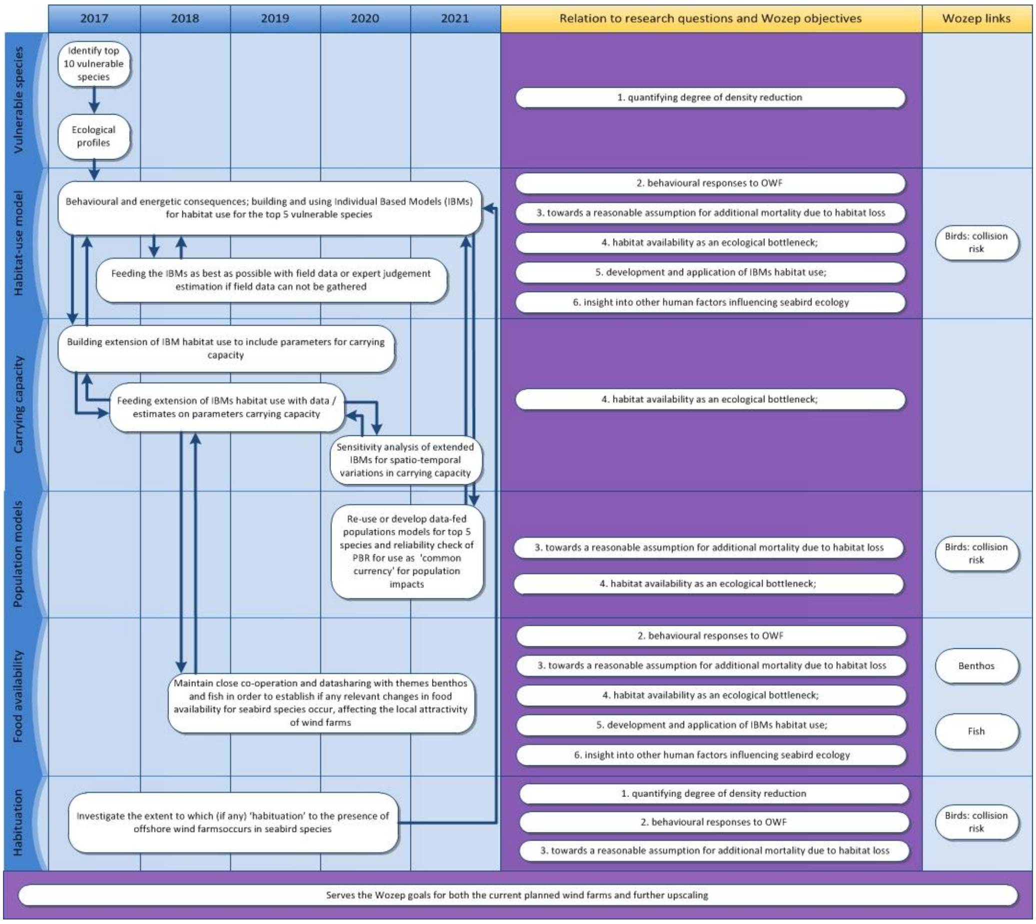

Figure 2.1 *Relationships between proposed research activities on seabird displacement and phasing of these activities over 2017-2021*

3 Birds: collision risk

3.1 State of knowledge at start of Wozep

Thousands of birds a year are suspected to collide with offshore wind turbines. At present, estimates of collision rates for birds are mainly produced using models such as the Band model. For onshore wind farms, it is possible to determine the number of victims by counting dead birds below the turbines. At sea, it is more difficult to determine the number of victims and therefore to validate the model. Visual observations have proven to be a poor way of observing collisions it is precisely when visibility conditions are poor (night, fog, strong winds and rain) that collisions are most likely to occur. Furthermore, radar monitoring is not the whole solution because as it is difficult to detect birds close to wind turbines and identification down to species level with radar is still in its infancy. As a result, automated systems with cameras are needed to monitor collisions. The first offshore projects using these cameras have started in Germany (Alpha Ventus), England (ORJIP) and the Netherlands (OWEZ/WT-bird), combining various methods in the attempt to register collisions and to automatically identify the species involved.

3.2 Research questions

The research questions from the Wozep workshop on 28 June 2016 have been changed slightly and specified into more detailed goals. Relevant research questions have also been added (category 2 and 3). Categories are not related to research priority.

Category 1: associated with fluxes, numbers of collisions and collision risk
1. What knowledge is already available on the subject (internationally)?
2. Is the dependence of number of collision victims on flux intensity indeed linear, as assumed in the Band model? It is considered that such a relationship may be more complex, e.g. flocks of birds flying by reacting to each other.
3. How does wind farm lay-out influence species specific flight behaviour under various circumstances?
4. How is species specific flight behaviour related to collision risk?
5. Can knowledge on effects of 'onshore wind farms' with respect to collisions with birds be used to come to more reliable estimates for the same parameters offshore?

Breaking down these questions into more detailed goals:
Ad 1. A better understanding of which factors determine size, species composition and spatial distribution of fluxes:
- Site dependence of fluxes (size, species composition, flight heights).
- Seasonality of fluxes (migration intensity as a function of time, or flight movements as a function of distance between colonies/roosts and foraging areas and specific foraging ecology).
- Timing of fluxes (in relation to daylight and/or visibility of wind turbines)
- Relations between fluxes and daytime densities as measured / estimated in offshore bird surveys (taking into account that daytime and nocturnal densities might differ considerably).

- Weather dependence of fluxes (including flight height) (wind force and direction, but also visibility) potentially hamper the timely detection of turbines and rotating blades by the birds.
- Individual species behaviour within fluxes, including avoidance and habituation.
- Influence of (operational) OWFs on flux characteristics (other flight heights relevant with respect to avoidance, mutual influences of flight paths of flocks of birds crossing a OWF, etc.).
- Influence of other human activities in or just outside OWFs on fluxes (e.g. active fishing vessels that attract gulls and modify their flying behaviour, potentially enhancing the flux and rendering them less attentive to their surroundings and thus more 'at risk' for collisions).

Ad 2. Better and more accurately measuring avoidance:
- Species, site and season specific measurements of avoidance (macro-, meso,- and micro-avoidance) in existing OWFs as a function of number, size and spatial configuration of the turbines

Ad 3/4/5 Better understanding of the probability of collision while crossing rotor swept area (RSA):
- Flight behaviour near the turbines (passing just once, or flying to and from; foraging head down; type of flight, e.g. flapping flight, gliding, etc.), including micro-avoidance. Determine exact flight paths within RSA considering weather and human activity in and around OWFs.
- More exact measurements (estimates) of flight speed. More exact measurements of flight height within an OWF and RSA, in combination with flight speed, dimensions and visibility of rotating rotor blade and visibility of rotating blade at various points in the (2D and 3D) range of RSA.
- Direct measurements of collisions (as much as possible species specific and dependent upon weather, visibility of turbines and relationship with lighting); since the probability of collision of birds crossing RSA equals $N_{collisions}$ divided by the proportion of the flux that did not show macro- and micro-avoidance.

The above mentioned parameters and driving factors are preferably researched in an *integrated monitoring program* deployed offshore. However, *individual input parameters* for collision risk modelling tools could also be validated in 'stand-alone' research projects.

Category 2: related to populations potentially 'at risk'
1. Are effects randomly distributed over age classes and sex?
2. What are the (sub)populations concerned?
3. Which of these are the relevant (sub)populations 'at risk'?
    a. Rate of natural annual mortality
    b. Size of relevant (sub)populations
    c. Population dynamics of (sub)populations 'at risk' – validation of parameters necessary for calculation of Potential Biological Removal (PBR) as a measure for level of acceptable additional mortality

Category 3: concerning mitigation measures
1. Are current mitigation measures necessary, efficient and effective?

Additional knowledge gap
During the workshops elaborating on the knowledge questions mentioned above, an additional knowledge gap was identified that might merit being addressed. This issue concerned the lighting of wind turbines. Effects of light are species specific. By increasing light intensity, the risk of attracting (migrating) birds to the OWFs may increase. But there may also be situations in which lighting of the wind farms does not affect flight behaviour or that birds might even be scared off by the lighting. Lighting of the turbines is thus thought to (potentially) enhance the risk of collision, at least in some circumstances. The exact effects of lighting can be measured and experimented with well within onshore wind farms. Currently research is also being undertaken on the possibilities to lower light intensities, in order to decrease the visibility of OWFs from the shore (at the request of coastal municipalities). In the Dutch province of Flevoland a test is being carried out in which the lighting of a wind farm is only turned on during the approach of an aircraft.

3.3 Wozep research 2016

In 2016 the following two preliminary studies concerning the issue of collision numbers and collision risk at OWFs were undertaken:

1. **Validation of collision numbers: a review of existing methods and techniques for field validation of collision rates amongst birds and bats at offshore wind turbines** This study will provide a series of factsheets on methods and techniques available or under development for estimating collision rates of birds (and bats) within OWFs. These factsheets provide information on:
   - Owner / developer
   - General description
   - Status
   - General characteristics
   - Technical specifications
   - Results offshore (performance)
   - Deployment / costs
   - Background information and reference projects

   Once complete, this study will be finalised by a proposal for 'terms of reference' for future deployment of (additional) methods and techniques for validating collision risk models such as the Band model.

2. **Inventory and analysis of international GPS-tagging databases for relevant species of land or freshwater birds in relation to collisions**
   The second study will provide an overview of available GPS-logger databases and the possibilities for use of these for questions concerning relevant (sub)populations potentially vulnerable to OWFs in the North Sea (with preliminary estimates of up to 0.6 PBR (Potential Biological Removal). These species should be regarded as 'vulnerable' because 1) the populations are small, 2) a significant share of the flyway population is found in the North Sea, 3) a large proportion of the population makes the crossing to the UK and back and/or 4) they possibly make use of 'concentrated' migration routes across the North Sea. These (sub) populations merit particular attention with respect to future spatial planning of OWFs and/or for actual options for effective mitigation. Therefore, for these populations validation of the assumptions used in the collision risk models so far is urgently needed. An analysis of the existing

databases with GPS data for the relevant populations of these species will become available by the end of 2016. These results can both be used to adjust the input for the parameters in the collision risk model (Band model) (hopefully providing more detailed information on individual flight behaviour for these species) and to provide an insight into the potential effectiveness of establishing OWFs with bigger and fewer wind turbines that are more widely spaced out as a mitigation measure for collision incidents.
On the basis of the survey and the analysis of the databases, a decision can also be made on whether additional field work (such as GPS tagging after 2016) is useful for these species. Relevant species are: Bewick's swan *(Cygnus columbianus)*, brent goose *(Branta bernicla)*, red knot *(Calidris canutus)*, curlew *(Numenius arquata)*) (migratory 'land birds') and great skua *(Catharacta skua)*, lesser black-backed gull *(larus fuscus)*, great black-backed gull *(Larus marinus)* and herring gull *(Larus argentatus)* (seabirds).

3.4 Proposed research 2017-2021

1. **Extension of the operational WT-Bird system on OWEZ until (at least) March 2018.** Leading to better approximation of numbers of actual bird collisions at sea in relation to actual flux measurements and, therefore, also to better estimates of collision risks. As far as possible more species specific and more information on circumstances with increased collision risks. Ultimate goal: validation of Band model (collision risk model) output with real collision data.
   Priority 1: It is absolutely crucial to obtain a solid validation of the collision victim rates as predicted by the actual Collision Risk Model of Band. A better validation is needed to be more confident about the need, the costs and the effectiveness of the mitigation measure as proposed at present (e.g. the need for fewer and larger turbines).

2. **Integrated monitoring programme: fluxes, numbers of collisions, collision risk & displacement**
   This monitoring programme will be based on Wozep 2016 research "a review of existing methods and techniques for field validation of collision rates amongst birds and bats at offshore wind turbines". Proposed locations: Borssele (including T0) and OWEZ. Deployment of the systems is not foreseen until 2019. This research proposes an integrated monitoring programme, aiming at detecting collisions of birds and bats, and simultaneously carrying out measurements of species-specific fluxes of both groups. A multiple sensor approach is needed for measuring species specific fluxes, avoidance behaviour/rates and collisions. This should be done at different spatial scales: around the OWF, within the OWF and in the rotor-swept area (RSA).

   This way, the programme should result in species-specific collision risk figures. Apart from collision risk figures this research will generate data on species specific flight behaviour parameters used for collision risk modelling. Ultimate goal: understanding (species specific) fluxes in and around OWFs, avoidance rates and validation of Band model (collision risk model) output with real collision data. Depending on the sensors used, the research will provide an opportunity to cross check collision risk figures gathered at OWEZ with WT-bird (depending on findings from preliminary study 1 of 2016).

Proposed locations for this research are the Borssele area and/or OWEZ. The Borssele wind farm sites will be developed from 2019 onwards and provide an opportunity for a BACI study (Before-After-Control-Impact). Apart from the above mentioned ´integrated monitoring programme' related to collisions, the site could be used for studies on seabird densities, displacement behaviour and validation on different methods used for monitoring bird densities (see Chapter 2). Research topics could include flight speeds, flight heights, fluxes and bird densities. Wind turbines in the Borssele area will be larger and spaced further apart compared to those that are now operational on the Dutch Continental Shelf (DCS). The site will therefore provide an opportunity for research on the influence of wind farm configuration/lay-out and wind turbine characteristics on ecological impacts.
Priority 1: It is absolutely crucial to obtain a solid validation of the collision victim rates as predicted by the actual Collision Risk Model of Band. A better validation is needed to be more confident about the need, the costs and the effectiveness of the mitigation measure as proposed at present (e.g. the need for fewer and larger turbines).

3. Study on the number of collision victims amongst 'land based birds' during migration and effectiveness of mitigation measure

Millions of so called 'land based migratory birds' migrate over the North Sea. Predictions show that, during these periods, mainly passerines will collide with wind turbines. Most systems that can measure collisions offshore are however, limited in their ability to trigger on these small passerines. Therefore, for these species, land-based studies are more suitable when conducting research on the number of collisions victims and the effectiveness of the mitigation measures.
Focus: migrating (land) birds and gulls

Subprojects:

A. Desk study into number of collision victims in relevant and representative onshore wind farms. Preference: use data that compared collision numbers with flux measurements. Comparison of actual numbers with band modelling outputs.

B. Field study effectiveness mitigation measure migrating birds:

1) Offshore location Borssele: T0 -fluxes
Attempt to quantify the effectiveness of mitigating collision victim incidence in migrating land birds by turning turbine blades out of the wind ("feathering") during peak migration periods (exceeding the level of e.g. 500 bird tracks per km per hour measured by specialised radar installations). This research involves a check of the rationale for this mitigation measure for Borssele (based on observations and calculations from OWEZ, Krijgsveld *et al.* 2015[10]), by actually measuring / estimating which percentage of total migration over a season will be saved by feathering the turbine blades during peak migration levels exceeding the proposed threshold.

10 Krijgsveld, KL, Fijn, RC, Lensink, R. 2015. Occurrence of peaks in songbird migration at rotor heights of offshore wind farms in the southern North Sea https://www.rvo.nl/sites/default/files/2015/08/OWEZ%20migratie%2015-314_Final_Report_20150618.pdf

2) Onshore location: relevant (turbine type, location) onshore wind farm. Same as under 1). Simultaneously with search for actual collision victims. Combination with effects of light.
Priority 1: It is very important to know to what extent the prediction of the reduction of collisions among migratory birds as a result of the mitigation measure of feathering the turbine blades during peak migration periods is accurate. If this mortality reduction turns out to be significantly less, cost reduction can be achieved by applying the measure less rigorously if, on the other hand, mortality reduction is calculated (or measured) to be higher, the mitigation may be applied more frequently.

4. Changes in flight behaviour as a consequence of wind turbines.
Focus: Herring Gull & Lesser black Backed Gull

Little is known of flight behaviour of individual birds in wind farms and near the rotor swept area of wind turbines. Avoidance behaviour (micro-, meso- and macro-) is an important parameter in the Band model, strongly determining the results of the model. Increasing our knowledge of flight behaviour in wind farms and near the RSA is therefore crucial. Research proposal 2 would give more insight in to this behaviour but is not planned until 2019. Until then research is aimed at validating some parameters of the Band model such as flight speed, flight height and micro-avoidance.

Research could involve the deployment of new GPS-loggers on individuals of focus species and deployment of cameras on individual turbines. Getting more insight in flight behaviour at OWFs is most representative and desirable. However, chances that individuals with GPS loggers enter OWFs are rather small. Events of micro-avoidance are also very limited. As an alternative the research could be carried out on a location where breeding colonies are in the vicinity of (onshore) windfarms, increasing the chance of measuring events. This research could be combined with research proposal 6.
Priority 1: The number of collision victims that are predicted in the KEC are near or on PBR levels for large gulls (herring, great black-backed and lesser black-backed gull). Further development of offshore wind energy is limited by predicted collision victims among these species. Integrated systems that measure actual collision victims offshore are not planned until 2019 (research no 2). Until then research is aimed at validating parameters of the Band model.

5. (Sub)populations of concern
Focus: top 10 species with highest number of collisions relative to PBR values - priority is given to large gull species. By knowing in more detail which exact (sub)populations of birds do actually regularly visit (and thus make up the flux) in existing as well as planned OWF sites, we obtain better insight into the actual impact that collisions may constitute for bird populations and thus for conservation targets. Research involves both desk studies and field studies. The desk study should focus on the analysis of already available datasets of GPS-logged birds of the top 10 relevant species.

Field studies could involve the deployment of new GPS-loggers on individuals of (sub)populations at risk as well as the deployment and use of cameras registering bird movements (fluxes) at (potential) wind farm sites (see 4). Catching and logging birds at actual or potential wind farm sites could be an option for priority species. Options for catching and logging birds at OWF sites should be evaluated in a feasibility study prior to the actual research. This research could be carried out in combination with research proposals 4 and 7. *Priority 1*: It is very important to know which (sub)populations we are potentially dealing with at each proposed site. Particularly for devising tailor-made mitigation measures makes the results of this research of the utmost importance.

6. **Population dynamics and PBR validation**
   Focus: top 10 species with highest number of collisions relative to PBR values - priority is given to large gull species. Combination is possible with research proposed in chapter 2

   Modelling population dynamics of each of the relevant (sub)populations of the top 10 species vulnerable to colliding with wind turbines. Validation of parameters used for PBR (PBR = 0.5 *Rmax * Nmin * Rf), and more particularly the recovery factor Rf, should be carried out.

   Cross checks of the population models and reliable calculation of Potential Biological Removal (PBR) for each of these species, as a 'safe' level of additional mortality due to collisions a (sub)population can sustainably support. *Priority 1*: It is of the utmost importance to confirm whether the use of PBR is justifiable for all (sub)populations potentially 'at risk' to additional mortality due to collisions and that the parameters used for these calculations concur with the real population dynamics parameters from the field-fed model(s), regardless of e.g. current population trends.

Unaddressed knowledge questions
Knowledge questions regarding other human activities in- or outside of OWFs, such as fishing are not part of the scope of Wozep and therefore no research proposals are formulated for these questions. As addressed in chapter 10, these activities are part of the passage and shared use pilot and should be investigated in that programme. However, as we feel these questions are very important, we will maintain the questions within the MRP 17-21 as a reminder.

Priority species:
The cumulative analyses (KEC, 2016) carried out so far suggests that the number of predicted collisions for herring gull, lesser black-backed gull and great black-backed gull will result in increased annual mortality rates near PBR levels. In order to minimise the risk of near future wind farm developments not being consented, there is an urgent need to decrease the uncertainty in the assumptions made in the impact assessment process. This holds true for assumptions made in the collision risk modelling tool and for assumptions made in threshold setting parameter (PBR).

Protection regime and breeding/non-breeding status in the Netherlands are shown for the three species.

Species	Bird directive Annex III	SPA's	Breeding Bird	Non Breeding Bird
Herring Gull	X		X	X
Lesser Black Backed Gull	X	X	X	
Greater Black Backed Gull	X		(X)	X

A fully integrated monitoring programme providing robust evidence on the number of birds colliding with wind turbines will only be operational in 2019 at the earliest. On the short(er) term, focus will therefore be on research that could decrease uncertainties in input parameters used in the collision risk modelling tool (Band, 2012). Dedicated species specific research on flight behaviour in wind farms and near wind turbines (amongst which flight speed, flight height and macro-avoidance) is proposed from 2017 onwards. It is expected that this data has to be gathered with different techniques and on different locations: a combination of on- and offshore research, GPS-tags with accelerometers mounted on breeding birds and cameras attached to or near turbines.

Thresholds for acceptable impact levels are now based on the PBR. However, evidence on affected (sub)populations and/or affected colonies is largely lacking. It is therefore important that the use of PBR is justifiable for all concerned (sub)populations and that the parameters used for its calculation concur with the real population dynamics parameters from the field-fed model(s), regardless of e.g. current population trends. A better understanding is therefore also required of the size of these populations (breeding and non-breeding) and factors driving the population to increase or decrease. At least for these gull species reliable data-fed population models must become available and/or should be updated. It is expected that part of this study will be desk based, analysing existing data. However, field work is also involved.

We suggest that the (field) research on flight behaviour, concerned (sub)populations/colonies and populations dynamics is combined as much as possible at locations with a reasonable chance of substantial fluxes being observed near wind turbines and rotor swept areas.

Bird species that occur in high densities in the coastal zone (< 12 NM) and in lower densities further offshore are not regarded priority species (such as sandwich tern, common tern, eider, common scoter). However, if spatial planning of OWFs changes to more coastal area's, potential conflicts could arise with these species. In that case species specific research on flight behaviour and or habitat use including displacement behaviour might be needed.

3.5 Phasing of activities for 2017-2021

Deployment of the systems for an integrated monitoring system is not anticipated until 2019. Until then, prolongation of the operational WT-Bird system/ flux radar on OWEZ is very important to gather data on the numbers of actual bird collisions at sea. Go/No Go decisions will be made yearly on the prolongation of WT-bird. For some species the predicted number of bird collisions is near PBR levels hence posing a consenting risk to (near) future OWFs. It is therefore of the utmost importance to validate the assumptions made for collision risk modelling and impact assessments as soon as possible for priority species, starting in 2017.

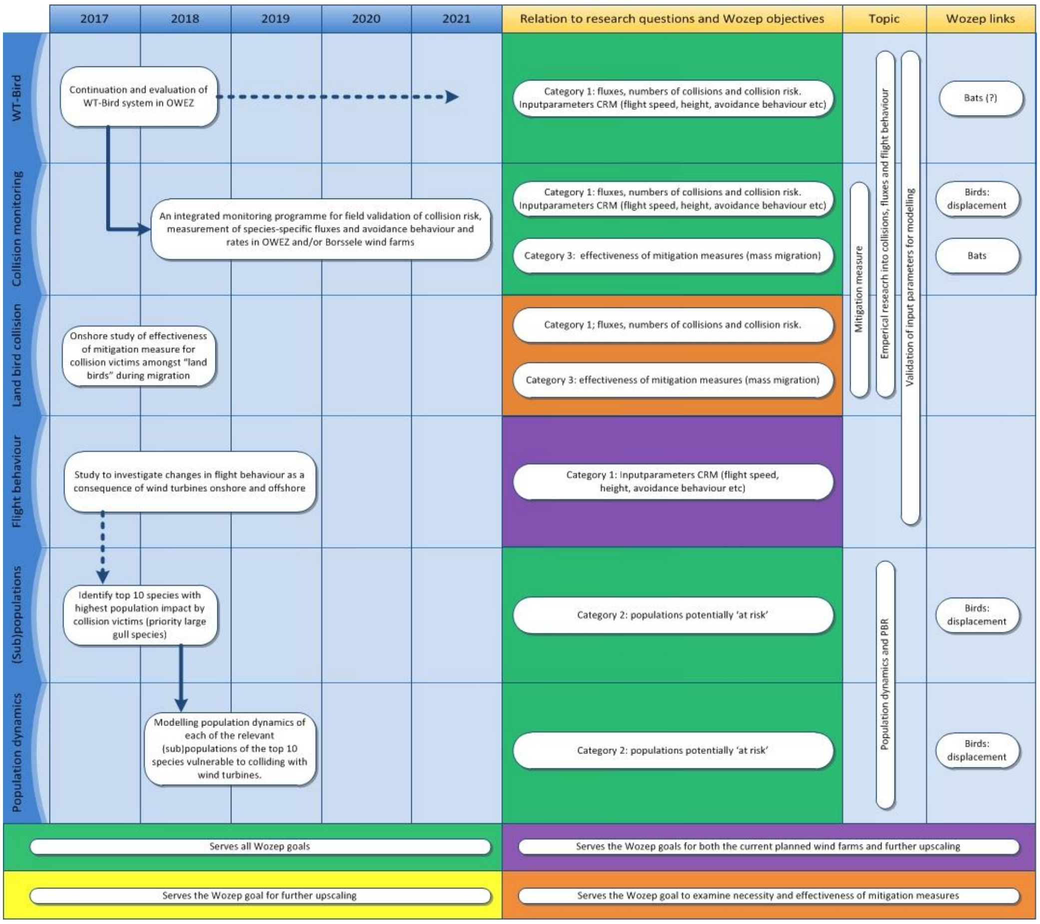

Figure 3.1 *Relationships between proposed research activities on collisions and phasing of these activities over 2017-2021*

4 Bats

4.1 State of knowledge at start of Wozep

There are still many gaps in our knowledge about bat distribution and behaviour at sea. In recent years, preliminary studies looking at bats in the Dutch North Sea have yielded evidence for the assumption that structural migration across the North Sea is found in at least one, but possibly up to three, different bat species[11]. Migration is definitely a characteristic of Nathusius' pipistrelle (*Pipistrellus nathusii*), but possibly also of the parti-coloured bat *(Vespertilio murinus)* and the common noctule *(Nyctalus noctula)*. During previous rounds of wind farm construction, it was not yet known that bats can also collide with offshore wind turbines. This subject has been studied in more detail in recent years only. The KEC has suggested that the population of Nathusius' pipistrelles in particular could be adversely affected by the planned OWFs. Because of the precautionary principle, mitigation measures are required in this latest round of wind farm construction to limit bat mortality.

4.2 Research questions

1. How many bats annually fly across the southern North Sea?
   a. What percentage is this of the population that migrates along the southern North Sea coast?
   b. Of the number of bats that fly across the southern North Sea, what percentage is seasonal migration, what is dispersion and what is off-flow?
   c. What is the relevant population of Nathusius' pipistrelle and what is its size and trend?
2. What is the number of annual bat mortality as a result of collisions with offshore wind turbines?
3. Taking into account population size, trend and collision risk, is the number of bats at risk from collision relevant?
   a. Can we improve the input parameters of the Potential Biological Removal (PBR)?
4. Why are bats attracted to wind farms?
   a. How does this behaviour affect collision risk?
   b. At what height do bats fly in OWFs?
   c. How long do bats remain in wind farms?
5. Can mitigation measures be made more specific to reduce wind turbine down time?
   a. Can other mitigation measures be applied?

4.3 Wozep research 2016

Survey and desk study on population size
A desk study to look at both the total population on the European continent and the number of bats that cross the North Sea to Great Britain. This includes a survey sent to regional experts within different countries to investigate the state of the knowledge within different regions. This study will establish a clearer picture of the number of bats occurring across the European continent and therefore of the

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[11] Boshamer & Bekker, 2008; Jonge Poerink *et al.,* 2013; Lagerveld *et al.,* 2014a, 2014b, 2015

resulting effect of offshore wind energy on the total population. The report for this study is expected in December 2016.

Pilot on thermal imaging cameras and telemetry
This study investigates two new and innovative techniques to study bats at sea. For practical purposes both techniques are being studied in a pilot on land. The first technique uses a combination of bat detectors and thermal imaging cameras. The thermal imaging cameras allow the recording of bat behaviour at night. Currently a test set-up is in place around a wind turbine in the Wieringermeer and data is being gathered.

The second technique is the use of telemetry to follow bats to track the travelled route as closely as possible. Telemetry uses a network of receiving stations to determine the location of transmitters that can be attached to different animals. In the pilot study that is currently being conducted only the range and possibilities of the receiving stations, transmitters and tracking algorithms are being investigated. Additionally an inventory of possible locations for receiving stations is drafted to assess the possibilities for a full deployment of this technique along the coast and offshore. No animals are fitted with transmitters at this stage of the research.

The report on the results of the two pilot studies is expected at the end of November 2016.

4.4 Proposed research 2017-2021

1. *Automated Radio Telemetry*
   In the process, so far automated radio telemetry has been mentioned repeatedly as the best research method to investigate the flight behaviour of bats. Because Nathusius' pipistrelles are so small, they can't be equipped with GPS transponders to follow their movements. The next best thing is Automated Radio Telemetry. Whenever a study animal equipped with an automated transmitter is within the range of the towers, the system automatically collects the data from the transmitter and registers its location. The system is less accurate than most GPS systems, however, the price per transmitter is also a fraction of the price of a GPS transponder. The system will allow us to follow individual bats as they come within range of the receiving stations. With a sufficient number of receiving stations and tagged animals it should be possible to gain more insight into the number of bats that fly across the Southern North Sea, what percentage this is of the population of bats that fly along the North Sea coast and the distribution between migration, dispersion and off-flow. This would require a network of receiving stations at least along the Dutch coast and at installations offshore, but preferably also in the rest of the Netherlands and in other European countries. When the system and transmitters are registered to MOTUS[12], access to data registered by other receiving stations will also be available. Therefore, it would be smart to seek both national and international collaboration to increase the number of receiving stations and tagged animals as much as possible. This kind of research can also be applied to study

[12] The Motus Wildlife Tracking System (Motus) is a coordinated network of radio-telemetry arrays managed under a common database that facilitates tracking movements and behaviours of small organisms at local, regional, or even hemispheric scales. Motus is a program of Bird Studies Canada in partnership with collaborating researchers and organizations. More information is available at www.motus.org.

(smaller) birds, which could also provide valuable information related to the effects of offshore wind. Of course, the actual deployment of radio transmitters and the corresponding receiving stations depends on the outcome of the current feasibility study in 2016. If started, this research should continue until at least the end of Wozep and provisions should be made for continuation afterwards.
Priority 1: In order to obtain any reliable estimate of the number of migrating Nathusius' pipistrelle that actually cross the North Sea, we need to determine what proportion of individuals that arrive at the Dutch west coast stays inland or starts following the coastline and which proportion just continues westward on its way to the United Kingdom. Automated radio telemetry seems the only way to find an answer. This method has already been used successfully to track bats offshore in North America (Stantec et al., 2016). The information is crucial to assess whether mitigation for bat collisions is actually required or not and, if so, to what extent. Additionally, this method might help provide some insight into the dwell time of bats within wind farms and why they are attracted to wind farms.

2. *Continuation and expansion of bat detector research*
   Since 2013 data has been collected on the presence of bats at offshore locations using bat detectors. In subsequent years the programme has been extended to additional locations, both on- and offshore (18 locations in total, 8 offshore). The research has been quite successful, but continuation is needed to gain further insight and to make results more statistically robust. Additionally, expansion to more locations will give a better impression of the presence and distribution of bats at sea. Furthermore, the addition of bat detectors at greater heights will give insight into the flight height of bats at sea and therefore the probability of them entering the rotor swept area of offshore wind turbines. This project should continue until at least the end of the Wozep programme.
   Priority 1: Continuation and expansion of the current monitoring of bat presence offshore is crucial to better underpin both distribution and behaviour of bats at sea, and particularly at OWFs. This information needs to be more robust than it currently is, in order to design more tailor made (and thus cheaper) mitigation measures to reduce incidence of bat casualties, as well as to provide better estimates of bat collision (and barotrauma) rates.

3. *Continuation of the research which assesses the possibilities to combine bat detectors and thermal imaging cameras*
   The pilot study on the combination of thermal imaging cameras and bat detectors has shown promising results so far. Additionally, algorithms are being developed in this pilot study to distinguish flying objects in general from irrelevant images (such as passing clouds and/or moving rotor blades) in order to reduce the actual viewing time of the footage. These results may also become useful for registering nocturnal bird movements around (offshore) wind turbines. However, there are some doubts whether the effective range (high enough resolution) of thermal imaging cameras will be sufficient to cover the entire rotor-swept area of offshore wind turbines. If it is concluded that thermal imaging cameras are not the right method to observe bats at offshore wind turbines, alternatives should be investigated.
   Priority 1: Considering that thermal imaging cameras currently seem to be the most effective method to observe bat behaviour at wind turbines is seems logical to continue to develop this method and look towards possibilities for adaptation to offshore conditions. Such a system may supply much more

precise estimates of the numbers of bats that collide with offshore wind turbines in the North Sea. Additionally, it could supply more information about the specific behaviour of bats in and around OWFs and possibly more information about when and under which circumstances the risk of collisions increases significantly. Therefore, it will give us more insight into the answers to questions 2 and 4a, b, and c. Additionally, this methodology is likely to be applicable to small nocturnally migrating passerines as well, a group of birds potentially vulnerable to collisions but very difficult to detect and identify with current methods.

4. *Continuation population survey and desk study*

   The survey that was undertaken in 2016 can be repeated and/or extended to receive updated information. The survey might have triggered the receivers to compile more information on bats, especially in countries where data is limited at this time. This could lead to new and better information in the future. It is worth keeping an eye on the developments in this field and to redo or partially update the survey if signals point towards the possibility of valuable new information.

   Priority 2: As the current knowledge on population size of Nathusius' pipistrelle is being collated in the current 2016 desk study, further continuation and refinement of this approach might lead to better estimates of (proportions of) populations at risk. However, as long as the accuracy of the baseline data (especially those from the huge 'hinterland' of the distribution range of Nathusius' pipistrelle as far east as the Ural) is not improving, the priority of extending this work into 2017 and further does not seem to be the highest.

5. *Analysis of existing data and boost for voluntary work in the Netherlands*

   In the Netherlands, there is quite a long history of mostly voluntary research work on bat populations. This research consists mostly of data collected in bat boxes and other known roosts. This kind of research has accumulated a lot of data over the years, but often resources are lacking to do a thorough analysis of the data. Although the results from data analysis are not directly relevant to offshore wind, they can give more insight into the general population dynamics of the relevant bat species. It may be beneficial to further boost this voluntary work by sponsoring bat boxes, ringing and providing funding to access professional assistance when needed. This will help to gain more general information on Nathusius' pipistrelle in particular and bats in general. Other benefits for including these volunteers and their work in the WOZEP project is that their bat boxes can be used to capture migratory bats for the automated radiotelemetry study (see above). Mark-recapture experiments in an open population (immigration & emigration) require a much higher sampling frequency than the current monitoring effort, therefore a boost is needed to enable this to happen.

   Priority 3: These types of studies will provide useful information in particular when mark-recapture experiments are incorporated in the future ringing study to assess the stopover duration. Knowledge of the stopover duration can be used to estimate the number of individuals passing through the area. This activity is very likely to provide useful background information on general migration strategies of bats in general and for Nathusius' pipistrelle in particular, but does not seem to be as crucial to answering the identified knowledge gaps as other proposed activities. However, this proposed activity is expected to be very low-cost, which makes it good value for money for the information gathered.

4.5 Phasing of activities for 2017-2021

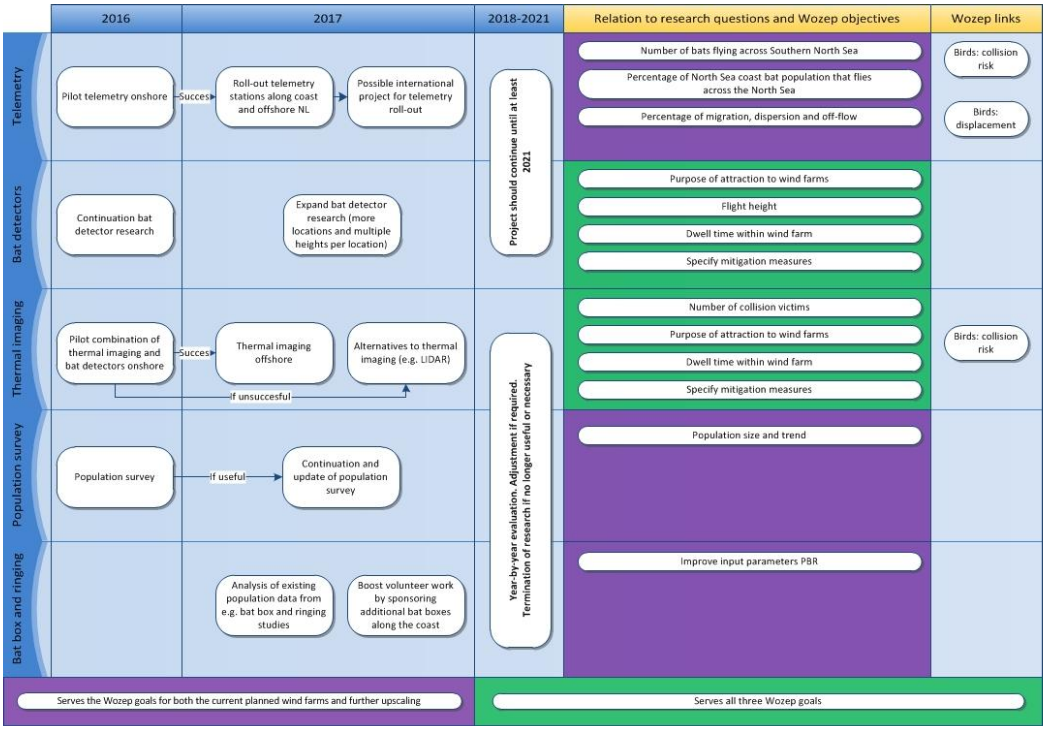

Figure 4.1 *Relationships between proposed research activities on bats and phasing of these activities over 2017-2021*

5 Marine mammals

5.1 State of knowledge at start of Wozep

Sound propagation
Development and validation of Aquarius models.
The suit of sound propagation models; Aquarius has been developed by TNO and was recently validated against measured sound levels during the construction of two OWFs. However the model has not yet been updated with the new insights gained during this validation process.

Individual behaviour and fitness
Harbour porpoise
Sound levels due to piling that can induce a Temporary threshold shift (TTS) or a behavioural response have been determined under laboratory conditions using two captive individuals. The thresholds in the wild will differ from those determined in a silent laboratory basin due to higher levels of ambient noise. Where some information on noise levels in the wild was available, an average of the levels in the lab and the wild is assumed to be a realistic worst-case (as levels cannot be determined as precisely as in a lab) for the implementation of the knowledge in the Framework Ecology and Cumulation.

Over the last years the number of strandings of dead harbour porpoise along the Dutch coast have been stable with annual numbers fluctuating between 500-1000 individuals. Annually, about 50 of these animals are investigated and the cause of death is determined where possible. Tissue samples are gathered from each animal and other physiological data is recorded, not all of which has directly been analysed, with most remaining in storage. In Europe, high concentrations of PCBs have been found in harbour porpoise. These high levels could have an influence on the health status of the harbour porpoise population of the North Sea. The levels of toxic substances in animals of the Dutch continental shelf is investigated in 2016 under the 2016 Wozep year plan. The possibilities of data exchange have been explored with the countries surrounding the North Sea that have their own long term stranding network with research on porpoise carcasses.

Habitat use and population dynamics
Harbour porpoise
In Germany and Denmark a lot of research on the effects of pile driving on harbour porpoise has been undertaken: e.g. determining porpoise densities before, during and after construction of an OWF with a CPOD network, tagging and air-gun field experiments to determine the small and large scale movements of the animals and sound level thresholds for behavioural response. These experiments provided insights into porpoise behaviour in the areas influenced by underwater noise due to pile driving. All monitoring and field research confirms that porpoise densities return to normal following pile driving, however the time required for this differs between different studies. Whether these are the same individuals as the previously disturbed individuals that are motivated by the importance of the area or new naïve individuals that have no knowledge of earlier noise disturbance remains to be examined.

The interim Population Consequences of Disturbance model (iPCoD) was used to estimate population effects with input for duration and level of auditory disturbance due to piling of the anticipated Dutch and entire North Sea OWF projects.

Overall seasonal and spatial densities and distributions are investigated through both national and international surveys such as the SCANS I-III projects.

5.2 Research questions

Sound propagation

1. Are the sound propagation predictions accurate enough to base the impact assessment for marine mammals on them? If not how can they be improved to decrease the uncertainty in the predictions?

Species of concern

2. Is it correct to assume that harbour porpoise are more sensitive to disturbance due to underwater noise than seals especially when considering the entire sound spectrum of piling noise?
3. Which other species are relevant in the North Sea when taking into account the impact of underwater noise and the barrier effect when developing more OWFs?

Individual behaviour and fitness

4. Do we need to consider the sound frequency level when determining the impact of piling noise on the disturbance threshold of marine mammals and will this change initial assumptions on thresholds?
5. What is the effect of the activity on the displacement of different species, do all species return to the site after the noise producing activity has ended and when? Are there permanent effects on the behaviour of marine mammals, and does it lead to increasing sensitisation or habituation?
6. What are the effects of underwater noise on the energetics of the harbour porpoise and how fast do they recover? Are effects of underwater noise on the energetics of seals relevant?

Habitat use and population dynamics

7. How do individual energetic costs impact the population? How can the research results from knowledge question 6 be translated into parameters that can be used for models such as iPCoD and DEPONS?
8. Does food availability motivate marine mammals to return after disturbance and what further information do we require on this topic?
9. How can we translate effects of underwater noise on individual seals to the population? Can an Individual Based Model for seals be developed?
10. Which factors determine whether or not a habitat is suitable for harbour porpoise (i.e. abiotic parameters, prey availability) and how do these relate to the probability of survival outside such a habitat. What is the distribution and behaviour of marine mammals in the North Sea (foraging area, production area etc.)? Does this vary between seasons? Also answer these questions for seals depending on the answer for question 2.

11. What is the exact carrying capacity of the North Sea for the different marine mammal populations, has the carrying capacity been reached and what are the limiting factor that determine population growth? What is the maximum impact that can be permitted due to construction of OWFs?
12. Which other activities affect marine mammals and how large are these effects? How do these effects interfere with determining the impact of the construction of OWFs (i.e. contaminants, fishery bycatch, human induced shifts in food availability etc.)?
13. How can we determine noise impacts from other foundation installation techniques? What is already known? We need a step by step plan to determine effects of other foundation installation techniques (vibratory, screw piling etc.).

5.3 Wozep research 2016

In 2016 the University of Utrecht, Veterinary department, investigated a population wide sample of harbour porpoise tissue on different toxic substances such as PCBs and other anthropogenic substances. This is an addition to an earlier pilot conducted under commission by the Ministry of Economic Affairs under the Harbour Porpoise protection plan (Camphuysen & Siemensma, 2011). That pilot focussed mostly on juvenile animals whilst the 2016 Wozep addition aims to create a population wide (calves, juveniles, adults, female and male) view of contaminant loading is harbour porpoise tissue.
Additional analysis of hearing organs will also be conducted to gain a bigger sample size on potential acoustical damage.

The Sea Mammal Research Company (SeaMarco) is currently working on a study of old husbandry data of two captive harbour porpoise to gain more insight into long term energetics. Additionally they also started a fasting study to see how fast these animals lose weight while fasting in different seasons.

The results of the 2016 Wozep research projects performed in 2015/6 will mainly contribute to our knowledge of harbour porpoise energetics and potential influences on their health from fasting (indirect effect of contaminants) and the occurrence of hearing damage.

5.4 Proposed research 2017-2021

Sound propagation

1. *Update the sound propagation model(s) Aquarius*
   The validation of the Aquarius model shows that the 3 models developed in recent years all underestimate the sound levels at greater distances (above 30 km). The reasons for this underestimation are multiple and due to both environmental variables and model constraints. Aquarius 3.1 can be updated in the short term to improve the predictions. Aquarius 2.0, which is more complex (and has a more accurate description of physical processes), will take longer to update. The validation however shows that the underestimation is mainly due to the low frequency components of the sound. An updated model will give a more accurate prediction of the sound propagation. Updating the model will also make it more suitable to use in different environments (deeper sea and different sediment types). This improved accuracy will however not improve predictions of the effect of sound on marine mammals if frequency dependence of the effect is not better understood. The decision to update the models should be taken after determining the ecological relevance of the low frequency sound as described under question 2.
   Priority 2: This question depends on the answer of question 4 and will become priority 1 if question 4 advises to adopt a frequency weighting.

Species of concern

2. *Carrying out a desk study to establish the sensitivity of seals to underwater noise due to construction of OWFs compared to harbour porpoise.*
   So far the KEC and its application in offshore wind site decisions considers the harbour porpoise as more sensitive to disturbance due to underwater noise due to their lower threshold for disturbance than the threshold found in seals. Thus

any measures taken to mitigate the effects of underwater noise on the porpoise population would be sufficient to prevent significant effects on harbour seal (and for grey seal as the hearing of both seal species seems to be similar). "Sensitive" was defined as behavioural changes described on the Southall scale from scale 5 and up (e.g. changes in locomotion speed, direction, cessation of vocalization and equivalent behaviours in the lab such as severe and sustained changes in trained behaviour). All animals in an area exposed to noise above this threshold are considered to be disturbed. No distinction was made between noise levels, leaving the area, ceasing to feed or communicate, or experience stress.

The disturbance threshold was determined in a basin with playbacks of piling noise. One of the drawbacks of this method is the limited possibility of producing the low frequency spectrum of the piling noise. Recently the validation of the sound propagation model demonstrated that the lower frequency components of sound travel further than expected prior to the validation. Seals can hear better at lower frequencies (under 250 Hz) than porpoise. This could be the reason why in the field the disturbance distance for harbour seal and harbour porpoise don't seem to differ as much as expected based on the thresholds found in the basin.

A desk study will be carried out in 2017 on relevant international literature to analyse the information on noise disturbance of seals compared to harbour porpoise. Within this study disturbance is defined as behaviour on the Southall scale 5 or above. Depending on the results, additional research on estimating/modelling effects of underwater noise on seals may be carried out from 2018 onwards.
Priority 1: This study will determine if/what follow up research is necessary to estimate the effects of the construction of OWFs on seals and to review if the current mitigation measures are effective for seals. It has to be carried out in 2017 as it will impact further research in Wozep.

3. *Which other species are relevant in the North Sea when taking into account the impact of underwater noise and the barrier effect when developing more OWFs?*
The results of the SCANS 2016 survey should provide us with answers to which other species are relevant. Species that are sighted regularly and in numbers significant to their population size are likely candidates for further consideration.
Priority 3: The research for porpoise and two seal species have higher priority over other species that occur in lower numbers in the North Sea and therefore have a lower chance of impact on population level.

Individual behaviour and fitness

4. *Advice on the necessity of devising frequency weighting for effect assessment of underwater noise on marine mammals*
In the US, frequency weighting is recommended, based on the latest research. An acoustic guideline developed for the navy includes a method for weighting and, in cases where not all the necessary information is available, suggests an alternative method. On the other hand an article by an international group of experts advises caution when applying weighting functions as suggested up till now and offers a suggestion for weighting that can be applied safely to several noise sources. A group of experts (i.e. the Dutch working group underwater

sound) will be asked to study these articles and reports and if available other articles on frequency weighting and advise on the necessity and consequences of frequency weighting for the Netherlands and if necessary devise the weighting functions to be used.
Priority 1: Disturbance thresholds form the basis of effect assessments for marine mammals. Frequency weighting influences both the determining of a threshold and utilisation of the threshold for impact assessments and have to be clarified as it will impact future impact assessments for wind farm developments.

5. *A pilot study of harbour porpoise tagging after consulting the ministry of Economic Affairs and stakeholders*
Animals will need to be tagged to be able to answer the questions how an individual animal reacts to disturbance due to underwater noise and whether or not an animal returns to an area where it was initially disturbed, how long the return time is and how long it takes before animals resume normal behaviour,. Depending on the sensors on the used tags, tagging will also provide information on how animals use the North Sea, the foraging grounds, the diving profiles, whether or not they have home ranges and how big those home ranges are. Tagging seals is routinely carried out in the Netherlands as part of the monitoring programs of the wind farms that have been constructed to date. Harbour porpoise on the other hand have not been tagged in the Netherlands. The discussion for the need and acceptability of tagging needs to be carried out before tagging can take place in the Netherlands. A report by Wageningen Marine Research commissioned by the ministry of Economic Affairs advises to carry out some pilot studies before a tagging study at a larger scale can be commissioned. Discussion with the ministry of Economic Affairs and subsequently with researchers and stakeholders is necessary before tagging can be implemented in the multi-year programme of Wozep.
Currently tagging studies are being carried out in the North Sea in Denmark. Results of these studies may provide insights in to the questions in the Netherlands as well. However, it is unlikely that information about the use of the Dutch Continental Shelf can be obtained by tagging studies in Denmark only (unless a large number of individuals are tagged).
Priority 1: The ecological model used in the KEC (and the models that may be used in the future) all rely on calculating the impact on the population of marine mammals by charting the effects on the fitness and behaviour of the individual. Where information is not available assumptions are made using the precautionary principle. Having actual information on the behaviour of the animals will improve the capacity of the models to predict the effects on the population.

6. *What are the effects of underwater noise on the energetics of harbour porpoise?*
The research strategy to estimate the impact of underwater sound on the vital rates of harbour porpoise is split into three approaches:

    1. Energy Management of captive individuals
    Seamarco is currently carrying out research as part of the Wozep 2016 programme on the energetics of harbour porpoise starting with an analysis of husbandry data and effect of fasting on weight and fitness of porpoise. The analysis of husbandry data will identify seasonal changes in blubber thickness and therefore reserves porpoise have in different seasons. When blubber thickness decreases porpoise have fewer

reserves to survive a period of starvation due to anthropogenic disturbance, supposing this would happen and no foraging alternative was at hand. The fasting study will reveal the rate of weight loss after a period of fasting during different seasons and water temperatures.

2. Feeding efficiency in relation to prey species
   These two studies will be followed up by another two or three studies carried out for the monitoring and research program of the Gemini windpark. These studies are determining the maximum food intake after fasting, weight gain based on a different diet (different fish species) and effect of anthropogenic sound on feeding efficiency. This research is complementary to the two energetics research studies mentioned above. Together they will help estimate the impact of underwater noise on the vital rates of harbour porpoise.
3. The GO-NOGO decision on further energetics studies will be based on the outcome of the current energetics studies. These outcomes can be used to determine the information need on energetics to further improve the estimates of effects of disturbance on vital rates and which studies need to be carried out to translate this research under lab conditions to the wild.

Priority 1: This has been judged as a high priority, no regret research and has already been initiated in 2016. The future research need on energetics will be determined when all the current energetics research has been completed.

Habitat use and population dynamics

7. *Translate the results of energetic research to parameters suitable for use in population models*
   As part of the Gemini monitoring programme a workshop will be organised where the findings of the research will be reported. The workshop will be followed up by an expert session to update the expert elicitation of the iPCoD model. SEAMARCO also keeps in touch with the developers of DEPONS to make sure that the research results can also improve the assumptions in this model.

   Priority 1: Although this is a crucial part of the research, it is already planned as part of the monitoring programme of windfarm Gemini for iPCoD. As part of Wozep a meeting will be organised with the developers of DEPONS to determine how this research can best help improve the DEPONS model.

8. *Investigate the changes in food availability before, during and after the construction of an OWF*

   As part of the monitoring programmes of earlier wind farms in the Netherlands C-POD recordings were made before, during and after the construction of wind farms to answer the question how construction impacts the density of porpoise. New techniques are now available to identify feeding behaviour (click trains and buzzes) in these recordings. These techniques can be used to reanalyse the C-POD data previously collected. With the improved analysis techniques the changes to the quality of the area as a foraging site can be determined. Questions that can be posed to this analysis are, a. which changes can be detected in feeding intensities during these three periods? b. What do these changes tell us about food availability in the context of underwater noise? c. What are the distances from the noise source where feeding ceases completely and at what distances does feeding resume (or continue) and what is the intensity of feeding in the areas not/less disturbed? This research has relations to Wozep subject fish question 4.

Priority 1: The disturbance of animals and changes to their behaviour due to underwater noise impacts their fitness amongst others by decreasing the likelihood of foraging directly because animals fleeing will be less likely to seek food in the meantime and indirectly because their food (fish) might also be influenced by underwater noise. This research will give us insight in to the effects of underwater noise on the feeding efficiency of harbour porpoise at the site influenced by the noise.

9. *Develop an Individual Based Model for seals*

As for harbour porpoise an Individual Based Model (IBM) for seals is considered to improve population dynamic modelling. This IBM development could be integrated with the grant application by Wageningen Marine Research to develop an Individual Based Model for three arctic seal species, with an option to develop a generic model. Once this model is developed it could also be applied to the harbour seal and grey seal by filling in the relevant parameters of the North Sea and these two seal species. Should this proposal be unsuccessful in gaining the necessary funds, an individual based model will be developed for the North Sea seals under Wozep. This will also depend on the results of the desk study in 2.

Priority 2: The priority of this research is currently 2 because it may already be developed as part of another programme. However the priority increases if the grant is not awarded and question 2 is answered positively.

10. *Determine the distribution and behaviour of marine mammals in the North Sea (foraging area, breeding area etc.) and the factors that make these areas important. Also answer these questions for seals depending on the answer to question 2.*

Analysis of harbour porpoise survey data for mother-calf pairs and feeding groups will demonstrate if there are regions of the (Dutch) North Sea that have an important function for the breeding or feeding of harbour porpoise. Identifying important areas can improve the assessment of effects of underwater noise as the disturbance of calving areas or important feeding areas will have a higher impact on the population. A feasibility study can be carried out to the effectivity of C-POD network (analogous to the SAMBAH project (www.sambah.org)) to improve the information on distribution of harbour porpoise in the North Sea.

Not only the number of animals present but also their condition can be used to determine habitat suitability. Using data from captive, stranded and bycaught animals on blubber thickness and size and shape of the animal (and therefore a measure of fitness) a reference chart of condition can be created. Using this chart aerial survey photos can be analysed to yield information on the fitness of animals in different parts of the North Sea in different seasons.

An analysis of stranding data from all the countries around the North Sea can further improve our understanding of the structure of the population and if animals of certain sexes and ages use different parts of the North Sea.

Priority 2: The analysis of aerial survey data was carried out previously and was based on data for 3 seasons. There are at the moment more aerial surveys available and the analysis can be carried out once more to determine if certain areas remain important over the years. If so research can be aimed at determining the factors that make these areas important. The aerial survey data is available so the analysis can be carried out in 2017. The analysis of stranding data can be carried out in 2017 as well, since holders of data of strandings around North Sea have shown their willingness to share data. Cooperation can be sought with the competent authorities of these countries to carry out the study in cooperation with them. The feasibility study should also be carried out in 2017 since establishing such a network, gathering data and analysing it will take time. The reference chart can be established in 2017 and if it is compatible with aerial survey data, the aerial survey data can be analysed further for condition of animals.

11. *Determine the maximum permissible impact on the North Sea population of harbour porpoise (and depending on the answer to question 1 also on the two seal species)*

Discussions on the topic of carrying capacity quickly established that determining carrying capacity of the North Sea, in particular the carrying capacity in a desired future situation with minimal anthropological effects, is an extremely complex task. Instead a good population model that takes into account density dependence and a good knowledge of food availability for marine mammals of concern can be developed that can calculate scenarios of the impact of different human activities (in this case multiple scenarios of wind farm development). This will identify scenarios where the population drops under a level determined by marine conservation policy necessitating mitigating measures.

However the development of such a model is no simple task either. The time was not sufficient in the expert session to determine how best to proceed to develop such a model in a stepwise manner from a conceptual phase to a full model; so the model can be used at the end of the Wozep programme but can be improved gradually as more research is carried out and more information becomes available. An expert workshop can be organized to specifically focus on this question. The results of this workshop will also inform research carried out to answer the previous questions in this document.

Priority 1: Such a conceptual model can greatly influence further research in to marine mammals in Wozep and needs to be organised as early as possible in 2017.

12. *Which other activities affect marine mammals and how large are these effects? How do these effects interfere with determining the impact of the construction of OWFs (i.e. contaminants, fishery bycatch, human induced shifts in food availability etc.)?*

The research in Wozep will first focus on the effects of underwater noise before considering the effects of other activities. The impact of other activities that produce impulsive underwater noise can however be calculated in a similar manner.

Priority 3: When the effects of underwater noise is sufficiently researched we can turn our attention to other human activities.

13. *How can we determine noise impact from other foundation installation techniques?*

    Currently the main foundation installation technique is piling. When other techniques become more commonplace we need to consider looking at these techniques in more detail.

    Priority 3:This question can be answered only when other foundation installation techniques are proposed.

5.5 Phasing of activities for 2017-2021

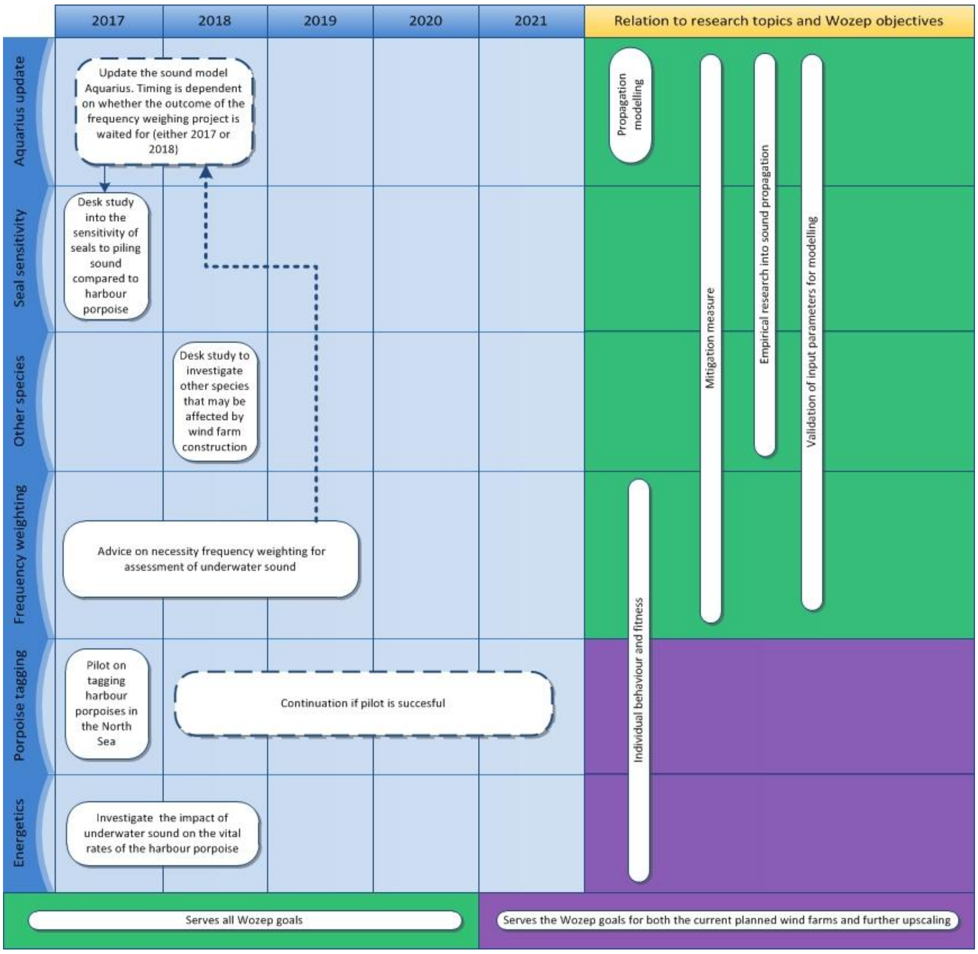

Figure 5.1 *Relationships between proposed research activities on marine mammals and phasing of these activities over 2017-2021 (part 1)*

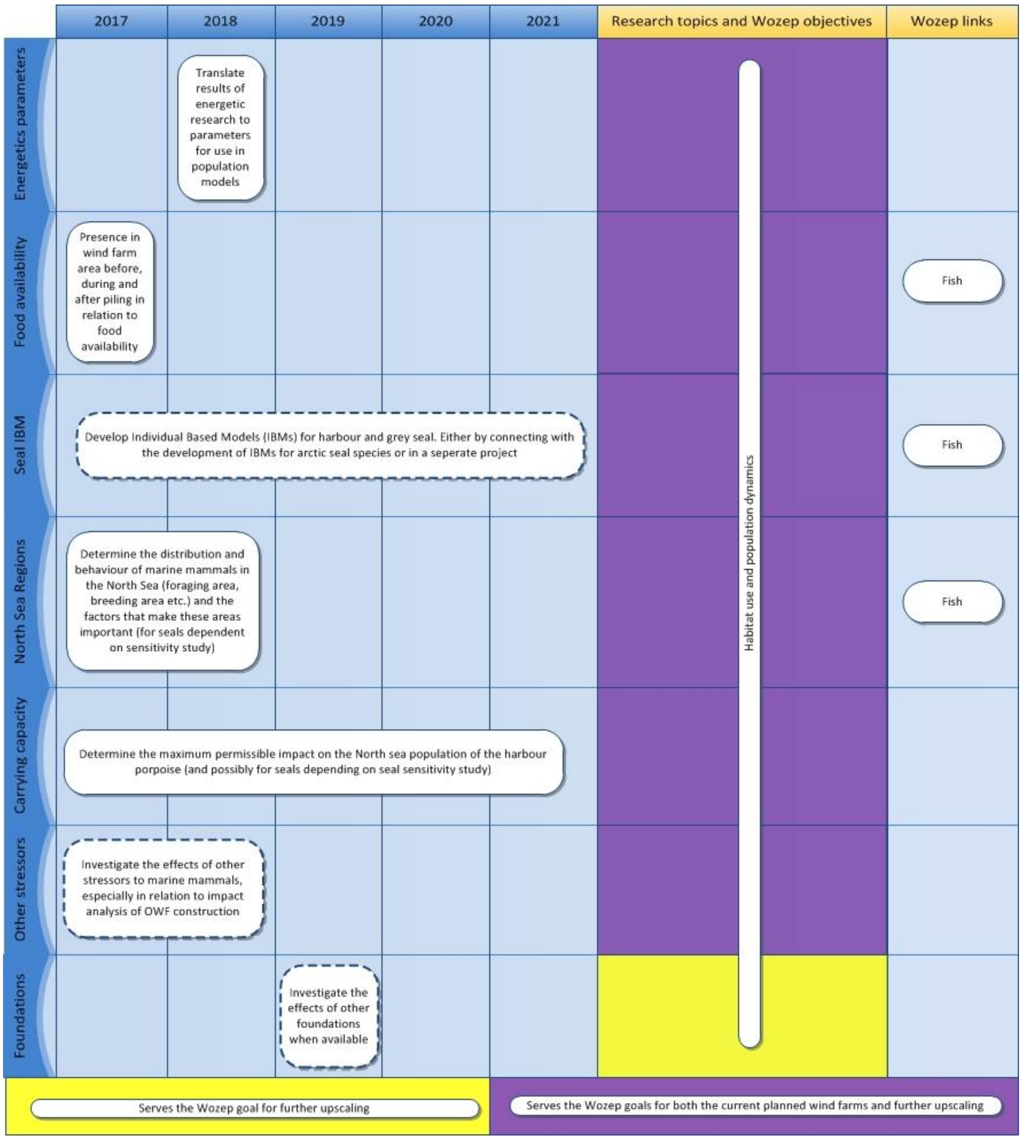

Figure 5.2 *Relationships between proposed research activities on marine mammals and phasing of these activities over 2017-2021 (part 2)*

6 Fish

6.1 State of knowledge at start of Wozep

Effects of OWFs on fish occur mainly during the construction phase. Pile driving of monopiles in to the sea bed can have a negative effect on fish and fish larvae. Therefore several mitigation measures are in effect, e.g. ramp up procedure to give the adult fish the opportunity to flee the area during pile driving. Fish larvae are planktonic and hence do not have the capacity to flee the pile driving area. Ample research has been carried out by Bolle et al. 2014 (*Effect of pile-driving sounds on the survival of larval fish; IMARES report*). It turned out that there are no significant negative effects of pile driving on fish larvae in the North Sea due to the fact that the effect circle of severe negative effects of pile driving is extremely small.

Although general information is available concerning the distribution of fish species in the North Sea, a lot remains unclear. Data about the presence and densities of marine fish populations are lacking. In addition, there are questions about the effects of OWFs on fish in the short term (acoustic disturbance and sediment dispersion) and in the long term (habitat change, operational underwater sound, electromagnetic fields and changes in fishing methods and fishing intensity).

Furthermore, more information is needed about the extent to which the impact on fish has a knock-on effect in the food chain (including accumulated effects) on marine mammals and seabirds that depend mainly/exclusively on fish. It is therefore important to have, and acquire, basic information about fish populations (including the prey of marine mammals and birds) in order to make a proper estimate of cumulative effects (whether or not also caused by changes associated with OWFs).

6.2 Research questions

Knowledge questions derived from the general Wozep goals are as follows:

Question 1. How does the presence of an OWF, including the exclusion of bottom trawling activities within the wind farm, affect local fish stock?

Note: Changes in (local) biomass of fish should be considered in conjunction with the availability of prey (macrozoobenthos).

To further refine these knowledge questions and make them suitable for research proposals, the following research questions have been formulated:

- To what extent does a higher density of prey for fish occur in offshore wind farms (both hard and soft substrate species)?
- To what extent does this lead to changes in fish biomass?
- To what extent does this result changes in total biomass of fish in the North Sea?

The positive effects of the exclusion of bottom trawling activities must be separated from the (potential) opposing effects of the potential increase in sport fishing.

- What effect does sport fishing have on the local fish stock and composition?

Also the influence of the physical presence of the piles has to be clear.
- Does impediment of the flow velocity and turbulence behind the piles via vertical mixing and longer residence times of the water mass in the wind farm lead to higher primary production and thereby indirectly to an increase in (local) fish biomass?
- Does turbulence behind the piles as a result of vertical mixing lead to destratification of the water column and if so, what are the effects? (This may be less important on the present locations of the Dutch wind farms in the North Sea than, for example, in the German Bight or in the Baltic Sea, but could become of more importance in the future).

Question 2. Which species are disturbed by electromagnetic fields, in what way (habitat loss, barrier effect, etc.) and to what extent?

Refined into research questions:
- What fish species can detect which fields (directly)?
- What indirect effects on fish (via presence/absence of benthos) are there?
- Are fish attracted to (weak) Electromagnetic Fields (EMFs)?
- Do fish experience (strong) EMFs as a barrier?
- How can models help to predict the real effects?
- If there are any observable effects on the individual level what are the effects on the population level?

Question 3. What are the population effects of electromagnetic fields on these species?

Refined into research questions:
- Do barriers lead to compartmentalisation of the North Sea as fish habitat?
- Do EMFs have a distorting effect on fish migration?
- Do different EMFs have different effects?
- If effects cannot be prevented, which mitigation measures are possible (e.g. increased burial depth, mantle, less voltage, AC vs. DC)?

Question 4. At what intensity are fish disturbed by underwater noise?

Note: Effects of underwater noise can be divided into effects during construction and effects during operation.

Refined into research questions:
- What effects does the construction of an OWF have on fish behaviour?
- What effects does masking (secondary sound overruling natural sounds) have on fish behaviour?
- What effects does particle motion have on the behaviour of fish?
- What effects does the additional sound pressure caused by passage of (recreational) vessels and OWF maintenance (service vessels) have on fish?
- Are OWFs in their operational phase avoided by fish?

Additional Question:

What is the risk that, as a result of non-linear interactions, certain pressure factors have critical limits above which the population-effects on fish suddenly become very large? It was decided to not address this question for the time being, since this does not involve the most important knowledge gap and it cannot be investigated experimentally in a straightforward manner due to its complexity. A desk study is not likely to provide a clear answer, but only approximate it.

6.3 Wozep research 2016

Project: Pilot study looking at the effects of electromagnetic fields on fish

Electromagnetic fields and their possible effect on marine organisms is a far underappreciated field of research. It is presently unclear if any fish species are affected. Research suggests that sharks and rays are very susceptible to the effects of electromagnetic frequencies.

An inventory was made of what electromagnetic fields (type/strength/etc.) occur around submarine power cables and what fields can be expected in the future in the North Sea when more offshore wind energy is planned. Additionally the sensitivity of the relevant North Sea species for these fields is documented. There are still many knowledge gaps when it comes to the impact of electromagnetic fields and their impact on marine organisms. The general consensus is that EMFs have no significant adverse effects on any organisms, but the research and conclusions to back that up are lacking. Anecdotal evidence tells another story. Many dose-effect studies were conducted with field strengths that don't occur around submarine power cables in the North Sea. There are reasons to assume that it is not the very high field strengths from these dose-effect studies that have adverse effects, but the very low EMFs that are in the same order of magnitude as the earth's magnetic field or EMFs that prey species can produce, which have adverse effects.

6.4 Proposed research 2017-2021

Note: It is emphasised that research on fish must be executed SIMULTANEOUSLY with research into other trophic levels and that it should be CONTINUOUS research. Furthermore it is recommended to focus on target species (sand eel, cod, sea bass and mackerel) to ensure that necessary research remains manageable.

1. *Disruption of fish behaviour by EMFs*
   There are several types of EMFs that can affect fish in different ways. An additional, disturbing EMF may complicate the detection of prey, or simplify it (i.e. when EMF causes shrimp to aggregate locally). Also attracting effects on fish can't be excluded (concentration of demersal fish is observed on the seabed, on top of a subsea cable). Furthermore it is not excluded that an EMF has a barrier effect (based on the anecdotes of fishermen who report catching no sole east of a subsea cable, but increased catches west of that same cable). At the same time the 'attraction' to EMFs should be determined for specific species (also taking into account temperature effects) by observing where fish are dwelling and foraging around submarine (power) cables. Anecdotal evidence by fishermen should be validated within this research project.

For field measurements in situ cameras or telemetry should be used (transmitters and receivers; near cables and further away). Additionally, the sensitivity of fish to EMFs (target species) can be determined in laboratory experiments. Dose-effect experiments can be carried out to establish behavioural responses and thresholds for species (groups) to true field strengths.

Field experiments are needed to assess the effect of EMFs as a migration barrier. Specific attention is needed for sharks and rays, as they may perceive very low field strengths and the impacts on these species are therefore possibly the highest.
Priority 1: The question of the effects of EMFs on fish recurs in most, if not all, EIAs and AAs for OWFs. The current assumptions of limited effects seem to be built on an incomplete understanding of how the species interact with natural and anthropogenic EMFs. More research is needed to address the remaining knowledge gaps.

2. *Carry out field measurements of EMFs.*

   To validate the modelled EMFs, field measurements should be conducted. This is a good opportunity to shed light on multiple other remaining questions, for example: Do water and sand (as substrate) influence the EMF in the same manner? To establish this, field measurements should take place above and under water. To this end the first part of the research should be on developing an underwater measurement device for EMFs suitable to North Sea conditions and able to measure the smallest EMFs in the field (same order of magnitude as earth's magnetic field). Also, gain insight in to the variables that make the fields stronger/ weaker as a first inventory in possible mitigation measures.

   Priority 1: While laboratory and field data help advance our understanding of the potential effects of EMF signatures, collection of additional data in the field is needed to better understand this interaction and how it may affect fish (and other marine animals).

3. *Population effects of EMFs on fish*

   Population effects of EMF are particularly relevant when large numbers of EMFs (by increasing numbers of OWFs) together affect multiple individual fish, for example by posing as a barrier. As an example, the European eel (*Anguilla anguilla*) is mentioned. Millions of euros are spent annually to improve the rapidly deteriorating eel stock by removing fish migration bottlenecks in inland waters (such as weirs, locks and pumping stations), but if the presence of EMFs by cables on the seabed stops eel from swimming into the estuaries in the first place, this is a waste of money and effort. From this perspective, this is an important issue. At present, the future development of OWFs after 2023 is still uncertain. The question focuses on the cumulative effects of EMFs on fish populations.
   Priority 2: When the results of research proposals 1 and 2 indicate that there may be significant impacts of EMFs on fish, it will be necessary to investigate how these impacts translate to population effects.

4. *Effect of exclusion of bottom trawling activities on local fish stocks*

   A distinction should be made between impacts on local fish stocks and the impact on fish stocks in the North Sea. In other words, is an OWF where no bottom trawling is allowed a refuge for fish? And if so, does this refuge only

attract and aggregate fish, resulting in a local increase in fish biomass and a compensating decrease in the surrounding area? Or is the local increase of fish biomass the result of increased production and does it also lead to an increase of the overall fish biomass outside the closed area? Quantitative research on this is however tricky, as shown by research undertaken by Wageningen Marine Research on the effects of closing off areas to commercial fishing.
Priority 2: An increase in fish biomass is often cited as a positive effect of OWFs. However, the evidence for this not conclusive. More evidence is needed to support this claim. Also, an increase in total fish biomass would also be relevant to commercial fishing activities.

Unaddressed knowledge questions
Knowledge questions regarding other human activities in- or outside of wind farms, such as fishing are not part of the scope of Wozep and therefore no research proposals are formulated for these questions. As addressed in chapter 10, these activities are part of the passage and shared use pilot and should be investigated in that programme. However, because we feel these questions are important, we will maintain the questions within the MRP 17-21 as a reminder. . The effects of underwater noise on fish have been studied in previous research programmes. Although some questions remain unanswered, there is not enough indication to warrant further investigation on this issue within Wozep at this moment. The same applies to wake effects of turbines on primary producers, where a lot of research has been done in Belgium.

6.5 Phasing of activities for 2017-2021

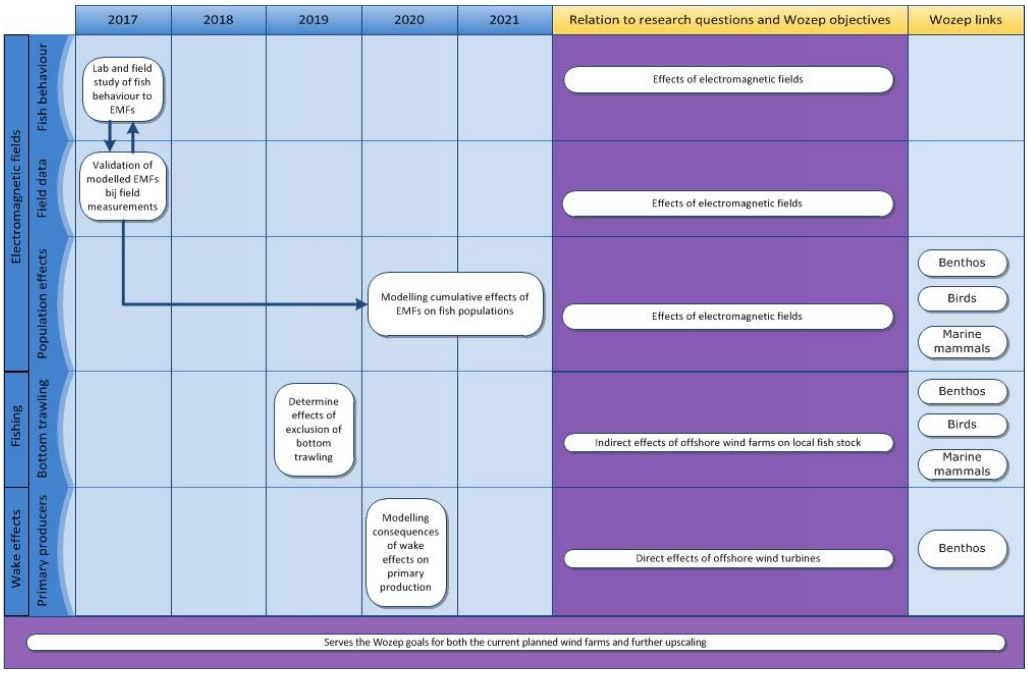

Figure 6.1 *Relationships between proposed research activities on fish and phasing of these activities over 2017-2021*

7 Benthos

7.1 State of knowledge at start of Wozep

Though the EIA, AA and KEC did not identify any significant effects requiring mitigation, it is often argued that OWFs may have a positive effect on biodiversity and even cause an increase in biomass due to the introduction of a hard substrate environment and by keeping out fishing activities that disturb the seabed. These benthic habitat effects are thought to reflect on improving foraging opportunities of species higher up in the food web, like predatory fish, birds and marine mammals. This is the main reason to spend monitoring effort on the long-term development of benthic habitats.

The effects on macrozoobenthic communities on soft and hard substrate have been monitored in all Round 2 OWFs. The statistical analysis of the BACI-design[13] data collection showed no significant changes inside the OWF compared to reference areas after 5 years of closure of the OWF. Some data suggested slightly larger individuals in soft benthic communities. The development of new hard-substrate communities, including rock-favouring fish species was evident. The overall development after permanent closure of OWFs was reasoned to be visible only after 10 – 20 years keeping in mind that the sediment disturbing (fishing) activities have been ongoing for over 50 years. We expect a comparable development in the operational OWFs of the Routekaart Wind op Zee (Roadmap Offshore Wind, 2016-2023), provided that they will remain closed for sediment disturbing activities during operation.
An important note is that the pilot to allow access for shipping and co-use (2017-2019) may turn out to be a confounding factor in assessing the long-term benthos development in OWFs with monitoring data to be collected after the year 2017. This implies an assessment lock on the time series till 10 years of operation.

Research indicated that bivalves react to piling noise transmitted through the sediment (surface) by closing at first instance (Kastelein, 2008[14]). Whether prolonged exposure also results in continued closure of the bivalves is not known. As the importance of effects during the operational phase of OWFs (20-30 y) is considered more relevant, further research into piling effects are not envisaged. Neither are the EMFs from charged intra-array and export cables considered a concern for zoobenthos.

The pressing question is whether any positive or negative effects would evolve during the lifespan of OWFs, realising that even more OWFs will be built to meet the renewable energy and CO2-emission targets and how these effects relate to the way of exploitation. A study in this area could also generate input for:

- building with nature
- opportunities in dismantling OWFs both in the context of the Beleidslijn Tijdelijke Natuur (Temporary Nature Policy) and cost efficiency
- effects like improving conservation status of food-web linked species and favouring exotic species in relation to the upscaling of areas covered by OWFs.

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[13] BACI: Before After Control Impact design where samples taken from the OWF and reference sites before and after installation of WTs are compared

[14] Kastelein, RA, 2008. effects of vibrations on the behaviour of cockles (bivalve molluscs). *Bioacoustics. The International Journal of Animal Sound and its Recording*, Vol. 17, pp. 53–102

The gaps in our knowledge are primarily linked to:

- effects of OWFs at larger scale (more turbine[foundation]s and OWF area)
- long term effects (>5 years) due to exclusion of sediment disturbance by fisheries
- changes in the benthos, plankton and fish populations having a knock-on effect on marine mammals and seabirds. Either by changes in the (local) food web, presence of OWFs ("stepping stones") or OWF-associated human activities (*e.g.* how marine areas with OWFs can be exploited, both for the benefit of nature as well as natural services).

7.2 Research questions

Knowledge questions derived from the general Wozep goals are as follows:

Question 1. What are the effects of the exclusion of benthic disturbance on the development of soft and hard substrate benthos in OWFs in the long term (> 5 years)?

To further refine these knowledge questions and make them suitable for research proposals, the following research questions have been formulated:

- What is the current benthic and demersal bottom trawling and other types of fishing intensity at the proposed OWF sites?
- What is the lag period after which impacts of OWFs (i.e. the exclusion of bottom trawling activities) are visible (5 years may be too short, considering it took 10 years before increased *Chamelea* clam densities were observed after excluding bottom trawling in the coastal zone)?
- What effects on the condition of benthos are measurable? (Biomass/shell, shell length, shell thickness, meat / energy storage tissue content)?
- What impacts on the macrozoobenthic species composition (biodiversity) and age distribution can be measured?
- What impacts on the growth rate of benthic species can be measured?
- What effects on soil integrity and sediment surface shear stress can be measured?
- What are the effects of OWFs on sediement characteristics?

Question 2. What demands do (extirpated) species have when it comes to substrate? How can positive effects be stimulated by 'building with nature' and enhancing conservation status?

Refined into research questions:

- What is the best way to reintroduce extirpated species like flat oyster (*Ostrea edulis*) beds and *Sabellaria alveolata* reefs in OWFs?
- Do larvae that only disperse over a limited distance settle more successfully in (a geographical series of) OWFs? I.e. validation of the "stepping stones" concept.
- Is introduction of various types of artificial hard substrate like reef balls, rock fill effectively increasing the (local) biomass (e.g. lobster, cod)?

Question 3. What role do foundations of OWF turbines play in the settlement and dispersal of alien (invasive) species?

Refined into research questions:

- Which alien species are considered to be a potential risk of becoming invasive alien species in the (sub) littoral?
- What is the competitive strength of invasive species relative to endemic species in the context of new artificial benthic substrate?

7.3 Wozep research 2016

Project 2016-1: International data analysis for benthos
Studying the effects of OWFs in the longer term means that future effects can be estimated more accurately and taken into account in any subsequent building of OWFs, for example by introducing scour protection, changes in exploitation. Analysing existing and new data now, will allow us to find answers to the question of what the effects are of large-scale OWFs. This may allow us to arrive at conclusions in the future about the best locations for OWFs, the best configuration, the best size, Temporary Nature, options for nature-based construction, and so on.

It is known that in Germany, the United Kingdom and Belgium extensive research is carried out on effects from OWFs with different types of foundation on benthic communities. A literature review of all available reports, publications and scientific articles gives a clear overview of the status of research and knowledge on this subject at an international scale. This is a simple, cost-effective way of enhancing our knowledge.

Project 2016-2: Combined OWEZ – PAWP benthos survey

The effects of offshore wind turbines on soft-substrate and hard-substrate benthos were assessed for OWEZ and Prinses Amalia Wind Park (PAWP) up to five years after the start of the operational phase in 2005 and 2006. The last research campaign in this long term project took place in 2011 and 2012. The results of this campaign suggest that slightly larger, although not statistically significant, individuals were found in the benthic communities of the soft substrate. On the turbines and the surrounding scour protection a distinct new community of species associated with hard substrate had gained a foothold on what used to be sandy sediment.

The question remains whether there are still no significant effects on benthos in the soft substrate after a longer period of time (>5 years after construction). In addition, there is also the question of how the community has developed on the hard substrate over the past 5 years (from 6 to 10 years after construction). This is important considering the knowledge gap of what the effects of the OWFs may be in the long term (since OWFs operate for >30 years), and what the implications are for upscaling (more OWFs) after 2023. The possible positive effects of OWFs may become clearer and opportunities may arise for 'building with nature' and/or the creation of 'temporary nature'.

Looking at the OWFs that have been operational for the longest time period, i.e. OWEZ and PAWP, may allow us to detect any possible long-term effects in the most efficient way.

The power analysis was conducted in order to see whether a field campaign of this kind will generate enough new information. On the basis of that analysis a decision will be made whether the field campaign will take place in early 2017.

7.4 Proposed research 2017-2021

Question 1. What are the long-term effects of the exclusion of benthic disturbance on the development of soft substrate benthos in the long term (> 5 years)?

The hypothesis that natural benthic communities associated with soft sediments will eventually return to their undisturbed state when left undisturbed is generally supported. How long such a restoration process takes in a closed OWF is unknown. In a protected part of the Dutch Coastal Zone *Chamelea* clam densities only returned after 10 years of excluding bottom trawling. Alternatively the restoration process will depend on the (Adaptive) Management options, but all without disturbind the seabed:

- in the OWF all activities that do not disrupt the seabed are allowed
- in the OWF only activities in direct relation to the OWF are allowed
- in the OWF a core zone is highly protected (fully closed) and margin open to non-disturbing types of co-use.

A higher biomass and biodiversity of the soft and hard substrate benthic community within the OWF could dissipate both from the turbine foundation towards inter-foundation sediments as well as outside the OWF. Both through increasing the local biomass production in the surrounding (entire) North Sea and by attracting mobile species that would shift to better settling and foraging opportunities. The question is how this influences the nett production in the North Sea and whether groups of organisms like fish and marine mammals would benefit.

Although it would be recommended for future reference to take the entire food chain into account, including phytoplankton and phytobenthos, the costs are considered disproportionate to follow up on this idea.

1. *Long-term monitoring of soft sediment benthos.*
   Long term soft sediment monitoring in the two OWFs OWEZ and PAWP. (Shifting the long term monitoring to GEMINI in the future might be considered because this OWF will be closed to navigation and any co-use other than wind energy)

   A long term monitoring dataset of the soft sediment benthos in the OWFs OWEZ and PAWP currently exists and any future research in these OWFs on benthic communities should connect to this dataset. The dataset contains a survey 1 and 5 years after start of operation (respectively 2007 and 2011 and a Baseline survey in 2003). In order to guarantee data comparison the 2017 (and 2021) survey should follow the same survey design and setup that was used in the previous years.

   The soft sediment campaign of 2017 can be replicated in February/March 2021 to add another year to the long term monitoring dataset (hard substrate monitoring is discussed in Proposal 2).

Priority 1: It is important to carry out assessments to understand the long-term changes of macrozoobenthos in the light of the planned largescale wind parks on the Dutch Continental Shelf and the rest of the North Sea. Effects may have prolonged and large-scale effects on higher trophic levels such as seabirds and sea mammals.

2. *Long-term monitoring of hard substrate benthos.*
   Long term hard substrate monitoring in the two OWFs OWEZ and PAWP. (Shifting the long term monitoring to GEMINI in the future might be considered because this OWF will be closed to navigation and any co-use other than wind energy).

   This project could be integrated with a project researching the settlement of invasive species B3a for at least the data collection and data sample analyses parts of the projects in order to reduce costs.

   A dataset of the hard substrate benthos in the OWFs OWEZ and PAWP currently exists and any future research in these OWFs on hard substrate benthic communities should connect to this dataset. The dataset contains a survey 1 and 5 years after start of operation (respectively 2007 and 2011). In order to guarantee data comparison the 2017 (and 2021) survey should follow the same survey design and setup that was used in the previous years.
   Priority 1: It is important to investigate the development of the hard-substrate species assemblage and the effects on the rest of the food web. A large area will be altered due to the introduction of artificial hard substrate.

3. *Biogenic structures*
   Pilot for multibeam / towed camera to detect biogenic structures (Oyster beds, *Lanice* reefs, *Sabellaria* reefs, *Einhornia* crusts).
   The 2017 survey may be used as a pilot for side-scan sonar / towed camera to detect biogenic structures (oyster beds, *Sabellaria* reefs) or the pilot may be planned separately when a suitable vessel is available within another project.
   Priority 1: Due to the fact that only point data will be collected, it is theoretically possible that for example developing biogenic structures are missed. To prevent this, additional survey techniques are needed. One of the most promising techniques is analysing backscatter data of multibeam images which will be investigated.

Unaddressed knowledge questions
No research proposals are formulated for knowledge questions 2 and 3. For question 2, opportunities are being investigated within a "building with nature" context. From Wozep we will keep a close eye on the developments. For question 3, few indications exist that this constitutes a problem at the moment. Of course, if present, invasive species will also be detected in the planned survey. If detected, this may yet lead to further investigation into this topic.

7.5 Phasing of activities for 2017-2021

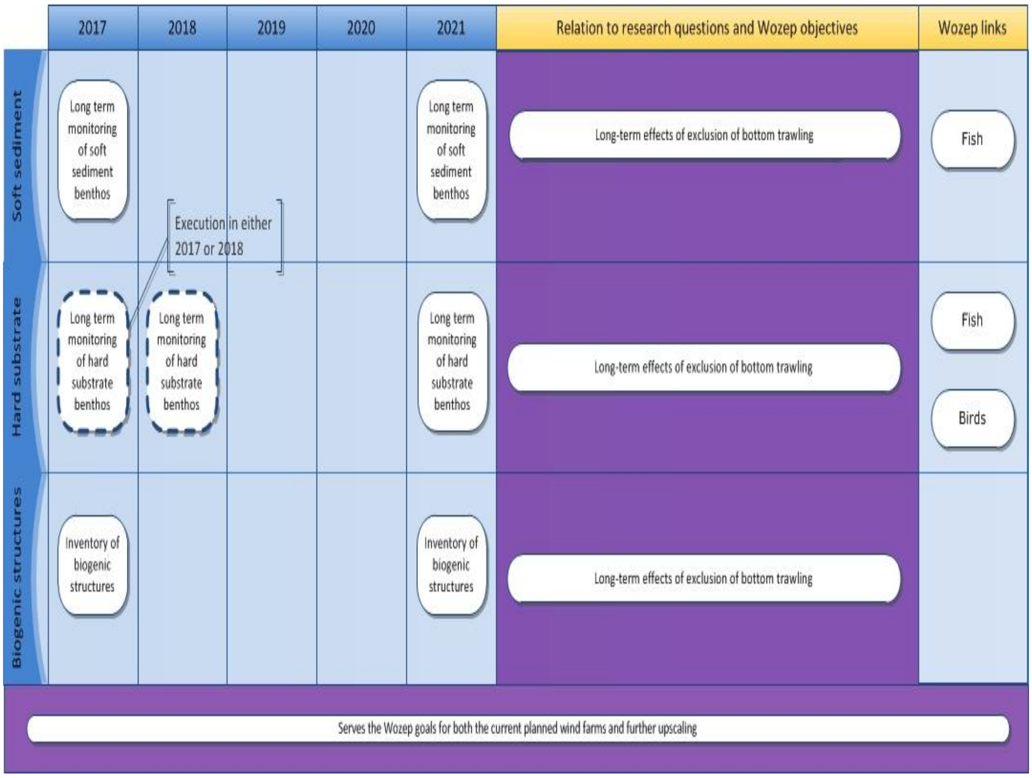

Figure 7.1 *Relationships between proposed research activities on benthos and phasing of these activities over 2017-2021 (part 1)*

8 Data- and information management

In general

In order to make robust analyses possible and to arrive at reliable and reproducible conclusions throughout the Wozep process, it is essential for data and information management to be properly organized from the beginning.
As already mentioned in Plan 2016 the requirements and underlying principles for clear and solid data and information management for Wozep are: a joint approach including third parties; a single location for data storage is preferred; traceability, quality and transparency of the data are the guiding principles; national and international standards should be implemented; joint data analyses must be possible for and by the various Wozep partners; use and reuse of data and information is encouraged (Marine Strategy Framework Directive, Natura 2000, EMODNET etc.); and international data exchanges should be easy to achieve (for example through EMODNET*).

Results data management project in 2016
In 2016 the implementation of OpenEarth approach for data management was started. The following results have been achieved:

- Data lab for Wozep was established.
- Contact was made with Eneco, Nuon and Gemini for archiving (in the coming period) datasets of OWEZ, PAWP, LUD and Gemini. This action will focus on the data sets that will be re-used in Wozep (as example for modelling or KEC calculations).
- A workshop will be performed in December 2016 with the bureaus that collect data in the Wozep projects in 2016; these parties will be informed and instruction will be given how to work in the data lab environment.
- Requirements for data delivery by the data collecting parties to the data lab were described and hopefully will be approved by RWS in 2016;
- There is a need for authorisation levels for data sets: when will data become public? Who is owner of the data? First agreements will probably be written at the start of 2017.
- Participation in the Data Ingestion project of EMODNET was realised as expected. Data from Wozep and earlier Wind at sea projects are being used as pilot for this project for ecological data within the European data network.

Data management plans for 2017-2021

- The plans for 2017 – 2021 are to improve both the data lab and organization to a professional level. This includes standardising data delivery, improving data quality, easy download and viewing services, software update(s) and improvements, and working in line with international agreements.
- Alongside this there are regular activities for carrying out data management, advising and helping data collecting parties.
- Good cooperation with the "Information House Marine" (IHM) Wageningen Marine Research will proceed. Data availability for the public will be achieved by the data portal of IHM.

9 International collaboration

The Wozep monitoring and research programme greatly values international collaboration. After all, the species concerned are not bound by national borders, and neither are the impacts. Therefore several of the proposed research projects for the Programme '17-'21 logically have a strong international component. Wozep will strive to build an international network of experts in these projects by, for example, hosting international workshops, organising and contributing to / participating in international joint research projects and by making all data internationally accessible through the Wozep data lab.

Parallel to Wozep, an international strategy is being developed that focuses on international collaboration through the Political Declaration on energy cooperation between the North Sea countries. Under this Political Declaration, four work areas have been identified. The Netherlands has offered to coordinate the first work area on Marine Spatial Planning (MSP), supported by the European Commission. Within this work area, participating countries will work on, among others, two high priority goals that are very relevant to Wozep: the development of a common environmental assessment framework (EAF), including a framework for a cumulative impact assessment, and increasing the availability and interoperability of marine data for planning, impact assessment, licensing and operations. Wozep will stay in close contact with the project leaders of this work area, to assure maximum alignment between these parallel projects.

Furthermore, Wozep team members will visit relevant international conferences and meetings (such as the Conference on Wind energy and Wildlife impacts (CWW) and Wind and Wildlife Research Meeting (WWRM)) whenever possible to both present the Wozep programme and results and collect information on relevant research projects around the world. Wozep team members also take part in several international working groups on relevant subjects, such as the Disturbance Effects on the Harbour Porpoise Population in the North Sea (DEPONS), International Energy Agency task #34 Working together to solve environmental effects of wind energy (IEA WREN), the international council for the exploration of the Sea Working Group on Marine Renewable Energy (ICES WGMRE) and the Offshore Renewables Joint Industry Programme (ORJIP), and there is a strong link (through the project group) with groups working on projects for the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR), Marine Strategy Framework Directive (MSFD),) and the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS).

With a subject as strongly international as the ecological impact of OWFs, international collaboration and connection is fundamental for a successful research programme. Therefore Wozep will, through the approaches described above, endeavour to become a monitoring and research programme with strong international appeal, connections and impact.

In future Wozep evaluation reports, special attention will be given to the completeness and effectiveness of the international network. The primary focus area will be the southern North Sea.

10 Prioritisation between topics

Birds, bats and marine mammals are considered high priority issues with respect to conservation status in the expanding area with offshore wind turbines. As birds and marine mammals are at the top of the food web of the North Sea ecosystem changes in the food and foraging opportunities that might result from the presence of OWFs render fish and benthos highly relevant as well.
Therefore, a well elaborated and balanced integration of research effort and logistics between topics is considered to be a better option to efficiently spend finances than strict prioritisation.

As mentioned in chapter 1.1, Wozep has been set up with the following three objectives:

1. Determine effectiveness of mitigation measures (in the context of the 40% cost reduction in the Energy Agreement).
2. Reduce (scientific) uncertainties of the knowledge gaps and assumptions from the KEC, EIA and AA.
3. Reduce uncertainties, knowledge gaps and assumptions regarding effects in the long term and upscaling of OWFs (in relation to OWF plans that may follow up on the roll-out of the Energy Agreement).

The scope of the KEC for cumulative impact assessment is the entire Roadmap for offshore wind development. Therefore the assessment of the Energy agreement[2] includes all future OWFs until 2023. The KEC specifically deals with birds, bats and underwater noise/porpoises. Where necessary mitigating measures are defined, which are further elaborated upon in the wind farm site decisions.

Effects of upscaling (more OWFs) and long term effects are not yet included in the KEC, but are important knowledge gaps. The life span of OWFs is about 30 years and KEC has only been predicting (with inaccuracies due to insufficient validation of assumptions) up until 2023, the deadline year of the Energy Agreement. Given the possible developments after 2023, it is important to incorporate these knowledge gaps in Wozep, to enable future deployment of offshore wind energy within ecological constraints. It is important to conduct this kind of research now, at this moment, to be prepared for questions that arise from the upscaling after 2023.

The knowledge questions from the KEC are prioritised and supplemented with the objectives for (cost) efficiency of mitigation and scaling up for the longer term. For the steps from knowledge gaps to prioritised research and –goals the process, as mentioned in chapter 1.2, has been followed.

In KEC knowledge gaps and assumptions have been identified, for which in the Wozep answers and/or validation will be generated. Validation of the assumptions can potentially show that KEC assumptions were correct, are still precautionary or have too little precaution. By comparing research results to the assumptions in KEC, it will be evaluated whether new insights could lead to adjustments in the results and conclusions of KEC. If so, the Wozep project team will advise the steering committee by outlining action perspectives. However, whether or not adjustments to KEC should be applied and, if necessary, how they should be applied, will not be decided within Wozep, but within the wind farm site policy process. After approval of the potential changes to KEC, it should be revised and checked for potential new knowledge gaps. In this manner the PDCA-cycle, as given in chapter 1.1, is followed.

When we look at possible prioritisation of the goals, the following line of reasoning can be set up: In KEC, assumptions have been made emanating from the Birds and Habitats Directive with respect to the application of the precautionary principle. Therefore, in covering knowledge gaps with assumptions, the latter tend to result in worst case estimates for the impact of the ecological effects. In order to validate those assumptions (whenever possible), the knowledge gaps masked by the assumptions have to be solved as best as possible.

Adjustment of KEC is important for later (re)specifying the mitigation measures included in the Wind farm site decision (or the degree of commitment of the mitigation measure), and towards the situation following the deployment of the Roadmap (after 2023).
Validation of assumptions / resolving knowledge gaps in the KEC is important for the future deployment of OWFs. If indeed more offshore wind energy is considered to be necessary, after fulfilment of the present Energy Agreement, and the rollout of OWFs is to be continued, we will have to understand in time (before new plans, new spatial planning and new plot decisions are underway) what the constraints from an ecological perspective are: what environmental space remains available for this future development, which are the ecologically optimal locations for OWFs and what are the possibilities and/or limits for effective mitigation.

The studies that specifically look at the long term effects are important for the realisation of offshore wind energy within ecological constraints.

How the prioritising between the three objectives is undertaken, depends on the political commitment and the development in the wind farm industry and nature. If the political commitment will remain targeted at the development of offshore wind after 2023, then the validation of KEC and the long term effects are most important. If the political commitment diminishes and becomes more conservative, the priority will shift towards a more conservative approach, without a development perspective. The focus will then be to solely abide by the law, which would lead to the validation of KEC and effectiveness of the mitigation measures becoming more important. By the time new mitigation measures will be developed by the market for species that are now not mitigated, there can be a shift in priority from long term securities to effective mitigation measures. Within the research topics, priorities can also shift, such as the establishment of new breeding colonies of protected species causing priority shifts in the list of bird species to be considered vulnerable to adverse impacts.

For the time being, the Wozep programme will aim to prioritise with respect to: 1) the validation of the assumptions in KEC and 2) the long term effects and 3) assessing necessity and (cost) efficiency of mitigation measures. The latter is at a lower priority because a lot of the research proposed in the Wozep topics will already (indirectly) contribute to the validation of the (cost) efficiency of mitigation measures.

The various studies are clustered according to the aims. See the figures in the phasing of activities section in each of the topic chapters. Some studies serve several of the objectives, as can be seen in the figures.

Intermezzo mitigation measures

In the Wind farm site decisions the following mitigation mesures are set (example from Draft wind farm site decision Hollandse Kust Zuid site I).

Regulation 4 Mitigating measures

1. Measures for the prevention of permanent physical harm and/or effects to porpoises and seals and the mortality of fish:

a. the permit holder must use one or more acoustic deterrent device(s) tuned to the relevant frequencies during piling work, including half an hour before piling work starts. In its piling plan, the permit holder will outline the type of deterrent it plans to use, including supporting evidence of its proven effectiveness;

b. piling work must adopt a soft start, ensuring that porpoises are given the opportunity to swim to a safe location. The piling plan should provide details outlining the duration and power of the soft start along with supporting evidence of effectiveness.

2. Measures to prevent disturbance to porpoises, seals, and fish (sound emission standard):

a. the underwater sound level during pile-driving work for the construction of the wind farm may never exceed the sound emission standard stated in the table below;

Sound level (dB re 1 μPa²s SEL on 750 meter of the sound)			
	Period		
Number of the wind turbines to be erected	January to May	June to August	September to December
55 - 63	163	169	171
49 - 54	164	170	172
43 - 48	165	171	173
39 - 42	166	172	174
35 - 38	167	173	175

b. the permit holder may exceed the sound emission standard stated in the above table by a maximum of dB re 1 μPa2s SEL1 for the first ten foundation pillars;

c. during the pile-driving work, the sound level must be continuously measured by or on behalf of the permit holder. The sound measurements for each foundation pillar driven must be sent to the Minister of Economic Affairs within 48 hours after completion of the pile driving of the foundation pillar concerned;

d. when consecutive sound measurements reveal that the underwater sound level during the pile driving of the foundation pillars does not exceed the sound emission standard stated in the table, the Minister of Economic Affairs can be asked to permit the lowering of the sound measurement frequency;

e. the permit holder prepares a piling plan and submits this to the Minister of Economic Affairs at least 8 weeks before the commencement of the construction;

f. the work must be performed in accordance with the piling plan as referred to in subparagraph e of this regulation;

g. the permit holder strives to produce as little underwater sound as possible;

h. the permit holder strives to produce underwater sound in a continuous period of time as short as possible.

3. Measures to limit collision victims among birds at rotor height during mass bird migration:

a. at night (between sunset and sunrise), during the period in which mass bird migration effectively takes place, the number of rotations per minute per wind turbine will be reduced to less than 1;

b. for the purpose of implementing this regulation, referred to in subparagraph a, the control system of the wind turbines will be linked to a system that effectively observes actual bird migration;

c. in a plan, the permit holder describes to which relevant transect bird density will be determined. The permit holder must submit this plan to the

Minister of Economic Affairs at least 8 weeks before the commencement of the construction;

d. the link mentioned in subparagraph b of this regulation will be executed within the plan mentioned in subparagraph c;

e. July 1st and January 1st of each year the permit holder reports how and in what way the regulation rules have been executed.

4. Measures to prevent collision victims among bats at rotor level:

a. the cut-in wind speed of turbines will be 5.0 m/s at axis height during the period of 15 August to 30 September between 1 hour after sunset to 2 hours before sunrise;

b. in case of a wind speed of less than 5.0 m/s at axis height, during the period referred to in subparagraph a, the permit holder will reduce the number of rotations per minute per wind turbine to less than 1;

c. within two months after the end of the period referred to in subparagraph a, the permit holder will produce a report outlining how this regulation is implemented and submit it to the Minister of Economic Affairs.

Connecting to passage & shared use

Passage of vessels up to a length of 24 m will be allowed from April 2017 onwards in the OWFs of OWEZ, PAWP and Luchterduinen, and the planned OWFs Borssele and Hollandse Kust. The OWF of Gemini remains closed for shared use, because the distance to the coast is too great to allow for adequate enforcement. Negotiations on more specific forms of shared use (e.g. fisheries) are still ongoing. At the moment, the Ministry of Economic Affairs is working on a framework for shared use. The expectations are that some types of fishery will be permitted up to a minimum distance of 50m from the wind turbines. The fishery types considered could include: angling or gillnet fisheries. Fisheries that disturb the bottom, like beam trawling, will not be permitted. Other activities, such as e.g. marine algae or shellfish nurseries are still under consideration.

These activities might influence the ecological effects of OWFs. For example, since birds are likely to be attracted to fishing vessels or other activities such as algae or shellfish nurseries, the fluxes (and thus of collision with rotating turbine blades) are likely to increase. Moreover, the presence of fishing vessels in or at the edge of an OWF can strongly influence the behaviour of the birds as well as the birds' awareness of the presence of hazardous objects such as the rotating blades of wind turbines. In order to increase our insight into the dose-effect relationships, more should become known about the relationship between shipping vessels and bird (particularly gull) behaviour.

The additional effects of passage and shared use of the OWFs will have to be monitored additionally, since so far effects of OWFs have been assessed without taking these factors into account. There will be a monitoring programme for passage and shared use, yet at this moment it is unclear what ecological research will be included in this programme. For now Wozep has not planned any research into this area as we believe these issues should be investigated within the passage and shared use monitoring programme. However, it is crucial that Wozep and the basic monitoring programme for passage & shared use will stay closely connected. Therefore Wozep will closely follow the developments in this programme.

11 Follow-up

This MRP '17-'21 will be the framework for Wozep for the coming years. Every November the Wozep project group will write an evaluation report describing the progress in answering the research questions, based on the results of the research projects in that year: what did we learn and is the quality of the results scientifically sound? The proposed upcoming research projects for the next year from this MRP '17-'21 will be re-evaluated: are the expected results still necessary and useful in relation to the Wozep objectives? Did new questions come up; either from our own research or from others? And last but not least, did priorities from policy makers change in a way that affects Wozep research priorities?

Based on the annual evaluation report a detailed Plan for the next year is written and submitted to the steering committee for approval. In this process the preparation group, the scientific parties and stakeholders play their role as they have done for the MRP '17-'21. The goal of this process is to keep the Wozep monitoring and research programme tailored, up-to-date, efficient and effective.

As is written in chapter 1, the plan-do-check-act cycle is used to have an up-to-date Wozep monitoring and research programme.