REPORT

Wozep midterm evaluation

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Enhancing Society Together

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Preface

The call for an increased sustainable energy production in The Netherlands and the role that offshore wind plays in that transition was clearly heard last year and played an important role in the election programs and the formation of a new political coalition. Wozep is the Dutch governmental ecological research program which investigates the effects on protected marine life and ecosystems resulting from (the upscaling of) offshore wind energy production. After five years of research, it was time to evaluate the program and consider what it has brought us and what remains to be achieved in this context. Royal HaskoningDHV was asked to conduct this midterm evaluation with the support from Rijkswaterstaat and with input from leading scientists from several topics.

The Wozep research program was started in 2016 based on the underlying idea that a central (government-driven) research program is more efficient and therefore cheaper than conducting research for each wind farm. In this way, the coherence of research projects can be monitored more effectively and efficiently. In the first year of Wozep, an extensive research program for the period 2016-2021 (later extended to 2023) was drafted containing knowledge questions each focusing on specific research topics.

This midterm evaluation provides an overview of the extent to which the knowledge questions that were formulated at the beginning of the program have been answered, whether the reliability of the knowledge is sufficient for use in policy and management, how new insights have been used and which knowledge gaps are still open. In addition, conclusions were made regarding priorities for research and which topics can be phased out. Insights are also given into how Wozep knowledge is applied in the process of policymaking and how the realization of offshore wind energy can be better achieved.

In the Dutch North Sea Agreement it was agreed to extend the Wozep program until 2030. The midterm evaluation report provides a solid basis for learning and improving the continuation of research and the further roll-out of wind energy at sea!

Annelies Bobeldijk, EZK (client Wozep until Januari 2022)

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Royal HaskoningDHV

Summary

In 2015, the Dutch Ministry of Economic Affairs and Climate (EZK) decided to set up an integrated monitoring and research programme to study gaps in our knowledge relating to the impact of offshore wind farms (OWFs) on protected species of the Dutch North Sea. This led to the establishment of the Dutch Offshore Wind Ecological Programme (Wozep).
The objectives of Wozep are:

- 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

Since the start of Wozep in 2016, the need for knowledge on the ecological state of the North Sea and the attention of both the government and the stakeholders has changed due to progressive insights and upscaling of wind energy at sea. To optimally contribute to the identification of the most important knowledge questions on the impact of offshore wind and because Wozep has been running for five years now, it is important to evaluate the results of Wozep. In 2019, EZK expressed its intention to extend the term of Wozep to 2030. An evaluation is therefore also important input to develop the scope of Wozep for the period up to and including 2030.

Midterm evaluation: aim and methodology
The aim of the evaluation is to clarify what knowledge has been gained, to what extent the original research questions of Wozep have been answered and how these results were used in policy and management. As basis for this midterm evaluation, an initial assessment was performed to assess the extent to which the knowledge questions have been answered. For each of the four research topics – *birds, bats, marine mammals, ecosystem effects* – a synthesis was produced (separate appendix), which was used as a starting point for a joint assessment with national and international experts in separate work sessions. Apart from the extent of answers to the knowledge questions also the focus of future research and the use of Wozep results in policy and management was discussed in these work sessions

This evaluation report provides per research topic:

- An overview of the answers to the knowledge questions
- An assessment to what extent the questions can be answered
- An overview of the conducted and planned research per knowledge question
- Reformulation of knowledge questions, if relevant
- Conclusions and recommendations

During the evaluation process it proved to be very useful for all actors and stakeholders involved in policy development, research, management and execution to analyse and structure the position and evolution of Wozep in relationship with the different position, role or responsibility of the stakeholders. Following the progress in the OWF policies and plans the results of Wozep are being used in the different steps of the

so called ‘OWF Policy Cycle’. This is described, analysed, and evaluated as a fifth topic. This summary will focus on the main findings, conclusions and recommendations.

Main findings and recommendations

- The results from research within Wozep are highly valued and are being used by policy makers, permitting agencies, the offshore wind industry, and other stakeholders. The way Wozep and KEC are set up is unique in Europe and the world
- During the past five years a lot of knowledge has been gained on the different topics that are part of Wozep. Especially on birds and marine mammals, big steps have been taken in creating a good knowledge base on the impact of offshore wind. For both species groups models have been developed that are already being used to predict the effects on populations. Much of the bat research is still in a preliminary phase, high research costs are involved and casualties at sea by collision are hard to detect. Research on the effects on the ecosystem has started with changes to oceanographic and abiotic conditions, it will continue with the indirect effects of these changes on populations of protected species.
- As this is a mid-term evaluation, much of the research is still ongoing. Part of the finished studies was focussed on possibilities of research and research methods and have led to follow up studies from which the results can be used to answer the knowledge questions. Nevertheless, many knowledge questions can be partly answered by Wozep research. The ongoing studies are assumed to deliver knowledge that will contribute to more answers to the remaining knowledge gaps.
- It is recommended to refine the knowledge questions, to have a clearer set of knowledge questions as a structure for Wozep research in the coming years. *Proposals for updated knowledge questions are part of previous chapters in this evaluation.*
- Studying the effectivity of mitigation measures is part of Wozep. Since only a few mitigation measures have been executed until present, therefore it is hard to study the effectivity. It is also difficult to measure the differences in for example casualties. However, there is discussion about the way mitigation should be studies under Wozep as this is still unclear. *It is recommended to further discuss and determine how the study into mitigation measures can be better incorporated into Wozep.*
- Many stakeholders and experts recommend collaborating with research programmes in other North Sea countries to find synergies, reduce research costs, validate and strengthen results and improve potential mitigation measures. *The evaluation team recommends exploring possibilities for one or two research priorities (or species) through existing intergovernmental networks and working groups. It is also recommended to promote and challenge researchers and research institutions to collaborate more and to develop concerted research proposals to national governments and research programmes.* These research efforts then strengthen each other in the interest of protecting species and ecosystems.
- The consultation group is regularly being informed on the progress within Wozep, which is important. However, the group members believe they can also actively contribute as a source of knowledge. *It is recommended to organise work sessions on relevant subjects, with possibilities to discuss issues and share knowledge.*
- Wozep works on reducing the uncertainties of the impact of OWF, which has already resulted in reduced costs for OWF companies. Clarity on the impact of OWFs also may lead to more innovations (for example bubble screens to mitigate the impact of underwater noise).
- Actively exchange information on Wozep progress is recommended with all parties involved (ministries, RVO, RWS, the consultation group) using the figures of the Offshore Wind Policy Cycle. Visualisations can help direct the use of research results within the policy cycle and can clarify how additional and updated knowledge questions will contribute to offshore wind policies

1 Introduction

In 2015, the Dutch Ministry of Economic Affairs and Climate (EZK) decided to set up an integrated monitoring and research programme to study gaps in our knowledge relating to the impact of offshore wind farms (OWFs) on protected species of the Dutch North Sea. This programme was established in response to a recommendation from Rijkswaterstaat (RWS), that knowledge gaps are primarily generic rather than specific for individual Offshore Wind Farms (OWFs). This led to the establishment of the Dutch Offshore Wind Ecological Programme (Wozep). The scope set out by EZK to RWS was issued in late 2015 for the period 2016 to 2021. In the “Monitoring and Research Programme 2017-2021” (MRP), the outline of the complete research and monitoring programme for the period 2017-2021 is set out. The Ministry has prolonged the period of the research programme to 2023. Wozep is strongly related to the Framework Ecology and Cumulation (KEC), which delivers input to Wozep and vice versa.

The objectives of Wozep are:

- Reduce (scientific) uncertainties concerning knowledge gaps and assumptions from 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 (*remark: cost reduction has been reached duet o subsidy free bids*).

Since the start of Wozep in 2016, the need for knowledge on the ecological state of the North Sea and the attention of both the government and the stakeholders has changed due to progressive insights and upscaling of wind energy at sea. To optimally contribute to the identification of the most important knowledge questions on the impact of offshore wind and because Wozep has been running for 5 years now, it is important to evaluate the results of Wozep. In 2019, EZK expressed its intention to use the term of Wozep to be extended to 2030. A substantial evaluation is therefore also important input to develop the scope of Wozep for the period up to and including 2030.

Rijkswaterstaat assigned Royal HaskoningDHV to execute this midterm evaluation of Wozep. The aim of the evaluation is to clarify what knowledge has been gained, to what extent the original research questions of Wozep have been answered and how these results were used in policy and management.

2 Evaluation method

To accomplish a midterm evaluation of Wozep the following steps have been executed:

1. A synthesis on the four research topics (birds, bats, marine mammals, ecosystem effects) was drafted, which contains:
    a. A summary of the results from the studies that have been carried out
    b. An assessment to what extent the knowledge questions of Wozep have been answered
    c. An assessment on how the results are used in policy and management
2. Work sessions with national and international experts and stakeholders were organised to:
    a. Gain input and feedback on syntheses
    b. Discuss the extent to which the knowledge questions have been answered
    c. Discuss the focus of future research
    d. Discuss the use of Wozep results in policy and management
3. Evaluation
    a. Overview of the answers to the knowledge questions
    b. Assessment to what extent the questions can be answered
    c. Overview of the conducted and planned research per knowledge question
    d. Reformulation of knowledge questions, if relevant
    e. Overview of the use of Wozep results in policy and management
    f. Conclusions and recommendations: per topic and overall/general

On the topic of ‘Ecosystem effects’, so far only general knowledge questions have been defined and limited research has been conducted. This is caused by the fact that the ecosystem effects were not part of the MRP as at the time it was not clear that this was an issue. Wozep started with research on direct effects on protected species, but later it became clear that also the indirect effects via the food chain need to be taken into account. Therefore, a pilot study started in 2018 to give an overview of possible impacts on an ecosystem level. In 2019 a model study was conducted to give insight into the effects of the upscaling of offshore wind on physical processes in the marine ecosystem. During this evaluation, the focus for Wozep on this topic has become clearer. In the synthesis, a research approach was proposed, which was discussed during the work session. Knowledge questions were defined based on input and discussions.

2.1 Syntheses

As a basis for this midterm evaluation, an initial assessment was performed to assess the extent to which the knowledge questions have been answered. For each topic, a synthesis was produced (separate appendix), which was used as a starting point for a joint assessment with subject matter experts in separate work sessions. In summary, the synthesis per topic consists of:

- A summary of the research results up until February 2021
- An initial attempt on answering the knowledge questions and a draft assessment of the quality of these answers
- An overview of the application of results in policy and management.

For the work session on the use of Wozep results in policy and management an overview of the different steps in the offshore wind procedure was produced, which can be described and analysed as the ‘Offshore Wind Policy Cycle’. It shows the role of the different organisations and which ecological knowledge is used for every step.

These syntheses were sent to the participants in advance of the work sessions. These can be found on the Wozep page of the Noordzeeloket.[i]

2.2 Work sessions

To assess and evaluate the Wozep research and the extent to which knowledge questions are answered, work sessions with experts were organised. Experts who are involved in the execution of the research were present and in addition, experts that are not involved but know a lot about the topic are invited. At least one expert from another country was invited.

The following online work sessions were conducted:

Birds
Date: 16 March 2021
Expert panel: Ruben Fijn (BuWa), Aonghais Cook (BTO), Allix Brenninkmeijer (Provincie Groningen), Martin Poot (CBS), Karen Krijgsveld (Ministry of Defence), Eric Stienen (INBO), Mardik Leopold (WMR), Maarten Platteeuw (RWS), Jos de Visser (RWS)
Facilitators: Jens Odinga (chair), Sophie de Reus, Audrey van Mastrigt (RHDHV)

Bats
Date: 29 March 2021
Expert panel: Bob Jonge Poerink (Ecosensys), Christian Voigt (Freie Universität Berlin), Dagmar van Nieuwpoort (RWS), Fiona Mathews (University of Sussex), Lothar Bach (Bach-Freilandforschung), Maarten Platteeuw (RWS), Martijn Boonman (BuWa), Sander Lagerveld (WUR)
Facilitators: Jens Odinga (chair), Sophie de Reus, Debby Barbé (RHDHV)

Marine mammals
Date: 22 March 2021
Expert panel: Anne-Marie Svoboda (LNV), Christ de Jong (TNO), Floor Heinis (TNO), Geert Aarts (WMR), Jakob Tougaard (Aarhus University), Lonneke IJsseldijk (Utrecht University), Martine Graafland (RWS), Meike Scheidat (WMR), Niels Kinneging (RWS), Roelant Snoek (Waterproof), Ron Kastelein (Seamarco)
Facilitators: Jens Odinga (chair), Sophie de Reus, Debby Barbé (RHDHV)

During the expert work sessions on the topics above, the experts were asked to reflect on the initial analysis of knowledge questions and answers provided in the synthesis, and were guided through an assessment by going through the following questions:

- To what extent can the knowledge questions be answered?
- Does the research within Wozep contribute to answering the knowledge questions?
- What other research outside of Wozep contributes to answering the knowledge questions?
- What topics or aspects are less relevant to focus on concerning meeting the Wozep objectives, and why?
- What topics require more focus and research concerning meeting the Wozep objectives, and why?

[i] *https://www.noordzeeloket.nl/functies-gebruik/windenergie/ecologie/wind-zee-ecologisch-programma-wozep/*

Ecosystem effects
Date: 22 April 2021
Expert panel: Jaap van der Meer (WUR), Tobias van Kooten (WUR), Luca van Duren (Deltares), Peter Herman (Deltares), Johan van der Molen (NIOZ), Steven Degraer (Royal Belgian Institute for Natural Sciences), Dagmar van Nieuwpoort (RWS), Maarten de Jong (RWS), Maarten Platteeuw (RWS)
Facilitators: Jens Odinga (chair), Sophie de Reus, Debby Barbé (RHDHV)

During the expert work session on ecosystem effects the suggested research approach was discussed, and knowledge questions were further refined.

Policy and management
In addition to work sessions with experts, an online work session with people involved in policy and permitting regarding offshore windfarms and nature from the ministries of EZK, IenW and LNV and RWS and RVO was conducted to assess the extent to which Wozep research results have been applied in policy and management.

Date: 19 May 2021
Participants: Joost Vermeulen (EZK), Teus van Hattum (LNV), Jeroen Vis (LNV), Jaap van der Sneppen (RVO), Henk Merkus (IenW), Raoul Syrier (RWS), Marco de Krieger (RWS), Wesley Fransen (RWS), Cees Schaap (RWS), Martine Graafland (RWS), Ingeborg van Splunder (RWS)
Facilitators: Job van den Berg (chair), Saskia Mulder, Debby Barbé (RHDHV)

During this work session the following questions have been discussed:

- Do you recognize the ‘Offshore Wind Policy Cycle’?
- Do you recognize the position of ecological knowledge in this chain?
- What opportunities for improvement do you see in the impact of Wozep research results in policy and management?

Consultation group
Date: 1 June 2021
Participants: Alma Scholten (Tennet), Marin van Regteren (Eneco), Serena Rivero (St. de Noordzee), Bastiaan Vader (NWEA), Sarah Verroen (Visned), Luuk Folkerts (Gemini), Marjolein Kelder (Natuur en Milieu), Sytske van den Akker (Vattenfall), Birte Hansen (Ørsted), Harm Dotinga (Vogelbescherming), Tim van Oijen (Vogelbescherming), Koen Broker (Shell), Ingeborg van Splunder (RWS), Dagmar van Nieuwpoort (RWS), Merijn Zandstra (RWS)
Facilitators: Job van den Berg (chair), Saskia Mulder, Debby Barbé (RHDHV)

During this work session the preliminary results of the workshops are discussed.

2.3 Evaluation

The evaluation consists of three parts:

- Evaluation of the four topics with knowledge questions and recommendations to refine the knowledge questions (Section 3)
- Evaluation of the use of research results in policy and management and evaluation of the governance around Wozep including recommendations on improvements (Section 4)
- An overall evaluation and general conclusions and recommendations (Section 5).

Based on the syntheses of Wozep research results and based on input from work sessions with experts, an evaluation is performed for the four topics. This evaluation starts with a summary of answers to the knowledge questions. Based on these answers, it was assessed to what extent these knowledge questions can be answered. This assessment is presented in a table for each topic regarding the relevant studies that delivered answers and includes ongoing and planned studies to answer these questions. These tables can be used by the Wozep team to keep an updated overview of knowledge questions and their answers from relevant studies. Where relevant, suggestions are made to refine the knowledge questions as part of the recommendations.

During the work sessions, the experts were asked to give their expert judgment on the focus for future research. The suggestions are included in the paragraph Focus for future research for every topic. The Wozep team will decide which of these suggestions will become part of the Wozep research in their yearly prioritization of the information that is needed.

The use of the Wozep results in the roadmap for Offshore Wind, site decisions, EIA and other documents and procedures were assessed in a desk study. During the work session, the use of the Wozep results in policy and management was discussed and how this could be improved. Also, the 'Offshore Wind Policy cycle' and the role of the different organisations in this cycle was discussed.

Lastly, an overall evaluation has been performed, this resulted in general conclusions and recommendations.

3 Wozep results and future focus

This section contains a summary of the Wozep research results on the impact of OWFs per research topic, i.e. birds, bats, marine mammals and ecosystems. To focus the research within Wozep, several knowledge questions (including sub-questions) were defined for each topic. For the purpose of this evaluation, these knowledge questions have been summarised into main questions for each of these topics. Below is an evaluation of the extent to which each of these knowledge questions can be answered, starting with a description followed by a summary in tables. The assessment of the knowledge questions is based on a first assessment by the authors of this evaluation, in combination with the feedback and input gained from a panel of subject matter experts in work sessions. Note that the conducted studies in the MRP can support several of these knowledge questions. Also, an overview of topics for future research is part of this evaluation. For more details and background to these findings, refer to the syntheses reports as outlined in Chapter 2 Evaluation method.

3.1 Birds

The research on birds can be divided into the impact on *habitat loss and displacement* and *collision risks*.

3.1.1 Answering the knowledge questions

3.1.1.1 Habitat loss and displacement

Knowledge question 1. What is the species-specific response of birds to operational wind farms?
The Wozep studies on habitat loss and displacement are preliminary and based on limited data, partly because of the limited presence of operational wind farms. A lot of effort has been put into the gathering of data, by doing field studies and using existing databases. Due to being in a preliminary phase of research and the large natural variation in the distribution of the birds on the North Sea it has not yet been possible to quantify the impact of displacement and habituation of seabirds due to the presence of OWFs. Several Wozep studies have been or will be started that will result in more information to answer this question (i.e. video surveys using high-definition camera's, tagging studies).

During the work session there was discussion on the availability of sufficient distributional data of seabirds on the Dutch North Sea. Some think there is not enough data available, especially from an undisturbed situation. Others think there is enough information on distributional data and good understanding of the abundance of seabirds in the (Dutch) North Sea, mostly based on data retrieved outside Wozep. There is also enough historical data available and a possibility to statistically evaluate data to say something about the undisturbed situation. It is hard to say whether there is a species-specific response, there is probably variation in the way individuals within a species respond to windfarms. But there is a lack of statistically reliable data. The above-mentioned surveys using high-definition camera's and tagging studies will also deliver on this topic in 2022/2023.

Knowledge question 2. Which species are most vulnerable to habitat loss and displacement?
The most vulnerable species are thought to be the red-throated diver and northern gannet, showing strong avoidance behaviour to OWFs. Sandwich tern, razorbill and common guillemot also demonstrate avoidance, probably to a lesser extent than red-throated diver and northern gannet. It is still unclear how vulnerable these species are and what the consequences of habitat loss and displacement due to OWFs will be. Besides these species there are other species that demonstrate avoidance such as certain gull species, which might also need to be considered in relation to collision risk. Additional mortality of displaced birds per species as a result of the presence of OWFs was calculated using elementary Individual Based Models (IBMs). The model parameters of these IBMs need to be improved based on field data.

Knowledge question 3. To what extent is the configuration of a windfarm of importance for the impact of habitat loss and displacement on birds?
Due to lack of operational OWFs with different configurations and sufficient survey data it has not yet been possible to analyse the impact of spatial configuration of OWFs. The Wozep study by Zuur (2018) reviews all internationally available data and is a good start for further research.

The Wozep radar study conducted in OWF Borssele looks at the use of the corridor in the OWF by birds and could give relevant information on corridor use which might be helpful to limit local habitat loss as well as habitat loss due to possible barrier effects (if a suitable habitat exists at the other side of an OWF). There are also several previous studies outside Wozep available, including international, that looked at the impact of configuration. However, these studies still do not provide reliable information on the importance of the configuration of a wind farm due to a lack of sufficient data.

Knowledge question 4. What is the impact of habitat loss and displacement on population level?
Population impacts were estimated using population models developed by Wozep. The impact of Dutch OWFs on the population of the five seabird species considered seems to be limited when confronted with the current offshore wind developments. The population models have limitations and can be improved based on field data. It is expected that the Dutch OWFs have a limited effect on the coastal species sandwich tern and red-throated diver, as these are strong coastal species and the Dutch OWFs are mostly planned further offshore.

Table 3-1 Knowledge gained on habitat loss and displacement of birds due to OWFs. The extent to which knowledge questions are answered are labelled, see legend below.

BIRDS: KNOWLEDGE QUESTIONS (and extent to which they are answered) *habitat loss and displacement*		
Answers to knowledge questions	**Research contributing to answers[ii]**	
	Published	**Ongoing and planned**
Main question: What is the impact of displacement and concurrent habitat loss due to the development of OWFs on individual seabirds of the different species as well as on these species' relevant population levels?		
1. What is the species-specific response of birds to operational wind farms?		
• Based on observations in LUD during a pilot study, razorbills, guillemots and gannets were observed inside the wind farm, suggesting that habituation may occur • Habitat maps have been developed for 5 bird species. Due to limitation in data in areas outside of the Dutch Continental Shelf habitat maps can be improved • Additional mortality was calculated using elementary IBM. Model parameters can be improved • It is not yet possible to quantify the displacement and habituation of seabirds, due to preliminary phase, large natural variation in distribution of birds and limited data available • Statistically, displacement of guillemots could not be determined due to limitation in the datasets available	1. Van Kooten et al., 2019 2. Zuur, 2018 3. Leopold, 2018 4. Leopold & Verdaat, 2018	7. GPS tracking research sandwich tern 8/9. Update ESAS database and additional survey MWTL 10/11. Aerial surveys using high-definition video and automatic identification

[ii] *Refer to the Appendix (A1) for the list of published, ongoing and planned research*

BIRDS: KNOWLEDGE QUESTIONS (and extent to which they are answered) *habitat loss and displacement*			
Answers to knowledge questions	**Research contributing to answers[ii]**		
	Published	**Ongoing and planned**	
2. Which species are most vulnerable to habitat loss and displacement?			
• Northern gannet and red-throated diver show strong avoidance • Razorbill, common guillemot and sandwich tern show weak avoidance • Oher species also show avoidance, such as certain gull species • It is still unclear how vulnerable these species are. The ongoing research may show that species are more or less vulnerable than initially expected	5. Leopold, 2016 2. Leopold et al. 2014 (KEC 1.0) - Dierksche *et al.* 2016 (outside Wozep)	10/11. Aerial surveys using high-definition video and automatic identification	
3. To what extent is the configuration of a windfarm of importance for the impact of habitat loss and displacement on birds?			
• It is not yet possible to analyse the impact of spatial configuration of OWFs due to insufficient survey data (there are not enough OWFs available)	2. Zuur, 2018	14. Bird fluxes, meso-avoidance and corridor use in Borssele	
4. What is the impact of habitat loss and displacement on population-level?			
• Elementary IBMs and population models have been developed • Impact on populations of five seabird species (mentioned in knowledge question 2) appears to be limited (based on IBMs) • Impact on populations of coastal species, sandwich terns and red throated divers, is expected to be limited, due to future OWFs mostly being planned further offshore • Additional data and boost in ESAS database • Larger shipping routes also impact bird behaviour and/or habitat use	1. Van Kooten et al., 2019 2. Leopold et al., 2014 (KEC 1.0)	8/9. Update ESAS database	

	Legend
	Wozep research has been conducted and the research question can be answered
	Wozep research has been (partially) conducted and question can be partially answered
	Wozep research has been conducted but the results do not yet contribute to answering the research question
	No Wozep research conducted yet

3.1.1.2 Collision risk

Knowledge question 1. What are the estimated numbers of collisions of migratory birds, coastal birds and seabirds?

- Migratory (non-sea)birds

In the Eemshaven Showcase project (with studies on an onshore windfarm), numbers of migratory birds that die due to collisions with wind turbines were measured. These numbers cannot be extrapolated to

OWFs but give an indication of possible mortality amongst migratory birds, because it is a coastal location where birds arrive from migration over sea.

- Coastal birds and seabirds

For several coastal and seabird species KEC 3.0 (Rijkswaterstaat, 2019) calculated the predicted mortality due to collisions and the results show that for several species the predicted mortality exceeds 10% of the Potential Biological Removal (PBR). In KEC 4.0 more species will be taken into account.

- General

  Due to the difficulty of field studies on the risks of collisions of OWFs with seabirds (casualties will disappear), so far most research has focused on modelling collisions. Several studies on this topic are planned or being conducted and include field measurements to validate and improve modelling collisions.

Knowledge question 2. Which species regularly visit existing and planned windfarm locations and how are their populations affected by collisions?

- Migratory (non-sea)birds

Species that migrate over Dutch waters, and for which the predicted additional mortality due to wind turbines was close to the PBR threshold are; Bewick's swan, brent goose, common shelduck, Eurasian curlew. To date, no studies have been able to quantify the impact of offshore collisions on populations of migratory birds.

- Coastal birds and seabirds

Species that either spend a substantial part of their lifecycle in the Dutch North Sea and for which the predicted additional mortality due to wind turbines was close to the PBR threshold are: great black-backed gull, lesser black-backed gull, herring gull, black-legged kittiwake, little gull, great skua, Arctic skua, black tern, common tern.[10] The Wozep data suggest that a relatively large number of large gulls visit the areas used for OWFs.

- General

There is good knowledge on bird distribution for coastal and seabirds, but population impacts are very site- and species-specific and many knowledge gaps remain regarding the behaviour of these birds in and around OWFs. The effect of collisions on bird populations can therefore not yet be determined. Currently, an update of the ESAS-database and a project with high-definition cameras are being executed, and coastal birds are being tagged. Results of these studies are expected in the coming years. The data and field measurements from these studies can be used to update and improve the models and to determine the actual population impact.

Knowledge question 3. To what extent is the configuration of a windfarm of importance for the impact of collisions on birds?

A lot of research under Wozep is focussed on data on (species specific) fluxes and behaviour in and around OWF's. This will help to answer this question in the future. Part of the aim of the study in OWF Borssele is to measure the use of the (shipping) corridor by birds. The properties of the wind turbines are taken into account in the current studies in the OWFs Luchterduinen[7] and Borssele[8].

Knowledge question 4. Which mitigation measures are necessary and possible to mitigate the impact of collisions?

The Eemshaven showcase project (on an onshore windfarm) showed that downtime is very effective. Ten wind turbines were shut down during ten nights with expected high bird migration. Not a single victim was found among these turbines, while during those same nights almost three times as many victims were found under the rotating turbines. The effectiveness of this mitigation measure has not yet been demonstrated for seabirds. In addition, no relationship was found between the intensity of bird migration (flux; numbers of

birds through a windfarm per unit of time) and the number of victims in the Eemshaven showcase. This is likely due to the research method, where victims of collisions are likely eaten before they are found.

Table 3-2 Knowledge gained on collision risk for birds due to OWFs. The extent to which knowledge questions are answered are labelled with colours, see legend below.

KNOWLEDGE QUESTIONS (and extent to which they are answered) Birds – collision risk		
Answers to knowledge questions	**Research contributing to answers**	
	Published	**Ongoing and planned**
Main question: To what extent are migratory non-seabirds, coastal birds and seabirds of the different species impacted individually and at population-level due to collisions with offshore wind turbines?		
1. What are the estimated numbers of collisions of migratory birds, coastal birds and seabirds?		
• The Showcase Eemshaven provided insights into the impact of an onshore windfarm on bird collisions. This knowledge is assumed to be partly useful for estimates on offshore collisions, however no concrete evidence is available. • Collision information on several coastal and seabirds is derived from KEC • In KEC 4.0 more species will be taken into account	3. Bouten et al., 2020 5. Klop & Brenninkmeijer, 2014 Rijkswaterstaat, 2015, 2019	13. Bird fluxes and macro- and meso-avoidance in LUD 14. Bird fluxes, meso-avoidance and corridor use in Borselle 16. Tagging coastal breeders
2. Which species regularly visit existing and planned wind farm locations and how are their populations affected by collisions?		
• A relatively large number of large gulls visits the areas used for offshore windfarms. In particular, herring gull, lesser black-backed gull, black-legged kittiwake, black tern, Eurasian curlew and common shelduck are common visitors. Information on migratory birds is less solid • New information on flight speed and flight height is collected • Some information on behaviour of seabirds was derived during an observation pilot on a platform (refer to Habitat loss and displacement, knowledge question 1) • The Band model has been updated to a stochastic model (not under Wozep). Wozep is investigating alternatives with Individual Based Models (IBM) • Information was gathered to calculate improved figures for use in collision rate models • Species-specific population models have been developed to create a tool to better assess the impacts of future OWFs on bird populations • Age distribution at sea differs from the theoretical age distribution used in the population models. As a result, if the proportion of adults in the population models is proven to be higher than currently assumed, the impact of additional mortality at the population level will be larger • Most victims in onshore wind farms (based on Showcase Eemshaven) are songbirds; thrushes, buntings, goldcrest and wren	1. Duijns et al., 2020 2. Kleyheeg-Hartman & Potiek, 2020 3. Bouten et al., 2020 4. Shinneman et al., 2020 5. Klop & Brenninkmeijer, 2020 6. Potiek et al., 2019a 7. Potiek et al., 2019b 10. Gyimesi et al., 2017 KEC Rijkswaterstaat, 2015, 2019 MWTL (incl. extension surveys outside coastal zone) ESAS-database	13. Bird fluxes and macro- and meso-avoidance in LUD 14. Bird fluxes, meso-avoidance and corridor use Borselle 15. IBM Lesser Black-backed Gull 16. Tagging coastal breeders Update ESAS-database KEC 4.0

KNOWLEDGE QUESTIONS (and extent to which they are answered) Birds – collision risk		
Answers to knowledge questions	**Research contributing to answers**	
	Published	**Ongoing and planned**
• Flux of migration in autumn is higher than spring, weather circumstances are very important (based on information from an onshore wind farm) • No relationship could be demonstrated between the intensity of the migration (flux, numbers of birds through a windfarm per unit of time) and the number of victims, probably due to the method used		
3. To what extent is the configuration of a wind farm of importance for the impact of collisions on birds?		
• A lot of research under Wozep is focussed on data on (species specific) fluxes and behaviour in and around OWF's. This will help to answer this question in the future • The Band model has been improved and will help to answer this question in the future	7. Potiek et al., 2019a	13. Bird fluxes and macro- and meso-avoidance in LUD 14. Bird fluxes, meso-avoidance and corridor use Borselle
4. Which mitigation measures are necessary and possible to mitigate the impact of collisions?		
• Temporary shutdown of wind turbines on nights with high intensity of bird migration is effective (based on Showcase Eemshaven – onshore wind farm, i.e. effects on song-/land birds)	5. Klop & Brenninkmeijer, 2020	

	Legend
	Wozep research has been conducted and the research question can be answered
	Wozep research has been (partially) conducted and question can be partially answered
	Wozep research has been conducted but the results do not yet contribute to answering the research question
	No Wozep research conducted yet

3.1.2 Focus for future bird research

3.1.2.1 Habitat loss and displacement

From the expert work session, it became clear that the following topics may require more research effort:

- Due to a lack of survey data on bird populations in and outside OWFs and limited knowledge on the behaviour of birds at sea, it was recommended to review studies and data outside Wozep
- Joining forces with international studies could provide additional insights, for instance in why species-specific variation in avoidance exists
- Upscale aerial surveys to gain additional information
- A power analysis can be used to assess whether the available data are sufficient for an assessment of the impact of displacement
- Focus on species in decline and attempt to determine if this decline is related to OWFs and/or other activities

- Focus on birds breeding in The Netherlands (e.g. large gulls and terns)
- A comparison could be made of population development between colonies, e.g. colonies within reach of OWFs and others
- Parallel to the seabird studies, research should focus more on the ecosystem effects of OWF construction and operation.

3.1.2.2 Collision risk

From the expert work session, it became clear that the following topics may require more research effort:

- Compare vital rates in colonies within and without OWF range
- Liaise with landowner for access to colonies for research and potential management
- Upscale models to cover the effects of the upscaling of OWFs, including international, then evaluate if the monitoring programme is sufficiently intensive for the required results (on all topics)
- Validate and improve collision models, using field measurements from ongoing and planned research as well as results from studies outside Wozep
  - Radar studies (e.g. Germany, UK) when available
  - Studies on the impact of configuration of OWFs in the Baltic Sea
  - Studies on the impact of corridors
  - Studies on mitigation measures such as start-stop measures and the use of different types of lighting
- Focus on the most vulnerable species
- Conduct high-frequency logging device studies to study the behaviour of birds in and around OWFs, which can provide input for collision risk models, IBMs or calculations on habitat loss. These studies can demonstrate differences in behaviour within individual species within windfarms (more GPS studies are good to proceed with). These studies are important for both displacement and collisions effects.

3.1.3 Conclusion

3.1.3.1 Habitat loss and displacement

Part of the knowledge questions can be answered. It is quite clear which species are most vulnerable to habitat loss and displacement; these are the red-throated diver, northern gannet, sandwich tern, razorbill, common guillemot. Population models show that the impact of the current offshore wind developments on the population of these five seabird species seems to be limited when taking into account the current OWF developments in the Netherlands. The Wozep research has enabled an update of the initial calculations on habitat loss and subsequent number of mortalities in the KEC; a worst-case footprint of 10% is being used in the calculations of the cumulative impact on habitat loss. It has not yet been possible to quantify the species-specific impact of displacement to say something about the impact of the configuration of OWFs.

Several studies have been or will be started that will result in more information to answer the four knowledge questions (video surveys using high-definition camera's, tagging studies). It is expected that Individual Based Models (IBMs), that are currently being developed under Wozep, may eventually provide more reliable information on the spatio-temporal responses of each species to the presence of OWFs, because of a more formalized representation of the knowledge on cause-effect relationships to be integrated in those models.

Proposed refinement of knowledge questions

1. Which species are vulnerable to habitat loss and displacement, when focussing on species in decline and species that breed in NL?
2. What is the species-specific response of birds to operational wind farms?
3. In what way does the configuration of a windfarm influence the impact of habitat loss and displacement on birds and in what way can it be adapted?
4. What is the impact of habitat loss and displacement on population-level?

3.1.3.2 Collision risk

Due to the difficulty of field studies on the risks of collisions of OWFs with seabirds, so far most research has focussed on modelling collisions. Several studies on this topic are planned or being conducted and include field measurements to validate and improve collision models. Research in an onshore windfarm along the coast provides an indication on the number of collisions of migratory birds and in the KEC the predicted mortality due to collisions of seabirds was calculated. The results also provide an indication of which species visit windfarms, but the effect of collisions on bird populations cannot yet be determined. The study in the onshore windfarm indicates that the standstill method is very effective as a mitigation measure.

Proposed refinement of knowledge questions

We recommend reformulating the knowledge questions and to use these to structure Wozep:

1. What are the estimated numbers of collisions of migratory birds, coastal birds and seabirds?
2. Which species regularly visit existing and planned windfarm locations and how are their populations affected by collisions?
3. In what way does the configuration of a windfarm influence the impact of collision risk on birds and in what way can it be adapted?
4. What is the effectiveness of the mitigation measures that are being used?

3.2 Bats

3.2.1 Answering the knowledge questions

Knowledge question 1. How many bats fly across the southern North Sea annually?

Two dedicated studies, one involving historical data and the other on model predictions, could not provide a good indication of the numbers of bats that fly across the North Sea. To estimate the number of bats that cross the southern North Sea, telemetry tags can be used in combination with the Motus network. The Motus network is an extensive collaborative research network that uses coordinated automated radio-telemetry to facilitate research and education on the ecology and conservation of migratory animals. By joining Motus, each registered project contributes to the work of other researchers as the receivers record all registered tagged animals.

Knowledge question 2. What is the spatial and temporal pattern of Nathusius' pipistrelle across the southern North Sea?

In combination with the Wozep research and research outside Wozep, experts think that this question could be answered to some degree. There are many data available on this particular species in France, UK, Belgium, The Netherlands and Germany. Combining these data with a predictive model, it should be possible to provide a good insight into the temporal patterns. On the other hand, identification of the spatial patterns is difficult and should be based on long-term monitoring data and a large geographical range (which is very expensive). These data are not yet available.

Knowledge question 3. What is the annual bat mortality as a result of collisions with offshore wind turbines?
The studies on bat mortality within Wozep are of a preliminary nature. Due to this, coupled with difficulties to detect casualties at sea and expensive research options, it has not yet been possible to quantify the additional annual bat mortality as a result of collisions. However, this question remains important to answer in light of the future OWF developments. The study by Lagerveld et al. (2020) on assessing the fatality risk of bats at OWFs compared different techniques on how offshore bat (and bird) fatalities could be monitored. All of the techniques still need to mature and/or be technically adjusted before they can be tested in the field.

Knowledge question 4. Is the number of bats at risk from collision relevant when taking into account population size, trend and collision risk?
The Rinnebat study in Germany showed that there is a relation between bat activity and collision risk. However, as of yet, it is impossible to assess the effect of fatalities on bat populations as the source populations are unknown. Only data on these source populations will provide more information on this topic, but this is very complicated and expensive. Until now an estimation of the population size is being used.

This is a sensitive question as all European bat species are protected under the Habitat Directive and therefore any harm done to an individual is illegal. To address this sensitivity, the question could be split into two separate questions, individual and population-level.

Knowledge question 5. Are bats attracted to windfarms and, if so, what causes this attraction?
The available research (from within and outside Wozep) has not provided certainty on this topic, since offshore telemetry stations are needed to answer this question. The costs for theses stations are extremely high. In Germany, offshore bat detector studies have shown that migrating bats behave differently when they meet a large or small structure. Additionally, based on expert opinion, it is expected that bats are attracted to OWFs since they are attracted to onshore windfarms. And at sea, the few structures that are present are oil & gas platforms and OWFs, to which bats are likely to be attracted too.

Knowledge question 6. Can mitigation measures be made more specific to reduce wind turbine down time?
At the start of Wozep, little was known about the presence of bats at sea. However, in recent years this has become much clearer. In particular, with the help of bat detectors, much more clarity has been obtained about the conditions in which bats occur at sea. This provided the opportunity for windfarms, positioned close to the coast, to apply curtailment measures in weather conditions in which bats 'choose to fly out to sea'. The current optimal curtailment strategy consists of increasing cut-in speeds to 5.5 - 6 m/s at easterly wind and an unaltered cut-in speed (the turbines default setting) during low temperatures and westerly wind. Additionally, the curtailment season was shifted to August 25th - October 10th. This new strategy results in a 12% lower loss in energy production and an estimated substantially lower risk of fatalities (15%) compared to the former mitigation strategy.

Table 3-3 Knowledge gained on bats due to OWFs. The extent to which knowledge questions are answered are labelled with colours, see legend below.

BATS: KNOWLEDGE QUESTIONS (and extent to which they can be answered)		
Answers to knowledge questions	**Research contributing to answers**	
	Published	**Ongoing and planned**
Main question: Are migratory bats adversely impacted by offshore wind farms on the North Sea and if so, how and to what extent?		

BATS: KNOWLEDGE QUESTIONS (and extent to which they can be answered)		
Answers to knowledge questions	**Research contributing to answers**	
	Published	**Ongoing and planned**
1. How many bats fly across the southern North Sea annually?		
• A feasibility study demonstrated that telemetry can be used to observe migrating bats. The tagging study of Nathusius' pipistrelle (using the Motus network) could potentially lead to an indication of the number of bats that cross the southern North Sea (relative numbers can be used)	2. Report Batweter: Haarsma et al. (2019) 4. Lagerveld et al., 2017a	10. Tagging and tracing of Nathusius' pipistrelle
2. What is the spatial and temporal pattern of Nathusius' pipistrelle across the southern North Sea?		
• The relevant population of Nathusius' pipistrelle is estimated at roughly 40.000 individuals with a bandwidth of 100 to 1.000.000 individuals. Due to this bandwidth a high uncertainty remains.	5. Limpens et al., 2017 6. Lagerveld et al., 2017b	10. Tagging and tracing of Nathusius' pipistrelle 11. Expanding the batdetector network
3. What is the annual bat mortality as a result of collisions with offshore wind turbines?		
• An assessment/guidance was made of the different approaches and techniques, which could be used for monitoring bat mortality.	1. Lagerveld et al., 2020	
4. Is the number of bats at risk from collision relevant when taking into account population size, trend and collision risk?		
• As of yet, it is impossible to assess the effect of fatalities on bat populations as the source populations are unknown • The genetic analysis study on bats could provide more insight into the vulnerability of the bat population when taking into account wind turbine mortalities.	5. Limpens et al., 2017	9. Genetic analysis bats
5. Are bats attracted to wind farms and, if so, what causes this attraction?		
• A feasibility study was performed to analyse bat flights around wind turbines, however the results provided insufficient insigths to answer this question • Only a fraction (maximum 10%) of the bat activity in a wind farm takes place at nacelle height. It is recommended to further investigate whether bat detectors on the nacelle provide a truly representative picture of flying altitudes	7. Lagerveld et al., 2017c Brabant et al., 2018	
6. Can mitigation measures be made more specific to reduce wind turbine down time?		
• A new curtailment strategy resulted in in a 12% lower loss in energy production and substantial lower risk of fatalities (15%)	3. Boonman, 2018 8. Lagerveld et al., 2017d	

	Legend

	Wozep research has been conducted and the research question can be answered
	Wozep research has been (partially) conducted and question can be partially answered
	Wozep research has been conducted but the results do not yet contribute to answering the research question
	No Wozep research conducted yet

3.2.2 Focus for future bat research

From the expert work session, it became clear that the following topics may require more research effort:

- Future research should focus more on determining the number of fatalities, offshore fatality risk and actual estimates of mortality rates
- A better understanding is needed of movement patterns along the coast of Northern Europe
- Considering the high costs involved for this kind of research, it is recommended to join forces with bird experts (cross-boundary) and to write a collaborative research proposal.

3.2.3 Conclusion

With the help of bat detectors, more clarity has been obtained on the conditions in which bats occur at sea and with radio-telemetry more information on the migration direction, conditions and percentages of bats choosing to migrate overseas is obtained. Also, Wozep research has ensured that the curtailment strategy for collisions with bats is more specific by taking into consideration the wind speed, wind direction and season. Other mitigation measures have not yet been identified or enforced.

Much of the bat research is still in a preliminary phase, high research costs are involved and casualties at sea by collision are hard to detect. And after almost a decade of research to assess the annual bat mortality as a result of collisions with offshore wind turbines, the difficulties in estimation remain. Nevertheless, experts felt that this is an important topic. To be able to answer the knowledge questions more and better data is needed. Therefore, it is essential to continue the research effort at sea and the development of techniques to determine the number of fatalities and estimating mortality rates at sea.

In addition, it became clear that international collaboration is essential to be able to provide a holistic view of what the effects of OWFs are on bats. Also, joining the Motus network could support an indication to the number of bats migrating across the southern North Sea according to experts.

Proposed refinement of knowledge questions

1. How many bats fly across the southern North Sea annually?
2. What is the spatial and temporal pattern of Nathusius' pipistrelle across the southern North Sea?
3. What is the annual bat mortality as a result of collisions with offshore wind turbines?
4. Is the number of bats at risk from collision relevant when taking into account population size, trend and collision risk?
5. Are bats attracted to wind farms and, if so, what causes this attraction?
6. Can mitigation measures be made more specific to reduce wind turbine down time?

3.3 Marine mammals

The effects on marine mammals can be divided into the effects on *harbour porpoise* and *seals* (grey seal and harbour seal).

3.3.1 Answering the knowledge questions

Knowledge question 1. What are the effects of impulsive and continuous noise (TTS, PTS) on marine mammals?

Harbour porpoise

In the past years, much in situ research has been conducted on the effects of impulsive underwater noise on the auditory system of the harbour porpoise. Additionally, necessary improvements have been made in the field of underwater sound propagation modelling. Wozep research has already led to better estimates of effect distances for possible hearing damage. Efforts were made to obtain even more certainty in the Temporal Threshold Shift (TTS) curve for harbour porpoise.

In recent years, much knowledge was generated on the importance of frequency weighting (the differences in sensitivity of species to different sound frequencies) in determining the effects of sound pollution. The ongoing and yet to be started studies should provide us with additional insights into how these differences in perception translate into the behavioural responses to sound pollution of marine mammals.

Based on the current information, researchers can predict whether TTS or PTS (Permanent Threshold Shift) will occur at certain frequencies. However, the effect of this on the individual animal or population remains uncertain.

Research is lacking on continuous noise, hearing recovery and duty-cycle for impulsive sounds. Regarding the latter, when the rate of pile driving changes, the impact on the generated TTS increases. To gain a deeper understanding of this topic, a research proposal has been submitted to the Living Marine Resources Programme of the US Navy (outside Wozep).

Seals

Limited research has been conducted on seals, as it was presumed that the harbour porpoise was the most sensitive to the underwater sound generated by pile driving. However, current frequency weighting research might provide a different view on this and could point out that possible effects on seals should be considered in more depth for future noise-related studies.

Knowledge question 2. What are the effects of OWFs (construction or operation) on the behaviour and habitat use of individuals?

Harbour porpoise

A distinction should be made between the construction and operational phase of OWFs. Most of the conducted research to date has been concerned with OWF construction, whereas research on the effects on behaviour and habitat use during the operational phase has only just started. The prioritisation of research of OWF construction is based on the severity of impact caused by impulsive sounds on marine mammals. The passive acoustic monitoring (PAM) study at the Borssele wind area during construction is expected to provide information on behaviour and habitat use of harbour porpoises during this phase but does not include individuals' reactions. The project can provide information on the use of the area by harbour porpoise and whether this changes with construction work. In 2021, the PAM study has started by determining the presence of harbour porpoises during the operational phase.

The APELAFICO project[iii], a project outside Wozep (but financed by and in cooperation with Wozep), will also contribute to answering this question. This study will collect data on pelagic fish communities in and around OWFs in association with acoustic conditions during construction (soft start procedure and Acoustic

[iii] *https://www.nwo.nl/en/projects/nwa123618004*

Deterrent Devices (ADD)) and operation. In combination with the PAM study this can provide essential information on whether food availability motivates harbour porpoises to return after disturbance.

Recently two workshops took place, which discussed the use of telemetry and biologgers for harbour porpoises. The use of telemetry techniques and biologgers can aid in relating data regarding their movements, behaviour, physiology and/or environment and aid in answering this knowledge question. Additionally, as harbour porpoises are free-ranging species and not bound by borders, international cooperation is recommended.

Seals

As mentioned above, a distinction should be made between the construction and operational phase of OWFs. More data on seals are available since they are relatively easier to investigate. For example, it is known if and how grey seals respond to OWFs due to detailed available data. Based on anecdotal data (observations), grey seals seem to be more responsive than harbour seals, but no scientific data on this is as yet available. Additionally, a dose-response curve is missing for harbour seals.

Previous limited observations demonstrated that seals appear to avoid wind farms. To gain more knowledge about this, a seal tagging study was initiated in 2019 in which 20 seals (10 common and 10 grey seals) in the Voordelta were tagged to be able to register their movements. This study holds data to provide insights into the behaviour and habitat use of seals.

Research outside Wozep provides additional insights into the behaviour of harbour seals to the construction of OWFs. The kind of research or publications were not explicitly mentioned. For future research it is recommended to make an overview of current research and publications on this topic. Additionally, the PAM study at Borssele wind area is expected to be of value on the effects of sound mitigation during the construction of an OWF on seal behaviour.

Knowledge question 3. What are the effects of OWF construction on the fitness of individuals?

Harbour porpoise

Researchers are beginning to be able to make crude predictions about how much it takes to cause metabolic stress in harbour porpoises. The study by Kastelein et al. (2016; 2018) showed that prey availability and seasonality are two factors that contribute to the fitness of the harbour porpoise and should be taken into consideration, as should prey availability (Leopold, 2015). Ongoing research projects, such as, the Borssele PAM network projects are expected to provide new insights into the feeding behaviour of the harbour porpoise during both OWF construction and operation.

Most studies on fitness have only been carried out on males and not on females. Additionally, a baseline for fitness is lacking, making it difficult to determine what the effects of OWF construction might be on the fitness of harbour porpoises.

Seals

The Wozep research question for seals focuses on determining whether the effects of underwater noise are relevant for the energetics of seals. The data from the 2019 tagging study are expected to contribute to this question. In addition, there is a long-term dataset available[iv], which has recorded 16 years' worth of data on food consumption, water temperature, growth and blubber thickness of the harbour seal. These data could provide more insight into the fitness of harbour seals and should be taken into consideration for future research.

[iv] *SEAMARCO is the owner of the dataset.*

Knowledge question 4. What are the effects of OWF construction on populations?

Harbour porpoise

There are currently two models available that can estimate the effects on population level, namely Depons and iPCoD model. Important to keep in mind that many uncertainties are remaining for both models. The iPCoD model, used by Wozep, was developed by the University of St. Andrews. This model has been used in a variety of KEC studies, which has also helped in the improvement of the model. Multiple studies are ongoing, which will provide data on habitat use and behaviour and help further reduce the uncertainties in the iPCoD model.

Seals

Wageningen Marine Research (WMR) is undertaking efforts to develop an IBM framework for Dutch seals (outside Wozep) to estimate the effects on seal populations. They have developed a tool which was tested recently with data on Dutch seals, but the results have not yet been interpreted. It is expected that the seal IBM will be able to provide information on seal populations since quite detailed information is available on seal trends and information from FishBase can be integrated into the model. Additionally, the seal tagging project in Borssele will provide input for the IBM.

Table 3-4 Knowledge gained on marine mammals due to OWFs. The extent to which knowledge questions are answered is labelled with colours, see legend below.

MARINE MAMMALS: KNOWLEDGE QUESTIONS (and extent to which they can be answered)		
Answers to knowledge questions	**Research contributing to answers**	
	Published	**Ongoing and planned**
Main question: What are the main effects of offshore wind farms (in construction and operational phase) on marine mammal populations (harbour porpoise, grey seal and harbour seal)?		
1. What are the effects of impulsive and continuous noise (TTS, PTS)?		
• Sound propagation models are sufficiently accurate to determine the impact on marine mammals. Uncertainties remain in the higher and lower frequency calculations. This can be improved by involving the modelling of sediment effects on sound propagation • It can be considered to apply frequency weighting in the sound frequency level, but the behavioural response thresholds are still missing • The relative difference in hearing sensitivity between harbour porpoise and seals cannot be directly translated to a relative difference in sensitivity to disturbance or to TTS or PTS	1. IJsseldijk & Aarts, 2020 5. de Jong et al., 2019 6. de Jong & von Benda-Beckmann, 2018 10. Kastelein et al., 2018	13. Frequency weighting calculations - SIMOX project
2. What are the effects of OWFs (construction or operation) on the behaviour and habitat use of individuals?		
• Depending on the life stage and food availability of the harbour porpoise, they may be more or less vulnerable to disturbances that decrease their foraging efficiency • A 4% body mass and blubber thickness decrease of the harbour porpoise was recorded when withheld from feeding	2. IJsseldijk & Doeschate, 2019 9. Kastelein et al., 2019 10. Kastelein et al., 2018	11. Passive acoustic monitoring in Borssele OWF during construction and operational phase 16. APELAFICO project

MARINE MAMMALS: KNOWLEDGE QUESTIONS (and extent to which they can be answered)		
Answers to knowledge questions	**Research contributing to answers**	
	Published	**Ongoing and planned**
• The Wadden area, the North Sea coastlines of Schleswig Holstein (Germany) and Denmark are possible regions of special importance for calving		
3. What are the effects of OWF construction on the fitness of individuals?		
• Prey availability and seasonality are two factors that contribute to the fitness of the harbour porpoise	9. Kastelein et al., 2019 10. Kastelein et al., 2018	15. Seal tagging study
4. What are the effects of OWF construction on populations?		
• Carrying capacity cannot be determined for any of the marine mammal species. KEC has provided a threshold for the harbour porpoise • Contaminants can be considered a limiting factor in the population growth of the harbour porpoise • It has been demonstrated that a mortality baseline is feasible based on harbour porpoise strandings • Model predictions from Aarts et al. can be used as input variable for IBMs	Monitoring & Research Programme 2017-2021 1. IJsseldijk & Aarts, 2020 2. IJsseldijk & Doeschate, 2019 3. Van de Heuvel-Greve et al., 2017 8. Aarts et al., 2016 9. Kastelein et al., 2019 10. Kastelein et al., 2018	12. Compare PCoD and DEPONS model 13. Frequency weighting calculations 15. Seal tagging Borssele

	Legend
	Wozep research has been conducted and the research question can be answered
	Wozep research has been (partially) conducted and question can be partially answered
	Wozep research has been conducted but the results do not yet contribute to answering the research question
	No Wozep research conducted yet

3.3.2 Focus for future research

From the expert work session, it became clear that the following topics may require more research effort:

- An important topic for future research is the effect of operational OWFs on the harbour porpoise and seals. Most of the research done so far has focused on the effects of OWF construction.
- Cumulative effects of multiple stressors and their single and combined effort on the fitness of the harbour porpoise and seals should be studied in more depth. The North Sea has many anthropogenic activities, which should all be taken into consideration.
- Parallel to the animal studies, research should focus more on the ecosystem effects of OWF construction and operation.
- The information available on harbour porpoise and seals varies greatly; this should be equalised. Especially for underwater sound related studies the harbour porpoise has received more attention. Frequency weighting could point out that seals should also be considered for future noise related studies.

- To assess the behaviour, habitat use and fitness of the harbour porpoise and seals, it is valuable to do more research on the prey availability and prey quality in and around OWFs during construction and operational phase.

3.3.3 Conclusion

Over the past years, much knowledge was gained on the effects of OWFs on marine mammals. Based on the current findings from research within and outside Wozep, researchers are able to predict whether TTS or PTS will occur at certain frequencies. The effect of impulsive noise during OWF construction on the hearing recovery and how this impacts the hearing thresholds is still unknown. The results were also used to reduce the uncertainties in sound propagation calculations, which means that the disturbance area can be calculated more precisely leading to reduced uncertainties in population models for the harbour porpoise.

In recent years, we have learned about the importance of frequency weighting (the differences in sensitivity of species to different sound frequencies) in determining the effects of OWF construction. This demonstrated that the harbour porpoise is not more sensitive than seals and that future research should also focus on the latter.

Improvements have been made to the Aquarius model, reducing the uncertainties in sound propagation calculations and leading to reduced uncertainties in the population model (iPCoD) for the harbour porpoise. Wozep research has also demonstrated that habitat model predictions can be used as input variables for individual-based models (IBMs) aimed at estimating the population level impact of human activities on harbour seals. Currently, an IBM for seals is being developed and tested on Dutch seal data.

The research on behaviour, habitat use and fitness is still in a preliminary phase, it will take more time and research to answer the questions on these topics. The current passive acoustic monitoring (PAM) study for harbour porpoises and tagging study for seals is expected to provide more insights into these topics. The Borssele PAM studies will be linked with the APELAFICO project (Leiden University) to assess the relation between food availability, habitat use and behaviour.

Finally, it is useful for Wozep to collaborate and find synergies with initiatives from LNV and North Sea bordering countries with regards to tagging of harbour porpoises and seals. A couple of workshops on this topic have taken place, where the willingness for cross-boundary collaboration was expressed.

Proposed refinement of knowledge questions

1. What is the effect of impulsive noise during OWF construction on the hearing recovery of the harbour porpoise and harbour and grey seal and how does this impact the hearing thresholds?
2. What are the effects during OWF construction on the behaviour and habitat use of individuals?
3. What are the effects during OWF operation on the behaviour and habitat use of individuals?
4. What are the effects of OWF construction on the fitness of individuals?
5. What are the effects of OWF operation on the fitness of individuals?
6. What are the effects of OWF construction on populations?
7. What are the effects of OWF operation on populations?

3.4 Ecosystem effects

Studies on ecosystem effects from OWFs are not part of the Monitoring and Research Programme 2017-2021 (MRP). However, due to the assumption that the planned upscaling of OWFs will indirectly influence protected species through changes to the ecosystem, preliminary studies on ecosystem effects have been conducted. This chapter contains a summary of the research results and suggestions for next steps for knowledge development into the bottom-up and top-down effects on protected species(-groups) from

large-scale OWF development. Due to the preliminary nature of this research and the exploratory phase it is in, the character of the evaluation on this topic differs compared to the previous topics.

When Wozep started fish and benthos were part of the programme as specific topic. Since the focus of Wozep is on protected species and their food, the prioritization of the research has changed; fish and benthos are now part of the research on ecosystem effects. In this context the former research on benthos and fish is briefly mentioned in the following paragraph.

3.4.1 Answering the knowledge questions

Several studies have been conducted (and some ongoing) to determine the potential effects from OWFs on fish and benthos. More specifically, these studies have focused on the effects from electromagnetic fields (EMF) from energy supply cables, the effects from (impulsive and continuous) sound on the behaviour of fish (Viszion, NWO research financed by RWS). The impact of EMF is still unclear, in the ongoing project ElasmoPower (NWO) further research on the impact of EMF on sharks and rays is conducted. Also, several benthos surveys have been conducted to determine changes to benthic communities in soft substrates and on hard substrate. So far, the results on benthos show that there is no difference between benthos inside and outside the wind farm. The knowledge questions on fish and benthos need to be adjusted to the ecosystem-approach that recently started but is not part of this midterm evaluation.

The initial knowledge questions to assess ecosystem effects have focused on the changes to the oceanographic and hydro-geomorphological conditions in the southern North Sea and their potential effects on primary production and changes in the marine food web as a result of large-scale OWFs. The preliminary studies on this topic (refer to appendix A1) have provided the following insights (also based on relevant information obtained outside this evaluation assignment[v]):

- Based on hydro-dynamic modelling it can be expected that there will be significant changes in current spatio-temporal stratification patterns
- As a consequence of the above, significant changes in primary production can be expected based on expected changes in hydro-dynamic conditions
- The expected changes to ecosystems vary across different areas in the North Sea. Whether these effects are negative or positive for certain species is not clear and requires more research
- There are missing links in knowledge between bottom-up (changes to abiotic processes) and top-down (impact on top-predators): zooplankton and fish. Changes in zooplankton imply changes in fish, which are important food for seabirds and marine mammals.

In summary, useful insights in ecosystem effects are gained on changes to abiotic processes resulting from large-scale OWF development (bottom-up effects) and on the direct effects and energy processes of protected species, i.e. top predators, (top-down effects). The research is still in a preliminary phase, many knowledge gaps remain on the top-down and bottom-up relationships between primary production and top predators. The train of models (hydro-dynamic, fine sediment, water quality and ecological modelling) that has been used and will be used in the future is very useful in gaining information on these relationships and the impact of OWFs.

Following the need for the knowledge described above, the initial knowledge questions have been refined, based on input from experts:

[v] *'Zoekgebieden Wind op Zee' expert sessions and Wozep webinar on ecosystem effects*

1. What conditions (abiotic and biotic) determine the preferred habitat of protected species (top predators) and how are these affected by large-scale OWFs?
2. What are the key species in the food web?
3. How can changes in food availability for generic species groups be determined from modelling?
4. What is the effect of the configuration of OWFs on ecosystems in the North Sea?

Table *3-5* contains the suggested knowledge questions and the first insights have been added.

Table 3-5 Knowledge gained on ecosystem effects due to OWFs. *The extent to which knowledge questions are answered is labelled with colours, see legend below*

ECOSYSTEM EFFECTS: KNOWLEDGE QUESTIONS (and extent to which they can be answered)			
Answers to knowledge questions	**Research contributing to answers**		
	Published	**Ongoing and planned**	
Main question: What are the expected changes to the North Sea ecosystem from large-scale OFWs that can indirectly affect populations of protected species?			
1. What conditions (abiotic and biotic) determine the preferred habitat of protected species (top predators) and how are these affected by large-scale OWFs?			
• Based on hydro-dynamic, fine sediment and water quality modelling, it can be expected that there will be significant changes in spatio-temporal stratification patterns (in temperature) • Significant changes in primary production can be expected based on changes in stratification patterns	1. Boon et al., 2018 2. Zijl et al., 2021 3. Van der Molen & Soetaert, 2021 4. Van Duren et al., 2021	10. APELAFICO project 11. Forage Fish project	
2. What are the key species in the food web?			
• Some existing knowledge of key species has led to the initiation of several projects: distribution of sandeel in shallow coastal zones and OWFs and the effects of construction and operation of OWFs on pelagic fish, birds and harbour porpoise		10. APELAFICO project 11. Forage Fish project	
3. How can changes in food availability for functional species-groups be determined from modelling?			
•		11. Forage Fish project	
4. What is the effect of the configuration of OWFs on ecosystems in the North Sea?			
•			

	Legend
	Wozep research has been conducted and the research question can be answered
	Wozep research has been (partially) conducted and question can be partially answered
	Wozep research has been conducted but the results do not yet contribute to answering the research question
	No Wozep research conducted yet

3.4.2 Focus for future research on ecosystem effects

The work session with experts has focused on gaining input for focus topics and knowledge questions for future research. For Wozep, the main aim on this topic is to gain insights into changes to the ecosystem from large-scale OWFs development and how these changes affect the populations of protected species.

The following approach and timeline for knowledge development on ecosystem effects is proposed:

- Short-term: develop foodweb and habitat use models for functional (species)groups
- Short- and mid-term: research relevant abiotic and biotic input parameters for ecosystem models
- Short- and mid-term: research relevant input parameters for individual-based models (IBMs)
- Long-term: develop species-specific IBMs (and validate them with findings from research of relevant input parameters)

Experts agree on this approach with the following suggestions:

- Start now to gather results towards input parameters for long-term species-specific IBMs
- Start with hydrodynamic conditions and how these affect prey availability up the food chain for (a selection of) top predators (focus on kittiwake, gannet, sandeel, marine mammals, sharks and rays)
- Tag and trace key species in the foodweb to gain additional insights into the food landscape, combining telemetry and otolith studies
- Focus on (geographical) areas where the largest effects can be expected
- Include research and modelling of the effects of more filter-feeding benthic activity high in the water column on the (far) offshore installations
- Extend current models from 1 year to 10 years for long-term effects
- Seek (international) cooperation with:
  - EU call for studies ecosystem effects
  - BANOS research in Germany on the effects of changes in stratification
  - CEAF
  - MONS
  - Sand extraction and replenishment research

3.4.3 Conclusion

For Wozep, the main aim on this topic is to gain insights into changes to the ecosystem from large-scale OWFs and how these changes affect the populations of protected species. To date, the Wozep research on this topic has focused and gained important insights into potential changes to hydro-dynamic conditions (bottom-up effects). A clear result is that OWFs cause changes in hydrodynamic conditions and affects the different areas in the North Sea physically in different ways, which ultimately results in different ecological effects. These first studies on ecosystem effects, in which a train of models is used, is unique and promising for future research on this topic.

From here onwards, more insight is needed to determine the indirect effects of abiotic and biotic changes to populations of protected species, linking bottom-up and top-down effects. Experts agree that species-specific individual-based models (IBMs) are a good approach to determine the indirect effects from OWFs.

To feed these models, food web and habitat use models for functional (species)groups should be developed in the short-term. As a next step, relevant abiotic and biotic input parameters for ecosystem models and finally IBMs should be defined.

Some of the research on these missing links has already commenced or has been planned, i.e., the distribution of sandeel in shallow coastal zones and OWFs (Forage Fish) and the effects of construction and operation of OWFs on pelagic fish and harbour porpoise (APELAFICO). However, additional interdisciplinary research is required to fill the knowledge gaps.

In addition to the above, there should be an aim to gain more insight into the cumulative effects of future use of the North Sea. To achieve this, it is recommended to find synergies with other research programmes including the MONS programme and international studies (e.g. French study linking fish population models to ecosystem models as a result of climate change, German research on the effects of stratification (BANOS)).

4 Use in policy and management

4.1 Introduction

The Dutch policy for offshore wind energy production on the North Sea is being developed in the context of a major challenge: *sustainable energy production while safeguarding a robust ecosystem and food supply.* This challenge is the starting point for the Offshore Wind Energy Act (OWEA) and the North Sea Programme. As stated in the OWEA and the National Water Plan[vi], OWFs are to be built in **search areas** in the North Sea. In 2018, a **roadmap** for the production of offshore wind energy up until 2030 was presented by the government. Within this roadmap, areas suitable to generate a total of 11 GW of offshore wind energy have been identified. However, to meet the goals of the climate agreement it is expected that another 10 GW will need to be realized before 2030 and 17 GW after 2030 (37 GW is needed in total). Currently, the North Sea Programme is drafted as part of the National Water Plan 2022-2027 and will contain additional areas where offshore wind sites can be developed before 2030. It also gives an outlook on offshore wind locations that can be developed after 2030. The final program will be published in March 2022.

After designating locations for wind energy production in the North Sea Programme, the Minister of Economic Affairs and Climate will develop an updated roadmap for the period after 2030. Based on this updated roadmap, the cumulative impact of offshore wind energy production on marine mammals, birds and bats is assessed, based on the Framework for Assessing Ecological and Cumulative effects (**KEC**).

After the assessment of the cumulative impact, **site decisions** are made. As part of the site decision, an Environmental Impact Assessment (**EIA**) is conducted as well as an **appropriate assessment** (AA), which looks into the ecological impacts at the designated site. Hence, the site decisions for each of the designated OWFs will consider the expected location-specific ecological effects. When required, mitigation measures are proposed and taken to attempt to prevent any significant negative effects.

Following the site decision, the Minister of Economic Affairs and Climate initiates a tender procedure in which commercial parties can compete for the permit that grants exclusive rights to the winning party to build and operate an OWF at the designated site, including associated connection to the energy grid. After winning the tender, a permit as part of the OWEA is granted and a Water decision is taken. In addition to the site decision and the Water decision, **work plans** are required to demonstrate how regulations and mitigation measures from the site decision are put in practice.

Knowledge development plays an important role in the above-mentioned process. Decisions are taken based on current knowledge and it is an obligation (from EIA and AA) to strengthen this knowledge base.

4.2 Offshore Wind Policy Cycle

During this evaluation process, it has proven to be useful to analyse and structure the position and evolution of Wozep in relation to the stakeholders involved in policy development, management and execution. Following the progress in the OWF policies and plans the results of Wozep are being used in the different steps of the so called ‘Offshore Wind Policy Cycle’ (see Figure 4-1). The policy cycle is an iterative process from policy development to implementation, execution and feedback, as visualised in the figure.

The concept of a policy cycle can be distinguished in four major phases:

- Policy development (define agenda and policies)
- Policy implementation (adoption, verification techniques)

[vi] *The Dutch National Water Plan is a policy document which broadly outlines the principles and direction of the national water policy and the related aspects of spatial policy for a period of 6 years.*

- Policy execution (methodological guidance, permits)
- Policy feedback (monitoring, evaluation), to be used to reconsider or update policy

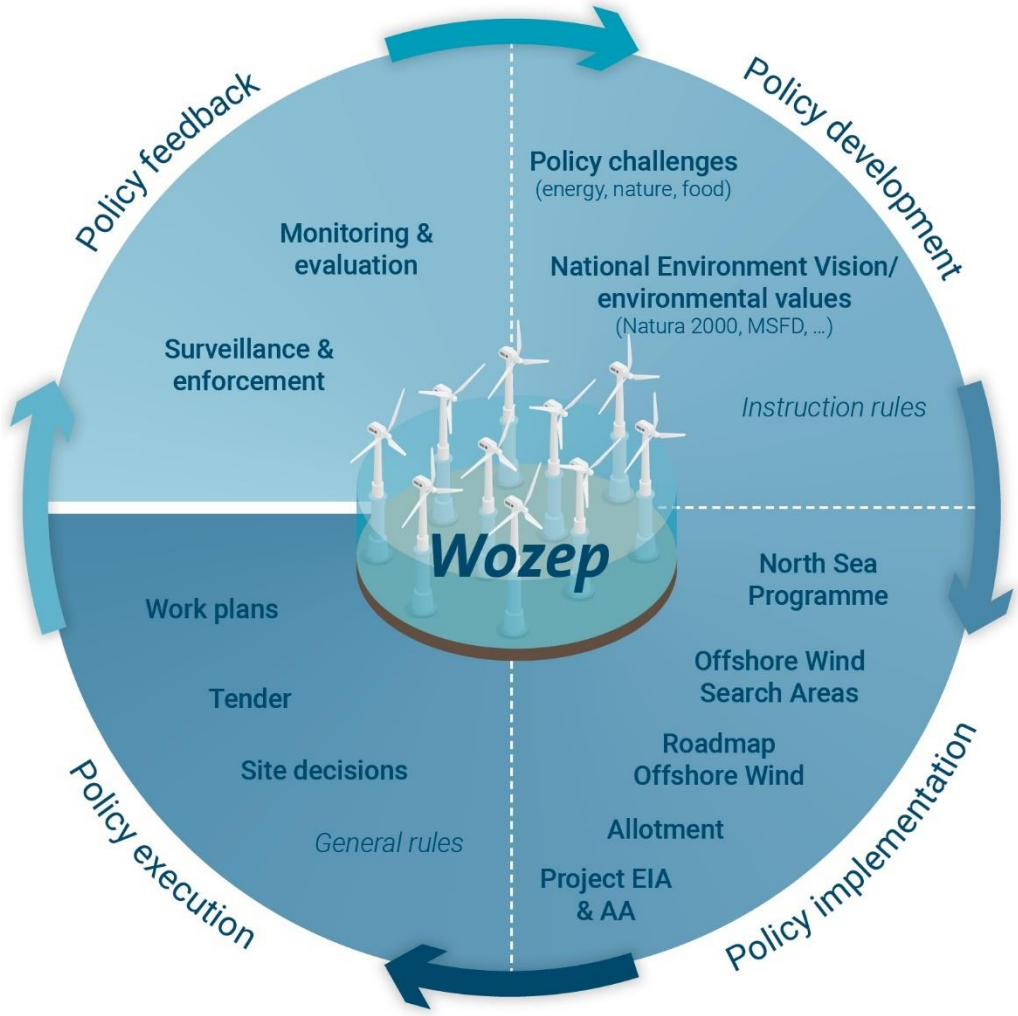

Figure 4-1 Offshore Wind Policy Cycle

An overview of above-mentioned steps in de Offshore Wind Policy Cycle including the organisations that play a role in these different steps can be found in Annex 2. This figure was discussed during the work session with these organisations. The most important findings are:

- The organisations mentioned in the figure recognize their position.
- The figure gives insight to the users in what way Wozep results are being used and can be used. It also gives insight to Wozep who the users are and what they need.
- All organisations find it useful to have this overview and to discuss the use of the Wozep results together. It can be used for internal use and in discussions with stakeholders.

4.3 Use of Wozep results

Ecological knowledge is used in almost all steps of the Offshore Wind Policy Cycle. In addition to the results from Wozep, results from other research and studies are also being used. This paragraph contains a brief description on how Wozep results are being used in the different steps of the policy cycle. The synthesis documents contain a more detailed description of this per subject. To clarify this, an overview is presented in Figure 4-2 below.

Current use of research results in the Offshore Wind Policy Cycle:

- **Offshore Wind Search Areas**: general information from Wozep and the KEC are used to designate search areas
- **Roadmap Offshore Wind**: calculations from the KEC are used to determine the cumulative effects of offshore wind energy production. Designated sites in the roadmap are partly based on these calculations
- **Subdivision of areas/allotment**: limited use of ecological knowledge
- **Project EIA and Appropriate Assessment**: drawn up by RWS ZD on behalf of EZK and for this purpose, specific knowledge and data from Wozep and the KEC are regularly used (i.e. the occurrence of species in certain areas, estimated numbers of collision victims and disruption days, and other effects). Potential mitigating measures are also described, including their effect. Calculations from the KEC are also used to describe the cumulative impact on Natura 2000 areas
- **Site decisions**: results and conclusions from the EIA and Appropriate Assessment are used, as well as knowledge from Wozep for regulations, substantiation of regulations and the description of the relevant mitigating measures. An example of this, is the underwater noise standard, which was drawn up on the basis of Wozep's knowledge and calculations in the KEC. This also applies to the regulations regarding bats
- **Tender**: up until now, ecology has not been a substantial part of tenders, with the exclusion of nature-inclusive designs. However, in the current tender for Hollandse Kust West, ecological measures to prevent or mitigate the impact or restore the ecosystem are an essential part of the bid. Wozep results and results from other studies can likely be used in current and future tenders
- **Work plans**: knowledge from Wozep with regards to specific mitigating measures can be used, in combination with results from other research or studies
- Wozep results are important input for the updates of the **KEC**. The KEC itself is an important source for various components in the Offshore Wind Policy Cycle. In turn, results of the KEC are being used as input for Wozep knowledge questions.

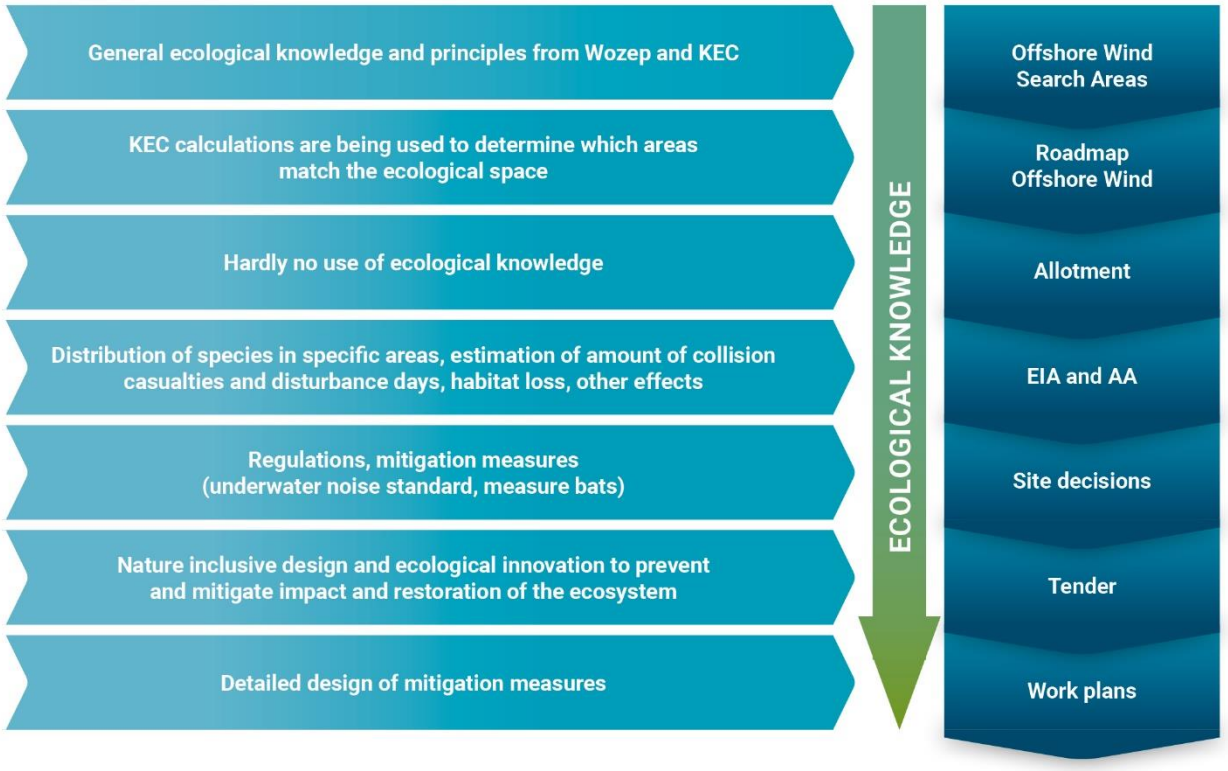

Figure 4-2 Overview of use of Wozep results (and other research results) in the different steps of the Offshore Wind Policy Cycle

Summary of feedback from organizations present at the work session on the use of Wozep results in the various steps of the Offshore Wind Policy Cycle:

- Wozep is a well-functioning research program which delivers results that can be used effectively and is well-connected to the outside world. The programme is important in gaining support for offshore wind production
- Wozep delivers useful insights into ecological processes, workable regulations and input for KEC
- Wozep works on reducing the uncertainties of the impact of OWF, which has already resulted in reduced costs for OWF companies. Clarity on the impact of OWFs may lead to more innovations (for example bubble screens to mitigate the impact of underwater noise)
- Communication on the programme, the results that focus on the steps in the policy chain and the timing of the delivery of new results could be improved to make the use of the results more effectively
- The currently planned offshore wind capacity matches the available 'ecological space', but when capacity will be increased there will be a point where unacceptable ecological effects occur. Therefore, it is necessary to think about compensation methods to create 'ecological space' for the future. Wozep should play a role in this, for example by drafting knowledge questions on this topic
- It was stressed regularly to join forces with research in other regions of the North Sea. Wozep team members are already active in several networks and working groups with representatives of research programmes from other North Sea countries (OSPAR, CEAF, ICES). It is challenging and time-consuming to operationalise collaborations and may currently not be high enough on the list of priorities of Wozep.

4.4 Conclusion

Wozep was initiated as an integral part of the offshore wind developments in The Netherlands. Wozep and KEC results (as well as other research results) are being used in all elements of the Offshore Wind Policy Cycle, but the focus of Wozep research is on the KEC, EIA, AA, Site decisions and mitigation measures. More general information is and can be used in the other steps. The knowledge base is being strengthened and knowledge is used in a cyclic way.

This evaluation has demonstrated that Wozep results are being used effectively and are valued by all stakeholders involved. The programme is also useful in other ways: it is important in gaining support for offshore wind production and reducing the costs for OWF companies.

The tables and figures designed during this evaluation can be maintained for an overview of the knowledge development and its impact towards the objectives of Wozep. They can also aid as communication tools, tailored to the needs of policy makers, wind farm operators, innovators and other stakeholders. This could increase the interaction and cooperation between Wozep and its various stakeholders.

Several suggestions have been done that could help to make Wozep even more effective, for example in communication, international cooperation and the role in future offshore developments.

5 Final considerations and recommendations

Based on the desk studies, input from the work sessions and the observations of the evaluation team, the following final considerations and recommendations are made.

5.1 Gained knowledge and answering the knowledge questions

- During the past five years a lot of knowledge has been gained on the different topics that are part of Wozep. Especially on birds and marine mammals, big steps have been taken in creating a good knowledge base on the impact of offshore wind. For both species groups models have been developed that are already being used to predict the effects on populations. Much of the bat research is still in a preliminary phase, high research costs are involved and casualties at sea by collision are hard to detect. Research on the effects on the ecosystem has started with changes to oceanographic and abiotic conditions, it will continue with the indirect effects of these changes on populations of protected species.
- As this is a mid-term evaluation, much of the research is still ongoing. Part of the finished studies was focussed on possibilities of research and research methods and have led to follow up studies from which the results can be used to answer the knowledge questions. Nevertheless, many knowledge questions can be partly answered by Wozep research. The ongoing studies are assumed to deliver knowledge that will contribute to more answers to the remaining knowledge gaps.
- There are no indications to cease certain (parts of) research due to irrelevancy or having obtained sufficient information to answer the knowledge questions.
- It is recommended to refine the knowledge questions, to have a clearer set of knowledge questions as a structure for Wozep research in the coming years. *Proposals for updated knowledge questions are part of previous chapters in this evaluation.*
- During the evaluation, it became clear that it is sometimes difficult to connect research results to specific knowledge questions. For some knowledge questions the answers can be found in several studies and some studies deliver answers to several knowledge questions. This makes it complex to get a good overview. *It is suggested to define specific research questions for each knowledge question, in order to directly connect the planned research to knowledge gaps.* The ultimate aim of this is to promote more purpose-driven research and improve the effectiveness of Wozep. The tables in Chapter 3 can aid to structure this process.
- Studying the effectivity of mitigation measures is part of Wozep. Since only a few mitigation measures have been executed until present, therefore it is hard to study the effectivity. It is also difficult to measure the differences in for example casualties. However, there is discussion about the way mitigation should be studies under Wozep as this is still unclear. *It is recommended to further discuss and determine how the study into mitigation measures can be better incorporated into Wozep.*
- A lot of relevant research is conducted outside Wozep. The results of these studies can possibly support answering the Wozep knowledge questions. *It is recommended to create and maintain an overview of all relevant research outside Wozep.* This will enable a more comprehensive assessment of the extent to which knowledge questions can be answered in future evaluations.

5.2 Focus for future research

- Experts *recommended to focus research on birds on vulnerable species or species in decline and birds that breed in The Netherlands. They also recommended to validate and improve models, using field measurements from ongoing and planned research as well as results from studies outside Wozep.*
- It was concluded that much knowledge is gained on the impact of impulsive noise on harbour porpoise during the construction phase of OWFs (TTS, PTS). This was given priority because of the expected

large impact of impulsive noise. According to the experts, *future research should focus on the impact of underwater noise on protected species during the operational phase and on the impact on behaviour and fitness of these species. For impulsive noise more knowledge is needed on hearing recovery.*

- Future research on bats *should focus more on determining the number of fatalities, offshore fatality risk and actual estimates of mortality rates. Additionally, a better understanding is needed of movement patterns along the coast of Northern Europe*. *Considering the high costs involved for this kind of research, it is recommended to join forces with bird experts (cross-boundary) and to write a collaborative research proposal*
- According to experts, *future research on ecosystem effects could start with hydro-dynamic conditions and how these affect prey availability up the food chain for (a selection of) top predators.*
- Many stakeholders and experts recommend collaborating with research programmes in other North Sea countries to find synergies, reduce research costs, validate and strengthen results and improve potential mitigation measures. *The evaluation team recommends exploring possibilities for one or two research priorities (or species) through existing intergovernmental networks and working groups. It is also recommended to promote and challenge researchers and research institutions to collaborate more and to develop concerted research proposals to national governments and research programmes.* These research efforts then strengthen each other in the interest of protecting species and ecosystems.
- Knowledge of actual impacts is necessary to improve predicted impacts. *There should be more focus on monitoring of actual impacts and the effectivity of mitigation measures.*
- The consultation group is regularly being informed on the progress within Wozep, which is important. However, the group members believe they can also actively contribute as a source of knowledge. *It is recommended to organise work sessions on relevant subjects, with possibilities to discuss issues and share knowledge.*

5.3 Use of Wozep results

- Wozep has delivered a substantial amount of information that is and can be used to assess the (cumulative) impact from OWFs on protected species. The research results form an important basis for several steps within policy, permitting and management, such as the KEC, Environmental Impact Assessments (EIA), Appropriate Assessments (AA), regulations, mitigation measures and Site decisions, but also for search areas and the Offshore Wind Roadmap
- The results from research within Wozep are highly valued and are being used by policy makers, permitting agencies, the offshore wind industry, and other stakeholders. The way Wozep and KEC are set up is unique in Europe and the world
- Wozep works on reducing the uncertainties of the impact of OWF, which has already resulted in reduced costs for OWF companies. Clarity on the impact of OWFs also may lead to more innovations (for example bubble screens to mitigate the impact of underwater noise)
- The currently planned offshore wind capacity matches the available ‘ecological space’, but when capacity will be increased there will be a point where unacceptable ecological effects occur. Therefore, it is necessary to think about compensation methods to create ‘ecological space’ for the future. *Wozep should play a role in this, for example by drafting knowledge questions on this topic*
- More innovations could help to minimize the impact on ecology and to create ‘ecological space’ to be able to further improve offshore wind developments in the future. *Wozep should identify the knowledge gaps and define knowledge questions that support the creation of ecological space.*

5.4 Inform and communicate

- Actively exchange information on Wozep progress is recommended with all parties involved (ministries, RVO, RWS, the consultation group) using the figures of the Offshore Wind Policy Cycle. Visualisations can help direct the use of research results within the policy cycle and can clarify how additional and updated knowledge questions will contribute to offshore wind policies
- The work session on the use of Wozep results proved that was very useful to bring policy makers and people that execute the policies together and to discuss the way the results are being used. This gives insight to the users in what way Wozep results are being used and can be used. It also gives insight to Wozep who the users are and what they need. *It is recommended to conduct regular meetings or work sessions to promote information exchange and collaboration between the various stakeholders and users within Wozep and the policy cycle.*

A1 List of conducted and planned Wozep research

The following research has been performed, is still ongoing or is planned within the MRP, which was the basis for the synthesis of research results and assessment of knowledge questions in this evaluation.

A1.1 Birds

References to Wozep studies on Bird *habitat loss and displacement*

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2. Zuur, A. (2018). *Effects of wind farms on the spatial distribution of Guillemots.* Highland Statistics Ltd.
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5. Mardik, F. Leopold (2016). *Seabirds? What seabirds? An exploratory study into the origin of seabirds visiting the SE North Sea and their survival bottlenecks.* Den Helder, Wageningen Marine Research (University & Research centre), Wageningen Marine Research report C046/17.

Ongoing and planned studies

6. Feasibility of tagging and tracking seabirds (Potiek & Duijns in prep.)
7. Tagging study Sandwich tern
8. Inventory ESAS database
9. Follow up study on expanding the ESAS database
10. Video surveys using high-definition camera's
11. Automatic recognition camera footage of birds and marine mammals

References Wozep studies on Bird *collision risk*

1. Duijns, S., M. Helberg, H. Verstraete, E.W.M. Stienen, R.C. Fijn, 2020. Origin of large gulls in the North Sea. Analysis based on ring recoveries. Bureau Waardenburg Rapportnr.19-257. Bureau Waardenburg, Culemborg
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4. Shinneman, S.M., van Loon, E.E., Wijers, B.C., Bouten, W., (2020). *Prediction and measurement of high intensity bird migration using meteorological radar data in Eemshaven windpark.*

5. Klop,E., A. Brenninkmeijer (2020). *Aanvaringsslachtoffers Windpark Eemshaven najaar 2018 & voorjaar 2019.* A&W-rapport 3189 Altenburg & Wymenga ecologisch onderzoek, Feanwâlden
6. Collier, M.P., Courtens, W., Van Daele, T., Verschelde, P., Stienen, E.W.M. & Fijn, R.C. (2020). *Survival rates of birds for use in population models. Analysis of ringing data.* Bureau Waardenburg Report 19- 194. Bureau Waardenburg, Culemborg.
7. Potiek, A., M.P. Collier, H. Schekkerman & R.C. Fijn (2019a). *Effects of turbine collision mortality on population dynamics of 13 bird species.* Bureau Waardenburg Report 18-342. Bureau Waardenburg, Culemborg
8. Potiek, A., N. Vanermen, R.P. Middelveld, J. de Jong, E.W.M. Stienen & R.C. Fijn (2019b). *Spatial and temporal distribution of different age classes of seabirds in the North Sea. Analysis of ESAS database.* Bureau Waardenburg report 19-129. Bureau Waardenburg, Culemborg.
9. Dirksen, S. (2017). *Review of methods and techniques for field validation of collision rates and avoidance amongst birds and bats at offshore wind turbines.*
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Ongoing and planned studies

13. Gyimesi A., J.J., Leemans, R.P. Middelveld, M.P. Collier &R.S.A. van Bemmelen (2020). *First results on bird fluxes and macro- and meso-avoidance in Luchterduinen. Interim report.* Bureau Waardenburg Report nr. 20-025. Bureau Waardenburg, Culemborg.
14. Bird fluxes, meso-avoidance and corridor use in Borssele
15. Individual-based model Lesser black-backed Gull
16. GPS tracking, diet use and breeding success of seabirds in the Borssele area
17. GPS-tracking of the Eurasian curlew

A1.2 Bats

References to Wozep studies on Bats

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