Royal HaskoningDHV

Offshore wind ecological programme 2016 - 2021 (Wozep)

Minutes workshop with specialists/researchers on 30 september 2016 – Theme Bats

General introduction

Wozep is part of the assignment from the Ministry of Economic Affairs, Energy Challenges 2020 Directorate (EZ ED 2020) for Rijkswaterstaat (RWS). The assignment was issued in late 2015. The objective for Wozep is to study the ecological impact of offshore wind in the North Sea. At the end of 2016 a logical and transparent monitoring and research programme for the period 2017-2021 has to be finalized and approved by the Wozep steering committee. To devise a strong, (cost) effective and efficient research programme, it is essential that the ministry, the Wozep project group, and specialists/researchers are involved in this process. This was done in two steps. During the workshop in June 2016 (government only) the project goals and main knowledge issues were defined. On September 29th the next step was made with specialists/researchers by discussing the main issues and knowledge gaps and formulating research questions for Wozep. The following reports describe the outcome of the workshops on September 29th of 2016. The results from the September workshops provide the basis of the monitoring and research programme which will be ready in November of 2016.

RWS Wozep team and tasks:

- Project manager MEP: Ingeborg van Splunder.
- Project manager KEC: Martine Graafland.
- Technical manager: Marijke Warnas.
- Birds: Suzanne Lubbe, Maarten Platteeuw.
- Bats: Maarten Platteeuw, Marijke Warnas.
- Marine mammals and underwater sound: Inger van der Bosch, Aylin Erkman.
- Benthos: Joop Bakker, Saa Kabuta, Paul Westerbeek.
- Fish: Joop Bakker, Paul Westerbeek.
- Data management: Kees Borst, Ingeborg van Splunder.

The objectives of the Offshore wind ecological programme are:

- Determine effectiveness of mitigation measures (in the context of the 40% cost reduction in the Energy Agreement).
- Reduce uncertainties surrounding the knowledge gaps and assumptions from the Framework Ecology and Cumulation (KEC), Environmental Impact Assessment (EIA) and Appropriate Assessment (AA).
- Reduce uncertainties surrounding the knowledge gaps and assumptions regarding effects in the long term and upscaling of wind farms (in relation to possible subsequent offshore wind farms after the roll-out of the Energy Agreement).

REPORT

List of attendees:

Ingeborg van Splunder	RWS, chairman
Marijke Warnas	RWS, mediator
Marjon Paas – van Oort	Royal HaskoningDHV, minutes secretary

Experts

Herman Bouman	Arcadis
René Janssen	Bionet Natuuronderzoek
Jasja Dekker	Jasja Dekker Dierecologie
Peter Lina	Naturalis
Martijn Boonman	Bureau Waardenburg
Willem Kuijsten	Royal HaskoningDHV
Bob Jonge Poerink	The Fieldwork Company
Sander Lagerveld	Wageningen Marine Research
Herman Limpens	Zoogdiervereniging
Jan Boshamer	Vleermuiswerkgroep Noord-Holland
Victor Loehr	RWS

Knowledge questions

The following knowledge questions have been formulated as a result of preparatory activities

1. How many bats per year migrate across the North Sea to and from Great-Britain?
    a. What percentage of the population is this?
    b. What is the relevant population?
    c. To what extent does true migration occur and what is "off flow"[1]?
2. What is the behaviour of bats at offshore wind farms?
    a. How does this behaviour affect the collision risk?
    b. At what height do bats fly in offshore wind farms?
    c. Are bats attracted to offshore wind farms? If so, why? Does this explain the behaviour around offshore wind turbines?
3. Are there specific migration routes across the North Sea?
    a. Are there differences in densities across the North Sea?
    b. Does narrow front migration occur along the coast and if so, what percentage of the population is involved?
    c. When taking the answers to sub question b into account, is the number of bats that is at risk from collision with offshore wind farms still relevant?
4. What number of bats per year dies as a result of collisions with offshore windfarms?
    a. Is there a difference in collision risk between wind turbines at different locations within a wind farm (e.g. edge of wind farm vs. middle of wind farm)?

During the day these questions changed as a result of the discussion with the specialists. The new knowledge questions are given below and in the summary table in these minutes. In general is mentioned that all questions are formulated as spatial, but not temporal processes. But time is also an important component to take into account: when do bats do what they do? Research has shown that the Nathusius' pipistrelle (*Pipistrellus nathusii*) is the most common species of bat in the region of the Southern North Sea offshore. Bats can be influenced by offshore wind in different ways. These ways are shown in Figure 1.

The following no-regret studies are conducted in 2016 within the offshore wind ecological programme:

- Population research desk study by the Dutch Mammal Society and Wageningen Marine Research.
- Pilot study on the behavior of bats which is studied by a combination of thermal imaging cameras and bat detectors at onshore wind turbines by Wageningen Marine Research.
- Pilot study on possibilities for telemetric stations by Wageningen Marine Research in cooperation with Bionet Natuuronderzoek and Batweter.
- Batdetector research along the coast and offshore by Wageningen Marine Research in cooperation with The Fieldwork Company.

[1] In this context 'off flow' is meant to describe the loss at sea of a non-substantial part of the population, of no consequence whatever to the durable survival of the population concerned.

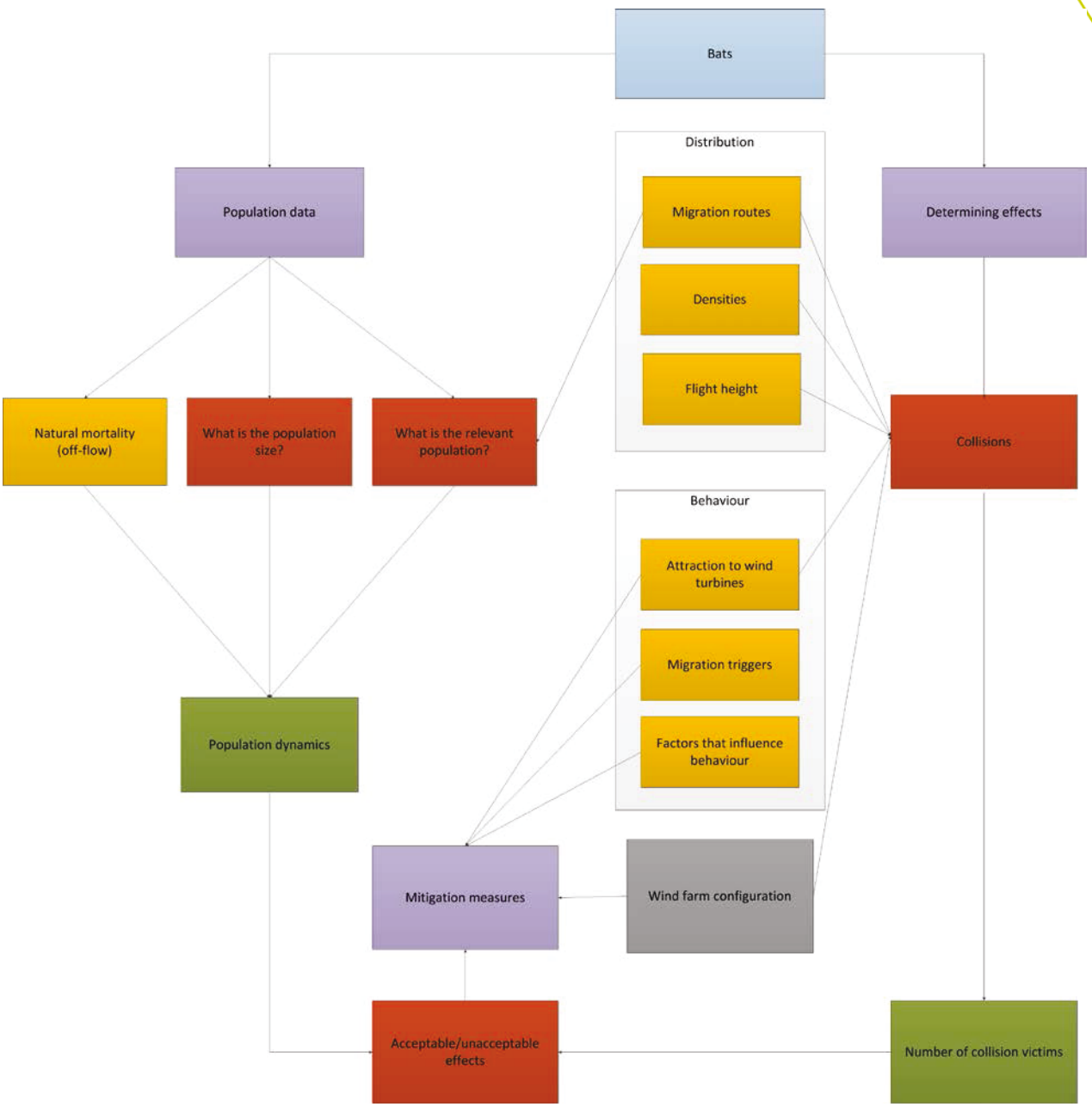

Figure 1: Overview of existing gaps in our knowledge in relation to effects of offshore wind on bats. Orange blocks give gaps in our knowledge. Dark orange blocks give priority of gaps in our knowledge, in which important assumptions are made in the KEC.

During the workshop the discussion regularly shifted from knowledge questions to research methods. Therefore, these minutes first discuss the questions and later the research methods. The questions and research methods are combined in the summary table at the end of this report. As a consequence of the discussion the knowledge questions can be refined to the following:

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

Knowledge questions discussed

1. What number of bats flies over the Southern North Sea per year?
    a. What percentage is this of the population that migrates along the Southern North Sea coast?
    b. Of the number of bats that flies across the Southern North Sea, what percentage is seasonal migration, what is dispersion and what is off flow?
    c. What is the relevant population of Nathusius' pipistrelle and what is its size and trend?

The question `What is the relevant population?´ is very complicated to answer since the distribution area of the Nathusius' pipistrelle is too big and widespread.. The natural occurrence of Nathusius' pipistrelle ranges from the Baltic States and Russia to the United Kingdom and Ireland. Additionally, the species migrates, therefore an individual might be seen as both a member of a local Russian population (bearing and weaning its offspring) and a Dutch population (mating and hibernating). As a result of the discussion the first question is refined from 'How many bats per year migrate across the North Sea to and from Great-Britain?' to´ What number of bats flies over the Southern North Sea per year?'.

2. What number of bats per year dies as a result of collisions with offshore windfarms?

Due to the major gaps in our knowledge in this respect, the KEC now works with a rough maximum estimate of one bat fatality per turbine per year. Modelling of collision victims is possible on land, but is not possible for offshore conditions, because the number of offshore collision victims can't be validated at the moment

3. Taking into account population and collision risk, is the number of bats at risk from collision relevant?
    a. Can we improve the input parameters of the Potential Biological Removal (PBR)?

It was concluded that the question 'are there specific migration routes across the North Sea?' isn't really relevant. Bats are attracted to offshore structures, so even if these did not exist before, mankind provides migration routes by constructing wind turbines and other offshore structures. We can assume that, within a certain period of time, bats will be present in all areas where mankind constructs offshore structures.

4. For what purpose are bats attracted to wind farms?
    a. How does this behaviour affect the collision risk?
    b. At what height do bats fly in offshore wind farms?
    c. How long do bats stay in wind farms?

In order to understand the behaviour of bats in wind farms and around rotor blades more knowledge is needed about wind- and temperature profiles in wind farms at different heights. These profiles are expected to be available from energy suppliers or Meteorological Services. Linking of these data to the available ecological data may provide more insight. One of the questions is 'how do insects respond to wind and temperature and how do bats subsequently react to this?'. During high wind speeds in lower

air layers bats might fly much higher (outside detection zone). Wind turbines are relatively warm, which might affect insect behaviour which could in turn influence bat behaviour.
If the number of wind farms increases, bats will spread over this larger amount of structures. The number of observations of bats at the current observation points may decrease without necessarily a decrease in the total population of bats. Also, the migrating population might increase because offshore structures could function as stepping stones. The fact that observations cannot be directly linked to the number of bats present should be taken into account when observations are analyzed.
Bats and insects may be attracted from a greater distance by wind turbines because of the lights on the wind turbines, because visibility of the offshore structure increases.
Bats have a fly- and- forage strategy and therefore eat frequently during migration. We expect that bats will use offshore structures as stopover sites during migration over the North Sea. Bats can hang on to the metal platforms of the wind turbines. A question is 'how long do bats stay in wind farms during a crossing?'.
Maybe different offshore structures attract bats in different ways. Research needs to be done for a longer period of time (several years) because the weather during the migration season might influence the research outcome significantly.

5. Can mitigation measures be made more specific to reduce wind turbine down time?
    a. Can other mitigation measures be applied?

The following mitigation measures were discussed:

- Attach a boom box (acoustic deterrents) on an offshore wind turbine to scare away bats. This measure has been proven effective for onshore wind turbines (-20%). The action radius of the boom box might be too small since the length of the offshore rotor blades is more than 200 meter. Also the energy supply of the boom box might be too high to make the wind turbine cost effective.
- Reducing turbine lighting might decrease the attraction rate to wind farms from the coast. Variable lighting is already being researched in connection to visibility issues for nearby residents.
- Put UV paint on the rotor blades. The idea is that the blades will be more visible to bats and therefore the bats can easily get around the blades. On the other hand they might be more attracted to the blades from a greater distance, putting them at greater risk. This can be tested on an onshore wind farm (preferably a bare, open area). The amount of collisions on the wind turbines need to be investigated. The result can't be copied directly from onshore to offshore, since the circumstances, and therefore bat behaviour, will be different.
- Improve the Dutch landscape for the survival of bats. In this way onshore death of bats maybe reduced or the population increased. Technically, this is not a mitigation measure, but compensation. This may not be the correct measure when it is the population that flies over the Southern North Sea towards the United Kingdom that needs to be protected.
- If we know why bats get attracted to offshore structures (Q4), it may be possible to attract bats from wind farm areas to other offshore structures without risk from collision and/or make offshore wind farms less attractive.
- If we know more specifically when and where (exactly) bats occur at the North Sea (in relation to the season, weather conditions and other potential triggers like insects) turbines can be switched off when the likelihood of bat presence is very high (unlike the current practice which only takes the wind speed into account). At this moment a spatial/temporal offshore bat migration model is being developed (based on the data of the current 2015/2016 monitoring project), but we do not have information about insect migration, a potential important predictor which might improve this model. Apparently insects can be easily observed with radar.

One of the objectives of the research is recalculating the KEC when more reliable data is available. Then the size of the mitigation measures can be determined in harmony with the effects of offshore wind.

Research methods discussed

A difficult issue is that it is impossible to have control sites: observations of bat migration, whichever method is used, requires a research site to mount equipment, so these are always offshore structures, even if they are as small as a buoy or a RIB. This means there is always an observation bias effect. It is therefore not possible to make truly objective measurements of what the presence, behavior and distribution of (migrating) bats offshore.

Population research desk study

Population research desk study by the Dutch Mammal Society (Zoogdiervereniging) and WMR is the starting point for research about bats. An indication of the population size is made using different substudies that are based on population research. This gives not only results of the research itself, but also stimulates more bat research in Europe.

A statistical approach which is used to determine the population size of birds, based on sightings, might also be used to estimate the bat population size. In order to answer the first knowledge question it is advised to invest in cooperation with researchers in the United Kingdom and Ireland rather than in the Baltic States, since a similar programme already started in the United Kingdom. Three proven crossings of the North Sea by Nathusius' pipistrelle have been documented in the last 3 years. Off flow can't be monitored directly (Q1b). A combination of research methods might answer questions about migration and dispersion.

Bat detectors
Wageningen Marine Research and The Fieldwork Company conduct research with approximately 12 bat detectors. Eight of these bat detectors are positioned offshore. This research needs to be continued and the number of bat detectors need to be increased. Maybe it is possible to place at least a few bat detectors in every offshore wind farm zone. The range over which a bat detector can detect a Nathusius' pipistrelle is about 20-50 meters. Therefore bat detectors need to be placed on different heights to determine at which height bats fly in wind farm zones (Q2b).
Research with bat detectors provides more knowledge about offshore occurrence of all bats (not only Nathusius' pipistrelle). At this moment only single and separate bat detectors are installed at the different offshore study areas. A grid of detectors within e.g. an offshore wind farm could give information on the density of bats.

Combination of bat detectors and thermal imaging cameras
The range of the thermal imaging cameras currently used in the study of Wageningen Marine Research is about 100 to 150 meter, this might not be enough to detect pipistrelles and observe their behaviour in the entire rotor-swept area of an offshore wind turbine. It is possible that cameras with greater range exist, which might provide a solution to this problem. Thermal imaging cameras in combination with bat detectors may be used to determine the number of collisions or collision probability. In addition thermal imaging cameras can be used to study behaviour of bats around wind turbines (staging times, foraging/travelling). These parameters can be used to eventually estimate the actual number of individuals based on the measured bat activity by bat detectors.

If it is concluded that thermal imaging cameras cannot be used for observe bat behavior and collisions offshore it might be useful to ask engineers what other possible innovative systems might be used to track individual bats within an offshore wind farm.

Automated Radio Telemetry
Ringing has been used as method to gain more insight in migration, population size, survival and reproduction of birds. Ringing of bats has a long tradition but has so far mostly been used only for mapping migration. To acquire sufficient information for bats to answer some of our questions, we would need a very large sample size, and a very intensive and long term (over 20 years) ringing programme, because the recapture rate with rings is quite low. Also ringing might negatively affects the survival rate of bats. Radio telemetry, using automated receivers and coded transmitters (such as used in the MOTUS programme, www.motus.org), has a much higher success rate than ringing and gives not just two locations, but multiple locations which gives more insight into how the bat flew. This is especially true when the locations where transmitters and receivers are applied are chosen strategically. The locations where transmitters and receivers need to be placed dependent on the question. Receiving stations can be positioned inside wind farm zones, along the coast, at drilling platforms, offshore markers of RWS, onshore near the coast and locations of assembly points of bats based on morphology and landscape. When the network of receiving stations is dense enough, this research will provide information about: 'Where does the bat come from, where is it going and how long does it take to fly from A to B'.
This method will give better results if the programme is carried out internationally. Some first basics for the European MOTUS network were agreed upon at a workshop in Lund (e.g. used frequency). Setting up an international programme (some sort of collaboration agreement) could be hugely valuable to gain information on *Nathusius' pipistrelle*, but also other bat species and (particularly smaller species of) birds. This method can also be used for other types of ecological research. Statistical power analysis might be an option to estimate beforehand what effort (number of transmitters and receivers) would be necessary to gain useful information.

Boost for voluntary workers
Place additional bat boxes on useful transects based on landscape in the Netherlands and other countries. Volunteers can be mobilized by NGO's to check the bat boxes (www.vleermuiskasten.nl), or actively sought along these transects. Placing bat IR portal detectors with some of the bat boxes

would give additional valuable information. These transects might give more information about migration patterns along the coast. It can't be determined which percentage of the total population is caught in the bat boxes.

Potential Biological Removal (PBR)
At this moment PBR is being used to estimate the effects of offshore wind on the bat population. It is concluded that at this time PBR is the best available knowledge for estimating population impacts on bats. An analysis on existing data can give more insight in the recovery factor and maximum potential population growth rate used in PBR. Still the question about 'which population needs to be taken into account?', is hard to answer when you try to estimate the PBR. It might be possible to use results from studies about population dynamics from other countries to gain the appropriate information. Asking questions (as in the Population research desk study by the Dutch Mammal Society) will hopefully stimulate research in other countries.
When PBR is used in a study for new wind farms it is important to take background mortality from existing wind farms into account. The current mortality influences the current amount of bat observations.

Describe existing knowledge
Knowledge available in heads of bat experts needs to be unlocked. What are the possibilities to boost the analysis of this data? For instance the knowledge on the next topics:

- Presence of maternity groups.
- Behaviour of bats and difference in migration behaviour between males and females.
- What are the migration triggers (amount of wind flow, season, temperature)?
- Why do bats cross the North Sea?
- How can we analyze the observations in bat boxes?

LiDAR and radar
With lidar and radar a signal is transmitted and after some time it will be absorbed again by reflection. The difference between LiDAR and radar is that LiDAR makes use of laser while radar uses radio waves. Therefore much smaller objects can be detected using LiDAR compared to the radar used for bird studies. A radar is installed on different wind farms for the purpose of bird research. It is expected that the bird radars that are currently being used can't distinguish bats from certain bird species and therefore LiDAR might be a good addition to this research or a suitable alternative to infrared or thermal imaging cameras.
The question is 'which combination of LiDAR, radar measurements, telemetric stations, bat detectors and thermal imaging cameras on one position is the most efficient to gather te needed data?'.
If we decide to use radar or LiDAR measurements this can also be useful for research on birds. Because bats need to eat frequently during migration, it is possible that bat migration is triggered by insect presence (Q4). If it is possible to track insect migration with radar or LiDAR, we could predict more accurately when bats are at risk of collision with offshore wind turbines. Therefore start with a desk study on whether it is possible to observe bats and/or insect migration with radar or LiDAR. Continue to determine which species of insects migrate. The next step is to determine if these species of insects are food for bats.
LiDAR could also be used to map different wind profiles or air layers. If we are also tracking individual bats, this could give us more insight into how these different layers are used by bats and how this influences their behaviour.

Apart from radar and LiDAR it would be useful to ask engineers what other possible innovative systems might be used to track individual bats within a wind farm.

Modelling collision risk offshore
A model has been developed to estimate collision victims onshore. Technically this model works offshore. However, the validation of the amount of offshore collision victims would be needed, which is problematic offshore. Additionally, the specifications of offshore wind turbines are very different than onshore wind farms (much bigger and the rotor is closer to the ground), making application of onshore models difficult, if not impossible. Behaviour of bats is also expected to be different in onshore wind farms compared to offshore wind farms. Possibly, bats will dwell longer in offshore wind farms due to the lack of other foraging and shelter opportunities in the surrounding area. This would increase the risk of collision.

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Answering knowledge questions

To answer the questions completely a lot of research is necessary. Different methods help to answer the knowledge questions. A combination of methods improves the knowledges about bats. In the summary table below are the methods suggested, organized by the knowledge questions. Conclusion is that to gain a better understanding of the subjects in most cases a combination of research methods is needed. One of the conclusions was that a set-up of automatic telemetry stations and placement of a greater amount of bat detectors on different heights is expected to make the most headway into answering most of the questions and to gain more insight into the methods needed to answer some of the more difficult questions. To determine the cumulative effects of wind farms cooperation with other countries is required.

Summary table

Tightened knowledge questions	Possible Research Methods
1. What number of bats flies over the Southern North Sea per year?	Population research desk study is starting point, further research into population Great Britain and Ireland is good starting point. Automated radio telemetry Combination of bat detectors and thermal imaging cameras.
a. What percentage is this of the population that migrates along the Southern North Sea coast?	Telemetric stations Boost for voluntary workers (sponsor additional bat boxes along the coast), possibly in combination with ringing of bats.
b. Of the number of bats that flies across the Southern North Sea, what percentage is seasonal migration, what is dispersion and what is off flow?	Combination of telemetric stations and bat detectors can give more insight into questions about migration and dispersion.
c. What is the relevant population of Nathusius' pipistrelle and what is its size and trend?	Can't really be researched in the Netherlands. This should be the topic of international (European) research.
2. What number of bats per year dies as a result of collisions with offshore windfarms?	Thermal imaging cameras combined with bat detectors. Investigate possibilities for LiDAR or other innovative system to record bat behaviour.
3. Taking into account population and collision risk, is the number of bats at risk from collision relevant?	More knowledge about the answers to question 1 and 2 is needed to provide better understanding on this subject.
a. Can we improve the input parameters of the Potential Biological Removal (PBR)?	Analysis of existing large data set from voluntary work in the Province of Noord-Holland will provide better understanding of bat population dynamics. Use PBR on the bat population flying over the Southern North Sea (only relevant population that can be distinguished). Possibly nvestigate statistical method (occupancy modelling) used for birds to estimate population size based on existing data.
4. For what purpose are bats attracted to wind farms?	Thermal imaging cameras combined with bat detectors. Automated rodiotelemetry: radio tagged bats can show whether bats stay for a longer period in turbine park or that they "snack and go". Investigate possibilities for LiDAR or other innovative system to record bat behaviour.
a. How does this behaviour affect the collision risk?	Possible follow-up after more is known on question 4.
b. At what height do bats fly in offshore wind farms?	Bat detectors on different heights. Possibly LiDAR or other innovative system to record bat behaviour. Thermal imaging cameras combined with bat detectors.
c. How long do bats stay in wind farms?	Bat detectors (possibly combined with thermal imaging cameras) and automatic telemetry stations will give us more insight into this subject.
5. Can mitigation measures be made more specific to reduce wind turbine down time?	Investigate possibilities to track insect migration with radar (desk study). Investigate specification of meteorological circumstances for migration (e.g. temperature).
a. Can other mitigation measures be applied?	Investigate experiences with acoustic deterrents, UV paints and possible compensation measures.

Offshore Wind Ecological Program (Wozep) 2016 – 2021

Minutes workshop with specialists/researchers on 29th September 2016 – Theme Benthos

General introduction

Wozep is part of the assignment from the Ministry of Economic Affairs, Energy Challenges 2020 Directorate (EZ ED 2020) for Rijkswaterstaat (RWS). The assignment was issued in late 2015. The objective for Wozep is to study the ecological impact of offshore windfarms in the North Sea. At the end of 2016 a logical and transparent monitoring and research program for the period 2017-2021 has to be finalized and approved by the Wozep steering committee. To devise a strong, (cost)effective and efficient research program, it is essential that the ministry, the Wozep project group, and specialists/researchers are involved in this process. This was done in two steps. During the workshop in June 2016 (government only) the project goals and main knowledge gaps were defined. On September 29th the next step was made with specialists/researchers by discussing the main issues and knowledge gaps and formulating dedicated research questions for Wozep. The following report describes the outcome of the benthos workshop on September 29th of 2016. The results of the September workshops provide the basis of the monitoring and research program which will be finalized in November of 2016.

The objectives of the Offshore Wind Ecological Program are:

- Determine effectiveness of mitigation measures (in the context of the 40% cost reduction in the Energy Agreement).
- Reduce uncertainties surrounding the knowledge gaps and assumptions from the Framework Ecology and Cumulation (KEC), Environmental Impact Assessments (EIA) and Appropriate Assessments (AA).
- Reduce uncertainties surrounding the knowledge gaps and assumptions regarding effects in the long term and upscaling of windfarms (in relation to possible construction of subsequent offshore windfarms after the implementation of the Energy Agreement).

REPORT

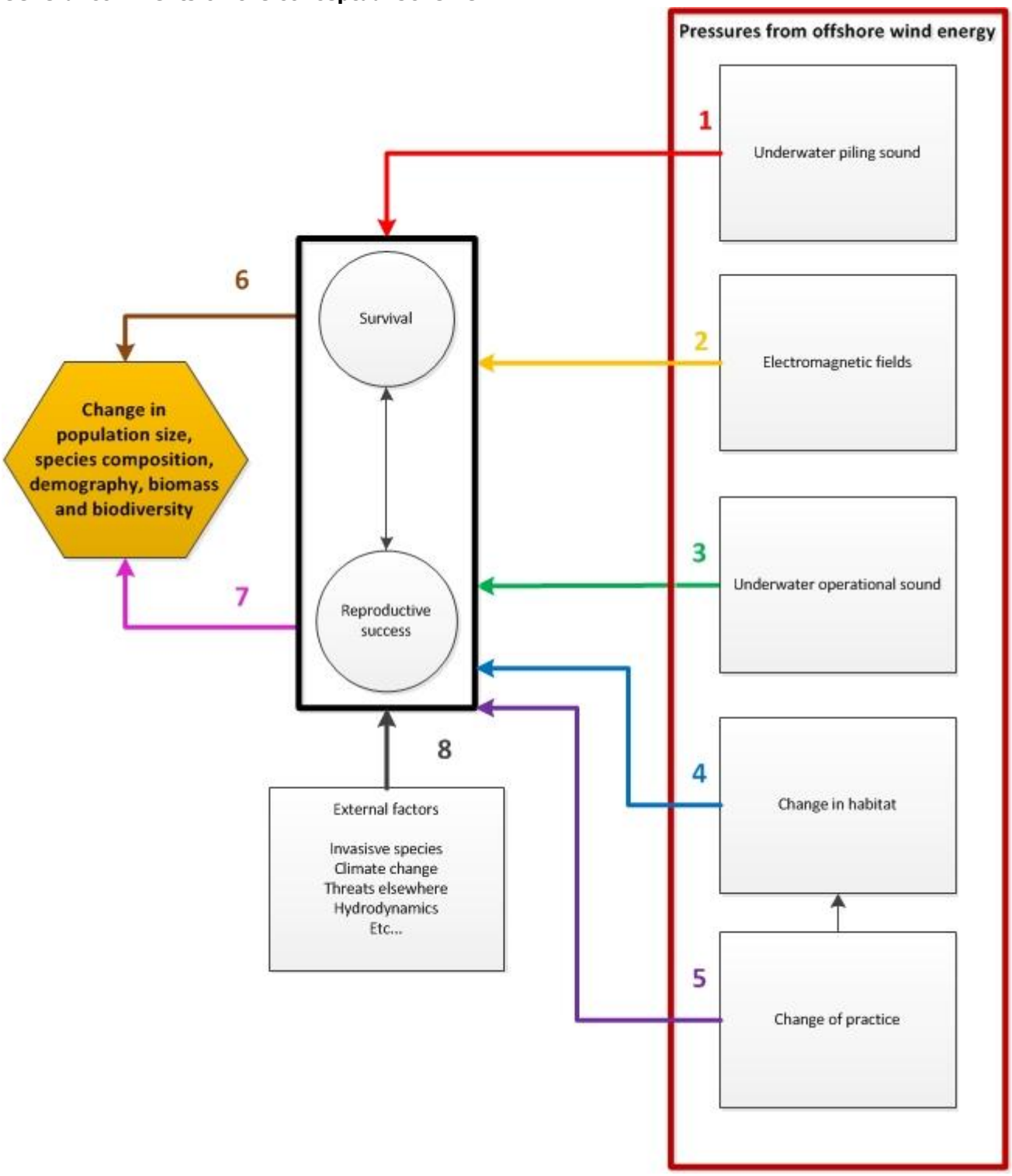
List of attendees:

Paul Westerbeek	RWS ZD, Moderator
Martin de Haan	Royal HaskoningDHV, minutes secretary
Saa Kabuta	RWS WVL
Joop Bakker	RWS WVL
Joël Cuperus	RWS CIV

Experts:

Ingrid Tulp	Wageningen Marine Research
Joop Coolen	Wageningen Marine Research
Johan Craeymeersch	Wageningen Marine Research
Tobias van Kooten	Wageningen Marine Research
Wouter Lengkeek	Bureau Waardenburg
Vincent Escaravage	NIOZ
Arjen Boon	Deltares
Edwin Verduin	Eurofin AquaSense
Thomas Vanagt	eCOAST

General comments on the conceptual scheme



In the present conceptual scheme representing the pressure factors on benthos communities the following aspects are not considered:

- the time and space scales at which the pressures are exerted and at which the effects should be measured.
- on which manner the accumulation of effects should be taken into account.
- to what extent import and export between the wind farm and the surrounding areas occur and how this might influence the pressure/effect relation.
- how the use of the wind farm for other activities should be integrated in the scheme.

Knowledge questions

1. What are the effects of the exclusion of bottom trawling on the development of soft substrate benthos in the long term (> 5 years)?
2. What demands do these species have when it comes to substrate? How can positive effects be stimulated by 'building with nature'?
3. What is the risk that invasive alien species settle on the foundation of offshore windfarms, and what risk does this induce to native species?

Regarding question 1. Effect of exclusion of bottom trawling activities on soft substrate benthos

The collection of all available information on the spatial and temporal distribution of fishing intensity should have the highest priority. The highest possible spatial and temporal resolution is required for these observations. Since obtaining such information is not equally easy for all market players, this part of the study should be excluded from the tender.

Both the practice and the exclusion of bottom trawling activities affect benthic species and their habitat and the intensity of these effects is strongly dependent on the type of habitat (Collie et al., 2000; Underwood, 2007; Lengkeek & Bouma 2010; Diesing et al, 2013 Rijnsdorp et al, 2016).

It's interesting to know whether changes in soft substrate benthos within the wind farm relate to changes outside the wind farm.

For example, could this result in an increase in production around the turbines whether from a true optimization of the ecosystem functioning within the wind farm or from an active migration of benthos towards the wind farm? Answering this question is required to ascertain whether such an increase in production truly contributes to a net increase in food availability for fish and other higher trophic levels within the ecosystem taken at large (the wind farm and its surroundings) or simply corresponds to a geographical shift of the resources. A mere shift in biomass may lead to negative consequences.
Such displacement of macrofauna towards the wind farm mostly concerns mobile benthic species whereas the migratory movements for sessile species remains restricted to the larval phase.

The foundations of the wind turbines represent an increase of the area that is suitable to the settlement of hard substrate species and are expected to lead to increased levels of biodiversity and production, at least locally.
The importance of taking the entire food chain into account was mentioned in order to estimate the effects of the wind farm on the ecosystem functioning. Given the evaluation of all the compartments of the ecosystems and their interactions is far beyond the scope of the present benthos monitoring program; alternative approaches will have to be designed for an integrated assessment of the ecosystem functioning.
The wake effect (turbulence) of the turbines might indirectly induce strong effect on the nutrient balance and consequently on the ecosystem functioning. Events of weakened stratification have been observed in the German Bight and also possibly on the Dogger Bank.
Finally, the effects of excluding bottom trawling on benthic communities must be considered and several participants stressed that impact and reference areas have to be chosen very carefully, taking into account adequate knowledge on the actual bottom trawling intensity in the different study areas.

Mentioned relevant studies:

- Destratification in the German Bight. Research on the density decrease of *Chamelea* clams along the coast after exclusion of the beamtrawl fishing.

Regarding question 2. Substrate requirements of benthos, construction opportunities for 'building with nature'

The Building with Nature program deals with the reintroduction of flat oysters banks where the central question concerns the most suitable substrate conditions for flat oysters and other indigenous reef building species. Substrate containing shell debris appeared favorable for the

successful establishment of the flat oyster larvae together with the actual presence of larvae in the water column. Research has shown that the distance flat oyster larvae can travel before settling is quite limited (in the order of a few km). The introduction of rocks as scour protection was also mentioned as a suitable habitat for crayfishes. An additional question would be: How can positive effects on benthos within the wind farm be stimulated by measures as those developed within the Building with Nature approach?

Mentioned relevant studies:

- Duren, L.A. van et al. 2016. *Rijke riffen in de Noordzee - Verkenning naar het stimuleren van natuurlijke riffen en gebruik van kunstmatig hard substraat*. Deltares-rapport no. 1221293-000. 82 pp. (In English: Rich reefs in the North Sea - Exploration to stimulate natural reefs and use of artificial hard substrate).
- Ongoing study: Pilot re-introduction of shellfish reefs in the Voordelta. A collaboration of Ark, WNF, Bureau Waardenburg, Imares and SAS consult.
- Smaal, A.C., Kamermans, P., van der Have, T.M., Engelsma, M. & H.W.J. Sas. 2015. Feasibility of Flat Oyster (*Ostrea edulis*) restoration in the Dutch part of the North Sea. IMARES report C028/15.
- Van der Have, T.M., & E. van der Zee, 2016. Terugkeer van de platte oester in de Waddenzee. Verkenning naar een mogelijk herstel van platte oesterbanken in de Waddenzee. Bureau Waardenburg Rapportnr. 16-091, Bureau Waardenburg en Altenburg & Wymenga, Programma naar een Rijke Waddenzee.

Regarding question 3. Risk of settlement of invasive exotic species, risk for indigenous species

Background to this question is that due to the introduction of hard substrate in the form of foundations of wind turbines so called 'stepping stones' might be created, leading to unwanted spread of invasive alien hard substrate species.
This is also an important issue within the European Marine Strategy Framework Directive. Possibly international programs like OSPAR/HELCOM will also impose an obligation on member states to monitor hard substrate invasive alien species.
Beforehand, some participants questioned however the relevance of this issue based on the following argumentation:
There are presently ample opportunities for alien hard substrate species to spread anyway, for example via shipwrecks, artificial reefs, buoys, oil and gas drilling platforms. Additionally the effect of wind farms on the progression of invasive species might not be exclusively restricted to hard substrate species where it is also suggested that some soft substrate alien species could get an easy foothold through the exclusion of bottom trawling activities.

Aan alternative question was proposed: What is the role of wind farms in the spread of invasive alien species? This formulation indicates that wind farms are only responsible for a portion of the hard substrate present in the North Sea and keeps a broader scope about all forms of facilitation in favor of any invasive species with either hard or soft substrate affinities.
It is emphasized that this topic has to be considered at an international level, taking into account the entire North Sea.

Mentioned relevant studies:

- Bouma, S., 2012. Indicators for non-indigenous species in the Marine Strategy for the Dutch part of the North Sea. Dutch approach and available data for Further development. Report, Bureau Waardenburg.
- Artificial Reefs research.
- De Mesel, I., F. Kerckhof, A. Norro, B. Rumes & S. Degraer, 2015. Succession and seasonal dynamics of the epifauna community on offshore wind farm foundations and their role as stepping stones for non-indigenous species. Hydrobiologia. doi: 10.1007/s10750-014-2157-1
- The PhD research work of Joop W.P. Coolen, investigating the epifouling biodiversity of oil & gas platforms in the North Sea. Stepping stone part to be published very soon. Invasive species work: Coolen J.W.P., W. Lengkeek, S. Degraer, F. Kerckhof, R.J. Kirkwood & H.J. Lindeboom, 2016. Distribution of the invasive Caprella mutica Schurin, 1935 and native Caprella linearis (Linnaeus, 1767) on artificial hard substrates in the North Sea: separation by habitat. Aquatic Invasions 11: 437–449.

Research questions

Regarding question 1. Effect of exclusion of bottom trawling activities on soft substrate benthos

Research questions are:

- What is the current fishing intensity at the proposed wind farm sites?
- What is the bottom structure and composition on a spatial scale relevant for the observation of the effects of fishery exclusion on benthos?
- What is the period in which impacts of wind farms (i.e. the exclusion of bottom trawling activities) are visible? (5 years may be too short, considering it took 10 years before increased *Chamelea* clam densities were observed after excluding bottom trawling in the coastal zone).
- What effects on the condition of benthos are measurable? (biomass/shell, shell length, shell thickness).
- What impacts on the benthic species composition (biodiversity) can be measured?
- What impacts on the growth rate of benthic species can be measured?
- What effects on soil integrity can be measured?
- What effects on the grain size can be measured?

Regarding question 2. Substrate requirements of benthos, construction opportunities for 'building with nature'

The following questions are relevant:

- What is the best way to reintroduce flat oyster beds in wind farms?
- What is the best way to increase native biodiversity in windfarms?
- Given that the larvae of the flat oysters only disperse over a limited distance, a successful settlement within the wind farm should imply the proximity of mature oysters in the neighbourhood. Are mature oysters and/or larvae found close to/within the wind farm area?
- How effective is the introduction of various types of hard substrate, reef balls, rock fill etc. to increase the (local) biodiversity and biomass of hard substrate benthos (e.g. crayfish)?

Regarding question 3. Risk of settlement of invasive alien species, risk for indigenous species

The following questions are relevant:

- Which alien species pose a risk to become invasive alien species?
- What is the competitive strength of invasive species relative to native species?
- Does the introduction of wind farms significantly increase risks involved with the presence of alien invasive species, and how does this relate to the benefits for native biodiversity?

Methodologies

It is emphasized that research on benthos must be executed SIMULTANEOUSLY with research on other trophic levels and that it should be CONTINUOUS research.

Regarding question 1. Effect of exclusion of bottom trawling activities on soft substrate benthos

Mentioned studies and methodologies for determining the impact of the exclusion of bottom trawling activities on benthos are:

- Determine current fishing intensity on the proposed wind farm site.
- Determine which species have already (presumably) disappeared as a result of chronic impact of bottom trawling.
- Benthic dredge samples should be collected from a small fishing vessel that can reach the area near the poles and take samples from this point outwards along transects pointing at different directions, resulting in a star-shaped sampling pattern. Dredge samples should also be taken outside the wind farm for reference purposes.
- Side scan sonar should be deployed in order to monitor landscape heterogeneities such as natural reef structures.
- Parallel Video recording will be used for validating the observations made with the Side scan sonar, also for monitoring epibenthos (most sensitive organism to bottom trawling) and for monitoring mobile benthos species which may interact strongest with electromagnetic fields.

It is mentioned that quantitative analysis (densities) of rapid-moving epibenthic species such as shrimp is hardly possibly (they flee, video sampling delivers only chance hits), but that for sessile species (Sea anemones, sea pens, shells, etc.) and slower species such as lobster and crab quantitative analyses (for example, for determination of differences in density inside and outside of the wind farm) are possible.
Mentioned are box corer and benthic dredge samples. Box corer is well suited for the monitoring of smaller, short-lived species (r-strategists) on a smaller spatial scale and the benthic dredge method has been designed for examining densities of larger, long-lived species (K-strategists) on a larger spatial scale.
Side scan sonar can be used to get a first impression on the presence of natural reef-building species. Video recordings can be made on spots of interest, potentially followed by benthos sampling. In a pilot project the feasibility of these techniques could be investigated. Camera techniques are used or are currently being developed in the UK and by the University of Groningen.

Regarding question 2. Substrate requirements of benthos, construction opportunities for 'building with nature'
Mentioned potential research methods are:
Literature review.
- Keeping up-to-date with (inter)national research activities (e.g. Deltares report "Rijke riffen in de Noordzee").
- Conduct an experiment, e.g. with adding additional substrates and reintroducing *Ostrea edulis*.

Regarding question 3. Risk of settlement of invasive exotic species, risk for endemic species
Mentioned studies and methodologies are:
- Risk assessment literature research.
- Building on research with scraping samples of oil and gas platforms.
- Continue monitoring carried out at T1 and T5.

Summary table

Refined knowledge questions	Research questions	Methodologies
		SIMULTANEOUS and CONTINUOUS
Impact closure windfarm for bottom trawling activities on benthos. Effects on benthic species. Effects on soil. Does a windfarm lead to local increase in primary production due to turbulence and/or extended waterbody residence time within the windfarm?	Current fishing intensity. Period after which impacts are visible. Effects on the condition (biomass / shell, shell length, shell thickness). Are the effects on the benthos composition (biodiversity); measurable? Effects on growth rate. Effects on soil integrity. Effects on grain size. (see research questions on 'Fish' working group)	Determine current fishing intensity on the proposed windfarm site. Define species that have (presumably) disappeared by trawl fishery. Take benthic dredge samples (with a small ship). Also take samples outside the park (reference). Determine current soil morphology and composition. Examine added value of video compared to boxcorer sampling in pilot surveys. Examine the added value of the scan sonar compared to boxcore sampling in pilot surveys. Experiments to determine the difference between local production or relocation of biomass.
Building with nature, substrate requirements Which natural builders can be defined? Which requirements are there for settlement (besides substrate)?	What is the best approach for reintroduction of oyster? How can larvae moving over a limited distance successfully settle down (only within large areas)? How effective are reef balls, rock fill etc. (e.g. for crayfish)?	Literature review. Keep up-to-date with international research. Conduct experiments in a wind farm.
Establishment invasive alien species, native species issues What is the role of windfarms in the distribution of alien species? What invasive species are involved?	Do invasive alien species use windfarms as stepping stones? How does that compare to other hard substrates? What is the distance between stepping stones that can be bridged by aforementioned alien species?	Risk assessment literature. Build on research with scraping samples of oil and gas platforms. Continue monitoring carried out previously.

Royal HaskoningDHV
Enhancing Society Together

Offshore wind ecological programme 2016 – 2021 (Wozep)

Minutes workshop with specialists / researchers on 29 September 2016 – Theme Birds

General introduction

Wozep is part of the assignment from the Ministry of Economic Affairs, Energy Challenges 2020 Directorate (EZ ED 2020) for Rijkswaterstaat (RWS). The assignment was issued in late 2015. The objective for Wozep is to study the ecological impact of offshore wind in the North Sea. By the end of 2016 a logical and transparent monitoring and research programme for the period 2017-2021 has to be finalized and approved by the Wozep steering committee. To devise a strong, (cost) effective and efficient research programme, it is essential that the ministry, the Wozep project group, and specialists/researchers are involved in this process. This was done in two steps. During a workshop in June 2016 (government only) the project goals and main knowledge issues were defined. On September 29th the next step was made with specialists/researchers by discussing the main issues and knowledge gaps and formulating research questions for Wozep. The following reports describe the outcome of the workshops on September 29th of 2016. The results from the September workshops provide the basis of the monitoring and research programme which will be ready in November of 2016.

RWS Wozep team and tasks:

- Project manager MEP: Ingeborg van Splunder.
- Project manager KEC: Martine Graafland.
- Technical manager: Marijke Warnas.
- Birds: Suzanne Lubbe, Maarten Platteeuw.
- Bats: Maarten Platteeuw, Marijke Warnas.
- Marine mammals and underwater sound: Inger van de~~n~~ Bosch, Aylin Erkman.
- Benthos: Joop Bakker, Saa Kabuta, Paul Westerbeek.
- Fish: Joop Bakker, Paul Westerbeek.
- Data management: Kees Borst, Ingeborg van Splunder.

The objectives of the Offshore wind ecological programme are:

- Determine effectiveness of mitigation measures (in the context of the 40% cost reduction in the Energy Agreement).
- Reduce uncertainties surrounding the knowledge gaps and assumptions from the Framework Ecology and Cumulation (KEC), Environmental Impact Assessment (EIA) and Appropriate Assessment (AA).
- Reduce uncertainties surrounding the knowledge gaps and assumptions regarding effects in the long term and upscaling of wind farms (in relation to possible subsequent offshore wind farms after the roll-out of the Energy Agreement).

Report workshop birds

List of attendees:

Martine Graafland	Rijkswaterstaat Zee & Delta
Suzanne Lubbe	Rijkswaterstaat Zee & Delta
Maarten Platteeuw	Rijkswaterstaat Water, Verkeer en Leefomgeving
Suzan Tack	Royal HaskoningDHV, minutes secretary
Allix Brenninkmeijer	Altenburg & Wymenga Ecologisch Onderzoek B.V.
Jan Beekman	Arcadis
Karen Krijgsveld	Bureau Waardenburg
Ruben Fijn	Bureau Waardenburg
Judy Shamoun-Baranes	Universiteit van Amsterdam
Sjoerd Dirksen	Sjoerd Dirksen Ecology
Mardik Leopold	Wageningen Marine Research

Expert workshop Round 1: bird collisions

Introduction workshop 1

It is assumed that one of the most important negative ecological impacts of operational offshore wind farms consists of collisions of flying birds with the rotating blades of wind turbines. A short introductory presentation was given by Rijkswaterstaat explaining the current status of knowledge, priority species, empirical and theoretical models to calculate collision risks. Followed by a presentation by Sjoerd Dirksen Ecology on an inventory that is being conducted[1] regarding available methods and technology to be used to validate models that calculate collisions and offshore fluxes[2] of birds. Some initial conclusions of this inventory are:

- Differences between outcomes of onshore and offshore monitoring of bird collisions with wind turbines are likely to be much smaller than expected (although this is not precisely a result of this inventory).
- A number of devices are able to measure collisions between birds and wind turbines; however each one has its specific qualities and disadvantages.
- A number of devices are able to measure bird fluxes at various levels of scale (including size and species) and in three dimensions.

The presentations are included in appendix 1. Furthermore, a background document on bird collisions and offshore wind turbines was prepared as input to the workshop. This background document is included in appendix 2.

Passage of ships through- and shared usage of wind farm zones

Passage of ships up to 24 meters will be allowed from April 2017 onwards in all wind farms in the Dutch Exclusive Economic Zone (EEZ) (with the exception of wind farm Gemini). The shared usage of wind farm zones is still being discussed. The Ministry of Economic Affairs is currently developing a framework for shared usage. It is expected that some types of fisheries will be allowed up to a distance of 50 meters from the wind turbines, such as rod fishing and possibly gillnet fisheries. Fishery methods that touch the seabed will not be allowed. Permission for other kinds of activities such as algae farms or shellfish nurseries is still being discussed. Passage of ships and shared usage of wind farm zones will be monitored. The impact assessment of wind farm zones has been conducted so far without taking into account the impacts of passage of ships and shared usage. Hence, it is essential that Wozep links with the monitoring activities related to passage of ships and shared usage. The presence of fishing vessels (and their activities), or algae/shellfish farms in a wind farm may attract birds and therefore strongly influence bird fluxes and accordingly increase collision risk. The experts in the workshop indicate that bird attracting activities, such as the gutting of fish, should be conducted far enough outside the wind farm in order not to increase the collision risk. In order to better understand the relationship between the activity and related impacts, more knowledge should be obtained on the relationship between fishing vessels and birds. Sharing of the data on the activities of fishing vessels is currently still very limited. More information could possibly be obtained through:

- VMS-data, managed by RWS, which can provide more insight into the routes of fishing boats
- Researchers could join fishing boats to obtain more information on fishing methods and duration, this is for instance being done in France.

Knowledge questions

There are a number of knowledge gaps related to bird collisions. The following knowledge questions were formulated to fill these gaps[3]:

1. Which knowledge is already available internationally?
2. Which percentage of species specific fluxes of birds (depending on time and location) will collide with a wind turbine, depending on wind turbine characteristics (which so far have turned out to be relatively unimportant) and in relation to major factors of influence on collision rate such as horizontal and vertical avoidance rate and flight speed?
3. Is the dependence of the number of collision casualties on flux intensity indeed linear, as assumed in the Extended Band model? It is likely that the dependence is more complex.

[1] Report expected November 2016
[2] Flux: rate of bird passages
[3] Knowledge questions were formulated during an internal workshop of the government on 28 June 2016.

4. What is the impact of (parts of) a wind farm on the flight behaviour of various bird species under different circumstances (e.g. weather, flight direction, night vs day)?
5. What are the differences when considering turbine size, distance and configuration?
6. How can knowledge obtained in onshore wind farms be 'translated' to offshore wind farms?

A number of additional knowledge questions were added by the Wozep-team. Knowledge questions are related to populations at risk:
1. Are impacts randomly distributed among age and gender?
2. Which (sub) populations are impacted?
3. What is the relevant part of the populations at risk?
   a. Size of natural annual mortality.
   b. Size of relevant (sub) population.
   c. Population dynamics of populations at risk.

Knowledge question related to mitigation measures:
4. Effectiveness of mitigation measures

The knowledge questions related to collisions are grouped in three categories: empirical, input for models, and effectiveness of mitigation measures. These three categories were discussed in the workshop accordingly.

Empirical

Opportunities for studies to empirically determine collision causalities were discussed. The question was raised whether these studies should rather focus on critical species instead of on species groups. However it is difficult to focus on species, as many methods for measuring flux are as yet unable to identify the species and therefore species specific knowledge is largely lacking. The approach so far has therefore been top-down, starting with species groups. It was suggested to conduct a desk study into critical species to determine if it is possible to work more bottom-up. A first step in such an approach could be a desk study into population size and/or conservation status of all bird species that potentially occur in or migrate through the southern North Sea.

Discussion around possibilities for research related to bird collisions centred on three subjects: collision casualties, fluxes and probability of collision.

Collision casualties

As indicated in the introductory presentation by Sjoerd Dirksen a number of available devices are able to detect bird collisions. Improved detection does not mean that model based calculations are not needed any more. Models will always remain necessary for Environmental Impact Assessments (EIAs) and Appropriate Assessments (AAs) in order to determine the impact of a future wind farm related to collision casualties. Empirical data will however result in more accurate model calculations, which is urgently needed since validation offshore of the existing models is still largely lacking.

The impact of lights on collision casualties was discussed as an additional knowledge gap. By increasing the light intensity more birds could be attracted to a wind farm (especially in bad weather conditions, when birds are looking for a place to rest), while there might also be situations where light has no impact on birds or where birds are scared away by the lights. There is a chance that lighting will cause more collisions. The impact of lighting could be measured in onshore wind farms. Currently a study is being conducted into the possibility to dim lights in order to reduce the visibility from the coast. Furthermore, at the moment a test is being conducted in Flevoland where the lights of a wind farm are switched off, but when a plane enters a certain zone around the wind farm the lights turn on[4]. In this study, however, birds are not involved.

[4] More information via: https://www.nuon.com/nieuws/nieuws/2014/onderzoek-verlichting-windmolens-in-zuidelijk-flevoland/

Flux

There are a number of devices available that are able to detect fluxes. Cameras are able to detect birds at short range (e.g. flux through the rotor) both during the day and the night. Night vision (thermal imaging or infra-red) cameras are more expensive. Based on camera footage, information can be obtained on (i) the species spectrum, and (ii) flux intensity. Challenge for data analyses is that for the time being the data can only be analysed through actual viewing of the footage. However, automated image recognition is on its way, developing algorithms that allow the filtering of flying organisms such as birds and bats. The results for bats seem to be promising and this could substantially reduce the amount of time required for actual viewing of the entire footage. However, as long as a good working example is not available, we still have to plough our way through many hours of footage, or take systematic samples of the total footage. Direct measurements could be input for a flux collision model.

Probability of collision

There is a relationship between flight movements, fluxes and the number of collision casualties onshore, especially for migratory birds. The assumed avoidance rates and fluxes used as model input offshore may in some cases be verified on the basis of information from onshore wind farms. This could be done for wind farm Eemshaven, where about 90 species were found as collision casualties. Radar can be used to determine any differences in flight height above land or sea for bird species that migrate over land as well as over sea for bird species that migrate over land as well as over sea. On the other hand, much of the information available for OWEZ clearly suggests that avoidance behaviour at sea, even within the same species, is likely to be very different from that above land.

The behaviour of gulls offshore and onshore can be measured using GPS, data analyses could provide information relevant for Wozep, and part of these analyses are currently undertaken by Bureau Waardenburg (Gyimesi & Fijn *in prep*). The University of Amsterdam (UvA) recently published a paper[5] on the flight behaviour of gulls on sea and land. It is important to better understand the impacts of fishing vessels on the behaviour of gulls and accordingly the collision risk. It is known that particularly herring gull and great and lesser black-backed gulls are strongly influenced by the presence and activities of fishing vessels. Specifically for the Wadden Sea region, knowledge is available on the behaviour of gulls related to fishing vessels[6]. Data for the North Sea are also available from ship surveys and from the baseline study for OWEZ.

Macro and micro avoidance

The following definition of macro and micro avoidance was used:

- Macro avoidance: the phenomenon of birds avoiding entering a wind farm, or fly around it.
- Micro avoidance: the phenomenon of birds entering a wind farm but avoiding the rotor swept area (RSA).

Only the birds that fly through the RSA are at risk of collision.

Knowledge is available about macro avoidance, although it would be beneficial to obtain more data to better understand the impact of the presence of wind farm on the behaviour of birds. Bureau Waardenburg has conducted a desk study into all available data on avoidance, from which it seems likely that a limited number of birds fly through a wind farm. Experts agreed that GPS tracking of birds is relevant to obtain more knowledge about macro avoidance. Trackers could be programmed in such a way that when a bird enters a wind farm, measurements are taken every second (potentially even allowing to study micro avoidance), while outside of a wind farm measurements are taken for instance every three minutes.

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[5] N. Isaksson, T.J. Evans, J. Shamoun-Baranes & S. Akesson 2016. Land or sea? Foraging area choice during breeding by an omnivorous gull. Mov. Ecol. 2016, 4: 11 10.1186/s40462-016-0078-5

[6] Terrestrial and Marine Foraging Strategies of an Opportunistic Seabird Species Breeding in the Wadden Sea. Garthe S, Schwemmer P, Paiva VH, Corman AM, Fock HO, Voigt CC, Adler S. PLoS One. 2016; 11(8):e0159630. Epub 2016 Aug 15

To obtain more insight in micro avoidance it is more efficient to measure this in combination with actual actual collisions through the use of cameras connected to wind turbines. Cameras can be used to visualize the 3D flight path of birds near wind turbines. A system would be required with which the full rotor area an be observed. Additional attention should be given to use a system that is robust enough to operate offshore.

It was suggested to measure the behaviour of birds and accordingly the collision risk for a colony close by a wind farm, for instance the gull colony in IJmuiden. The birds could be tracked by GPS, to monitor macro avoidance, and possibly micro avoidance, because the probability that a gull from a colony close to a wind farm enters the wind farm and therefore also the RSA is higher. Furthermore, the behaviour near a turbine could be tracked via a camera system.

Input for models

Critical parameters
In the Netherlands the Extended Band model is used to calculate bird collision risks in offshore wind farms. Critical parameters for this model are:

a. Flight speed
b. Avoidance rates
c. Nocturnal activity
d. Daytime bird density
e. Proportion at rotor height
f. Turbine data

Some of these parameters are closely related to each other and are sometimes derived from each other, e.g. based on daytime bird density and assumptions about the percentage of flying birds, the nocturnal activity is determined. Parameters a. to d. are input for flux calculations. Parameters a. and f. are required to calculate the collision risk of a specific species passing through RSA. Lack of specific information on all these parameters currently limits the validity of the output of the Extended Band model[7].

During the workshop options were discussed to validate the input parameters of the Extended Band model:

- Last year (2015) Bureau Waardenburg conducted a study into the behaviour of gulls at sea and over land[8]. This desk study can be used to validate the input parameters of the Extended Band model.
- Combine the outcomes of GPS based research for different species. Compare data on flux before and after wind farm construction. So far EIAs and AAs are based on the assumption that the flux before and after construction is similar. However, it is reasonable to assume that the flux might be lower due to macro avoidance. To validate this assumption a measurement campaign is organized in Borssele, to obtain data before construction. This measurement campaign should be repeated after construction in 2019. Measurements could be carried out by aerial or ship-based surveys or by standardized camera systems.
- The OWEZ monitoring data include information about bird behaviour, flight patterns and weather conditions. Based on this information a qualitative estimate could be made about flight behaviour and the influence of wind turbines. In the short list studies, an initial detailing has been made, but this could be detailed further. Due to lack of time this has not been done in the short list studies. Hence, the available OWEZ data can be used to validate input parameters of the Extended Band model, or can indicate where knowledge gaps exist and therefore more data are required.
- Nocturnal activity for larger birds could be detailed through daily rhythm measurements via GPS. A GPS provides a continuous data source on behavioural patterns and spatial distribution. A relatively small sample of animals can be tracked this way, but a lot of information will become available. However, a lot of tracking data are already available. A qualitative analysis of this data

[7] Summarized during VUM symposium in 2015. Presentation by Bureau Waardenburg.
[8] This report of this study is currently in preparation.

would provide more insight into what information is available, at which level of detail, and provide insight into knowledge gaps.

Bird densities

Various studies have been conducted on the different methods to measure bird densities, for instance in the North Sea region. There are differences between measurements by boat, airplane or digital measurements by new high definition methods. It was suggested to:

- Form a working group to make an inventory of the different methods and discuss possible criteria for field work[9].
- Align the upcoming November boat measurements by Wageningen Marine Research (WMR) with measurements by plane.
- Compare a data set obtained by boat and plane, use both to determine flux and see where there are differences.
- Compare bird density estimates from the UK, on the basis of sparse surveys of oceanographic data and the modelled dependence of seabird densities upon these characteristics, with the outcomes of the Dutch measurement campaigns and related bird density data.

Bird densities near the coast fluctuate strongly among years, whereas experts expect that further offshore densities are more predictable. It would be interesting to understand the cause of these differences. OWEZ results show that it is critical to not only conduct field work (e.g. bird density measurements) in the offshore wind farm itself, but to include a larger area around the wind farm, especially the area up to the coast. Night time data on bird densities are very limited. Based on radar data, assumptions have been made on fluxes. More data should be obtained on night time densities and corresponding fluxes.

It was suggested to use MWTL[10] data as baseline data set. These are Dutch Continental Shelf wide measurements, which have been conducted for many years. The programme is relatively flexible, so baseline monitoring of new offshore wind farms or proposed new site locations for wind farms can easily be included. RWS owns the data.

Other relevant developments

During the workshop a number of other relevant developments and knowledge gaps were discussed.

Individual based modelling (IBM) could be relevant to determine collision casualties. The more knowledge is available about the factors that influence the choices of individual birds of a specific age, gender, species, or sub population, the better IBM can be used to estimate collision risk of specific species. IBM is mainly used for migratory species. For species which the operation of wind farms is critical, such as gulls, more insight is needed into the food supply, movements of fishing boats, weather conditions and the impact on behaviour[11].

To gain more insight in the behaviour of birds at sea it would be valuable if AIS data of fishing boats could be combined with data of bird measurement campaigns. This would also provide knowledge and insight in the impact of passage of ships through- and shared usage of wind farm zones.

Additional knowledge about a number of subjects would be beneficial to better understand collision risk:

- Behaviour of birds within wind farms and possible habituation. The measurement campaign that has been conducted for OWEZ included behaviour of birds within the wind farm. It was suggested to repeat some of the relevant measurements of the OWEZ measurement campaign to validate if habituation among bird species has occurred.

[9] For high definition methods (digital imaging etc.) specific for seabird densities JNCC (UK) has presented a proposal for setting quality standards in the Intergovernmental Offshore Wind Forum. For more conventional methods (boat measurements) existing criteria for field work are available.

[10] MWTL stands for “Monitoring Waterstaatkundige Toestand des Lands” (‘monitoring of the hydrological state of the country’) and in this context involves the regular and systematic seabird (and marine mammal) surveys of the Dutch Continental Shelf by airplane (http://www.buwa.nl/fileadmin/buwa_upload/posters/poster-zeevogels-tellingen-print-verkleind.pdf).

[11] For instance, see reference list on: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4985156/

- Impact of airstreams behind wind turbines. Airstreams might influence flight behaviour, and accordingly the risk for a bird to collide with a wind turbine. Smaller turbines might cause less or smaller airstreams compared to larger turbines.
- It could be that first year birds, which have recently learned to fly (in autumn), have a relatively higher probability to collide with a wind turbine due to a combination of inexperience and higher abundance.

Effectiveness of mitigation measures

To reduce the impact of collision the following mitigation measure is included in the site decision Borssele (site I to IV): "Limit collision victims among birds at rotor height during mass bird migration at night (between sunset and sunrise), during the period in which mass bird migration effectively takes place, the number of rotations per minute per wind turbine will be reduced to less than 1."
In practice this means that wind turbines are switched off during five or six nights per year. The effectiveness of the measure was discussed, as well as a number of alternatives.

Various options were discussed to measure the difference between downtime and operation, which is relevant to estimate the effectiveness of the mitigation measure:

- A German wind farm north of Borkum has not been connected to the electrical grid, therefore the turbines are not in operation. This provides the opportunity to study the impact of downtime and the impact of collision casualties. It should be checked weather or not this wind farm is still not connected to the electrical grid and if there are any possibilities to conduct a measurement campaign in this wind farm.
- The difference between collisions in downtime and operation could be validated in onshore wind farms. For instance in the Eemshaven. The Province of Groningen is currently considering to conduct this type of research in the Eemshaven.
- Monitoring in the new wind farms in Borssele should provide more insight in the effectiveness of this mitigation measure versus the costs of downtime of the turbines. It would be relevant to determine which part of the total bird migration is 'protected' by this measure in relation to collision risk during 'normal' operation of the turbines. Furthermore it would be relevant to obtain forecasts of mass bird migration at rotor height, for instance through the use of an early warning prediction model. Note that the current radar data on bird migration, obtained from the Ministry of Defence will be replaced from 2018 onward by the weather radar data, obtained by the KNMI.

A number of alternatives were suggested to reduce the number of collision casualties:

- Flight corridors within wind farm and between wind farms, plus optimal spacing between turbines could reduce the number of collision casualties.
- Scare birds away from wind turbines. This would results in more habitat loss, but less collision casualties.
- Optimal marine spatial planning based on bird density maps, relevant for future wind farm development after 2023.
- Lights on the blade tips, the effectiveness of this alternative was debated because lights might attract birds during bad weather conditions.
- Use of coloured blades, e.g. black and white.

Expert workshop Round 2: habitat loss

Introduction workshop 2

A short introduction by RWS was given to explain the knowledge questions related to habitat loss.

Knowledge questions

There are a number of knowledge gaps related to habitat loss. The following knowledge questions were formulated to fill these gaps[12]:

[12] Knowledge questions were formulated during an internal workshop of the government on 28 June 2016.

1. To what extent are numbers / densities of birds (per species) reduced due to the presence of wind farms?
2. What is the impact of wind farm configuration on reduction of numbers/densities of birds? What is the importance of flight escape corridors?
3. What is the actual additional mortality per species due to habitat loss? Is this indeed 10% of the number of birds displaced?
4. Does the 'non-breeding-season-area' determine the numbers / fitness of the species, per sub area of the North Sea?
5. Could Individual Based Models (IBMs) for seabirds form a basis to gain more insight into population development? Specific attention is required for the need to determine which population parameters are the most adequate to determine an acceptable norm for assessing impacts on populations.

Research on habitat loss

Three aspects of habitat loss were discussed: (i) possibilities to identify habitat loss, (ii) habituation, and (iii) carrying capacity.

Possibilities to identify habitat loss

The assumption in calculations carried out in KEC is that 10% of the seabirds displaced from operational wind farm footprint areas will die due to habitat loss, this mortality adding up to the annual natural mortality of the corresponding (sub)population(s). Experts suggested the following to validate this 10% assumption:

- Conduct a test in the field under relevant species to validate the 10% assumption.
- Validate the 10% assumption, comparing the figure with available data of waders being affected by habitat loss outside the breeding season. It is known that (some) waders have feeding territories even outside the breeding season. Hence, habitat loss among waders is relatively easy to identify[13]. This could provide insight in potential problems, but will not provide an answer to the relevance of the 10% assumption for offshore wind farms.

Two possibilities to gain insight into habitat loss were discussed: (i) via distribution of food availability, and (ii) via GPS tracking.

When considering the distribution of food availability for seabirds one needs to look into small and generally non-commercial fish species. Extensive monitoring of fish is expensive. It was suggested to focus monitoring / research on critical seabirds (such as razorbill) and their prey. Or it was suggested to combine fish monitoring for birds with fish monitoring for marine mammals.

It is expected that the offshore distribution of seabirds is divided over preferred areas that are used more intensively and other areas that are used distinctly less or even not at all. Such a geographical distribution is called patchy. It is expected that patchiness might occur during specific periods of the year, while during other times distribution of seabirds might be more evenly spread. Key question here is whether areas that are used less or not at all, are 'empty' because there is limited or no food available, or because there are not enough animals to make use of these areas. It would be beneficial to better understand this patchiness, how it might move over time and to compare it with overlap with marine spatial planning for offshore wind. Still, it seems logical to assume that, even when there would be 'not enough birds' to evenly spread out over the entire marine habitat, concentrations ('patchiness') will always be indicative for the best, most profitable marine feeding sites within the total array of potentially available marine areas. It was suggested to implement a measurement campaign through high definition measurements by plane during a couple of times per month in order to gain more insight in the offshore patchiness. MWTL data can be used to further plot the data. Experts concluded that due to existing uncertainties and lack of data the use of patchiness as an indication for habitat loss is not (yet) possible. However, some case analysis of existing data could give an indication of its feasibility.

Another possibility to gain more insight would be GPS tracking of birds. With GPS tracking of birds more information on the foraging behaviour of birds could be registered and analysed. The foraging

[13] For example work of Allix Brenninkmeijer in Oosterschelde

behaviour is an important parameter for various models through which the impact of habitat loss can be studied.

There is a substantial amount of existing data available about the distribution and demography of bird species, mostly based on onshore population surveys and studies at breeding colonies. These data could provide more insight in the annual survival rate. The existing data could provide clues for the question of how specific and predictable species are in their choice for wintering areas. The common guillemot could be used as a 'model species' due to its extensive distribution and the large amount of data available in the Netherlands as well as internationally. Based on available data an initial offshore habitat distribution model for the common guillemot could be developed. This will provide insight in additional knowledge gaps and necessary validation of parameters.

Habituation

Research on behaviour and habituation requires long term monitoring. Strictly speaking, we are not, at first, interested in individual habituation (or the lack of it) of seabirds to the presence of operational offshore wind farms, but rather in the question of whether the species as such tends to grow accustomed or not to windfarm presence. For the time being, the mechanism that might cause a recovery of an initial decrease of seabird density within a wind farm footprint area is irrelevant, while the fact in itself (do the birds return in original densities after a certain period of time) is extremely relevant in assessing the possible impact of habitat loss. Therefore, it is essential to make this distinction when developing a monitoring programme, since just determining whether certain species tend to (partly) recover their original pre-construction densities over time is a lot easier to investigate than whether individual birds tend to habituate. Continuation of current monitoring in and around existing wind farms is very important in order to gain insight in trends and developments. Three suggestions were given:

- Repeat the OWEZ monitoring, focus on displacement behaviour and possible differences between species and seasons.
- Start with GPS tracking to gain more insight in foraging behaviour and food intake of individual birds and any trends or developments over the years when more wind farms become operational.
- Start with the development of habitat use model, based on available data. Relevant data collected on shore could be used as an input to such a model.

Carrying capacity

Experts agreed that it is a challenge to determine the carrying capacity and any consequences of possible additional mortality due to habitat loss or the impact of habitat loss on breeding behaviour. So far assumptions have been made. It was suggested to develop a kind of base model. Based on the food demand of the actual population of seabirds[14] on the Southern North Sea or on the Dutch Continental Shelf, the minimum carrying capacity could be determined, as required during the wintering period in order to sustain the actual population. The minimum carrying capacity (in terms of food demand) could be linked to the availability of fish (based on biological data of the fishery sector through annual surveys). This is rather challenging because traditional annually fishery surveys are mainly (or exclusively) focused on commercial species and are expected not to be sufficient to determine the seasonal variability in food availability for seabirds.

The discussion concluded with consensus on possible research opportunities for those species in the Netherlands (common guillemot, razorbill, northern gannet) and internationally (red-throated diver, common scoter), where displacement seems to have potential impact. It was agreed that the most promising opportunities are to be expected in the development of a 'habitat-use-model' for those species that are vulnerable to displacement; such a model should be linked to species specific demography models. In order to develop such a habitat-use-model, assumptions will need to be made, e.g. regarding carrying capacity. The carrying capacity could be verified based on modelling of the calculated minimum and the theoretical maximum, whereby a sensitivity analysis can be made of the estimated additional mortality due to varying degrees of habitat loss depending on other assumptions

[14] This is the product of the number of bird days in the area considered and the individual daily food demand.

such as food availability. To carry out this type of modelling a lot of existing data can be used, in addition to data on possible parameters that require field measurements:

- Density maps or simulations, including preferred locations and locations of existing wind farms.
- Observations of (individual or species-specific) habituation.
- Observations of behaviour within and outside of wind farms.
- Data on mortality.
- Other relevant international data, e.g. from the UK.

The (development of the) model will have to provide an indication of additional knowledge gaps, sensitivities and areas to focus additional studies or research, the results of which could then feed into the habitat-use-model, such as:

- Continuation of current monitoring in PAWP and OWEZ (including passage and shared use) and possibly Gemini (without passage and shared use).
- Baseline (T0) GPS tracking focused on behaviour.

Impacts on population level due to collisions and habitat loss

Definition of population

The sea is not as uniform as is often thought. There may be several different (sub) populations even within the same species. It could be that the relevant populations are smaller than assumed so far, e.g. due to adult birds ranging less widely from their breeding colonies both during the breeding season and outside the breeding season.

In the Framework for Ecology and Cumulation (KEC)[15], the populations of seabirds relevant for the Southern North Sea have been modelled as well as possible. It was noted that for the development of the Framework for Ecology and Cumulation data for population models were either lacking or were subject to large differences between colonies.

Potential Biological Removal

In the Framework for Ecology and Cumulation the norm Potential Biological Removal (PBR) is used, as covered in the following formula:

$PBR = 0.5 * R_{max} * N_{min} * Rf$

R_{max} = maximum recruitment rate
N_{min} = population size
Rf = recovery factor (based on expert judgement)

Comments were made about N_{min} and Rf.

- Population size (N_{min})
  - Population size is critical for the outcome of PBR.
  - It was suggested to discuss with experts on specific migratory species which population size should be assumed.
- Recovery factor
  - For those populations that are already in decline the Rf should be more precise. It would be better to use existing 'real' population models based on empirical data for those populations that are in decline, instead of an assumption on the Rf.
  - Discuss with experts how the Rf could be made more reliable.
  - The gull colony in IJmuiden was mentioned as a good location to gain more insight in the population dynamics of gulls.

The use of PBR as a norm for 'acceptable' impacts on population level was discussed. Experts agree that it is a rather rough norm, but there seem to be no good alternatives. Experts were sceptical about the use of PBR for populations in decline. It would be better if a more direct, quantitative connection

15 https://www.noordzeeloket.nl/images/Kader%20ecologie%20en%20cumulatie%20t.b.v.%20uitrol%20Windenergie%20op%20zee%20Deelrapport%20A%20-%20Methodebeschrijving%20-%20Update%202016%20Hfdst%201.5%20en%205.6_5072.pdf

could be generated between the valuation of the Rf and the trend in population numbers. The use of PBR seems mostly relevant for closed populations (e.g. sandwich tern, also shown to be subject to a certain degree of vulnerability to displacement[16]). The question was raised at which levels of scale PBR can be used for (sub) populations. It was agreed that it does not seem relevant to use PBR for individual colonies or Natura 2000 areas.

Compared to the Ornis criterion of 1% the use of PBR seems logical. The Ornis criterion seems to be on the safe side which causes the available 'environmental space' for offshore wind farms to be more limited than necessary. Furthermore in order to determine the Ornis norm, data about the natural annual mortality of relevant species are required as well. Experts agree that PBR can be used as a first step in the process to determine impact on populations. But this should be followed by additional study into the critical species. It was suggested to focus on critical species (e.g. the top 10 based on Potential Biological Removal, or all species with an estimated additional mortality of > 0,10*PBR) in order to gain more insight and validate assumptions. This could consist of:

- Development of an Ecoprofile 2.0 for the critical species together with the key experts for a specific species. Whereby the key question is 'what is the relevant population in relation to existing and planned offshore wind farms?'.
- Determine of useful population / species-specific population models are available.
- Analysis of relevance of PBR versus outcomes of population model. Calculate for a specific species the outcomes of a population model and compare this to the outcomes based on PBR. The outcomes can then be compared to the approach and outcomes in neighbouring countries, e.g. UK.

[16] V. Dierschke, R.W. Furness & S. Garthe 2016. Seabirds and offshore wind farms: Avoidance and attraction. Biological Conservation 202: 59-68.

Offshore Wind Ecological Program (Wozep) 2016 – 2021

Minutes workshop with specialists/researchers on 29th September 2016 – Theme Fish

General introduction

Wozep is part of the assignment from the Ministry of Economic Affairs, Energy Challenges 2020 Directorate (EZ ED 2020) for Rijkswaterstaat (RWS). The assignment was issued in late 2015. The objective for Wozep is to study the ecological impact of offshore wind farms in the North Sea. At the end of 2016 a logical and transparent monitoring and research program for the period 2017-2021 has to be finalized and approved by the Wozep steering committee. To devise a strong, (cost)effective and efficient research program, it is essential that the ministry, the Wozep project group, and specialists/researchers are involved in this process. This was done in two steps. During the workshop in June 2016 (government only) the project goals and main knowledge gaps were defined. On September 29th the next step was made with specialists/researchers by discussing the main issues and knowledge gaps and formulating dedicated research questions for Wozep. The following report describes the outcome of the fish workshop on September 29th of 2016. The results of the September workshops provide the basis of the monitoring and research program which will be finalized in November of 2016.

The objectives of the Offshore Wind Ecological Program are:

- Determine effectiveness of mitigation measures (in the context of the 40% cost reduction in the Energy Agreement).
- Reduce uncertainties surrounding the knowledge gaps and assumptions from the Framework Ecology and Cumulation (KEC), Environmental Impact Assessments (EIA) and Appropriate Assessments (AA).
- Reduce uncertainties surrounding the knowledge gaps and assumptions regarding effects in the long term and upscaling of wind farms (in relation to possible construction of subsequent offshore wind farms after the implementation of the Energy Agreement).

REPORT

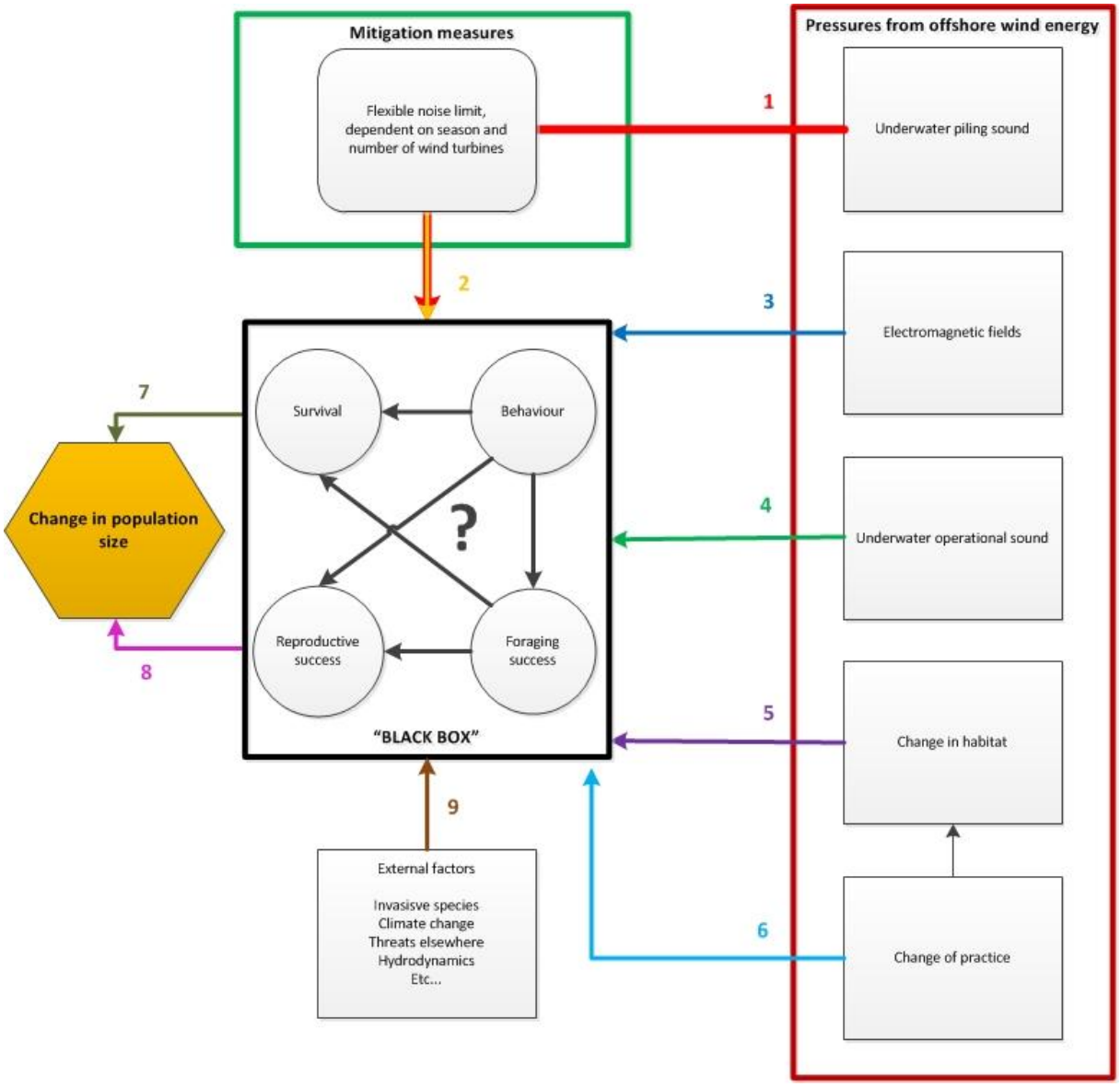
List of attendees:

Paul Westerbeek	RWS ZD, Moderator
Martin de Haan	Royal HaskoningDHV, minutes secretary
Saa Kabuta	RWS WVL
Joop Bakker	RWS WVL

Experts:

Erwin Winter	Wageningen Marine Research
Ingrid Tulip	Wageningen Marine Research
Johan Craeymeersch	Wageningen Marine Research
Tobias van Kooten	Wageningen Marine Research
Roelant Snoek	Waterproof
Wouter Lengkeek	Bureau Waardenburg

General pressure flowchart



Knowledge questions

1. How does the presence of a wind farm, including the exclusion of bottom trawling activities within the wind farm, affect local fish stock?
2. Which species are disturbed by electromagnetic fields, in what way (habitat loss, barrier effect, etc.) and to what extent?
3. What are the population effects of electromagnetic fields on these species?
4. At what intensity are fish disturbed by underwater noise?

Honing knowledge questions, including available research information (nationally and internationally)

Regarding question 1. Effect of exclusion of bottom trawling activities on local fish stocks.
A distinction should be made between impacts on local fish stocks and the impact on fish stocks in the North Sea. In other words, is a wind farm where no bottom trawling is allowed a refuge for fish? And if so, does this refuge only attract and aggregate fish, resulting in a local increase in fish biomass and a compensating decrease in the surrounding area? Or is the local increase of fish biomass the result of increased production and does it also lead to an increase of the overall fish biomass even outside the closed area? This is relevant, because an increase in total fish biomass could also be positive for commercial fishing activities. Quantitative research on this is tricky, as shown by research done by Wageningen Marine Research on the effects of closing off areas for commercial fishing.
An additional complication is that in 2017 the wind farms (except the Gemini wind farms) will be opened to recreational passage (vessels <24 meters). This is expected to include the permission of sport fishing from ≥ 50 m distance from the turbines. It will be monitored how many ships will pass through the wind farm and which activities are undertaken.

It was noted that sand eels play a more important role in the ecosystem because of their high seasonal abundance (as stock food of fish and fish-eating birds) than previously thought. Sand eel spends its life almost continuously in the sand. Only to spawn and forage they move into the water column. The fish is fat-rich and available early in the year (March-April), which is interesting in connection with the agenda for pile driving.

During the discussion an additional research question was formulated: Does the presence of a wind farm increase the local primary production due to wake effects behind turbines or as a result of longer residence times of the waterbody within the wind farm?

Mentioned relevant studies / findings:
- Wageningen Marine Research, Research into the effects of closed areas.
- American research into abolishing stratification by presence of wind farms.
- Aerial photographs of Belgian wind farms reveal turbulence flow at high water flow rates.
- Observations of two meters deep pits behind piles.

Regarding question 2. Disruption of fish species by electromagnetic fields (EMF)
There are several types of electromagnetic fields (EMF) that can affect fishes in different ways. An additional, disturbing EMF may complicate the detection of prey, and also possibly even simplify it (i.e. when EMF cause shrimp to aggregate locally). Also attracting effects on fish can't be excluded (concentration of demersal fish is observed on the seabed, on top of a subsea cable). Furthermore it is not excluded that an EMF has a barrier effect (based on the anecdotes of fishermen who report catching no sole east of a subsea cable, but increased catches west of that same cable).

Mentioned relevant studies:
- Models that predict the influence of EMF on fish.
- Exploratory desk study by Waterproof and Bureau Waardenburg: 2016. Potential effects of electromagnetic fields in the Dutch North Sea - Phase 1 - Study Desk (draft report available).
- American research into the effects of EMFs on species (BOOM).

Regarding question 3. Population effects of electromagnetic fields on fish
Population effects of EMF are particularly relevant when large numbers of EMF (by increasing numbers of wind farms) together affect multiple individual fish, for example by posing as a barrier. As an example, the European eel is mentioned. Millions of euros are spent annually to improve the rapidly deteriorating eel stock by removing fish migration bottlenecks in the inland waters (such as weirs, locks and pumping stations), but if the presence of EMFs by cables on the seabed stops eel from swimming into the estuaries in the first place, this is a waste of money and effort. From this perspective, this is an important issue. At present, the future development of offshore wind farms after 2023 is still uncertain. The question focuses on the cumulative effects of EMFs on fish populations.

Regarding question 4. Disturbance of fish by underwater noise
In addition to the negative impacts during the construction phase (pile driving) there are also potential effects of continuous underwater noise from wind turbines in the operational phase.
Effects of underwater noise on organisms can arise from two factors: sound pressure and particle motion. Much research has focused on effects of sound pressure. Effects of the particle motion is much less known.
On the impacts of noise on behaviour very little is known: do fish swim away, does habituation take place, what are the impacts on migratory fish species? Also the effect of 'masking' (drowning out natural sounds by a secondary sound source, such as a wind turbine in operation) is still largely unknown.

Mentioned relevant studies:
- Research Loes Bolle (WMR) et al. on the impacts of pile driving on larval stages of fish.
    - Bolle et al., 2016. Effect or pile-driving sounds on the survival of larval fish. Advances in Experimental Medicine and Biology 875 (2016) -ISSN 0065-2598 - p. 91 - 100.
    - Neo et al. 2016. Sound exposure changes European seabass behaviour in a large outdoor floating pen: Effects of temporal structure and a ramp-up procedure. Environmental Pollution 214 (2016). ISSN 0269-7491 - p 26-34.
    - Bolle et al. 2014. Effect or pile-driving sounds on the survival of larval fish. IMARES (Report / IMARES Wageningen UR C182 / 14) - 33 p.
- Research of disruption of predator-prey relationship by passing ships.
- Research by Wageningen Marine Research on impacts of sound (pile driving and seismic investigation) on population dynamics (commissioned by oil - and gas industry, expected: 2017-2018).

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

Research questions

Regarding question 1. Effect of absence of bottom trawling activities on local fish stocks
Changes in (local) biomass of fish should be considered in conjunction with the availability of food.

Research questions are:
- To what extent does a higher density of food for fish occur (both hard and soft substrate species)?
- To what extent does this lead to a local increase of the fish biomass?
- To what extent does this result in a higher total biomass of fish in the North Sea?

The positive effects of the exclusion of bottom trawling activities must be separated from the (potential) opposing effects of the potential increase in sport fishing.
- What effect does sport fishing have on the local fish stock and composition?

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

Regarding question 2. Disruption of fish species by electromagnetic fields
The following questions are relevant:
- What fish species can detect which fields (directly)?
- What indirect effects on fish (via presence/absence of benthos) can be determined?
- Are fish attracted to (weak) EMFs?
- Do fish experience (strong) EMFs as a barrier?
- How can models help to predict the real effects?

Regarding question 3. Population effects of electromagnetic fields on fish
If there are any observable effects on an individual level it is not excluded that there are effects on a population level. The following questions are relevant:
- Do barriers lead to compartmentalization of the North Sea as fish habitat?
- Do EMFs have a distorting effect on fish migration?
- Do different EMFs have different effects?
- If effects cannot be prevented, which mitigation measures are possible (e.g. increased burial depth, mantle, less voltage, AC vs. DC)?

Regarding question 4. Disruption of fish by underwater noise
Effects of underwater noise can be divided into effects during construction and effects during operation.

Relevant research questions are:
- What effects does the construction of a wind farm have on fish behaviour?
- What effects does masking (secondary sound overruling natural sounds) have on fish behaviour?
- What effects does particle motion have on the behaviour of fish?
- What effects does the additional sound pressure caused by passage of (recreational) ships and wind farm maintenance (service ships) have on fish?
- Are wind farms in their operational phase avoided by fish?

Methodologies

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

Regarding question 1. Effect of exclusion of bottom trawling activities on local fish stocks

The following studies and methodologies to determine the impact of the exclusion of bottom trawling activities and the impact of recreational fishing are mentioned:

- Determine the availability of food for fish by monitoring hard and soft substrate.
- Determine the extent to which fish swim in and out of the wind farm. Use acoustic research, camera techniques, transmitters with detection.
- Determine growth velocity inside and outside the wind farm.
- Determine the species composition inside and outside the wind farm.
- Provide a link with piscivorous birds (cameras) and mammals (CPOD).
- (Real time CPOD under development).
- Use registration data from catches of the Dutch Charter Boat Association (DNCV).
- Examine stomach contents of caught fish (in collaboration with fishermen).
- Use aerial surveys to validate radar/AIS ship count data within wind farms to find out whether radar/AIS provides a correct impression of the number of ships present in a wind farm.
- Based on the previous, validate the commercial fish catch by using the ratio between reported catch and observed boats.
- Monitor actual catches by taking samples to validate the modelled outcome.

Regarding question 2. Disruption of fish species by electromagnetic fields

For this question it is also recommended to zoom in on target species (sand eels, cod, sea bass, mackerel) to ensure that the necessary research is manageable. In addition, specific attention is needed for sharks and rays, as they may perceive very low field strengths and the impacts on these species are therefore possibly the highest.

Mentioned studies and methodologies for determining the effects of EMFs on fish are:

- Execute field measurements of EMFs.
- Determine 'attraction' to EMFs (also take into account temperature effects) by observing where fish are dwelling and foraging.
- For field measurements use in situ cameras or telemetry (transmitters and receivers; near cables and further away).
- Determine the sensitivity of fish to EMFs (target species) in the laboratory.
- Build on research into the effects of pulse fisheries.

Regarding question 3. Population effects of electromagnetic fields on fish

Mentioned studies and methodologies are:

- Look into anecdotal evidence of fishermen who claim to observe compartmentalization due to the blocking effect of EMFs from cables on certain fish species.

Where effects have been demonstrated:

- Make models of the blocking effect on relevant species.
- Determine the effects of possible mitigation measures:
    - increase burial depth (entirely or partly to create 'passages' for fish);
    - reduce the "permeability" of the mantle;
    - use a lower voltage;
    - determine the difference in effect between AC (lower field strength) and DC (less transmission losses, more expensive).

Regarding question 4. Disruption of fish by underwater noise
Mentioned studies and methodologies are:

- Execute a continuous noise measurement (to be linked to overall studies).
- Run a pilot study with a top down approach: at what level of disturbance an effect on the population level starts to occur?
- Use of so-called floating pens to determine dose-effect relationships of target species.
- Research to which extent masking (as a result of continuous sound by an operational wind turbine) disrupts communication and predation.
- Use research of impact of sound effects by pile driving and seismic research on population dynamics; look for synergy.
- Execute particle motion studies with specialist equipment to 'measure' effects on fish behaviour.

Summary table

Honed knowledge questions	Research questions	Methodologies
		SIMULTANEOUS and CONTINUOUS Zoom in on target species (sand eels, cod, sea bass, mackerel).
Influence wind farm on fish stocks Consider local effects and impacts on the entire North Sea. Does fish biomass increase due to additional production or are there only distribution changes by attraction? What is the impact of passage of (recreational) vessels, including sports fishing? Does a wind farm create a local increase of the primary production caused by turbulence due to wake effects behind turbines and/or prolongation of residence time of the water mass within the wind farm?	Food availability for fish (both hard substrate and soft substrate associated species). Increase in local fish biomass? Difference in predators of hard substrate macroinvertebrates and soft substrate macroinvertebrates? Does this lead to a higher biomass of fish in the North Sea? What are the effects of sports fishing on fish stock and composition? Does inhibition of the flow velocity and turbulence behind the piles through longer residence times and vertical mixing lead to higher primary production and indirectly to an increase in fish biomass? Does turbulence behind the piles by vertical mixing lead to destratification and if so, what are the effects?	Food density hard and soft substrate species. Camera techniques. Growth velocity determination. Species composition. Link to piscivorous birds (cameras) and mammals (CPOD). Real time CPOD in development. Migration patterns entering and leaving the wind farm boundaries. Fish catch information from sports fishing sector. Dietary studies (in cooperation with sports fishermen). Acoustic survey.

Honed knowledge questions	Research questions	Methodologies
		SIMULTANEOUS and CONTINUOUS Zoom in on target species (sand eels, cod, sea bass, mackerel).
Disruption of fish by EMC What types of EMFs have an effect? Is the possible effect of an EMF only disruptive or also attractive?	Which fish can detect which fields directly? Which indirect effects via benthos can be determined? Which fish are attracted to (weak) EMFs? Do fish experience (strong) EMFs as a barrier? How can models help to predict the real effects?	EMF measurements in the field (also measure temperature!). Laboratory experiments (sensitivity of target species for different fields). Field measurements in situ with cameras or telemetry. Link with pulse fisheries research. Validation of models by recording what happens in situ.
Population effects of EMF Do cables form a migration barrier? Does this lead to compartmentalization?	Do EWMFs of cables lead to the partitioning? Do different EMV have different effects? Do EMFs have a distorting effect on migration of fish? If effects cannot be excluded, which mitigating measures are possible? (e.g. burial depth, mantle, less voltage, AC - DC)	Compile and check fishermen anecdotes. Modelling (data by count). Determine the effects of possible mitigating measures.
Influence of underwater noise Separate impacts of construction (pile driving) from impacts in the operational phase: continuous sound (masking). Consider sound pressure and particle motion. Anticipate on additional sound caused by ship passage including wind farm service vessels.	Which effects does construction of a wind farm have on the behaviour of fish? Which effects does masking by continuous noise in the operational phase have on fish behaviour? What effect does particle motion have on the behaviour of fish? What effects does the additional sound caused by ship passage (recreational vessels) and maintenance (servicing ships) have? Do fish avoid wind farms in operation?	Continuous noise measurement (to be linked to overall studies). Model study top down: when does noise disturbance actually have impact at the population level. Floating pens: dose-effect relationships target species. Research to what extent masking effects occur on communication and predation. Use research (effects of pile driving sound and seismic research on population dynamics) done by Oil and Gas Industry; look for synergy. Particle motion studies (specialized equipment) to 'measure' effects on fish behaviour.

Offshore wind ecological programme 2016 – 2021 (Wozep)

Minutes workshop with specialists/researchers on 29th September 2016 – Theme Marine Mammals and underwater sound

General introduction
Wozep is part of the assignment from the Ministry of Economic Affairs, Energy Challenges 2020 Directorate (EZ ED 2020) for Rijkswaterstaat (RWS). The assignment was issued in late 2015. The objective for Wozep is to study the ecological impact of offshore wind in the North Sea. At the end of 2016 a logical and transparent monitoring and research program for the period 2017-2021 has to be finalized and approved by the Wozep steering committee. To devise a strong, (cost)effective and efficient research program, it is essential that the ministry, the Wozep project group, and specialists/researchers are involved in this process. This was done in two steps. During the workshop in June 2016 (government only) the project goals and main knowledge issues were defined. On September 29th the next step was made with specialists/researchers by discussing the main issues and knowledge gaps and formulating research questions for Wozep. The following reports describe the outcome of the workshops on September 29th of 2016. The results from the September workshops provide the basis of the monitoring and research program which will be ready in November of 2016.

RWS Wozep team and tasks:
- Project manager MEP: Ingeborg van Splunder.
- Project manager KEC: Martine Graafland.
- Technical manager: Marijke Warnas.
- Birds: Suzanne Lubbe, Maarten Platteeuw.
- Bats: Maarten Platteeuw, Marijke Warnas.
- Marine mammals and underwater sound: Inger van den Bosch, Aylin Erkman.
- Benthos: Joop Bakker, Saa Kabuta, Paul Westerbeek.
- Fish: Joop Bakker, Paul Westerbeek.
- Data management: Kees Borst, Ingeborg van Splunder.

The objectives of the Offshore wind ecological programme are:
- Determine effectiveness of mitigation measures (in the context of the 40% cost reduction in the Energy Agreement).
- Reduce uncertainties surrounding the knowledge gaps and assumptions from the Framework Ecology and Cumulation (KEC), Environmental Impact Assessment (EIA) and Appropriate Assessment (AA).
- Reduce uncertainties surrounding the knowledge gaps and assumptions regarding effects in the long term and upscaling of wind farms (in relation to possible subsequent offshore wind farms after the roll-out of the Energy Agreement).

List of attendees

Aylin Erkman:	RWS Z&D, chair
Inger van den Bosch:	RWS WVL and Wageningen UR, mediator
Audrey van Mastrigt:	Royal HaskoningDHV, minutes secretary

Experts:

Martine van Oostveen	Royal HaskoningDHV
Ron Kastelein	Seamarco
Floor Heinis	Heinis Waterbeheer en advies
Christ de Jong	TNO
Sander von Benda Beckman	TNO
Rene Dekeling	Ministry of Defence and Ministry of Infrastructure and Environment DGRW
Lonneke IJsseldijk	Utrecht University
Jaap van de Meer	VU Amsterdam
Meike Scheidat	Wageningen Marine Research
Geert Aarts	Wageningen Marine Research
Erwin de Winter	Wageningen Marine Research, joined in the afternoon

Knowledge questions

During the marine mammal workshop the attendees were given 12 knowledge questions. In preparation of the workshop the experts were asked to consider their answers to these questions taking into account the following points:

- Is this list of knowledge questions sufficient to be able to reduce the uncertainties when determining the impact of offshore wind farms on marine mammals? In addition to these knowledge questions are there other relevant knowledge questions?
- What research methods should be used per knowledge question? Which methods/ research results are available and can be used to answer the knowledge questions?
- Are the proposed research methods feasible? When can results be expected?
- To what extent do the research methods answer the knowledge questions? Will the knowledge questions be answered fully or partially?

During the workshop each knowledge question was discussed taking the above points into account. Additional knowledge questions were also discussed.

These minutes provide a summary of the discussion per knowledge question and highlight the most important conclusions. At the end of the minutes a summary table is included which addresses per knowledge question the additional research questions discussed, an overview of the current available information and additional research methods that were suggested.

Knowledge questions discussed

General

1. **(a)Is it correct to assume that harbour porpoises are more sensitive to underwater sound than seals when considering the entire sound spectrum of piling noise? (b)Do we need to consider the sound frequency level when determining the impact of piling noise on the disturbance threshold of marine mammals and will this change the initial assumption?**

This knowledge question consists of two sub questions. The first question should be answered prior to answering the second question. In addition the question should clearly define what is meant by 'sensitive' and 'disturbance'. For this question WOZEP needs to distinguish between different types of impacts from underwater noise (i.e. displacement, avoidance, foraging behaviour, masking, stress and other physiological effects). Thus what is meant by 'disturbance', only avoidance or should other underwater noise effects determined by Southall (2007) also be considered?
It is difficult to answer the first question whether or not harbour porpoises are more sensitive to underwater noise. During the discussion there were as many different reasons to agree with this statement as to disagree. Field studies show that seals react at a similar distance to piling noise when compared to harbour porpoises (Hastie et al, 2015), however the duration of the reaction is very variable and differs per individual (Russel et al. 2016). However research in a basin shows that the disturbance threshold of a harbour porpoise to piling noise is lower than that of seals (Seamarco., 2011, Kastelein 2013).
The long term impact should also be considered and not just the direct impacts. For example harbour porpoises feed almost continuously, while seals have to manage their time between feeding and hauling out. Potentially, depending on the moment of impact, there could be a difference in the effect of loss of feeding time between the species. In addition site fidelity should also be considered. Seals are known to show high site fidelity. The construction of a wind farm in a seal foraging area or near a breeding site, forces the animals to endure the effects of the sound (Hastie et al. 2015, Russel et al. 2016) or to shift to a non-familiar area, this could have long term implications on the seal's fitness.

When determining the total impact of the potential wind farm sites in the Netherlands the distance from shore was also considered. Based on the distribution currently the chance for a harbour porpoise to enter a wind farm site is higher than the chance for a seal to enter in the areas where the wind farms are planned on the Dutch continental shelf because seals are more philopatric and usually stay close to the coast. However it does occur that seals travel larger distances from shore to forage.
A recent study done at a windfarm site in The Wash, UK looked at the impact of pile driving on the response of harbour seals (Hastie et al, 2015). A desk study should be carried out to answer this first question using the information from the above mentioned studies and other similar studies. If the desk study concludes that the sensitivity of the seals are similar to that of the harbour porpoise than the cumulative effects of the windfarms should be calculated for the seals in the same way it has been done for the harbour porpoise.

(1b) *Do we need to consider the sound frequency level when determining the impact of piling noise on the disturbance threshold of marine mammals and will this change the initial assumption?*
If the answer to 1a is no, then impact of noise frequency could be one of the reasons why field studies show that the disturbance area is the same for both species. Thus further research should also take frequency into account.
National Oceanic and Atmospheric Administration (NOAA) in the US advises in a technical guidance published in 2016 the use of frequency weighting when determining effects of anthropogenic sound on marine mammals. A paper published by Danish and American researchers, (Tougaard et al. 2014) also advises the use of frequency filters. These studies provide the input for a desk study in which the effect of frequency weighting on the disturbance threshold can be calculated for pile driving sounds in the field, in a controlled environment and from model predictions. The results of the desk study can then further determine whether additional research needs to be carried out in the field or in the lab.

Additional comment after the meeting: Tougaard also argues for accounting for the duration of the signal (Leq, short), not just the frequency weighting, as this corresponds closest to perceived loudness of the signal.

Acoustic

2. After validation of the Aquarius model using large distances, are there still knowledge gaps that need to be addressed?

This question can only be answered once the report which TNO is working on is published. It has been included in this list to have a complete overview of the research questions, but will be discussed with TNO in a separate meeting.

Impacts offshore wind

3. What is the effect of the activity on the displacement of different species, do species return to the site after the noise producing activity has ended and when? Are there permanent effects on the behaviour of marine mammals, and does it lead to increasing sensitisation or habituation?

The distance between the animal and the sound source also determines the response of the species. Thus this should be incorporated in the question. Research using C-pods and aerial surveys during construction of wind farms show that harbour porpoise reactions varied, while some studies show a return time of hours others show a return time of up to 2-3 days. Though not directly comparable a tracking study with seals showed that in this specific area some individuals returned within 2 hours. For porpoises it is unclear whether these animals are the same individuals that were originally disturbed or that these animals are new individuals that were not exposed to the piling noise. This question can only be answered by following individual harbour porpoises and study their behaviour after being exposed to piling noise. WMR has written a report on the feasibility of tagging in the Netherlands in which they advise a step by step approach.

So far research shows that in the long term habituation and sensitisation doesn't occur as far as behaviour of porpoises in the basin goes. However research results using sonar do show that for some species habituation occurs. Harbour porpoises are also found in areas with a lot of human activity such as the Ems. Thus it seems logical that habituation occurs instead of sensitisation.

Additional comment after the meeting: In a captive study seals there was evidence that repeated elicitation of the acoustic startle reflex leads to rapid and pronounced sensitisation of sustained spatial avoidance behaviour (Götz & Janik 2011).

The following research method was proposed: Harbour porpoises make a clicking noise when they are feeding and produce buzzes as they close on prey. The sounds produced during feeding seem to stop for a while when the animals are disturbed. New algorithms are now able to better identify these feeding episodes. Existing C-pod data can be reanalysed to determine whether or not harbour porpoises feed in the area after disturbance has ceased and if the feeding intensity is the same as before piling. This research does not indicate whether or not they are the same animals as before piling. If they are new animals they probably didn't know there was noise disturbance in the area. Only tracking the animals can deliver the information on whether animals disturbed by sound return to the area once sound ceases to be produced.

Additionally the following questions can be considered to have a good view of effects of sound on the individual:

- A behavioural response study on seals: Look at the research results of the study in the Wash, UK[1]. The seal studies conducted by Seamarco can be used to validate these results
- What is the dose-effect relation of TTS for seals?(surface audiogram seals)?: As seals spend a significant time with their head out of the water the noise exposure for seals is different than for harbour porpoises.
- What is the masking effect of piling on seals and harbour porpoises? The sound measurements of seismic surveys show that at longer distances from the noise source the time between the impulses becomes shorter. This makes listening to important biological signals between pulses harder. Therefore at these distances masking could become a serious issue.

4. Does food availability play a role in marine mammal return after disturbance and what do we need to know about that?

Food does play a significant role in the behaviour of the marine mammal. For example seals are attracted to aquacultures. Even when a pinger is used to scare off the seals some seals will risk hearing damage for food.

Research shows that disturbance impacts foraging behaviour. Research and observations also show that the response of the marine mammals varies and depends on the specific circumstances in which the individual is and the personality of the individual.

We need more information on the effects of sound on lower trophic levels and on the interactions between trophic levels in the presence and absence of sound to be able to answer this question*?*

5. What are the effects of underwater sound on the energetics of the harbour porpoise and how fast do they recover? Are effects of underwater sound on the energetics of seals relevant?

Currently Seamarco is conducting a study on the energetic cost for harbour porpoises due to disruption by underwater sound. The study consists of two sub studies. The first is a historical analysis of husbandry information. The second sub-study is study on the reduction in body weight and blubber thickness after 2-24 hours of fasting. This study aims to determine how much weight harbour porpoises loose after fasting a day per week and how much the individual animal needs to eat to return to a healthy weight. After these studies have been completed, further research may be conducted looking at the maximum food intake after fasting and the weight gain associated with diets consisting of different species of fish. The results of this study can be used to determine which other additional research is needed to understand what the impact of underwater noise is on the harbour porpoise.

However this research alone will not answer the entire knowledge question. Seamarco's research will help to understand the effects on the energetics of harbour porpoises. From there on further research can be proposed. Other questions that arise are: how do results in a controlled environment relate to wild population of harbour porpoises? What impact does long term fasting have on the population? Does long term fasting have an effect on growth and reproduction of harbour porpoises?

Whether impacts of underwater sound on the energetics of seals is relevant and requires further research, depends on the outcomes related to knowledge question 1a.

Population dynamics

6. How do individual energetic costs impact the population? How can research results from knowledge question 5 be translated into parameters that can be used for models such as iPCoD and DEPONS?

It was suggested to intensify the knowledge exchange between researchers that are conducting research on energetic costs of underwater sound and the developers of the iPCoD en DEPONS model, to make sure research results can be used as input for these models. A new expert elicitation for iPCoD will be organised. Prior to that expert elicitation meeting experts will receive the most recent and relevant research results. After that the experts will answer the iPCoD questions again during the elicitation meeting.

The current assumptions that are used for the iPCoD model and DEPONS model need to be improved. The discussion concluded that density dependence should be included in the model. To improve the model, and improve the knowledge on the impact of energetics on the population level of marine mammals two steps were identified:

- Step 1: Improve iPCoD model through research and expert elicitation. Inform if the information from energetics research can improve assumptions of DEPONS model. Make use of newly available knowledge such as research results from German offshore wind farms and Gemini which used c-pods to measure disturbance distance and disturbance duration (not the individual animal but the area).
- Step 2: focus on understanding food/prey availability and prey distribution in the North Sea

Additional comment after the meeting: In step 1, a comparison should be carried out between the models. This will give insight into different results for same scenarios when different models are used.

7. Individual Based Model for seals (currently under development)

Wageningen Marine Research has made some first steps towards the development of individual-based-models for seals. For example, one study focusses on the impact of seals on the fish stocks and on the impacts of piling on the behaviour of seals. The development of IBMs for seals has potential, given the accurate monitoring of population developments, a database of >300 GPS tracked seals and information on the abundance and distribution of their prey (DFS survey). Currently, impacts on energetics are not included in the study. Also insight into long-term effects of human activities on seals are still missing.

8. What determines whether or not a habitat is suitable for the harbour porpoise (i.e. abiotic parameters, prey availability etc.) and how does this relate to the survival chance outside the suitable habitat. What is the distribution and behaviour of marine mammals in the North Sea (foraging area, reproduction area etc.)? Does this vary between seasons? Also answer these questions for seals depending on the answer for questions 1a.

The following information on food preference and distribution of harbour porpoises is available:

- Mardik Leopold's PhD research: gives insight on the food preference of harbour porpoises. This research focusses mostly on data from stranded harbour porpoises that live near the shore.
- Studies on sand eel distribution: Sand eel is one source of food that harbour porpoises prefer. There is information on the distribution of sand eel, however less is known about the density of sand eel in in the North Sea.
- C-pod data in existing wind farms can give an idea whether harbour porpoises forage in these areas
- Results/data SCANS II and III surveys: This information can be used to determine harbour porpoise distribution and to identify breeding areas. During the SCANS surveys harbour porpoise calves are identified and calves are used as a proxy for reproduction areas. The SCANS survey data also includes locations where feeding frenzies occur. This data has not been analysed yet.

The following additional research was proposed to better understand food/prey preference and distribution. This information can be used to develop a habitat model:

- Identify which information is already available by asking experts in this field.
- A detailed ecological fish survey (including prey species) of the North Sea is needed. However we do realise that this is a long-term study that is difficult to carry out. Participants think that Wozep is the programme that can set this research in motion.
- Research by tagging harbour porpoises: tagging before disturbance (baseline), then disturbance and then return. Determine how large the sample size needs to be. Tagging harbour porpoises is much more difficult than seals.
- Research into the link between displacement of prey fish species and their return and the following return of marine mammals could also be very valuable (tag both fish and marine mammals)
- Make a model for harbour porpoise fitness based on the shape and size of captive, stranded and bycaught animals. Compare the data with animals seen in the wild (using HD aerial camera footage or drone photos).
- If possible compare fitness between mother/calf and non-nursing animals.

- In deeper waters mother and calf can be separated while the mother is hunting for food. When the calf is left alone it is vulnerable and could get lost. Use stranding data and compare this with the stomach content of the calf.

9. What is the exact carrying capacity of the North Sea for the different marine mammal populations, has the carrying capacity been reached and what are the limiting factor that determine population growth?

The actual carrying capacity of the North Sea is not known, especially the carrying capacity where the anthropogenic influences are minimised. It is better to focus on the current size of the population. The research should focus on developing a population model that can determine which amount of disturbance impacts the population size to such an extent that the population size drops under the ASCOBANS norm. Mortality rate is an important aspect to include in this model, as is density dependence and recovery. Thus questions such as, what is the maximum allowable mortality rate and or decrease in reproduction, are important to be able to answer the knowledge question.

Additional impacts in relation with cumulative effects offshore wind

10. Which other species are relevant in the North Sea when taking into account the impact of underwater noise and the barrier effect when developing more offshore wind farms?

The white-beaked dolphin and common dolphin are found closer to the coast. White-beaked dolphins are far less sensitive for underwater noise than harbour porpoises. Minke whales are found on the Dogger Bank, Minke whales are sensitive for acoustic disturbance, such as sonar. During the discussion it was concluded that the population size of these other species should be determined. How does the Dutch continental shelf relate to the distribution of these species? The SCANS III survey, flight surveys, boat surveys and stranding data can be used to estimate the population size of the other species. Only then can we determine if these species are relevant to offshore wind farms on the Dutch continental shelf and decide if further research is needed on the effects of underwater sound on these species.

Additional comment after the meeting: Geelhoed & Polannen Petel, 2011 mention that three species can be seen as native to the North Sea based on regular occurrence: the Minke whale, the White-beaked dolphin and the Bottle-nosed dolphin.

11. Which other activities affect marine mammals and how large are these effects? How do these effects interfere with determining the impact of the construction of wind farms (i.e. contaminants, fishery by-catch, human induced shifts in food availability etc.)?

The experts identified this question as a relevant question. Some experts suggested to first focus on the impulse noise activities such as seismic research as this is comparatively easy to achieve, however other activities might have just as large or larger impact on the marine mammal populations. A decision needs to be made which type of activities should be included in the calculation of cumulative effects. The research needed will follow from this choice.

Other noise producing activities in the North Sea should be included in the models. Currently TNO is in contact with John Harwood to discuss the possibility to include seismic research in the iPCoD model. It was suggested that an additional workshop/meeting should be organized to discuss this topic.

There is a register which includes impulsive noise activities that have occurred in the North Sea. However this register is based on activities in the past and doesn't include activities that can be expected in the future.

12. How can we determine sound impact from other foundation techniques? What is already known? We need a step by step plan to determine effects of other foundation techniques (vibratory, screw piling etc.).

It is decided to postpone research into effects of alternative foundations techniques until it becomes clear which techniques seem feasible to use in the future.

Additional knowledge questions

13. Are there visual impacts- from moving wind turbine blades- at the surface for marine mammals? Do these visual impacts cause avoidance or does it attract the marine mammal?

This question was not discussed in any depth during the meeting.

Additional comment after the meeting: Seals use visual cues to navigate, and will likely detect (rotating) wind turbines at large distances (several kilometres). This could act as a deterrent, and influence for example the exchange between colonies (e.g. Zeeland and the Wadden Sea).

14. What is the effectiveness of the mitigation measures?

Germany has a lot of practical experience with offshore wind. The research from these German offshore wind farms can be used to answer this question for porpoises. The most recent research results from Bioconsult are now available. These results show that the disturbance distance for porpoises is reduced when reducing the amount of underwater noise through mitigation.

Additional comment after the meeting: We suggest to collaborate with the Germans to analyze the data in the context of Dutch questions (effect frequency weighting on hearing (i.e. different weather conditions, unmitigated vs mitigated disturbance distances)) to validate the assumption that SEL is a good predictor of disturbance. Also useful for validating models for predicting mitigated pile driving.

15. Are marine mammals equally sensitive in different seasons?

To answer this question for harbour porpoise, stranding data can be used. However it was mentioned during the session that the number of strandings seem to be relatively stable throughout the year. Furthermore it is not clear how stranding relates to sound disturbance.

In general the reproductive period is thought to be a vulnerable period for marine mammals. The research results from the energetics study Seamarco is working on could be used to identify whether there is a seasonal variance in de data. Hypothetically, during the winter the impact of fasting on a harbour porpoise could be larger than during warmer seasons also taken into account food availability during different seasons.

Additional comment after the meeting: Seals show a strong seasonal pattern in their behaviour, energy requirement and distribution. For seals, sensitivity will also be different between seasons. Therefore the reaction of seals and the effect a disturbance event might have, depends on where the disturbance takes place and the annual life-cycle of seals. During the winter months, harbour seals spend more time foraging and travel further offshore. For grey seals, most intensive foraging is expected in spring and summer. During the pupping and moult seasons, seals are sensitive to disturbance near the haul-out sites in the Wadden Sea and Delta region. In spring, activities along the Dutch coast might restrict exchange of pregnant harbour seals returning to breeding sites in the Wadden Sea, while in late autumn this could hold true for grey seals.

16. What is the total impact of the windfarm? What is the total impact during the operational phase?

Currently fishing is not allowed within wind farm sites. However small scale fishers are in discussion with the Dutch government to allow small scale fishery in wind farm sites.

To answer the above question other relevant research questions arise such as: How do harbour porpoises behave within or near an operational wind farm? Do seals show the same or different behaviour? What is the impact of the windfarm on the population? Wat is the impact on marine mammals when the wind farm site becomes a zone open for fishing? What other activities will be allowed within the wind farm? What impact will these activities have on seals and harbour porpoises? What happens to the prey species of marine mammals?

Where do harbour porpoises go when they are disturbed? Is food available in those areas? And is that area free from activities that cause disturbance?

The wind farms can have a positive impact on one species while at the same time having a negative impact on another species. Thus it is important to distinguish between short term impacts versus long term impacts.

17. Wat is the impact of the wind farm on the marine ecosystem?

Currently research is conducted on the impact of wind farms on currents and turbidity. However these studies do not look at the impact of these changed current and turbidity conditions on the marine ecology.

Relevenant studies mentioned

General

1. Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene Jr., D. Kastak, D.R. Ketten, J., H. Miller, P.E., Nachtigall, W.J. Richardson, J.A. Thomas & P.L. Tyack, 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. Aquatic Mammals, 33(4), 411–521
2. Hastie, G.D., D.J.F. Russell, B. McConnell, S.Moss, D. Thompson and V.M. Janik, 2015. Sound exposure in harbour seals during the installation of an offshore windfarm: predictions of auditory damage. Journal of Applied Ecology 52: 631-640. doi:10.1111/1365-2664.12403 and Russell et al. 2016. Avoidance of wind farms by harbour seals is limited to pile driving activities. Journal of Applied Ecology. doi:10.1111/1365-2664.12678
3. Kastelein, R.A. D. van Heerden, R. Gransier & L. Hoek, 2013 Behavioral responses of a harbor porpoise (Phocoena phocoena) to playbacks of broadband pile driving sound. Mar. Environ. Res. 92, 206-214.
4. SEAMARCO, 2011. Temporary hearing threshold shifts and recovery in a harbor porpoise and two harbor seals after exposure to continuous noise and playbacks of pile driving sounds. SEAMARCO Ref: 2011/01
5. Russell, D.J.F., G.D., Hastie, D. Thompson, V.M. Janik, P.S. Hammond, L.A.S. Scott-Hayward, J.Matthiopoulos, E.L. Jones and B.J. McConnell, 2016. Avoidance of wind farms by harbour seals is limited to pile driving activities. Journal of Applied Ecology. doi:10.1111/1365-2664.12678
6. Tougaard, J., A.J. Wright, P.T. Madsen, 2014. Cetacean noise criteria revisited in the light of proposed exposure limits for harbour porpoises. Mar. Pollut. Bull.

Impacts offshore wind

7. Gotz, T. & Janik, V. (2011) Repeated elicitation of the acoustic startle reflex leads to sensitisation in subsequent avoidance behaviour and induces fear conditioning. BMC Neuroscience, 12, 30.

Additional impacts in relation with cumulative effects offshore wind

8. Geelhoed, S. & T. van Polanen Petel, 2011. Zeezoogdieren op de Noordzee; Achtergronddocument bij Natuurverkenning 2011. Wageningen, Wettelijke Onderzoekstaken Natuur & Milieu, WOt-werkdocument 258.

Table 1 gives a summary of the knowledge questions that were discussed during the workshop.

Table 1. Summary of discussion. Per knowledge question additional research questions, available information and addition research methods are identified. (The information in this table only reflects the information that was discussed during the workshop)

#	Knowledge questions	Research questions	Available information	Additional research methods
1	*Is it correct to assume that harbour porpoises are more sensitive to underwater noise than seals when considering the entire sound spectrum of piling noise? Do we need to consider the sound frequency level when determining the impact of piling noise on the disturbance threshold of marine mammals and will this change the initial assumption?*	*What is meant by sensitive? What behavioural or physiological effects are considered disturbance?* *A Wageningen Marine research study funded by Eneco will study the behavioral response of wild seals to pile driving.*	*Hastie et al. 2015.* *Russell et al. 2016.*	*Carry out a desk study to answer the first part of the question, which also considers other aspects such as displacement, long-term avoidance, foraging behaviour, masking, stress and other physiological effects.* *Use US studies with frequency filters, and Tougaard et al. 2014 approach and compare.* *Also more information currently generated by airgun study by SEAMARCO & TNO that can inform the relevance of frequency weighting.*
2	*After validation of the Aquarius model using larger distances, are there still knowledge gaps that need to be addressed?*	*Can we improve prediction of the Aquarius model to incorporate frequency content of the signal in the prediction to support effect assessment with frequency weighting?*		
3	*What is the effect of the activity on the displacement of different species, do species return to the site after the noise activity has ended and when? Are their permanent effects on the behaviour of marine mammals, and does it lead to increasing sensitisation or habituation?*	*What is the severity of disturbance in relation to the distance of the animal from the source of disturbance?* *Do the same individuals return to the sites that were exposed to the impulse noise?*		*Additional comment after the meeting:* *Requires tagging of porpoises. Assess feasibility.* *Satellite tags – also consider deployment by launcher (e.g. ARTS system). Provide long-term movement patterns.* *Short-term – DTAGs, provide information of duration of cessation of feeding. Also echoes detected says something about what species porpoises are feeding on in different environments.* *Use existing distribution data (aerial surveys porpoises and seal telemetry data) to study the intensity of use and fidelity to areas. Ultimately study long-term effects of windfarms constructed in the*

#	Knowledge questions	Research questions	Available information	Additional research methods
				Netherlands and elsewhere (e.g. Germany) on marine mammals. *Can be addressed for seals using existing satellite tags?*
4	*Does food availability play a role in marine mammal return after disturbance and what do we need to know about that?*	*How do prey species/fish react to disturbance?* *How are mm and their prey related spatially? Is prey distribution a limiting factor for the distribution of mm in the Dutch waters?*	*Research shows that disturbance impacts foraging behaviour.*	*Additional comment after the meeting:* *Design an experiment to study the amount of disturbance a mm is prepared to endure to come back to feed.*
5	*What are the effects of underwater sound on the energetics of the harbour porpoise and how fast do they recover? Are effects of underwater sound on the energetics of seals relevant?*	*How do results in a controlled environment relate to wild population of harbour porpoises? What impact does long term fasting have on the population? Does long term fasting have an effect on growth and reproduction of harbour porpoises?*	*Seamarco study on the energetics of harbour porpoise and underwater noise.*	*Will be determined when the results of the current energetics studies become available.*
6	*How do individual energetic costs impact the population? How can the research results from knowledge question 5 be translated into parameters that can be used for models such as iPCoD and DEPONS.*			*(1) Improve/compare iPCoD model and DEPONS model through expert elicitation and research. Make use of newly available knowledge such as research results from German offshore wind farms and Gemini which used c-pods to measure disturbance distance and duration (not the individual animal but the area).* *(2) Focus on understanding food/prey availability and prey distribution in the North Sea* *Additional comment after the meeting:* *(3) Use a -data rich species (e.g. seals) to define the key elements that influence population-level effects of human disturbance, particularly focus on the role of density dependent processes.*

#	Knowledge questions	Research questions	Available information	Additional research methods
7	*Individual Based Model for seals (currently under development)*		*Wageningen Marine Research is working on this model for seals.*	*Additional comment after the meeting:* *Study on the energetic costs of different activities* Define behavioural differences between age groups, and in different seasons
8	*What determines whether or not a habitat is suitable for the harbour porpoise (i.e. abiotic parameters, prey availability etc.) and how does this relate to the survival change outside the suitable habitat. What is the distribution and behaviour of marine mammals in the North Sea (foraging area, reproduction area etc.)? Does this vary between seasons?*	*What is the importance of the North Sea for harbour porpoises, can important habitats be identified?*	*-Mardik Leopold's PhD research* *- Studies on sand eel distribution* *- C-pod data* *- Results/data SCANS II and III surveys*	*(1)First identify which information is already available by asking experts in this field.* *(2)A detailed ecological fish survey (including prey species) of the North Sea is needed.* *(3)Harbour porpoise tagging research behaviour before disturbance (baseline), then disturbance and then return* *(4)Research into the link between displacement of prey fish species and their return and the following return of marine mammals could also be very valuable (tag both fish and marine mammals?)* *(4) Develop model for harbour porpoise fitness based on (the shape of) captive, stranded and bycaught animals. Compare this with animals we see in the wild (HD aerial camera footage or drone photos?) Compare fitness between mother/calf and non-nursing animals?*
9	*What is the exact carrying capacity of the North Sea for the different marine mammal populations, has the carrying capacity been reached and what are the limiting factor that determine population growth?*			*Develop a population model that can determine which amount of disturbance impacts the population size to such an extent that the population size drops under a sustainable norm (for the harbour porpoise this is the ASCOBANS norm)*
10	*Which other species are relevant in the North Sea when taking into account the impact of underwater noise and the barrier effect when developing more offshore wind farms?*	*How many other species can be found in the North Sea? What is the population size/density within the Dutch Continental Shelf?* *How does the Dutch continental shelf relate to the distribution of these species?*	*The SCANS III survey, flight surveys, boat surveys and stranding data can be used to estimate the population size of the other*	

#	Knowledge questions	Research questions	Available information	Additional research methods
11	*Which other activities affect marine mammals and how large are these effects? How do these effects interfere with determining the impact of the construction of wind farms (i.e. contaminants, fishery by-catch, human induced shifts in food availability, etc.)?*	*Focus on activities that produce impulse noise first. How can we cumulate the effects of existing activities with the effects of offshore wind?* *Make a choice on which other activities have priority and need to be addressed in the early stages of the Wozep.*		*Additional comment after the meeting:* *Study long-term impacts of shipping on harbour porpoise and seal distribution.*
12	*How can we determine sound impact from other foundation techniques? What is already known? We need a step by step plan to determine effects of other foundation techniques (vibratory, screw piling etc.).*		*There is a register which includes impulsive sound sources in the North Sea.*	*Expand the register with planned activities in the future*
Additional question				
13	*Are there visual impacts- from moving wind turbine blades- at the surface for marine mammals? Do these visual impacts cause avoidance or does it attract the marine mammal?*	*Similar to birds and bats, does the visual appearance of wind turbines lead to attraction or avoidance at large distances.*		*Additional comment after the meeting:* *Collate all individual tracking data on seals (from all countries) to measure long-distance avoidance or attraction.*
14	*What is the effectiveness of the mitigation measures?*		*Bionconsult results German offshore windfarm*	*Additional comment after the meeting:* *Collaborate with Germans to analyse data to address questions like: is SEL, weighted/unweighted for frequency good predictor for disturbance distance. How can we predict effectiveness of mitigation?*
15	*Are marine mammals equally sensitive in different seasons?*			

#	Knowledge questions	Research questions	Available information	Additional research methods
16	*What is the total impact of the windfarm? What is the total impact during the operational phase*	*How do harbour porpoises behave within or near an operational wind farm? Do seals show the same or different behaviour?* *What is the impact of the windfarm on the population?* *What is the impact on marine mammals when the wind farm site becomes a fish free zone?* *What other activities will be allowed within the wind farm?* *What impact will these activities have on seals and harbour porpoises?* *What happens to the prey species of marine mammals?* *Where do harbour porpoises go when they are disturbed?* *Is food available in those areas? And is that area free from activities that cause disturbance?*		*Additional comment after the meeting* *Potentially, the large seal tracking database contains data which can serve for this purpose*
17	*Wat is the impact of the wind farm on the marine ecosystem?*		*Wind farm site decision Borselle study on impact of wind farm on turbidity and currents*	*Connect results of Wind farm site decision study to ecological implications*