REPORT

Input from workshop on bat fatalities from offshore wind

Client: RWS WVL

Reference: BJ6193-RHD-XX-XX-RP-EO-0001

Status: Final/1.0

Date: 28 May 2024

Rijkswaterstaat
Ministry of Infrastructure and Water Management

Royal HaskoningDHV
Enhancing Society Together

HASKONINGDHV NEDERLAND B.V.

Laan 1914 no.35
3818 EX Amersfoort
Netherlands
Water & Maritime

+31 88 348 20 00 **T**
+31 33 463 36 52 **F**
info@rhdhv.com **E**
royalhaskoningdhv.com **W**

Document title:	Input from workshop on bat fatalities from offshore wind
Subtitle:	
Reference:	BJ6193-RHD-XX-XX-RP-EO-0001
Your reference	
Status:	Final/1.0
Date:	28 May 2024
Project name:	KEC Vleermuizen Noordzee
Project number:	BJ6193

Classification
Project related

Appendices

Royal HaskoningDHV

Rijkswaterstaat
Ministry of Infrastructure and Water Management

Executive summary

On March 18, 2024, a workshop convened in Utrecht to address the presence of the Nathusius' pipistrelle (*Pipistrellus nathusii*) in the North Sea and the associated collision risks with wind farms. The primary objective was to refine the estimation of bat fatalities on the North Sea. Relevant for this estimation is the number of bats that collide with turbines annually. Key discussions centered around data availability, knowledge gaps, and avenues for future research.

Participants engaged in fruitful discussions regarding existing data and uncertainties. This note aims to capture these diverse viewpoints while gathering comprehensive information. The participants of the workshop, as well as international reviewers, reviewed this document and added their additional thoughts and feedback.

- The first goal of this project was to refine the assumptions for bat fatalities. The current reasoning lacks scientific substantiation, necessitating further research on population estimates, migration patterns, and behaviour. Alternative approaches discussed include using ratios and proportions or a conversion factor based on density.
- The second goal was to gain spatio-temporal insights. Translating current knowledge into a relative number of bat fatalities per OWF-area (relative impact factor) proved challenging. Some key insights include gaps in the MOTUS monitoring system hinder land-based migration understanding. Besides this, data is lacking in the northern North Sea but warrants investigation due to observed species presence.
- The final goal was to capture the required next steps that will lead to an improved quantification of bat fatalities from OWFs. The proposed steps include an enhancement of bat detection methods. It was noted that it is important to gain more knowledge about bat behaviour around wind turbines. It was suggested to better utilize existing data and improve land-based estimates for offshore scenarios.

It is evident that much remains unknown, but there is sufficient information to conceptualize possibilities for a new line of reasoning. The information in this note can guide further research and address existing gaps in knowledge. Large-scale research projects were proposed, as well as low-hanging fruit such as analysing existing data. Throughout the session, two potential new lines of reasoning were identified - a promising starting point for further exploration and development.

1. Introduction

This chapter contains the background, aims and approach for this report.

1.1 Background

Research and expert knowledge have shown that bats regularly occur at sea. For several years, it has been known that among other species, Nathusius' pipistrelle (*Pipistrellus nathusii*) crosses the North Sea from the European mainland to the United Kingdom and vice versa. During these migrations across the North Sea, bats may pass offshore windfarms (OWFs) and are at risk of collision and in lesser extent barotrauma.

In the Netherlands, the Offshore Wind Ecological Programme (Wozep) and Framework for Assessing Ecological and Cumulative Effects (KEC) guide the research and assessment of the impacts on (marine) ecology from offshore wind, including the impact on bats. The results from these programs provide input for environmental assessments and decision-making for OWFs in Dutch marine territories. The programs signalled the need to further qualify and quantify (when possible) the impact of bat collisions on populations, with a focus on Nathusius' pipistrelle (*Pipistrellus nathusii*) as input for an update of the KEC (version 5.0), Environmental Impact Assessments (EIA) and providing directions for future research.

To support assessments, the current mortality rate of bats in OWFs is considered to be 0-1 bats per turbine per year. In the application of this range, alike bird collision estimates, the worst-case numbers are always emphasized. This quantification is primarily based upon expert judgement based on the number of bat fatalities in onshore windfarms in The Netherlands.

1.2 Objectives and scope

Rijkswaterstaat (RWS) is leading the update of the KEC and has asked Royal HaskoningDHV (RHDHV) and a selection of subject matter experts to support them in this endeavor. The objective is to assess whether new knowledge could lead to the establishment of a new standard for the impact of OWFs on bats in the Netherlands. The scope for this objective is the impact of OWFs on the Nathusius' pipistrelle (*Pipistrellus nathusii*) population. To achieve this objective a workshop was conducted with subject matter experts with the following aims:

- To assess whether new knowledge could lead to a new assessment of the impact of OWFs on bats in the Netherlands.
- When possible, translate current knowledge into a relative number of bat fatalities per OWF-area to provide spatio-temporal insights for the most relevant OWF-areas in the Dutch North Sea.
- Capture the required next steps that will lead to an improved quantification of bat fatalities from OWFs.

The focus of the workshop was not on onshore wind farms or on other bat species (than Nathusius' pipistrelle), and not on mitigation measures. However, if important information about these topics emerged during the session, it has been included in this report. In addition, a summary of current (scientific) knowledge of the impact of OWFs on bats is not provided. For the latter we refer to the existing literature used as input for the workshop of which a list is included in appendix A.

Royal HaskoningDHV

Rijkswaterstaat
Ministry of Infrastructure and Water Management

1.3 Approach and experts consulted

The following approach was applied to achieve the abovementioned objectives:

1. Workshop design and preparations, including a synthesis of relevant science to create the content of the workshop.
2. Workshop with subject matter experts, held in Utrecht on Monday the 18th of March 2024. Present organisations and their roles are outlined in Table 1-1 below.
3. Description of the results from the workshop (this document).
4. Review and corrections of this document by workshop participants. This includes a review and suggestions for improvement by an international panel of subject matter experts. Additional remarks and information that was added after this review are indicated in *green text and italics*.

Table 1-1. Workshop participants and reviewing subject matter experts

Organisation	Attendees	Role
Workshop participants		
Waardenburg Ecology	2	Subject matter expert
Jasja Dekker Dierecologie	1	Subject matter expert
Vliegend goed	1	Subject matter expert
Bionet Natuuronderzoek	1	Subject matter expert
Altenburg & Wymenga	1	Subject matter expert
Ecosensys	1	Subject matter expert
Wageningen University & Research	1	Subject matter expert
Rijkswaterstaat	4	Wozep/KEC
Royal HaskoningDHV	3	Workshop facilitation and reporting
Review panel		
Wageningen Marine Research	1	Reviewing expert (was unavailable to attend in person due to illness)
Bat Conservation Trust	1	Reviewing expert
APEM Group	1	Reviewing expert
Leibniz Institute for Zoo and Wildlife Research	1	Reviewing expert

1.4 Workshop agenda

In a general sense, the impacts of OWFs on bats can be reasoned to result from a series of scenarios and circumstances. The steps in this process may look like this:

In scenario A and if the circumstances are B, C% of the bats depart the land to go offshore.
The flight at sea is influenced by situation D, E and F.
There is a chance G that they end up in proximity to a turbine, leading to a H collision risk.
The resulting I number of victims can be compared to the J size of the population, giving a yearly population reduction of K.

This workshop was tailored to address many of the unknowns in these process steps. Making the workshop agenda the following:

Part one: workshops

Workshop 1: addresses the different parameters that may (directly or indirectly) affect the collision risk.
Workshop 2: identifying spatial differences and discussing flight paths.
For this, the group of experts were split up, one group started workshop 1 and the other started workshop 2. After some time, the groups were switched.

Part two: plenary discussion

Topic 1: bat behavior around turbines.
Examples of discussed subjects: attraction rates, flight behavior, foraging behavior
Topic 2: bat population.
Examples of discussed subjects: population estimates, techniques to research the population size, the composition of the population.
Topic 3: impacts of OWFs.
Examples of discussed subjects: ecological factors and risks, mitigation.
Topic 4: ideas for a new line of reasoning

During the different workshops and discussions, ideas for future research, knowledge gaps and ideas for a new line of reasoning were collected.

2. Results

This chapter contains the most relevant results and discussions from the workshop with subject matter experts as outlined in the previous chapter. The contents and structure of these results have been adjusted according to its intended use and application for the KEC. Additional remarks and information that was added after the workshop are indicated in green text and italics.

2.1 Workshop 1: Collision risk parameters

See the table in appendix B for the list of parameters as discussed in workshop. This list also contains an expert judgement on the reliability of data and the relevance of each parameter in governing collision risks of bats in OWFs. The following parameters were discussed in the context of being related to collision risks.

Weather conditions

Air pressure
This parameter is challenging to evaluate in isolation, its significance becomes clearer when combined with other weather conditions. As a standalone variable, it does not carry substantial importance.

Windspeed and wind direction
These parameters are incredibly important when considering bat activity and collision risks. The frequency of occurrence of tailwinds in spring is different compared to autumn, therefore the effects may vary between the spring- and autumn migration. The effects may also vary depending on the location. When still onshore, the presence of tail winds may play a part in the bats' decision to cross the sea. In offshore scenarios, the effects may be less pronounced. If a bat has already committed to crossing and there are no nearby resting opportunities, it has no alternative but to continue flying, irrespective of any changes in wind speed or direction. In birds it was shown that windspeed plays a role in the most optimal flying height, the same may be true for bats, although this has not been demonstrated through research yet.

Addition after review:

- *One expert adds that the notion that the effects of tail winds may be less pronounced in offshore wind scenario's is very speculative. An alternative speculation is that in case bats have made the wrong decision to fly over sea in bad weather conditions they will not survive. It may also be possible to fly back to shore. If bats experience headwind during their crossing, they may be more inclined to be attracted to offshore wind farms, leading to an increased collision risk.*

Temperature
There are different opinions regarding the significance of this parameter. The experts scored the current data availability and reliability differently between spring and autumn migrations. The current knowledge on the autumnal data is more elaborate.

Additions after review:

- *One expert adds that the data reliability is also dependent on whether the data is collected at onshore or offshore locations. Weather recorders on land are generally closer to departure locations than offshore departure locations because there are fewer weather buoys offshore. Most onshore detectors are now deployed accompanied by a weather station.*
- *One expert adds that the bats won't start migrating in temperatures below 7-8 degrees Celsius. A source was provided which concludes this is due to the lack of insects to provide proper nutrition[1].*

[1] *Voigt, C. C., Sörgel, K., Šuba, J., Keišs, O., & Pētersons, G. (2012). The insectivorous bat Pipistrellus nathusii uses a mixed-fuel strategy to power autumn migration. Proceedings of the Royal Society B: Biological Sciences, 279(1743), 3772-3778.*

Cloud cover

There is currently a low data availability, but the assumption is that this parameter is not essential. Consequently, further research on its effects may not be necessary.

Addition after review:

- *One expert speculates that cloud cover is important in relation to orientation, and perhaps plays part in whether an individual decides to cross the North Sea.*

Moon phase and moon light

The parameter moonlight was subject to some discussion. It was mentioned that different studies reported different results regarding the effects of moonlight. Nevertheless, the importance of this parameter was generally considered low. Any effects on this parameter are assumed to be connected to insect availability and conditions to forage.

Additions after review:

- *One expert adds that the lunar phase was found to be a highly significant predictor for offshore bat occurrence. This observation may indicate a relationship with insect availability (which is sometimes synchronized with the lunar phase), predation risk, or both. Moon light, and the level of illumination, is different from moon phase and should be considered as a separate variable. A source was provided to confirm the notion that the parameter moon light produces mixed results in different studies[2].*
- *One expert stresses that both cloud cover and the moon could have an impact because it affects whether or not bats can see the turbines. The following substantiation to this statement was shared:*
    - *Bats are likely to first perceive the presence of offshore turbines by vision or somatosensation of the turbine wake.*
    - *According to literature, bats use vision to detect things outside the range of echolocation[3,4].*
    - *According to literature, their vision is well suited to detecting distant objects in dim light[5].*
    - *According to literature, some studies suggest that bats use visual, topographical cues to orientate themselves[6].*

Precipitation

The precipitation is scored to have a moderate to high importance; however, the current data reliability has been rated relatively low. This has to do with the fact that bat detectors may get wet, potentially compromising the data's reliability. It's also related to the lack of actual rain measurements offshore. The current data is typically based on model outcome, which may largely deviate from local circumstances.

Additions after review:

- *A source was provided to emphasize the importance of precipitation[1].*
- *One expert adds that in general, bat activity decreases when wind speed and precipitation increase. This statement was supported with a source[7].*

---

[2] *Lagerveld, S., Wilkes, T., van Puijenbroek, M. E., Noort, B. C., & Geelhoed, S. C. (2023). Acoustic monitoring reveals spatiotemporal occurrence of Nathusius' pipistrelle at the southern North Sea during autumn migration. Environmental Monitoring and Assessment, 195(9), 1016.*
[3] *Suthers, R. A., & Wallis, N. E. (1970). Optics of the eyes of echolocating bats. Vision Research, 10(11), 1165-1173.*
[4] *Boonman, A., Bar-On, Y., Cvikel, N., & Yovel, Y. (2013). It's not black or white—on the range of vision and echolocation in echolocating bats. Frontiers in physiology, 4, 248.*
[5] *Shen, Y. Y., Liu, J., Irwin, D. M., & Zhang, Y. P. (2010). Parallel and convergent evolution of the dim-light vision gene RH1 in bats (Order: Chiroptera). PLoS One, 5(1), e8838.*
[6] *Williams, T. C., Williams, J. M., & Griffin, D. R. (1966). The homing ability of the neotropical bat Phyllostomus hastatus, with evidence for visual orientation. Animal Behaviour, 14(4), 468-473.*
[7] *de Jong, J., Millon, L., Håstad, O., & Victorsson, J. (2021). Activity pattern and correlation between bat and insect abundance at wind turbines in south Sweden. Animals, 11(11), 3269.*

Turbine operation and design

Production of ultrasonic noise

This parameter relates to the production of ultrasonic sound by wind turbines and its attractive or repulsive effect. This parameter holds potential importance, based on several onshore studies mainly in the US, although the available data for European species is limited and research outcomes are contradictory. Consequently, the reliability of the existing data remains relatively low.

Addition after review:

- *One expert questions this statement, adding that the production of ultrasonic noise is not mentioned in two research reports on this topic. This statement was supported with two sources[8] [9].*

Cut-in windspeed and downtime facility

The cut-in windspeed of the turbine is an important factor, and the available data is deemed reliable. However, a concern arises regarding the definition of downtime, as the rotors of the turbines continue to move slowly. This does not mean that the speed at the tip of the blade is also slow and therefore it can still result in bat collisions. For this reason, the experts generally consider 1 rpm as a safe threshold.

Additions after review:

- *One expert adds that it is important to take note of the height at which the windspeed is measured at the turbine. Studies typically use the windspeeds at 10 meters altitude, whilst the measurements of windspeed to determine the cut-in windspeed are taken at the nacelle in wind turbines. In these circumstances, it is important to apply a correction factor.*
- *One expert questions whether the available data is collected onshore or offshore, as it cannot always be assumed that evidence is translatable across these different scenarios.*
- *One expert adds that according to his understanding, the blades are considered idling when they are not turning. It is possible to feather them to minimize the speed they turn to below 2 rpm. According to literature this has been shown to reduce fatalities (up to 60%) in onshore situations[10].*

Rotor speed

This parameter is of moderate to high importance and the available data is considered to be reliable.

Red light

This parameter is relatively low in importance. The reliability of the available data is also considered to be low. It is expected that the turbine itself attracts bats, rather than the red light. UV filters could reduce the attraction of insects and thus the attraction of bats.

Addition after review:

- *Three experts added that a paper published in the USA shows that red aviation light does not affect bat mortality in onshore turbines. Other published information mentions that bats are virtually unable to detect red light, making it a bat-safe light source. However, one expert adds that a publication by Voight et al. (2018) appears to contradict this sentiment[11].*

---

[8] Cryan, P. M., Gorresen, P. M., Hein, C. D., Schirmacher, M. R., Diehl, R. H., Huso, M. M., ... & Dalton, D. C. (2014). Behavior of bats at wind turbines. Proceedings of the National Academy of Sciences, 111(42), 15126-15131.
[9] Guest, E. E., Stamps, B. F., Durish, N. D., Hale, A. M., Hein, C. D., Morton, B. P., ... & Fritts, S. R. (2022). An updated review of hypotheses regarding bat attraction to wind turbines. Animals, 12(3), 343.
[10] Arnett, E. B., & Baerwald, E. F. (2013). Impacts of wind energy development on bats: implications for conservation. In Bat evolution, ecology, and conservation (pp. 435-456). New York, NY: Springer New York.
[11] Voigt, C. C., Rehnig, K., Lindecke, O., & Pētersons, G. (2018). Migratory bats are attracted by red light but not by warm‐white light: Implications for the protection of nocturnal migrants. Ecology and evolution, 8(18), 9353-9361.

Turbine design

Key factors include the rotor height and the lowest tip-height (the airgap between the water surface and lowest tip height). On land, turbines with low overall height but long blades are considered undesirable. However, it remains uncertain whether the same is true for offshore turbines as the effects depend on the flight height distribution of the bats.

Additions after review:

- *One expert adds that it is known from literature that larger wind turbines increase the fatality rate, due to a greater rotor area and higher tip speeds. A source was provided to confirm this statement[12].*
- *Two reviewers add that larger wind turbines can be more efficient in terms of power production per square meter of rotor area, leading to fewer casualties per megawatt.*
- *One expert adds that during a previous workshop, it was discussed that a mitigation method used for birds was to increase the height of the lower blade swept zone. However, bats appear to exhibit exploratory behaviour (flying up and down) as they reach a turbine (comments from a German stakeholder), thus this mitigation measure may be less useful for bats.*

Presence as resting spot

Wind turbines could serve as significant resting spots for migrating bats, expanding the time the animal is in the wind farm. Although the data reliability is currently low, the observations on existing offshore wind farms, oilrigs and service ships indicate moderate to high importance.

Additions after review:

- *One of the reviewers would not classify the data reliability as low and noted that the spatial pattern of the acoustic presence of bats at the North Sea is shaped by bats who perform diurnal stopovers at sea (and thus are recorded two nights).*
- *One reviewer provided a research report on this topic[13].*

Timing

Time of day

Some consider this to be a very strong predictor, others deemed it not essential to include in modelling studies. Bats predominantly fly during the night. If they fail to reach their destination (either land or a resting place) during dark hours, they may continue flying into the early morning. The data reliability for this factor is considered to be high.

Migration

The periods during which migration occur are of great importance. In general, the timing of the spring migration is harder to predict than the autumnal migration. This difference is caused by limited data availability, proper analysis has not yet been done.

Within the migration window, bats may wait for favourable conditions to start the migration. Within this window of migration, the environmental conditions mostly determine this timing. If the bats are unable to feed appropriately due to factors as droughts or heavy rainfall, low temperatures or prey availability, the bats may take longer to depart from the coastline. The experts recommended placing bat detectors near different landscape features in order to ascertain the onset of migration.

[12] Lagerveld, S., Noort, C. A., Meesters, L., Bach, L., Bach, P., & Geelhoed, S. (2020). Assessing fatality risk of bats at offshore wind turbines (No. C025/20). Wageningen Marine Research.
[13] Boshamer, J. P., & Bekker, J. P. (2008). Nathusius' pipistrelles (Pipistrellus nathusii) and other species of bats on offshore platforms in the Dutch sector of the North Sea. Lutra, 51(1), 17.

Addition after review:

- *Not all reviewers agree with this recommendation and some question whether it is possible to make a distinction between resident and migratory individuals.*

The question remains whether this can be directly linked to offshore migration. In addition, the general behavior of bats during the spring migration and autumn migration may differ: the spring migration is showing a more diffuse pattern. There could be a bigger risk during the autumn migration, as diurnal stays may occur more frequently.

Additions after review:

- *One expert adds that the difficulty may lie in ascertaining the appropriate departure locations before the onset of migration.*
- *One expert adds that female bats that survived winter and migrate back to their breeding colonies are of great value for the population, because they will reproduce.*
- *Two experts question the statement that diurnal stays occur more frequently, stating that this behavior is not well known or studied.*

Year

Findings in bat studies may differ between different years. This is a result of parameters such as environmental conditions creating different circumstances every year.

2.2 Workshop 2: Spatial differences

This workshop focused on defining spatial differences in the migration on the North Sea. The participants were divided into two group to discuss this subject in break-out sessions.

Areas on the Southern North Sea with high collision risk can differ between spring migration and autumnal migration. The migration in the spring is generally more diffuse and therefore areas with a higher collision risk are harder to predict.

The experts were divided on whether areas could be designated where a higher concentration of Nathusius' pipistrelle can be expected. The first group of experts asserted that the northern part of the Southern North Sea is likely less important for the migration of Nathusius' pipistrelle compared to the southern part of the Southern North Sea. This statement is supported by research conducted by one of the experts, where it was observed that individuals of the species primarily fly along the mainland coast and there only have been a few sightings of the species around the Wadden Sea Islands. The second group of experts indicated that they do not want to designate this area as less important for the migration of Nathusius' pipistrelle because there is still uncertainty about the migration of populations from the Baltic states and Scandinavia. They pointed out that there are also observations of Nathusius' pipistrelle in the northern part of the Southern North Sea. Not all areas of the Southern North Sea have been studied regarding the presence of this species. In the southern part of the Southern North Sea, multiple studies have been conducted which confirmed the presence of Nathusius' pipistrelle migrating in this area of the North Sea. For the northern part of the Southern North Sea, research data which could either confirm or refute the view of the first group of experts, is lacking. Additionally, the second group of experts mentioned that other species such as the Parti-coloured bat (*Vespertilio murinus*) are regularly encountered in this part of the North Sea. Also, common noctule (*Nyctalus noctula*) is occasionally found in this region (North) on oil rigs. The second group of experts indicate that conducting a study on the occurrence of Nathusius' pipistrelle in this area of the Southern North Sea is essential. This can be accomplished by studying existing research data. For instance, Norway has substantial data that could provide insight into the species' migration. Additionally, research using stable isotope ratios or genetic markers can help determine individual origins.

The distinction between the two areas described above, drafted by the first group of experts, is indicated on a map (see Figure 2-1).

Additions after review:

- *One expert questioned the statement that the spring migration pattern is more diffuse.*
- *One expert questioned the notion that species composition differs between the different parts of the North Sea.*
- *Several experts stressed that it is impossible to put a line on a map based on the current data, and an argument against doing so is that a line on a map may be taken out of context.*
- *One expert noted that all observations of Noctules at the Dutch North Sea likely refer to individuals from local populations. Seasonal migration of Noctules over the North Sea has not yet been proven by scientific research. A source was provided to confirm this statement[14].*
- *One expert added that there is data available that assesses the relative importance of the Northern part of the North Sea. Three studies where provided that show less detections compared to the Southern North Sea. Still, additional research would be preferred[15] [16] [17].*
- *One expert questions the data availability to substantiate the distinction between the areas, with the addition that offshore data may be useful, but onshore data most likely not.*
- *One expert adds that research reports that the stable isotope method may not be as promising as previously thought. A source was provided to confirm this statement[18].*

---

[14] *Lagerveld, S., & Mostert, K. (2023). Are offshore wind farms in the Netherlands a potential threat for coastal populations of noctule?. Lutra, 66(1), 39-53.*

[15] *Hüppop, O., & Hill, R. (2016). Migration phenology and behaviour of bats at a research platform in the south-eastern North Sea. Lutra, 59(1-2), 5-22.*

[16] *Lagerveld, S., Gerla, D., van der Wal, J. T., de Vries, P., Brabant, R., Stienen, E., ... & Scholl, M. (2017). Spatial and temporal occurrence of bats in the southern North Sea area (No. C090/17). Wageningen Marine Research.*

[17] *Bach, P., Voigt, C. C., Göttsche, M., Bach, L., Brust, V., Hill, R., ... & Seebens‐Hoyer, A. (2022). Offshore and coastline migration of radio‐tagged Nathusius' pipistrelles. Conservation Science and Practice, 4(10), e12783.*

[18] *Kruszynski, C., Bailey, L. D., Courtiol, A., Bach, L., Bach, P., Göttsche, M., ... & Voigt, C. C. (2021). Identifying migratory pathways of Nathusius' pipistrelles (Pipistrellus nathusii) using stable hydrogen and strontium isotopes. Rapid Communications in Mass Spectrometry, 35(6), e9031.*

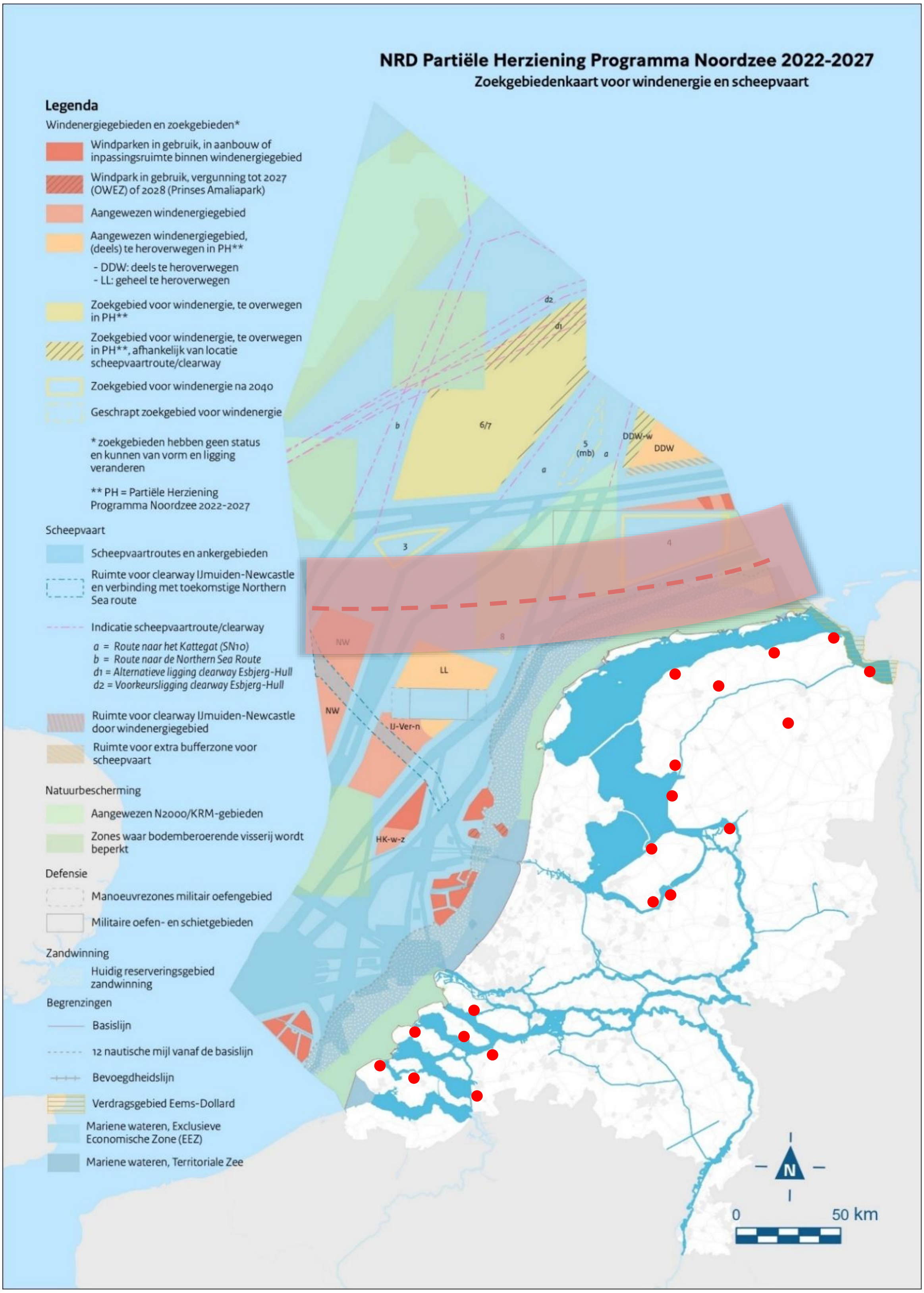

Figure 2-1. Map with search areas for turbines (in Dutch) Source: Rijksoverheid, 2024.The red dots on the map indicate where extra measuring points for the MOTUS wildlife tracking system are preferred. The dotted red line indicates a possible distinction between an area where more activity of the Nathusius' pipistrelle is expected (south of the line) and an area where less activity of the Nathusius' pipistrelle (north of the line) is expected. The pink buffer indicates that the exact location of a possible divide is uncertain.

Understanding the migration patterns of Nathusius' pipistrelle across the North Sea is essential to evaluate the impact on bat fatalities caused by collisions with turbines. The current understanding of the migration of Nathusius' pipistrelle is that most of these individuals migrate over land by following the coastline and only a handful makes the journey across the North Sea to reach England. *One expert comments that this is not in line with the results of the summary of the autumn tracking report (RWS), as this study only focusses on small area of the coast, and results indicate that further south (outside the study area) bats might also depart onto the sea*. However, there are significant gaps between the MOTUS (MOTUS Wildlife Tracking System) stations on land which confirms or refutes the theory that individuals of Nathusius' pipistrelle mainly migrate over land. Or at least, the effect of these gaps on the change of detection of tags has not yet been properly addressed in the analysis. This results in an incomplete representation of the migration of Nathusius' pipistrelle. Expanding the MOTUS network onshore and offshore, is essential to obtain a clearer picture of migration onshore and offshore and therefore migration across the sea. During the discussion, offshore expansion was not discussed as thoroughly, most likely because it is a given that an expansion of the network offshore would be beneficial, whilst on land it is still a subject of discussion. These extra points are preferably places in Zeeland, Friesland and Groningen. Expansion of the MOTUS network in the North of the Netherlands is useful because this data can be compared to existing data from one of the experts. In addition to expanding the network on land, monitoring points offshore are also required. This expansion of the MOTUS network will allow for a better assessment of the overall migration dynamics. Experts have identified locations where new MOTUS monitoring points are needed, marked with red dots on the map (see Figure 2-1). Drawbacks of the MOTUS include that it cannot determine the flight altitude of bats, and that only the detections become known and not the behavior of the bats. It only shows the registrations, the taken path is up for interpretation, running the risk that it does not include changes in direction mid-flight.

Additions after review:

- *One expert added that when tagging bats, it could be a concern how long the tags remain on the individuals. A limited lifetime of the tags limits the data.*
- *Several experts mentioned that during the workshop, the preferred extra MOTUS monitoring spots were located onshore, but it was stressed that the biggest gap is the lack of a MOTUS network offshore. The brainstorm on the expansion of the MOTUS network on land could be useful under the condition that a network will be developed offshore. This helps in the interpretation of future results of crossing offshore and in answering more confidently which part of the population is at risk offshore.*
- *One expert mentioned that it could be beneficial to have a different research team analyze the tracking data, to see if this would produce different or more results.*
- *On the topic of drawbacks of the MOTUS system, one expert mentioned that the approach demonstrated in a research report by Lagerveld et al., (2016)[19] is not feasible in real-world scenarios. The expert adds that another system tested on P. kuhlii effectively calculates locations using GPS precision.*
- *On the topic of drawbacks of the MOTUS system, one expert mentioned that without complete coverage we can't know where the bats have been. Trapping and tagging bats is required, for which it is essential to consider the welfare implications. Only a small proportion of the population can be tagged, so it should be questioned whether this sample is representative.*
- *One expert added that in order to achieve a more precise estimate on the number bats that depart over sea, receivers are needed along the coast as well as offshore.*
- *Two experts added that a large positive characteristic of MOTUS is that it is an open system, and as is done in the North and Middle Americas, parties can cooperate nationally and internationally to expand the network. Relevant parties were encouraged to promote such cooperation.*

[19] *Lagerveld, S., Poerink, B. J., de Vries, P., & Scholl, M. M. (2016). Bat activity at offshore wind farms LUD and PAWP in 2015 (No. C001/16). IMARES.*

- *One expert states that if you want to have a more precise estimates on the number of bats departing over sea you need receivers at the coast (in the Netherlands, Belgium, Northern France and UK) as well as offshore.*
- *One expert commented that besides an expansion of the measuring points, an important factor to be considered is the maintenance of this network. A long-term contract was suggested, to make the maintenance secure.*

2.3 Bat behavior around wind turbines

Wind turbines attracting bats and impact on mortality

Wind turbines are believed to attract bats, as shown by observations of Nathusius' pipistrelle individuals near these structures[20]. Turbines equipped with detectors can detect Nathusius' pipistrelles within a range of approximately 30 – 40 meters[21] under ideal circumstances. If the species was randomly migrating over the North Sea, the chance of observing an individual near a turbine would be negligible. However, the repeated sightings of Nathusius' pipistrelle near wind turbines suggest that these structures could have an attractive effect on bats. That said, it is uncertain how many bats are not recorded, because their flight route doesn't cross a wind farm.

The actual mortality due to collisions is a result of the behavior of flying in the proximity of turbines. Therefore, we can consider two key factors:

- Attraction Rate: the rate at which bats are drawn to wind turbines.
- Collision Rate: the rate at which bats collide with the turbines. The collision rate is influenced by the attraction rate and other factors. Another example of an influencing factor is the flight height.

Addition after review:

- *One expert speculates that offshore windfarms like oil & gas platforms may be life savers for bats migrating offshore that do not make the cross. Bats migrating over the North Sea might experience the windfarms as potential foraging hot spots as these high structures are recognized as potential hot spots for insect concentrations. Thus, offshore windfarms may be regarded an expansion of bat habitats.*

Insects as a factor

Insects may also be attracted to wind turbines[22] [23] [24], raising uncertainty about the primary cause of attraction for bats[25] [26]. It remains unclear whether wind turbines themselves or the availability of prey (insects) play a more significant role. The presence of insects is highest during migration in the autumn. Insects have been noted on transition pieces, the mast and nacelle by several of the experts present during visits to turbines to place equipment, Notably, when cleaning the rotor blades of land-based wind turbines, many insects are observed to have collided with the blades. Whether this phenomenon occurs offshore as well requires further investigation.

---

[20] *Valdez, E. W., & Cryan, P. M. (2013). Insect prey eaten by hoary bats (Lasiurus cinereus) prior to fatal collisions with wind turbines. Western North American Naturalist, 73(4), 516-524.*

[21] *Behr, O., Barré, K., Bontadina, F., Brinkmann, R., Dietz, M., Disca, T., ... & Nagy, M. (2023). Standardised and referenced acoustic monitoring reliably estimates bat fatalities at wind turbines: comments on 'Limitations of acoustic monitoring at wind turbines to evaluate fatality risk of bats'. Mammal Review, 53(2), 65-71.*

[22] *Voigt, C. C. (2021). Insect fatalities at wind turbines as biodiversity sinks. Conservation Science and Practice, 3(5), e366.*

[23] *Jansson, S., Malmqvist, E., Brydegaard, M., Åkesson, S., & Rydell, J. (2020). A Scheimpflug lidar used to observe insect swarming at a wind turbine. Ecological Indicators, 117, 106578.*

[24] *Crawford, M. S., Dority, D. E., Dillon, M. E., & Tronstad, L. M. (2023). Insects are attracted to white wind turbine bases: evidence from turbine mimics. Western North American Naturalist, 83(2), 232-242.*

[25] *Rydell, J., Bogdanowicz, W., Boonman, A., Pettersson, S., Suchecka, E., & Pomorski, J. J. (2016). Bats may eat diurnal flies that rest on wind turbines. Mammalian Biology, 81, 331-339.*

[26] *Rydell, J., Bach, L., Dubourg-Savage, M. J., Green, M., Rodrigues, L., & Hedenström, A. (2010). Mortality of bats at wind turbines links to nocturnal insect migration?. European Journal of Wildlife Research, 56, 823-827.*

Additions after review:

- *One expert proposed that an appropriate mitigation tactic to reduce the potential of insects at turbines could be the inclusion of UV filters on all lights to reduce any attraction of insects.*
- *One expert added that the presence of insects could potentially be observed during the routine cleaning of the rotor blades.*

Attracting other bats
Bats lingering near a turbine echolocate. Consequently, the longer a bat remains in close proximity of a turbine, the higher the risk of collision both for that individual and for other bats, that are attracted to its echolocation calls.

Flight height
To gain insight into the flight altitude of bats near wind turbines, it has been proposed to do research with a thermal imaging camera. The use of a bat detector during this research can also provide insight in whether the species consistently utilizes echolocation during migration. A proposed location where the study can be conducted is the IJsselmeer because behavior of Nathusius' pipistrelle above large open water can be easily observed at this location.

Additions after review:

- *One expert disagreed with this notion, stating that IJsselmeer is a freshwater lake, and the abundance of insects is very different than on the North Sea. This difference can lead to behavioral differences such as lower flight height, making it harder to make this comparison.*
- *A research report on the topic of flight height was provided[27].*
- *One expert agrees that placing detectors at different heights is a useful exercise to cover a greater amount of airspace, including greater heights in the rotor swept zone where bats could be at risk. It was added that the range of each detector must be considered, as there may be overlap and the results should be considered in this context.*

Calculating flux
Wind turbines attract bats, causing them to remain close to the turbines. This behavior complicates the use of a bat acoustic monitoring system for defining flux.

As both bats and birds are known to migrate over the North Sea, often bird collision models are mentioned in the discussion around bats. The difference in behavior complicates the comparison: some bird species may avoid the turbines, whilst some bats may be attracted. It could be possible to extend the bird models to fit bats, but it would be required to add more variables, and thus needing more data. It was also mentioned that models built for Lesser Noctule (*Nyctalus leisleri)* could possibly be utilized for coastal migration of the Nathusius' pipistrelle.

Additions after review:

- *One expert added that in a modelling approach it would be good to distinguish the following steps:*
    1) *the statistical chance that a bat collides with a turbine when flying through the rotor zone,*
    2) *the effects of behavior in flight in wind parks and the consequences for collision risks,*
    3) *the number of bats that actually pass an offshore wind farm (the flux)*
- *Two experts mention that the flux model may not be applicable to bats.*
- *One expert adds that a dedicated analysis of offshore radar data in combination with the acoustic recordings may help to identify bat tracks in radar databases and hence reveal flight patterns of bats.*

---

[27] Brabant, R., Y. Laurent, B. Jonge Poerink & S. Degraer, 2020. Activity and behaviour of Nathusius' pipistrelle Pipistrellus nathusii at low and high altitude in a North Sea offshore wind farm. Acta Chiropterologica 21(2): 341-348.

- *One expert mentions the potential of using an occupancy model for determining the flux (or the relative size of the flux of Nathusius pipistrelle on the North Sea).*
- *One expert adds that models state that Lesser Noctules do not follow the same path. Individuals have a high deviation, and thus cannot be considered collectively. With this reason, the applicability of models using the Lesser Noctule is challenged.*

2.4 Population

Migratory behavior – what do we know

There are large differences in activity and numbers measured during between spring migration and autumn migration. There are also differences between the sexes, and whether the migrating bat is a juvenile or adult. The migrating population consists mostly of females and juveniles. During the autumn migration two to three peak events take place. The females arrive first, it was hypothesized that the males may arrive afterwards if they have decided to migrate, because the males are known to mostly stay put and skip the migration altogether. For the juveniles, it was mentioned that they have a high mortality. It is possible that only 50-70% survive to the next summer after hibernation. A lot of bats die during the autumn migration or hibernation. Additionally, juveniles do not reproduce during their first year.,

Additions after review:

- *One expert questioned the notion that only 50-70% of juveniles survive to the next summer and asks for a source to this information.*
- *One expert comments that there are a lot of assumptions in this paragraph.*

What encompasses the Dutch population?

There's a debate about what exactly constitutes the 'flyway' population and how it should be defined. Additionally, there is also a distinction between the ecological and legal flyway population. The ecological flyway population is larger than just the animals that migrate through the Netherlands (legal flyway population). Determining the size of the population is a complex task, as there are multiple populations that converge in the Netherlands. This includes migrants from Germany and the Baltic states, the north, as well as the native Dutch animals. The question remains: which of these groups should be included in the definition of the 'flyway' population, and how can an estimation of population size be made? In short, the 'flyway' population encompasses more than just the animals that migrate over the Netherlands, but the Netherlands is not responsible for the part of the flyway population that does not migrate over the Netherlands. A conclusion cannot be drawn based on the discussion.

Addition after review:

- *The following study made an estimated guess of the population[28].*

[28] Limpens, H. J. G. A., Lagerveld, S., Ahlén, I., Anxionnat, D., Aughney, T., Baagøe, H. J., ... & Schillemans, M. J. (2016). Migrating bats at the southern North Sea-Approach to an estimation of migration populations of bats at southern North Sea.

2.5 Impact

In this paragraph the impact of offshore windfarms on Nathusius' pipistrelles on individual and population level is described.

Ecological factors and risks

Cause of death

It is a common assumption that barotrauma is one of the main causes of bat mortality due to wind turbines. However, a recent study suggests that most of the fatalities are suggested to be caused by direct collision and not barotrauma. This could have a (minor) effect on mortality risk calculated from rotor diameter.

Addition after review:

- *One expert states that it is hard to separate the two, especially in the offshore situation as carcass studies do not exist. If the bat is close enough for barotrauma to affect the bat they will likely be hit by the blade and therefore no distinction can be made.*

Habitat loss or opportunities

Wind turbines in the North Sea are not known to cause habitat loss for bats. The possibility of wind turbines creating a barrier for migration is not expected to be a risk. The existing structures may even have a positive impact, providing the bats with safe opportunities for resting or foraging. The expert consensus regarding the net positive effects of wind turbines however is mixed.

On land the situation is different, there placement of wind turbines may lead to habitat loss, because the bats use these areas as foraging areas, and they lose foraging opportunities.

Addition after review:

- *One expert adds that bats often forage around or near wind farms. Thus, when you place wind turbines in an open habitat (agricultural land) then you add foraging habitat.*

Sex-specific mortality

As mentioned before, the offshore migration population is thought to mostly exist of females and juveniles. Females are the mainly responsible for recruitment, so this creates the added risk that only a few mortalities may have a large impact on the population. For example, if females face a higher risk during migration, it can lead to an uneven distribution of sexes within the population. If all females perish, it halts reproduction, and the population could collapse.

Dilution effect

The dilution effect of wind turbines on bats refers to the idea that the number of bat fatalities per turbine per year decreases as the bat population becomes smaller. The reasoning behind this is that with fewer bats, the chances of encountering a turbine and being killed decrease. However, most experts disagreed with this notion. They argue that research doesn't support this effect and that the fraction of the population that become bat fatalities per turbine per year remains consistent. Additionally, when assessing the effects of wind turbines on the bat population, one must always consider a worst-case scenario and therefore you can't rely on the dilution effect.

It was also discussed that wind turbines have an attractive effect on the bats, and the calls of bats may attract more bats. Due to this attraction a possible dilution effect doesn't have to lead to less victims of collision.

Additions after review:

- *One expert states that this is all highly speculative. In the Netherlands there is a remarkable increase in population numbers in several other species of bats, likely the result of a historical recovery. Thus, the claim that the population is constant cannot be made.*
- *One expert adds that when the population gets smaller, the impact of every collision will be larger, and closer to the 1% mortality threshold.*

Individuals observed

The experts wondered what kind of individuals of Nathusius' Pipistrelle are observed near offshore wind turbines. It is possible that only the weaker individuals are being observed because they are looking for food and shelter at sea. The bats that do not utilize these locations and/or fly at higher altitude are not recorded and therefore the individuals observed may not represent the total population that migrates across the sea.

Addition after review:

One expert states that other experts disagree about the 'weaker individual hypothesis' because the rotor-swept area of wind turbines intersects with the migration corridor of bats. For instance, standing near the most western turbine on the Afsluitdijk with thermal cameras reveals that bats collide with the blades during their migration in a direct line. This direct line of flight suggests a migratory flight, instead of a foraging flight. If the 'weaker individual hypotheses' would apply, instead of migratory flight a foraging flight should have been observed, because the bats require energy-intake.

Mitigation

Where should the focus lie?

This session is focused on bats at sea. Some concern was raised whether this is the right place to focus on, as the number of bats that cross is relatively small, and the majority of the population migrates along the coast. It may be better to allocate the resources for future research to the bat mortality that occurs on land and to focus on land-based mitigation because this has more impact.

Additions after review:

- *One expert states that not much research has been done offshore. This includes acoustic monitoring in the rotor swept area of offshore turbines. There is no MOTUS station offshore in the Dutch North Sea. It was speculated that it would be better to mitigate onshore but more offshore research is certainly useful.*
- *One expert agrees with this message very strongly and considers it an important result of the discussion.*

Downtime facility

There was some concern regarding the current guidelines for the downtime facility. It was mentioned that the blades are still slowly rotating with a speed of 2 rpm (*1 rpm for IJmuiden Ver, Alfa en Bèta*). This is not so much an issue around the nacelle, but it can be near the tips of the rotor blades. The tips are still able to reach a speed of 30-40 km/h. This has been the subject of study on land where the preference was a rpm of 0,25 to 0,5. It was mentioned that the majority of the bats may still be victims of collision at these slower turbine speeds.

Wind turbine design

The design of the wind turbine is likely to influence the number of collisions. On land, it has been observed that bats mostly fly at lower heights. A wind turbine design with a low tower height and long rotor blades appears to be the most high-risk design. Therefore, the design of offshore wind turbines (which have a larger rotor swept area and a low rotor tip, in comparison to wind turbines on land) may be more dangerous than wind turbines on land.

Additions after review:

- *One reviewer states that the comparison between offshore and onshore wind turbines is not straightforward, and safety should be evaluated based on more nuanced factors. To illustrate this point: offshore turbines are larger, with a bigger rotor area, but they also produce more power (higher MW). A 100 MW wind farm could be built using 50 small turbines on land, each producing 2 MW, or as a 10-turbine, 10 MW offshore wind farm. If you consider the victims per produced MW, you get a more nuanced approximation of the dangers of different wind parks.*
- *One expert adds that the behaviour is likely to be completely different at sea. Some of the German stakeholders at a different workshop in the same theme suggested that bats investigate the offshore wind turbine, flying up, down and around.*

3. Approaches for a new line of reasoning

Two ideas emerged during the work session to determine a line of reasoning to reach a more realistic assumption for the number of bat fatalities from OWFs.

Idea 1: Instead of calculating a range in absolute numbers, use ratios and proportions to calculate the impact

Approach

Instead of offshore windfarms being the focal point, focus on individual process steps that the bat takes that lead to collision. Break down the process into stages to determine the percentage of additional mortality and uncertainty of each stage. Density maps might be helpful as a base in this approach. Strategically placed stationary automated bat detectors can be used to validate the maps.

Unknowns

- While we don't know the exact population size, we do have a range (bandwidth). Knowing the percentage of additional mortality allows us to assess acceptability within this range.
- The general behavior and collision rates of bats around wind turbines are uncertain.
- The number of bats that go out to sea is uncertain, as well as under which conditions bats decide to cross.

Key steps

Consider factors like whether individuals go out to sea, the numbers near turbines, the favorability of the weather conditions, attraction to turbines, and duration spent near them. Perhaps consider the effects of bats attracting others bats and the attraction to insects. From the attraction to turbines and the duration spent near them follows the amount that is expected to collide.
Keep improving the population estimates.

Calculations

Use ratios and proportions to analyze the impact. Unknowns may be estimated with the use of assumptions or expert elicitation estimates.

Additions after review:

- *One expert added that it is very tricky to use the number of bat detector recordings to determine bat abundance.*
- *One expert considers the ORNIS criteria and the ABRvS's mention of them, and concludes that this approach seems inadequate for projects with costs as large as this. The expert recommends Akerboom et al. (2021)[29] for further insights.*
- *It is still necessary to determine the methods of measuring required factors such as the number of individuals, the amount of attraction to turbines and the number of bats that is likely to collide.*
- *One expert expressed concern with an approach based on modelling only, explaining that studies on land have shown that estimations are typically too low. Meaning the actual number of victims will be a factor 10 or 100 times higher than a model will predict. These differences could be caused by the temporal changes in behavior that models do not account for.*

[29] *Akerboom, S., Backes, C., Buij, R., & Lagerveld, S. (2021). Wind Energy Development and Protection of Vulnerable Species: An Interdisciplinary Study of Ecological Effects and Legal Instruments in the Netherlands. Available at SSRN 3839332.*

Idea 2: Make use of a conversion factor which translates density to number of victims

Approach

This approach follows the German methodology. This methodology uses a conversion factor to translate the acoustic bat activity to a number of victims. It is necessary to first establish the ratio between detector activity and the number of observed victims in windfarms on land. Once the relationship between presence recordings and victims is clear, then this conversion factor can be used offshore. This method can be expanded by improving the population estimates and taking into account the percentage of bats that go out to sea.

Unknowns

- This method is currently used on land, how this applies to the situation offshore is uncertain.
- The current nationwide trend in the Netherlands is not known. However, experts mentioned data that is available but not analyzed yet.
- According to the latest knowledge one out of every five bats went out to sea, the current ratio may be different.
- The behavior of bats around wind turbines is generally unknown.
- It is uncertain how accurate the data is collected by acoustic bat detectors. It is not known how many bats migrate without calling. The study using bat detectors and infrared cameras on the IJsselmeer is a good option to test this accuracy.

Key steps

Research the German methodology of using a conversion factor by consulting publications and contacting relevant experts. Then use the available Dutch data to develop a similar conversion factor or test the applicability of the German conversion factor. Use this conversion factor in combination with offshore densities to estimate the number of victims.

If the activity data is not sufficient, it may be possible to use a stepwise line of thinking similar to idea 1. First, the bat data on land is collected. To this data a ratio is applied, corresponding to the ratio of bats that cross the sea according to telemetric studies. Then, the German factor is applied. In this way an estimate is achieved of the potential collision victims.

Calculations

Develop a conversion factor or utilize the existing German factor. Use this to translate population numbers or density into number of victims.

Additions after review:

- *One expert thinks this is the quickest method, as much data of acoustics and victims in existing onshore wind farms is available. With this data estimations and margins of error can be better quantified. It could be the first step to a translation towards offshore.*
- *One expert adds that this approach has been mentioned and discussed in a research report[30].*
- *One expert did not consider this idea to be likely to produce reliable results, due to the difference in properties of the wind turbines on land and offshore, and the difference in habitats. The factor used in Germany is mostly based on inland data, and here the species composition is very different from*

[30] *Lagerveld, S., Noort, C. A., Meesters, L., Bach, L., Bach, P., & Geelhoed, S. (2020). Assessing fatality risk of bats at offshore wind turbines (No. C025/20). Wageningen Marine Research.*

the North Sea. Such a factor would have to be determined in a location with similar properties. The same argument is true for the comparison with the IJsselmeer.

- *One expert considers the only option that will likely produce reliable results will be to measure the collision rate. This expert was missing this option as an 'idea 3'.*
- *One expert proposed 'understanding the behavior of bats and the attraction (or not) by turbines offshore' as an additional idea to be processed in a line of reasoning. This idea includes using bat detectors on different heights and in the nacelle to understand the value of detections at different heights.*
- *One expert adds that it is still necessary to determine the methods of measuring required factors such as the number of individuals, the amount of attraction to turbines and the number of bats that is likely to collide.*
- *Experts supplied the information that bat detectors have a 40-meter detection range, at another point it was mentioned that bat detectors have a 25-meter range. Detection will represent the species within the range of the tower, and not the blade tip.*

4. Knowledge gaps and required research

A summary of the knowledge gaps, possible actions and required research mentioned during the session.

4.1 Knowledge gaps

The table below (Table 4-1) summarizes the topics and their associated knowledge gaps.

Table 4-1. Summary of the subjects and their knowledge gaps.

Subject	Knowledge gaps
Population	• The population size of migrating bats and foraging bats is unknown. • There is currently no concise definition on what encompasses the 'flyway' population that can be used as the 'reference population' in impact assessments.
Migration	• The exact conditions under which the bats decide to start their migration are unknown, as well the percentage of bats that migrate. • It is not known how many bats migrate without calling.
Wind turbines	• It is uncertain what wind turbine design leads to less bat collisions offshore, no specific research has been conducted on the flight altitude of Nathusius' pipistrelle near offshore wind turbines. • It is uncertain whether wind turbines offer significant resting opportunities for migrating bats. The expert consensus regarding the positive effects of wind turbines is mixed. • It is uncertain whether offshore wind turbines attract insects in the same manner and proportions as observed on onshore. Offshore radar is able to detect insects. • It is uncertain whether the current downtime facility is sufficient in preventing bat collisions. The concern was raised that the blades are still slowly rotating, creating a hazardous situation.
Spatial patterns	• Research data from the northern part of the Southern North Sea is lacking or not analyzed for this theme. • The northern part of the Southern North Sea currently cannot be deemed with certainty a less important area. A factor in this uncertainty is the migration of populations from the Baltic states and Scandinavia. • It is uncertain whether there are areas that can be proven by data to have higher bat densities, or higher collision risks.
Monitoring	• The amount of collision victims is unknown and very hard to determine, after collision bats will fall into the water. • The accuracy of Bat Acoustic Monitoring System for defining flux is uncertain due to the behavior of the bats around wind turbines. • By exclusively monitoring at offshore locations that may serve as resting opportunities, it is possible that the recorded bats represent only part of the population. The bats that don't utilize these locations and/or fly at higher altitude are not recorded.

Additions after review:

- *One expert states the conditions under which bats decide to migrate cannot be called 'unknown'. Adding that within the Wozep program several studies have been published which are focused on the occurrence of migratory bats at sea and factors shaping their migration.*
- *One expert adds that new monitoring projects with thermic cameras may record the first observations of (potential) collisions.*

4.2 Possible actions and future research

Measure the fatality risk
The most direct approach entails recording the amount of bat collisions. Modern sensors and a combination of methods would be necessary.

Expand MOTUS radiotelemetry network
Add receiver stations to the existing MOTUS network based on the pinpointed locations from workshop 2 and offshore. The MOTUS system has the potential to be further utilized through open cooperation with other European countries.

Genetic (DNA & isotope) research
Investigate the origins of bat populations and migration patterns using DNA and isotope analysis.

Bat behavior research around OWFs

- Use bat-detectors (including thermal imaging cameras) to study bat behaviour in and around offshore wind farms (OWFs). This can also be conducted at the Ijsselmeer, which is similar to bat behaviour on sea but easier to investigate. Although the IJsselmeer is a suitable location for research, it's crucial to distinguish between studying migratory patterns and foraging behavior. It is essential to carefully design the research setup to ensure accurate measurement of the phenomenon that is being investigated. Even then, it is yet unsure whether in which capacity the results will translate to the situation offshore.

Addition after review:

- *One expert adds that they believe that this is key. Understanding bat behaviour around turbines and therefore the likelihood of collision is the big question. Understanding whether we're not picking up bats with acoustic systems because they're echolocating is another key piece of evidence to inform future studies. If cameras are used stereoscopically then they have the potential to map flight paths and detect collisions.*

- Utilize the MOTUS radio-telemetry network to determine the frequency and duration of bat visits.
- Review whether to focus research efforts on autumn migration or spring migration.

Radar data analysis
Radar data from existing OWFs (e.g., OWEZ, Luchterduinen, Borsselle, Gemini) and meteorological masts (MET-masts) can provide valuable insights. If this does not yield the desired result, it can be decided to purchase a different radar that also considers wing beat patterns.

Concerning the Luchterduinen data, it was mentioned that it could be worth researching whether insect activity could be extracted from this data.

Addition after review:

- *One expert is in great support of researching the Luchterduinen data for insect activity.*

Combine radar data analysis with bat detector data

When observing an individual bat using a bat detector, we often lack information about its flight behavior beyond the fact that it is present and emitting echolocation calls. By cross-referencing the bat detector data with radar data collected at the same date and time, we can gain insights into the flight movements of the individual bat. Although it must be noted that radar may not be a good method for determining flight behavior near turbines because of the reflection on the radar image.

Examples of research question may be:

- Does the bat fly in a straight line? If so, from which direction to which direction?
- Alternatively, does it engage in foraging behavior? Are subsequent bat detector observations consistent with the same individual?

Investigate the possible positive effects of OWFs

- Investigate the impact of OWFs on local bat populations, on land the wind farms were mentioned to add to the foraging habitat due to the insect availability in open areas. It is important to investigate similar effects offshore.

Using male calls for population estimation:

- Estimate bat densities in the Netherlands by recording the mating calls of males.
- Determine the male-to-female ratio to estimate population size.

Consult other countries

Examine the approach used by other countries, such as Germany, to assess the number of bat fatalities from offshore wind turbines.

Consult existing data

By consulting the data from Norway, it may be possible to gain more insight into the migration of Nathusius' Pipistrelle.

Exploring different methods and tools

- Investigate the combined use of (insect) radar data along with bat detectors.
- Explore the application of thermal cameras/detectors at sea to record bat activity. Utilize modern sensors like WT-bird.

Additions after review:

- *The MOTUS systems is particularly suitable for presence/absence recording.*
- *The reviewing experts were asked to offer an indication which steps in future research they deemed most promising. There was not a unanimous answer. It is likely that a combination of methods is necessary.*
- *One expert added the statement that in particular more collaboration with England would be very beneficial.*
- *Even with specialized radar systems, it is hard to distinct between bats and birds.*
- *On the topic of radar analysis, one expert asked to fact check and receive information from the University of Amsterdam (UvA) group.*

5. Conclusion and next steps

This chapter contains the next steps required following this workshop and the results captured in this report.

5.1 Achievement of goals

The goal of this initiative is to enhance the existing guidelines regarding the impact of offshore wind farms (OWFs) on bats in the Netherlands. Specifically, we focus on the impact of OWFs on Nathusius' pipistrelle (*Pipistrellus nathusii*). To achieve this, a workshop was organized with subject matter experts. Here, we explain the extent to which the goals were accomplished.

Goal 1: Determine a line of reasoning to reach a more realistic assumption for the number of bat fatalities from OWFs.
The objective is to assess whether new knowledge could lead to the establishment of a new standard for the impact on bats of OWFs in the Netherlands.
It is not possible to adopt a more scientifically substantiated assumption for the number of bat fatalities within the current line of reasoning. To adopt a more scientifically substantiated number, further research is needed to improve population estimates, enhance our understanding of migration patterns, and obtain accurate data on behavior and collision risks.

Instead of changing the current line of reasoning to a different number, two different methods of updating the line of reasoning were discussed:

- **Idea 1:** Instead of calculating a range in absolute numbers, use ratios and proportions to calculate the impact.
- **Idea 2:** Make use of a conversion factor which translates density to number of victims.

Further steps to update the current line of reasoning could be to identify which essential resources, data, and tools are necessary for successful implementation. Gaps in the current capabilities and knowledge should be addressed to make the new line of reasoning as accurate as possible.

Goal 2: When possible, translate current knowledge into a relative number of bat fatalities per OWF-area (relative impact factor) to provide spatio-temporal insights for the most relevant OWF-areas in the Dutch North Sea.

It was deemed not possible to translate current knowledge into a relative number of bat fatalities per area. The new insights on a spatio-temporal scale can be summarized as follows:

Areas for Nathusius' pipistrelle:

- The experts were divided on whether areas could be designated where a higher concentration of Nathusius' pipistrelle can be expected.
- The southern part of the Southern North Sea has been well-studied and confirmed to host migrating Nathusius' pipistrelle.
- Nathusius' pipistrelle bats follow the coastline, with only a few crossing the North Sea to England. However, the summery of the autumn tracking report only focusses on small area of the coast, and results indicate that bats might also depart onto the sea further south (outside the study area).Gaps in the MOTUS monitoring system on land hinder a complete understanding of their migration mainly on land.

Importance of Northern Area:

- The northern part lacks sufficient research data, but observations of the species in this area warrant further investigation.
- Some experts caution against dismissing the northern area's importance due to uncertainties about migration patterns from the Baltic states and Scandinavia.
- Other bat species are also observed in the northern region, emphasizing the need for research.

Goal 3: Capture the required next steps that will lead to an improved quantification of bat fatalities from OWFs.
The key steps to achieving quantification are: improving bat detection, gaining more knowledge about bat behavior around wind turbines, and assessing collision risk. Many methods have been proposed for further research to enhance this knowledge. The most easily achieved set of tasks involves utilizing existing data. Additionally, there was significant interest in improving land-based estimates for use in offshore scenarios.

5.2 Concluding remarks

During the session, insight was gained into the current situation regarding research on bats migrating over the North Sea. It is evident that much remains unknown, but there is sufficient information to guide further research and address existing gaps in knowledge. Large-scale research projects were proposed, as well as low-hanging fruit such as analyzing existing data. Throughout the session, we identified two potential new lines of reasoning—a promising starting point for further exploration and development.

Addition after review:

- One expert expressed concern with focusing all effort on only Nathusius' pipistrelle, and not consider the range of other species on the North Sea.

Royal HaskoningDHV

Rijkswaterstaat
Ministry of Infrastructure and Water Management

Appendix A: Literature as input for the workshop

The following list of (scientific) literature was used as a starting point for the workshop with subject matter experts. In addition to this list, two notes were provided by Wageningen Marine Research containing the preliminary results from acoustic studies on spring and autumn migration of bats to and from The Netherlands from the UK (Norfolk).

Title and link to publication	Autor(s) and year of publication
Bats in Dutch offshore wind farms in autumn 2012. Lutra, 57(2), 61–69. https://www.zoogdiervereniging.nl/~zoogdier/sites/default/files/publications/Lutra%2057%282%29_Lagerveld%20et%20al_2014.pdf	Lagerveld, S., Poerink, B. J., Haselager, R., & Verdaat, H. (2014)
Spatial and temporal occurrence of bats in the southern North Sea area (nr. C090/17), Wageningen Marine Research, 54 pp. https://www.noordzeeloket.nl/publish/pages/187416/spatial_and_temporal_occurrence_of_bats_in_the_southern_north_sea.pdf	Lagerveld, S., Gerla, D., van der Wal, J.T., de Vries, P., Brabant, R., Stienen, ... Scholl, M. (2017)
Stilstandvoorziening als mitigatie voor Vleermuizen in OWFs. https://www.noordzeeloket.nl/publish/pages/184351/stilstandvoorziening_als_mitigatie_voor_vleermuizen_in_owfs.pdf	Boonman M. (2018)
Offshore Occurrence of a Migratory Bat, Pipistrellus nathusii, Depends on Seasonality and Weather Conditions. https://www.noordzeeloket.nl/en/functions-and-use/offshore-wind-energy/ecology/offshore-wind-ecological-programme-wozep/bats/reports-bats/	Lagerveld, S., Poerink, B. J., Geelhoed C. V. (2021)
Home range and habitat use of common noctules in the Dutch coastal zone. https://www.noordzeeloket.nl/publish/pages/216422/home-range-and-habitat-use-of-common-noctules-in-the-dutch-coastal-zone.pdf	Lagerveld, S., Janssen, R., Stienstra K., Boshamer J., Puijenbroek, M., Noort C.A., & Geelhoed C.V. (2021)
Spatiotemporal occurrence of bats at the southern North Sea 2017-2020. https://www.noordzeeloket.nl/publish/pages/221831/spatiotemporal-occurence-of-bats-at-the-southern-north-sea-2017-2020.pdf	Lagerveld, S., Geelhoed C.V., Wilkes T., Noort C.A., Puijenbroek, M., Wal van der J. T., Verdaat H., Keur M., & Steenbergen J. (2023)
Bat 1: Estimate of bat populations at the southern North Sea (WU& Research Nr. C014/17, DMS Nr. 2017.08) Supporting note to ZDV (Nr. 2016.031, Migration bats at the southern North Sea), Wageningen University & Research and DMS, 15 pp. https://www.noordzeeloket.nl/publish/pages/187416/bat_1_-_estimate_of_bat_populations_at_the_southern_north_sea_-_supporting_note_to_zdv_report_no_201.pdf	Lagerveld, S., Limpens, H.J.G.A., Schillemans, M.J. & Scholl, M. (2017)
Migrating bats at the southern North Sea - Approach to an estimation of migration populations of bats at southern North Sea (Nr. 2016.031), Zoogdiervereniging (Dutch Mammal Society), Nijmegen/ Wageningen Marine Research, 76 pp. https://www.noordzeeloket.nl/publish/pages/187416/migrating_bats_at_the_southern_north_sea_-_approach_to_an_estimation_of_migration_populations_of_bat_1.pdf	Limpens, H.J.G.A., Lagerveld, S., Ahlén, I., Anxionnat, D., Aughney, T., Baagøe, H.J., ... Schillemans, M.J. (2017)
Methods for assessing fatality risk of bats at offshore wind turbines. https://www.noordzeeloket.nl/publish/pages/184354/methods_for_assessing_fatality_risk_of_bats_at_offshore_wind_turbines.pdf	Lagerveld S., Noort C.A., Meesters L., Bach L., Bach P., Geelhoed C.V. (2020)

Appendix B: Collision risk parameters

This section contains the handouts that were written on during the workshop about collision risk parameters. Group 1 worked together on one handout; the other handouts were worked on individually.

Table 5-1. The completed handout from group 1, in which the parameters for various categories were assessed by the experts in terms of reliability and priority. A scale of 1 to 5 was used, where 1 indicated that something was not reliable at all or had no priority, and 5 meant that something was highly reliable or had very high priority. This group decided they also want to distinguish spring and autumn migration.

Handout group 1					
Category	**Parameter**	**Reliability**		**Priority**	
		Spring	Autumn	Spring	Autumn
Weather conditions	Temperature	?	5	?	1
	Air pressure	-	-	-	-
	Windspeed	?	5	5	5
	Wind direction nearby coast	Probably 5	5	5	5
	Wind direction offshore	? - 5	1 - 2	?	?
	Cloud cover	Probably 1	Probably 1	Probably 1	Probably 1
	Moonlight	1	1	1	1
	Precipitation	1	1	3	3
Wind turbines	Production of ultrasonic noise	?	?	3	3
	Cut-in windspeed	5	5	5	5
	Velocity of rotorblades	5	5		
	Height of rotorblades				
	Red light	1	1	1	1
	Density of wind turbines				
	Downtime facility	5	5	5	5
	Presence as resting place				
Timing	Time of day	Night	Night	Night	Night
	Migration				
	Year				
	Moon phases				
Spatial occurrence	Location on sea				
	Distance to coast				
Bats	Population size	1	1	5	5

Table 5-2. The completed handout from expert 1 of group 2, in which the parameters for various categories were assessed by the experts in terms of reliability and priority. A scale of 1 to 5 was used, where 1 indicated that something was not reliable at all or had no priority.

Handout expert 1			
Category	**Parameter**	**Reliability**	**Priority**
Weather conditions	Temperature	5	4
	Air pressure	5	2
	Windspeed	5	5
	Wind direction	5	5
	Cloud cover	3	1
	Moonlight	3	1
	Precipitation	3	4
Wind turbines	Production of ultrasonic noise	2	1
	Cut-in windspeed	5	5
	Velocity of rotorblades	5	5
	Height of rotorblades	5	4
	Red light	5	3
	Density of wind turbines	5	3
	Downtime facility	5	5
	Presence as resting place	1	3
Timing	Time of day	5	3
	Migration	3	5
	Year		3
	Moon phases	?	2
Spatial occurrence	Location on sea	5	5
	Distance to coast	5	5
Bats	Population size	5	5

Table 5-3. The completed handout from expert 2 of group 2, in which the parameters for various categories were assessed by the experts in terms of reliability and priority. A scale of 1 to 5 was used, where 1 indicated that something was not reliable at all or had no priority.

Handout expert 2			
Category	**Parameter**	**Reliability**	**Priority**
Weather conditions	Temperature		5
	Air pressure		1
	Windspeed		5
	Wind direction		5
	Cloud cover		3 (orientation)
	Moonlight		2
	Precipitation		5
Wind turbines	Production of ultrasonic noise		? 3
	Cut-in windspeed		? 1
	Velocity of rotor blades		5
	Height of rotor blades		?
	Red light		?
	Density of wind turbines		? 2
	Downtime facility		5
	Presence as resting place		5
Timing	Time of day		1
	Migration		3
	Year		4
	Moon phases		2 (possibly)
Spatial occurrence	Location on sea		5
	Distance to coast		3
Bats	Population size		3

Table 5-4. The completed handout from expert 3 of group 2, in which the parameters for various categories were assessed by the experts in terms of reliability and priority. A scale of 1 to 5 was used, where 1 indicated that something was not reliable at all or had no priority.

Handout expert 3			
Category	**Parameter**	**Reliability**	**Priority**
Weather conditions	Temperature	5	4
	Air pressure	3	3
	Windspeed	4	5
	Wind direction	5	5
	Cloud cover	2	1
	Moonlight	2	2
	Precipitation	2	4
Wind turbines	Production of ultrasonic noise	2	2
	Cut-in windspeed	5	4
	Velocity of rotor blades	5	3
	Height of rotor blades	5	4
	Red light	2	2
	Density of wind turbines	5	2
	Downtime facility	3	3
	Presence as resting place	1	2
Timing	Time of day	5	1
	Migration	3	5
	Year		3
	Moon phases		2
Spatial occurrence	Location on sea	5	5
	Distance to coast	5	4
Bats	Population size	1	5

Table 5-5. The completed handout from expert 4 of group 2, in which the parameters for various categories were assessed by the experts in terms of reliability and priority. A scale of 1 to 5 was used, where 1 indicated that something was not reliable at all or had no priority.

Handout expert 4			
Category	**Parameter**	**Reliability**	**Priority**
Weather conditions	Temperature	5	4
	Air pressure	5	2
	Windspeed	5	5
	Wind direction	5	5
	Cloud cover	3	1
	Moonlight	3	1
	Precipitation	3	4
Wind turbines	Production of ultrasonic noise	2	1
	Cut-in windspeed	5	5
	Velocity of rotor blades	5	5
	Height of rotor blades	5	4
	Red light	5	3
	Density of wind turbines	5	3
	Downtime facility	5	5
	Presence as resting place	1	3
Timing	Time of day	5	3
	Migration	3	5
	Year		3
	Moon phases	?	2
Spatial occurrence	Location on sea	5	5
	Distance to coast	5	5
Bats	Population size	5	5