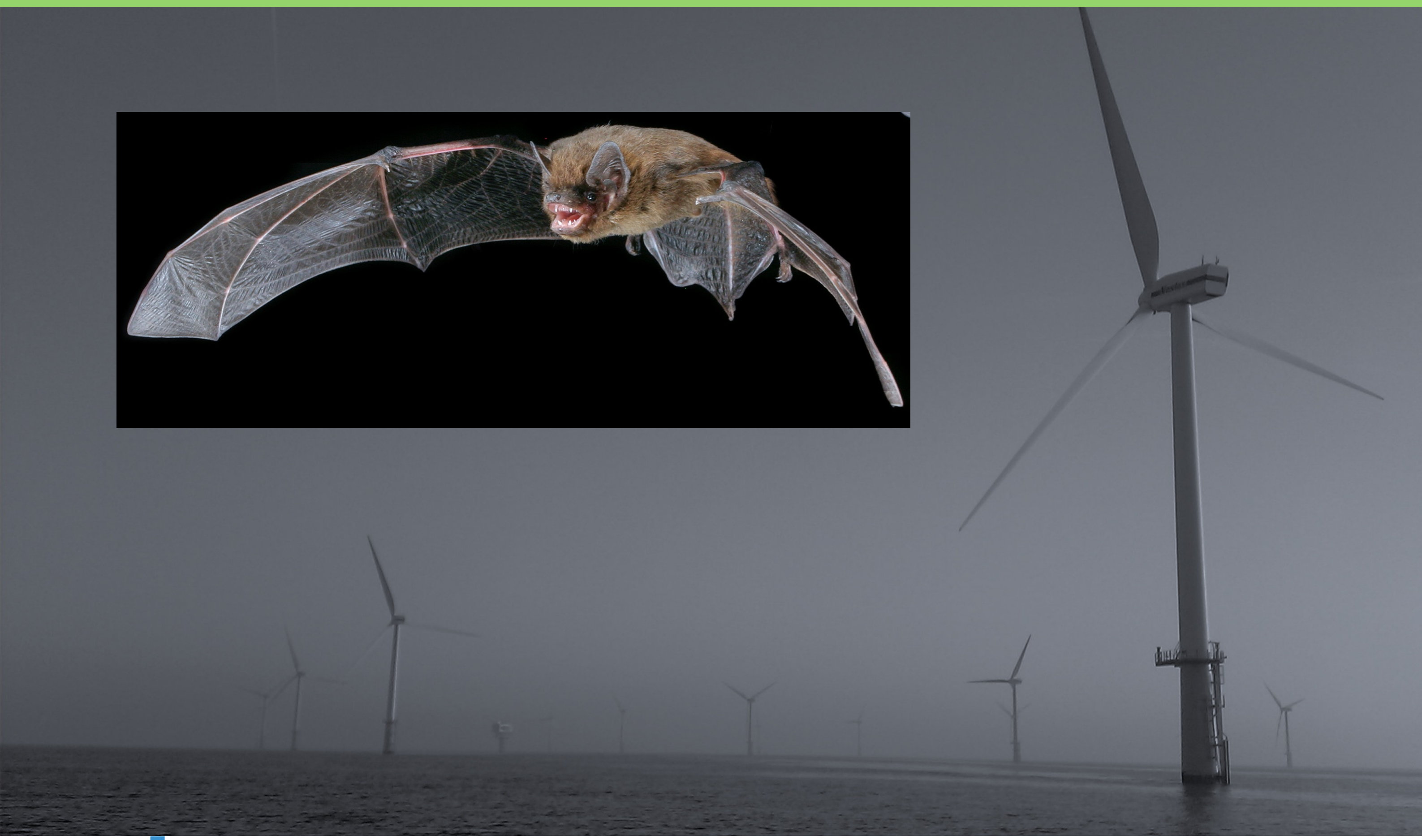
ASSESSMENT OF BAT CASUALTIES AT OFFSHORE WIND FARMS IN THE NETHERLANDS AND CUMULATIVE IMPACTS ON THE NATHUSIUS' BAT POPULATION - A METHODOLOGY OUTLINE -



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ASSESSMENT OF BAT CASUALTIES AT OFFSHORE WIND FARMS IN THE NETHERLANDS AND CUMULATIVE IMPACTS ON THE NATHUSIUS' BAT POPULATION:
- A METHODOLOGY OUTLINE -

Client:

Rijkswaterstaat
Ministry of Infrastructure and the Environment

Contact persons:	Marije Wassink, Henri Zomer, Meik Verdonk, Dagmar van Nieuwpoort, Martine Graafland
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Authors:	Bob Jonge Poerink (Ecosensys)
	Robin Brabant (Royal Belgian Institute of Natural Sciences, MARECO)
	Oliver Behr (Oekofor GbR)

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In cooperation with:

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CONTENTS

1. INTRODUCTION

Offshore wind farms in Europe have been found to have a detrimental impact on bat populations, primarily due to bat collisions with turbine blades, resulting in increased mortality rates (Voigt *et al.*, 2012). Research on bats in onshore wind farms indicates that bats are attracted to wind turbines due to the presence of insects, potential roosting sites or lighting, thereby increasing the risk of collisions (Cryan *et al.*, 2014; Guest *et al.*, 2022; Voigt *et al.*, 2018). The most vulnerable species are often migratory bats, which travel long distances and may encounter wind farms along their migration routes (Lehnert et al., 2014).

Bats undertaking seasonal migration between summer roosts and wintering areas can cross large areas of open sea (Ahlén *et al.*, 2009). This is also the case in the southern North Sea, where several bat species have been recorded. Nathusius' pipistrelles (*Pipistrellus nathusii*), common noctules (*Nyctalus noctula*), parti-colored bats (*Vespertilio murinus*), Leisler's bats (*Nyctalus leisleri*) and Northern bats (*Eptesicus nilssonii*) have been observed at offshore oil rigs and platforms (Boshamer en Bekker, 2008). Surveys with acoustic bat recorders also confirmed the presence of bats in offshore wind farms (OWFs) even at large distances from the coast (Jonge Poerink et al., 2013, Lagerveld et al., 2017 & 2022). The migrating bat species Nathusius' pipistrelle is more often detected over the North Sea compared to other bat species. In the period 2015 – 2020 more than 85% of all bats recorded over the North Sea with ultrasonic passive recorders were Nathusius' pipistrelles (Lagerveld et al., 2017 & 2022). Other bat species recorded over the North Sea are found offshore only incidentally or as a vagrant species. Given the presence of bats offshore and the known impact of onshore wind farms on them, offshore wind farms also present risks to bats.

The Dutch Offshore Wind Ecological Programme (Wozep) guides the research and assessment of the impacts on (marine) ecosystems from offshore wind energy developments in the Netherlands, including the impact on bats. To effectively assess plans or site decisions for new wind farms, the Framework for Assessing Ecological and Cumulative Effects (KEC) has also been established. Wozep and KEC provide input for environmental assessments and decision-making for OWFs in Dutch marine territories. The Wozep and KEC programs signaled the need to further refine and quantify the impact of bat collisions of offshore windfarms on populations, with a particular focus on Nathusius' pipistrelles. This information is necessary to be able to reconsider current worst-case assumptions, and as a guidance for KEC, Environmental Impact Assessments (EIAs) and future research as well as for the management of current and future wind farms at sea.

Legal conservation status
The European Habitats Directive (HD) is protecting all European bat species. The overall objective of the HD is to maintain and restore natural habitats and species of wild fauna and flora of Community interest to a 'favourable conservation status'. A favourable conservation status can be described as a situation where a species is prospering (extent/population) and has good prospects to do so in future as well. Nathusius' pipistrelle is one of the bat species listed in Annex IV of the HD (i.e. 'animal and plant species of community interest in need of strict protection'). Consequently, the collision risk and the impact of the OWFs on the conservation status of this species should be determined for the Dutch EEZ (Exclusive economic zone). Currently (2024) the conservation status of Nathusius' pipistrelle in the Netherlands is 'moderately unfavourable'.

To support EIAs, the current mortality rate caused by OWFs in the Dutch EEZ is estimated at 0-1 bats per turbine per year (Leopold *et al.*, 2014) and included in KEC1.0 (Ministerie van Economische Zaken & Ministerie van Infrastructuur en Milieu, 2016). This quantification is based on the limited data that were available in 2014 and was mainly based on expert judgement and information on casualties in onshore wind farms. Therefore, it should be regarded as a rough estimate. In EIAs, the maximum estimate of one bat per turbine per year is frequently used as a worst-case fatality rate. This might however lead to an overestimation of the number of collisions. Nathusius' pipistrelles are found offshore during the migration periods of this species in spring (April – June) and autumn (August – October) (Jonge Poerink & Dekker, 2018; Lagerveld et al., 2017 & 2022). Since the expert judgement of 0-1 bats per turbine per year was made in 2014, additional data were gathered on the offshore occurrence of Nathusius’ pipistrelle. This available dataset could aid defining a more accurate and evidence-based estimate of the average number of bat casualties at offshore wind turbines and underpin effective mitigation measures.

Rijkswaterstaat aims to more accurately and systematically estimate the number of bat casualties in offshore wind farms located in the Exclusive Economic Zone (EEZ) of the Netherlands and assess its impact on the population of Nathusius’ pipistrelle. On behalf of Rijkswaterstaat, Ecosensys, in cooperation with the Royal Belgian Institute of Natural Sciences and Oekofor GbR, designed an assessment methodology.

This report presents a methodology for estimating the number of bat casualties at offshore wind farms located in the Exclusive Economic Zone of the Netherlands. It also outlines a method for assessing the cumulative impacts of these offshore bat casualties on the Dutch population of Nathusius’ pipistrelle bats.

The report includes:

- A summary of the available data on bats in the southern North Sea.
- An explanation of the assessment strategy that can lead to an estimate of bat casualties at offshore wind farms.
- A description of the methodology used in Germany to calculate the expected number of collision victims caused by onshore wind turbines.
- An evaluation of whether the German methodology can be applied to the Dutch context for calculating bat casualties and population effects caused by offshore wind turbines. This includes assumptions made to adapt the methodology for offshore conditions, as well as potential points of discussion and uncertainties.
- An identification of the data required for the Dutch context and an assessment of its availability.
- A description of a methodology to assess the population size of Nathusius’ pipistrelle in the Netherlands.
- A description of a method to assess the fraction of the Dutch population migrating through offshore windfarms.
- Recommendations for future research to enhance the development of the methodology.

2. AVAILABLE DATASETS SOUTHERN NORTH SEA

2.1 Acoustic data

2.1.1 Monitoring locations and years

Acoustic data of bats over the North Sea in the Dutch EEZ were first collected in 2012 at two offshore wind farms in the Dutch EEZ (Jonge Poerink *et al.,* 2013). Until 2020 data were collected at 18 offshore locations as part of the Wozep monitoring program (Lagerveld *et al*., 2017 and 2022). Passive recorders were mounted on offshore oil platforms, meteo masts, wind turbines and Offshore High Voltage Stations (OHVS). In 2015 and 2016 bats were also monitored with passive recorders at 4 onshore locations (ID's 5, 6, 8, 11 in Figure 1) situated at the coast of the Netherlands. An overview of offshore and onshore ultrasonic recorder locations in the Netherlands for the monitoring period 2012 – 2020 are shown in Figure 2.1 and, table 2.1. All recorders were positioned at a height of 15 – 33 m above mean sea level.

Table 2.1. Overview of the monitoring locations and years in the EEZ of the Netherlands and Belgium

Location	EEZ	Structure	Height	Monitoring year												
				2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
OWEZ Meteomast	NL	Mast	15	x	x	x										
PAWP WTG 22	NL	Wind turbine	15	x	x											
PAWP OHVS	NL	OHVS	15			x	x	x	x	x	x	x				
IJmuiden meteo mast	NL	Mast	19			x	x									
Luchterduinen	NL	OHVS	15				x	x	x	x	x	x				
Europlatform	NL	Platform	15				x	x		x	x	x				
Lichteiland Goeree	NL	Platform	15				x	x	x	x	x	x				
Belwind OHVS	B	OHVS	20				x	x	x	x	x	x				
C-power OHVS	B	OHVS	15				x	x		x	x	x				
Neptune platform L10A-AC	NL	Platform	17					x	x	x	x	x				
Neptune platform K12-BP	NL	Platform	20					x	x	x	x	x				
Gemini OHVS 2 Buitengaats	NL	Platform	26					x		x	x	x				
Wintershall P6-A	NL	Platform	23					x	x	x	x	x				
Dana P11-B	NL	Platform	25								x	x				
Wintershall K13-A	NL	Platform	25								x	x				
Petrogas P9-A (Horizon)	NL	Platform	33							x	x	x				
Petrogas Q1-A (Helder)	NL	Platform	25							x	x	x				
C-power turbine G01	B	Wind turbine	17						x							
C-power turbine G01	B	Wind turbine	94						x							
C-power turbine G03	B	Wind turbine	17						x							
C-power turbine H01	B	Wind turbine	17						x							
C-power turbine H02	B	Wind turbine	17						x							
C-power turbine H02	B	Wind turbine	94						x							
C-power turbine I01	B	Wind turbine	17						x							
C-power turbine I02	B	Wind turbine	94						x							
C-power turbine I03	B	Wind turbine	17						x							
C-power turbine J01	B	Wind turbine	17						x							
C-power turbine J01	B	Wind turbine	94						x							
Norther OHVS cable deck	B	OHVS	19										x	x	x	x
Norther WTG B01	B	Wind turbine	19											x		
Norther OHVS 1st deck	B	OHVS	23													x
Northwester II OHVS top deck	B	OHVS	36.5									x	x	x	x	
Northwester II cable deck	B	OHVS	18													x
Scheurwielingen MOW 4	B	Mast	10									x	x			
Wandelaar MOW 0	B	Mast	10										x	x	x	
Westhinder MOW 7	B	Mast	25													x

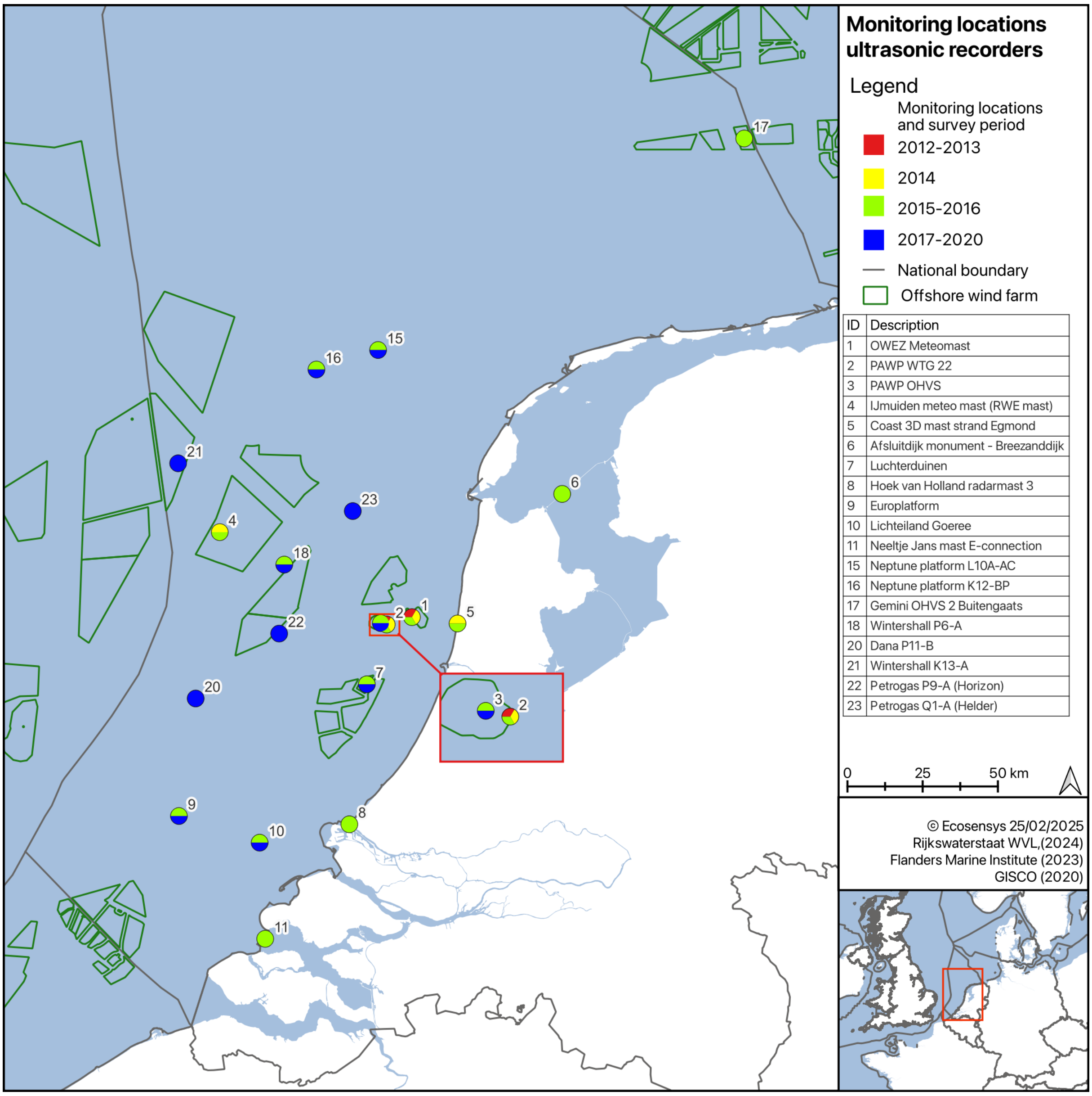


Figure 2.1. Acoustic monitoring locations and survey periods 2012 -2020 in the Dutch EEZ (data sources: Jonge Poerink et al., 2013, Lagerveld et al., 2014b, 2017 & 2022 and Wozep).

In addition, acoustic data were collected at the North Sea near the Dutch EEZ in Belgium (Brabant *et al*., 2019 & 2021) and Germany (Hüppop & Hill, 2016 and Seebens-Hoyer *et al*., 2020).
The Belgian surveys are carried out by the Institute of Natural Sciences at several locations in Belgian waters. The data were collected in OWFs and on platforms from the Flemish Agency for Maritime Services and Coast. In 2017, acoustic data were also collected at nacelle height (94 m) at several wind turbines within the C-Power wind farm.

An overview of offshore and onshore ultrasonic recorder locations in the Belgian EEZ for the monitoring period 2015 – 2024 is shown in Figure 2.2. and table 2.1. Except for the recorders at nacelle height, all Belgian offshore recorders were positioned at a height of 10 – 36.5 m above mean sea level. The recorders at nacelle height were positioned at 94 m above mean sea level.

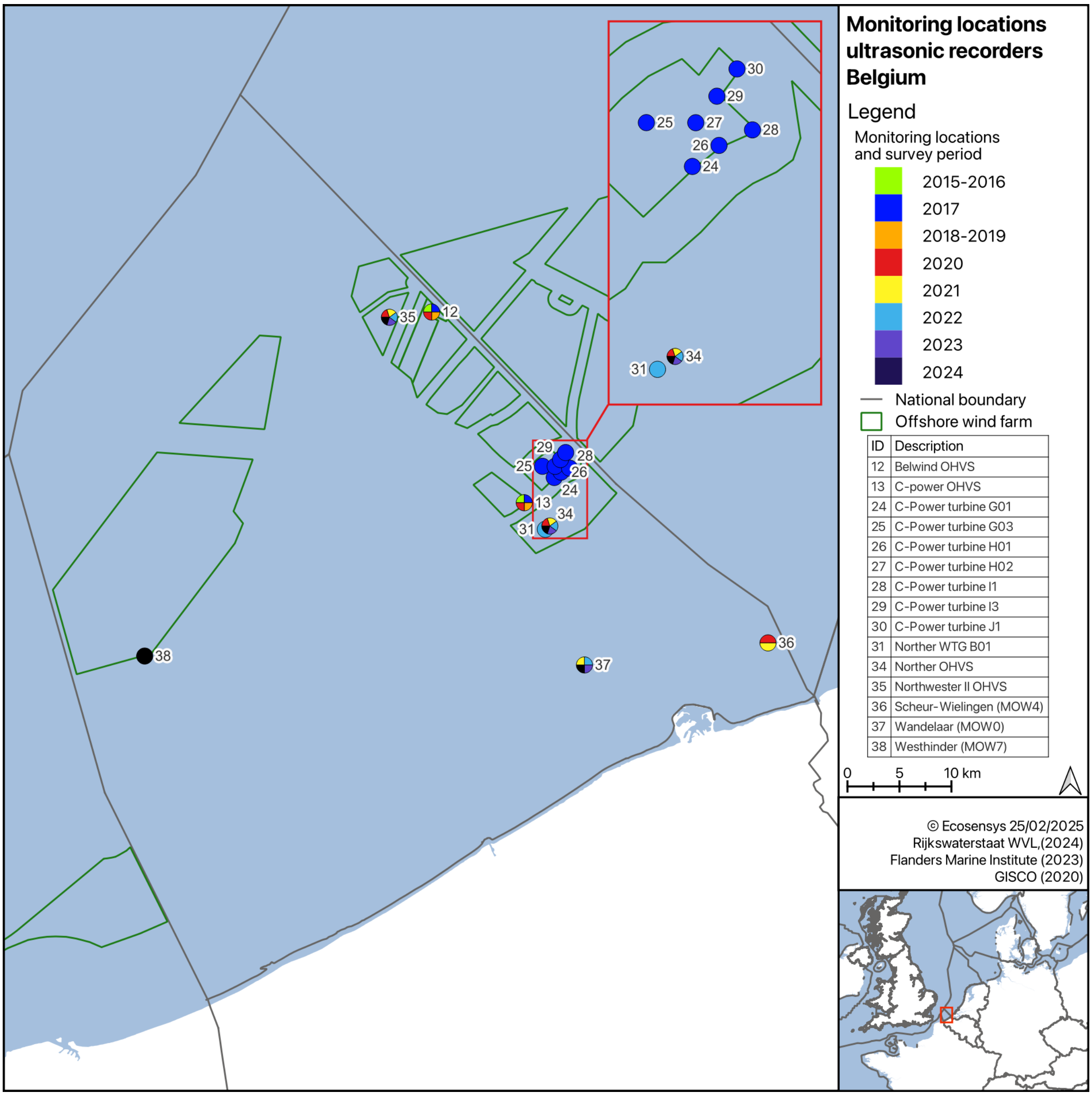


Figure 2.2 Offshore acoustic monitoring locations and survey periods 2015 -2024 in the Belgian EEZ (data source: KBIN-MARECO)

Hüppop & Hill (2016) collected acoustic data at the offshore research platform FINO 1 (see figure 2.3) from August 2004 to December 2015 the system was operational throughout the year in approximately 3530 out of 4148 nights from sunset to sunrise. The recorder at FINO 1 was positioned at 22 m above mean sea level. From 2017 to 2019, offshore data were collected at the research platforms FINO 1 and FINO 3, the buoy Nordseeboje II, the light house of Helgoland and the Island of Helgoland (Seebens-Hoyer *et al.,* 2020).

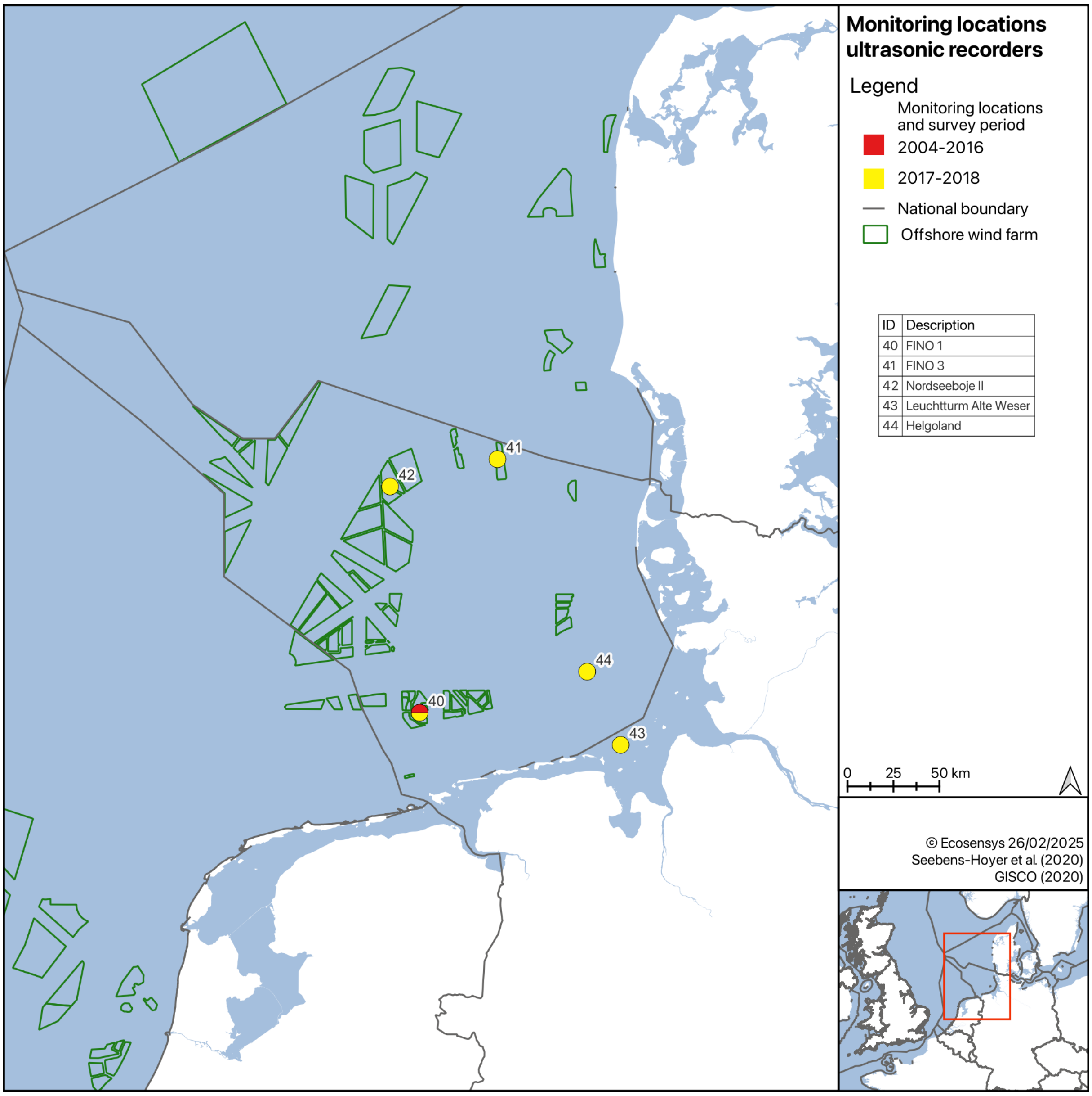


Figure 2.3 Offshore acoustic monitoring locations and survey periods 2004 -2018 in the German EEZ (data source: Seebens – Hoyer et al., 2020)

2.1.2 Monitoring periods

The monitoring periods for the different locations and monitoring years as well as the quality of the dataset in the Dutch EEZ are presented in figure 2.3. The quality of the collected datasets is determined by the monitoring period, the performance of the recorders and sensitivity of the microphones. Monitoring periods with constant poor microphone performance, downtime or extreme noise levels are classified 'poor'. Monitoring periods with alternating periods of good and bad microphone performance or extreme noise levels are classified 'moderate'. All other monitoring periods are classified 'good'.

Figure 2.4. Overview of the monitoring locations - years in the Dutch EEZ, the monitoring periods and the quality of the acoustic datasets (graph 'A' above: period 2012 – 2017, graph 'B' below: period 2018 – 2020). The blue lines mark periods of the Nathusius' pipistrelle migration peaks in spring and autumn.

The monitoring periods for the different locations and monitoring years as well as the quality of the dataset in the Belgian EEZ are presented in figure 2.4.

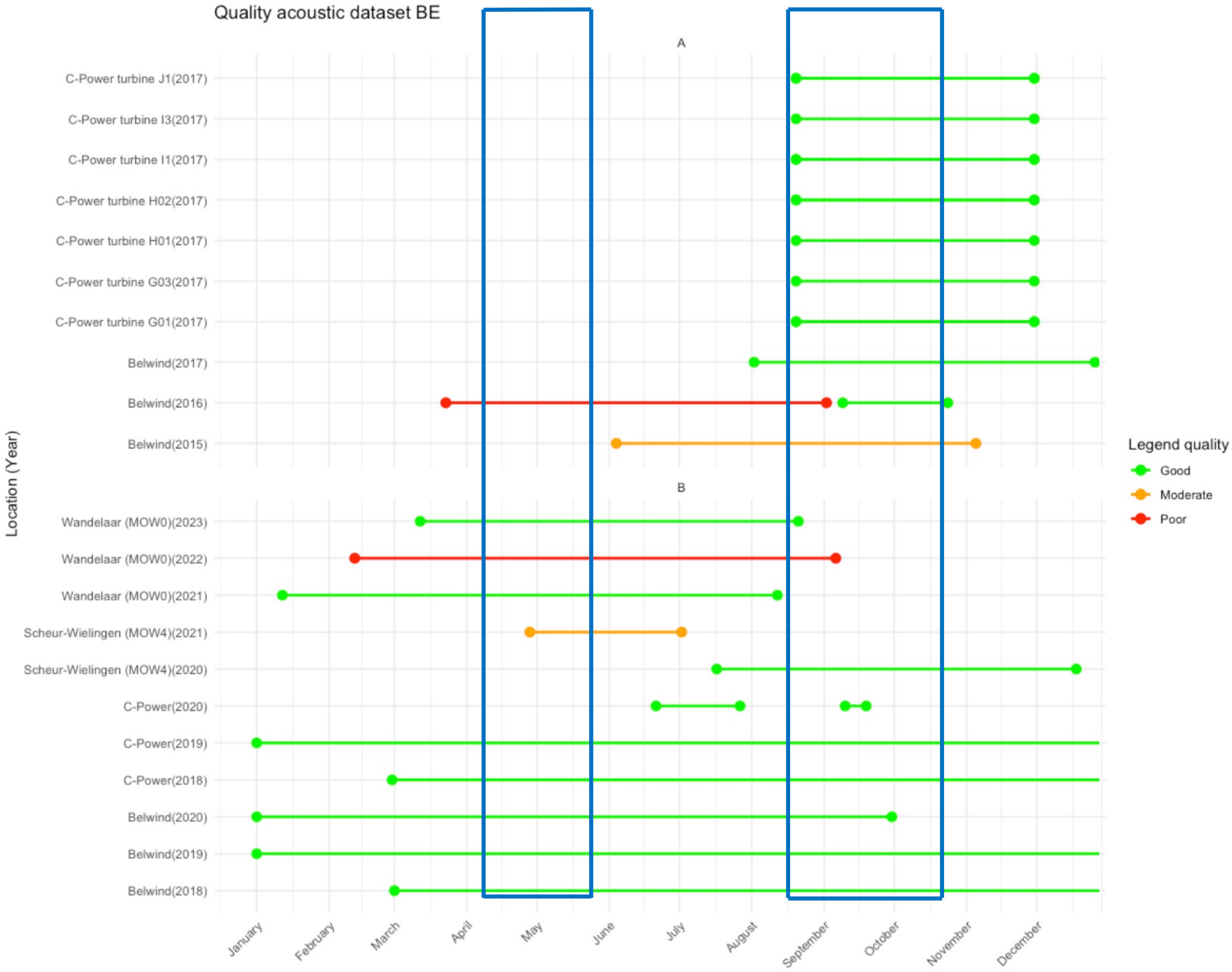


Figure 2.5. Overview of the monitoring locations - years in the Belgian EEZ, the monitoring periods and the quality of the acoustic datasets (graph 'A' above: period 2015 – 2017, graph 'B' below: period 2018 – 2023). The blue lines mark periods of the Nathusius' pipistrelle migration peaks in spring and autumn.

2.1.3 Acoustic dataset

In Table 2.3, the number of Nathusius' pipistrelle recordings per location and year is summarized.

Table 2.3. Number of recordings of Nathusius' pipistrelle at monitoring locations within the Dutch and Belgian Exclusive Economic Zones (EEZ) for each combination of monitoring location and monitoring year.

Location	EEZ	Structure	Height	number of P. nathusii recordings per monitoring year													Total
				2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	
OWEZ Meteomast	NL	Mast	15	185	152	286											623
PAWP WTG 22	NL	Wind turbine	15	25	44												69
PAWP OHVS	NL	OHVS	15			113	16	37	57	8	60	37					328
IJmuiden meteo mast	NL	Mast	19			1315	28										1343
Luchterduinen	NL	OHVS	15				16	25	8	126	65	154					394
Europlatform	NL	Platform	15				47	32		5	12	4					100
Lichteiland Goeree	NL	Platform	15				99	323	412	285	83	3					1205
Belwind OHVS	B	OHVS	20				1264	15	1	53	172	4					1509
C-power OHVS	B	OHVS	15				-	-	-	87	72	11					170
Neptune platform L10A-AC	NL	Platform	17					28	125	1334	39	0					1526
Neptune platform K12-BP	NL	Platform	20					20	3	15	39	4					81
Gemini OHVS 2 Buitengaats	NL	Platform	26					57		27	38	27					149
Wintershall P6-A	NL	Platform	23					780	8	210	208	99					1305
Dana P11-B	NL	Platform	25								447	233					680
Wintershall K13-A	NL	Platform	25								120	42					162
Petrogas P9-A (Horizon)	NL	Platform	33							0	34	95					129
Petrogas Q1-A (Helder)	NL	Platform	25							8	24	16					48
C-power turbine G01	B	Wind turbine	17						17								17
C-power turbine G01	B	Wind turbine	94						2								2
C-power turbine G03	B	Wind turbine	17						30								30
C-power turbine H01	B	Wind turbine	17						7								7
C-power turbine H02	B	Wind turbine	17						19								19
C-power turbine H02	B	Wind turbine	94						6								6
C-power turbine I01	B	Wind turbine	17						16								16
C-power turbine I02	B	Wind turbine	94						1								1
C-power turbine I03	B	Wind turbine	17						7								7
C-power turbine J01	B	Wind turbine	17						7								7
C-power turbine J01	B	Wind turbine	94						0								0
Norther OHVS cable deck	B	OHVS	19										4	36	0	15	55
Norther WTG B01	B	Wind turbine	19											0			0
Norther OHVS 1st deck	B	OHVS	23													112	112
Northwester II OHVS top deck	B	OHVS	36.5									2	0	14	0		16
Northwester II cable deck	B	OHVS	18													21	21
Scheurwielingen MOW 4	B	Mast	10									111	0				111
Wandelaar MOW 0	B	Mast	10										42	0	125		167
Westhinder MOW 7	B	Mast	25													0	0
			Total	210	196	1714	1470	1317	726	2158	1413	842	46	50	125	148	10415

Between 2015 and 2020, a significant number of Nathusius' pipistrelle recordings were collected. This dataset is a starting point for further data analysis. However, acoustic monitoring from 2021 to 2024 was limited to only a few locations in Belgium, resulting in a much lower total number of recordings each year.

2.1.4 Acoustic results

At offshore acoustic monitoring locations, the number of detections is relatively low compared to onshore locations. At offshore locations the average percentage of nights with detections of Nathusius' pipistrelle was 11%. At onshore locations this percentage was 66% (Lagerveld *et al.*, 2017). Lagerveld *et al*. do not report the exact numbers of detections per night. However, it can be concluded from the presented graphs that during these nights, the number of offshore detections was significantly lower compared to onshore locations (Lagerveld et al., 2017).

The acoustic data collected in a Belgian wind farm at 16 meter above mean sea level (MSL) and at nacelle height (94 m MSL) show a significant decrease of bat activity at nacelle height (Brabant *et al.,* 2019). The data of Brabant et al. (2019) are summarized in table 2.4.

Table 2.4 Number of bat recordings per Batcorder from 8 August until 30 November 2017 installed in the C-Power wind farm (Belgian EEZ). Low, number of recordings at 16 m above mean sea level (MSL); High, number of recordings at 93 m above MSL; Records, number of bat recordings.

Turbine	Height	Records
G01	Low	23
	High	2
G03	Low	35
H01	Low	11
H02	Low	26
	High	6
I1	Low	17
	High	1
I3	Low	7
J1	Low	23
	High	0
	Total	151
	Average low	20.3
	Average high	2.3

Table 2.4 shows that the number of recordings at nacelle height is significantly lower compared to the number of recordings at 16 m above MSL. The average number of recordings at 94 m (MSL) were around 10% of the number of recordings made at 16 m (MSL). It should be noted however that the survey comprised only a limited number of sampling points during a single autumn migration period in 2017.

The range of recordings at nacelle height is limited to 0 – 6 recordings for the whole autumn migration period. This is far below the average number of recordings normally found at the same height at onshore wind turbines in coastal areas (Bach *et al*., 2020a).

2.2 Telemetry data

2.2.1 Telemetry dataset

Aside from acoustic data, Lagerveld *et al*. (2017 and 2022) also collected telemetry data of tagged Nathusius' pipistrelles and common noctules (Lagerveld et al., 2021 and 2024a). The common noctules were followed with a GPS logger. A total of 36 different individuals were tagged with GPS loggers and provided spatial data. During the autumn migration periods from 2018 to 2020, a total of 409 Nathusius' pipistrelles were tagged and tracked using Motus automated telemetry receivers (Lagerveld et al., 2024a). Additionally, 41 Nathusius' pipistrelles were tagged and monitored during the spring migration periods of 2021 and 2022 (Lagerveld et al., 2024b).

2.2.2 Telemetry results

The telemetry data of common noctules indicate that this species is predominantly terrestrial, exhibiting minimal activity in maritime habitats. By tagging 36 common noctules, a total of 14 GPS fixes were obtained over the North Sea (1.2% of the data, n=1145), reaching a distance of only up to 2.7 km from shore. Therefore, the potential negative impacts from offshore wind farms on this species are low.

The telemetry research of Nathusius' pipistrelles confirmed that most individuals are migrating along the Dutch coast (Lagerveld *et al*., 2024a). Approximately 69% of the tagged bats showing directional movement were migrating south along the coast. A relatively small percentage (6 - 10%) of the tagged bats departed over sea directly from the study area in North-Holland. Eight Nathusius' pipistrelles departed over sea. Only one individual certainly crossed the North Sea and was detected in the UK (Lagerveld *et al.*, 2024a). According to Lagerveld *et al.* (2024a) some of the tagged bats that initially followed the coast may have migrated over sea further south along the coast. Therefore Lagerveld *et al*. (2024a) regard the overall percentage of 6-10% of bats departing over sea as a conservative estimate. It should be noted however that Nathusius' pipistrelles are also hibernating in the western part of the Netherlands, and tagged individuals might not be detected further south because they have arrived at their hibernacula.
Of the 41 Nathusius' pipistrelles that were tagged and tracked in spring 2021 and 2022 at the East coast of the UK, 23 bats were detected in the UK and 15 bats were detected overseas in Belgium, the Netherlands and Germany (Lagerveld et al., 2024b).
Despite tagging many bats, the current data on North Sea crossings of Nathusius' pipistrelles is too limited to accurately estimate the number of bat casualties at offshore wind farms (OWFs). While these telemetry data do not provide enough information to determine the actual number of offshore bat fatalities, they can still be useful to better understand the mechanisms of offshore bat migration.

3. BAT POPULATION IMPACT ASSESSMENT STRATEGY

According to the European Union Habitats Directive (Council Directive 92/43/EEC) the population of Nathusius' pipistrelle should be maintained or restored to a 'favorable conservation status'. To assess the impact of OWFs in the Dutch Exclusive Economic Zone (EEZ) at population level of that species, the following principal steps have to be taken:

1. Collision risk assessment: Estimate the average number of bat casualties / offshore wind turbine.
2. Cumulative risk assessment: Estimate the total number of bat casualties to be expected each year at OWFs within the Dutch EEZ.
3. Estimate the size of the population of Nathusius' pipistrelle in the Netherlands.
4. Assess the impact of the yearly cumulative number of bat casualties caused by OWFs within the EEZ on the conservation status of the population of Nathusius' pipistrelle in the Netherlands.

In the following paragraphs the abovementioned steps are elaborated.

3.1 Collision risk assessment strategy

3.1.1 Theoretical collision risk models

For onshore wind farms, the number of casualties can be estimated by carcass searches. Under offshore circumstances, carcass searches are impossible. Collided bats will drop to the seawater surface and be washed away or removed by seabirds and other marine organisms quickly. Alternative techniques like thermal imaging and radar technology could detect colliding bats. However, the technical challenges of using these technologies under offshore circumstances and the low number of bats passing OWFs lead to a low chance of detecting a collision. Before these techniques will shed light on the collision risk of bats in OWFs, many years of research at different turbines will be needed.

The collision risk for bats can also be estimated with theoretical collision risk models. Several collision risk models, like ProBat and Chirotech, are available to predict the number of bat casualties at wind farms on land and to calculate bat-friendly cut-in wind speeds (wind turbine start-up wind speeds). Most of these models are validated by carcass searches in combination with acoustic measurements.

ProBat is a mathematical / statistical model that estimates the site-specific collision risk for bats, based on acoustic monitoring of the bat activity (at nacelle height). The algorithms of the ProBat model are based on the comparison of acoustic data and bat casualty data collected in onshore wind farms in Germany. These data were collected and analyzed as part of the extensive German national RENEBAT research program (RENEBAT I-III, Behr *et al*. 2015 & 2019), commissioned by the Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety), which was focusing on reducing bat collisions in onshore wind farms. To develop the ProBat model, the number of casualties per wind turbine per night were compared to the acoustic bat activity measured at the nacelle each night. Acoustic activity data were recorded with microphones mounted at the nacelle of wind turbines, directed downward along the wind turbine tower. By comparing a large set of nightly acoustic data with corresponding casualty data, the model's algorithms enable the estimation of collision casualties at specific wind turbine types and locations based solely on acoustic data.

The acoustic data were collected using recorders from the type 'Batcorder' (ecoObs GmbH, Germany) and 'Avisoft recorder' (Avisoft Bioacoustics, Germany) now available as 'BATmode' (bioacoustictechnology GmbH, Germany)**.** Because of the dimensions of modern rotor blades and the limited sampling distance of bat recorders, only a relatively small part of the total volume of the rotor swept zone can be sampled in this way. For a species like Nathusius' pipistrelle the recorded area is restricted to a maximum range of 25 – 35 m distance from the microphone and due to the position of the microphone only restricted to the area below the nacelle (Simon et al. 2015, Voigt et al. 2021).

As the data of the RENEBAT projects were gathered all over Germany, the ProBat algorithms are therefore based on data from a variety of landscapes and bat habitats, including mountains and forested areas. Data from coastal wind farms were underrepresented in the dataset on which previous versions of ProBat were based, but this was improved in the latest version (2019) by adding more data gathered in wind farms in coastal areas in e.g. Niedersachsen and Mecklenburg-Vorpommern

Wind farms located in open coastal areas are the most similar to offshore wind farms. Since the ProBat model is not specifically designed to estimate bat casualties at offshore wind farms, using the algorithms developed for coastal areas would be the best approach for making offshore estimates. However, there are differences between bat activity in coastal wind farms and offshore wind farms that need further investigation and consideration. For instance, migrating bats near the coast may exhibit 'drift migration.' This occurs when unfavorable wind conditions, such as strong headwinds from inland areas, cause bats to concentrate along the shoreline (Ijäs et al., 2017). Nathusius' pipistrelles, in particular, tend to avoid flying over large bodies of water, resulting in higher densities of bats migration along the coast (Ciechanowski et al., 2015). In contrast, bats already flying over the North Sea are unlikely to show drift migration. Wind farms located offshore can also attract migrating bats due to lighting or adverse weather conditions. These factors require careful consideration when applying the collision risk model.

The distribution of bat activity relative to the distance from the nacelle of the wind turbine was already taken into account within the RENEBAT project, from which a correction formula for various rotor sizes was developed (Hochradel *et al.* 2015). The wind turbines that were investigated by the RENEBAT project and which provided the data for the ProBat model were relatively small by today's standards, with a hub height of approximately 98 meters and a rotor diameter of approximately 70 meters. The currently installed wind turbines in Dutch and Belgian water have a hub height ranging between 59 and 108 m (LAT). Ongoing developments result in larger wind turbines and the generation of offshore wind turbines which will be operational by 2030 will reach a hub height of up to 165m. As the rotor swept zone increases with larger turbines, so does the likelihood of collisions with rotor blades. Additionally, the tip speed of rotors can also increase up to a certain limit, which may result in higher casualty rates for larger wind turbines. At the same time, the minimum rotor tip height rises with higher turbine towers. Since bat activity generally decreases with height, this will reduce the risk of collision casualties. It is also worth noting that the rotor-swept zone of offshore wind turbines is positioned at a lower level compared to similarly sized turbines onshore.

To predict casualties, acoustic measurements are conducted at the nacelle throughout the entire bat season (March – November). To date, data collected at nacelle height in the southern North Sea are limited (see Table 2.4). Within the Dutch EEZ, no nacelle-level data have been collected under the Wozep program. However, in the Belgian EEZ, some measurements at nacelle height were conducted in 2017 at wind turbines in the Belgian wind farm C-Power (Brabant et al., 2019). These measurements were limited to only a part of the autumn migration period, meaning that most of the collected data are suboptimal for use as input for the prediction model.

3.1.2 Application of collision risk models at sea

Strategy

To estimate the number of casualties at sea based on currently available data, the following approaches are conceivable:

1. **A “worst-case” approach**: data from measurements taken at approximately 15–35 meters above sea level are used as if they were collected from the nacelle. Since bat activity decreases with height, this approach would likely overestimate the actual number of casualties. The worst-case approach is presented below in a flow diagram (figure 3.1).
2. **Extrapolation of acoustic bat activity:** . Measurements taken at approximately 15–35 meters above sea level could be used to estimate activity at nacelle height, based on knowledge of bat activity stratification across different heights.

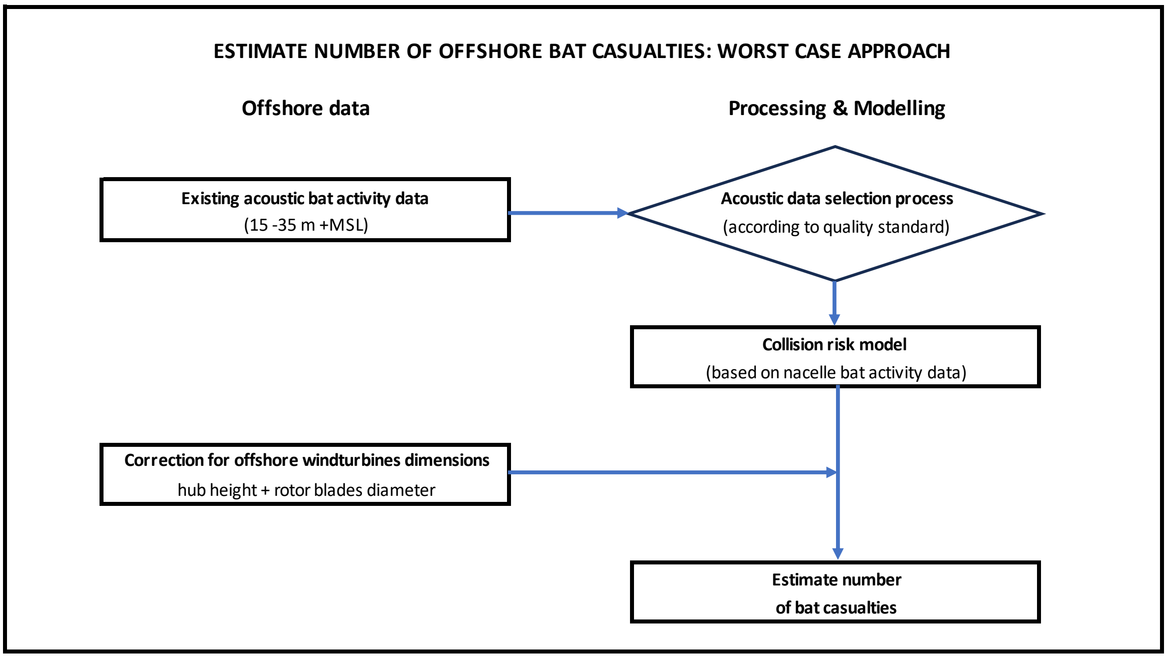


Figure 3.1 Flow diagram of the ‘worst case’ approach to estimate the number of bat casualties at offshore wind farms

In the last decade, significant knowledge has been acquired regarding the vertical distribution, or stratification, of bat activity. Most data on bat activity stratification comes from acoustic studies conducted on measurement masts and cranes (Hurst *et al.* 2017; Meyer 2022; Roemer *et al.* 2017 and 2019; Wellig *et al.* 2018;). In recent years, it has become common practice in some parts of Germany to install an additional microphone in the tower of a wind turbine, alongside the standard microphone in the nacelle. Some of this data is publicly available and can be used as a data source (Bach et al. 2020,).

A recent study funded by the Bundesamt für Naturschutz (Federal agency for nature conservation in Germany) focused on the vertical distribution of bat activity in Germany (Oekofor, in preparation). The combined effects of rotor diameter and turbine height have been analyzed by sampling the altitudinal stratification of bats with microphones positioned at different heights at the base, tower, and nacelle of wind turbines.

The study was conducted at six different locations at one wind turbine per site, in four different natural regions within Germany. At each wind turbine, one microphone was installed in the nacelle, two microphones were placed on the tower and one at ground level during the years 2022 and 2023. By combining the data from this extensive study with a large dataset collected by Bach (2020) at wind turbines in Northern Germany and 31 turbine-years of site assessment studies that included both, turbine and tower microphones, a thorough analysis of bat activity stratification under various weather conditions was achieved. An example of bat activity density in relation to the horizontal distance from the turbine mast and height is shown in figure 3.2. The findings on the vertical distribution of bat activity from this study can be used to refine collision rate calculations for different hub heights and rotor diameters in the ProBat software and to adapt the ProBat model to the dimensions of offshore wind turbines (personal communication with Oliver Behr, Oekofor GbR). The results will further allow to combine data sampled at different heights of turbines in one model correcting for sampling height.

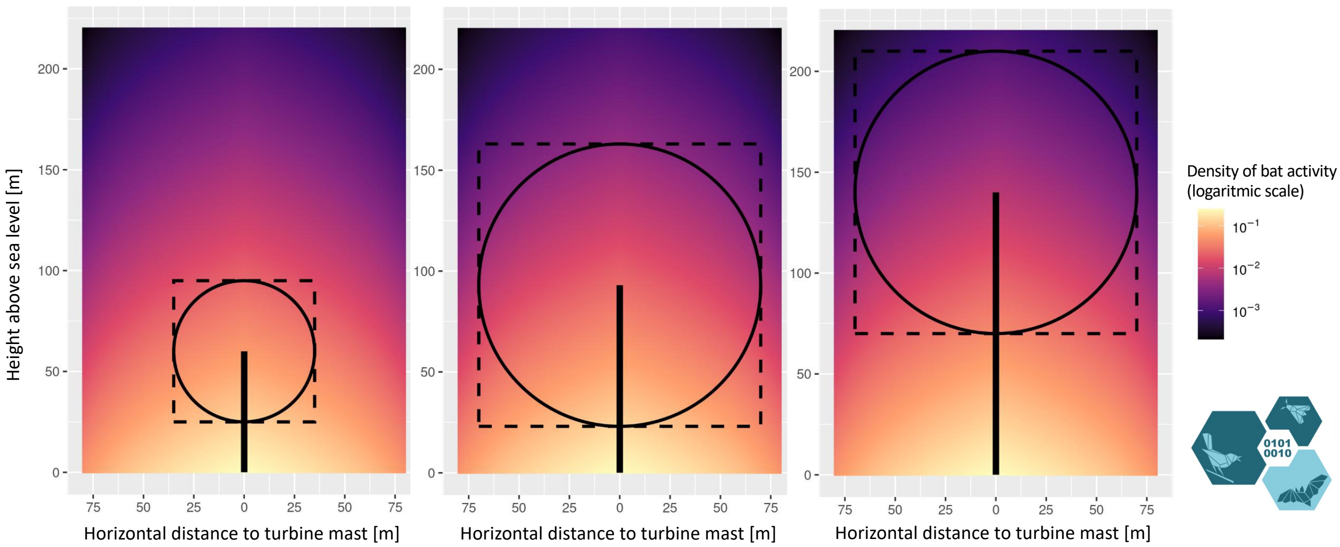
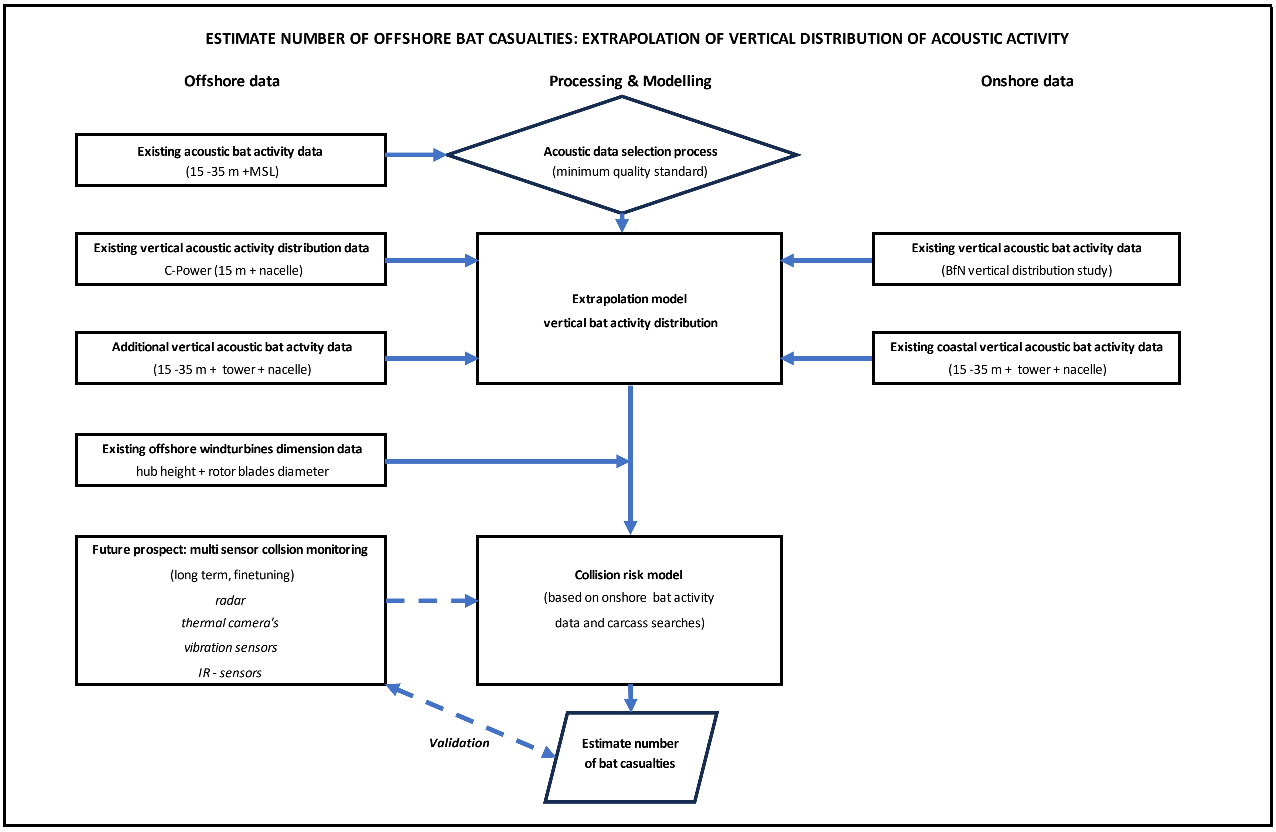


Figure 3.2 Vertical distribution and distance to the turbine mast of bat activity in relation to turbine height (source: Oekofor GbR)

The vertical distribution extrapolation method is presented below in a flow diagram in figure 3.3.

Figure 3.3 Flow diagram of the vertical distribution method to estimate the number of bat casualties at offshore wind farms



Input data

The necessary input data for the application of collision risk models at an OWF are listed here below. It is essential that the acoustic input dataset is complete, consistent, and thoroughly reviewed beforehand.

For each monitoring location - year combination the following input data are required to achieve a consistent model output:

OWF data

- Site name
- Geographic Coordinates (at least one decimal place, preferably more; please specify the format, e.g., UTM)
- Number of turbines
- Surface area of the OWF
- Type of structure (mast, oil platform, wind turbine etc.)
- Maximum height of the structure

Wind turbine data

- Type of wind turbine
- Tower height
- Rotor diameter
- Rotor speed (n/min)

Acoustic survey data

- Type and version of the ultrasonic recorder
- Height and orientation of the microphone
- Installation method (e.g. drilling, magnetic mount, clamps etc.)
- Settings: min. frequency, gain, threshold value, post trigger time
- Microphone calibration before and/or after the recording?
- Was microphone sensitivity monitored during recording using test signals ?
- Sensitivity data of the microphone: Figures or tables showing sensitivity values during recording (e.g., "TSL" analysis in bcAdmin for the Batcorder, or "Reference Level" under "Evaluation" in BATmode (Avisoft recorder).
- Validity Period:
    - Recording Period
    - Details of Downtime of the recorder (e.g., periods when microphone sensitivity deviated from the calibrated value by more than ±6 dB).

Wind and Temperature Data of the WT

- Period: as long as possible, ideally several years per WT
- File Content:
    - timestamp (time) with time zone specification (including summer/winter time)
    - wind speed (m/s) and ambient temperature (°C) for the respective WT (potentially precipitation data) in 10-minute intervals
- Verify if the timestamp refers to the start or the end of the 10-minute interval (This varies by manufacturer.)

Bat activity data

- Period: as long and complete as possible, at least covering the spring and autumn migration periods of Nathusius' pipistrelle
- File Content:
    - Timestamp with time zone specification (including summer/winter time)
    - Species identification as detailed as possible (especially identification of the Nathusius' pipistrelle; raw acoustic detection data are not required)

In order to apply the model on offshore situations, it is important to collect bat activity data at sea using the same types of recorders and recorder settings, to ensure consistency with the model. In table 3.1 an overview of the type of ultrasonic recorders used at each location and monitoring year is given.

Table 3.1. Overview of the type of ultrasonic recorders used at each location and monitoring year (BC=Batcorder, AV=Avisoft recorder)

Location	EEZ	Structure	Height	Type of recorder / monitoring year												
				2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
OWEZ Meteomast	NL	Mast	15	BC	BC	BC										
PAWP WTG 22	NL	Wind turbine	15	BC	BC											
PAWP OHVS	NL	OHVS	15			BC	BC	BC	AV	AV	AV	AV				
IJmuiden meteo mast	NL	Mast	19			BC	BC									
Luchterduinen	NL	OHVS	15				BC	BC		AV	AV	AV				
Europlatform	NL	Platform	15				BC	BC		AV	AV	AV				
Lichteiland Goeree	NL	Platform	15				BC	BC	AV	AV	AV	AV				
Belwind OHVS	B	OHVS	20				BC	BC	AV	AV	AV	AV				
C-power OHVS	B	OHVS	15				BC	BC		AV	AV	AV				
Neptune platform L10A-AC	NL	Platform	17					BC	AV	AV	AV	AV				
Neptune platform K12-BP	NL	Platform	20					BC	AV	AV	AV	AV				
Gemini OHVS 2 Buitengaats	NL	Platform	26					BC		AV	AV	AV				
Wintershall P6-A	NL	Platform	23					BC	AV	AV	AV	AV				
Fino3	NL	Mast	22					BC								
Dana P11-B	NL	Platform	25								AV	AV				
Wintershall K13-A	NL	Platform	25								AV	AV				
Petrogas P9-A (Horizon)	NL	Platform	33							AV	AV	AV				
Petrogas Q1-A (Helder)	NL	Platform	25							AV	AV	AV				
C-power turbine G01	B	Wind turbine	17						BC							
C-power turbine G01	B	Wind turbine	94						BC							
C-power turbine G03	B	Wind turbine	17						BC							
C-power turbine H01	B	Wind turbine	17						BC							
C-power turbine H02	B	Wind turbine	17						BC							
C-power turbine H02	B	Wind turbine	94						BC							
C-power turbine I01	B	Wind turbine	17						BC							
C-power turbine I02	B	Wind turbine	94						BC							
C-power turbine I03	B	Wind turbine	17						BC							
C-power turbine J01	B	Wind turbine	17						BC							
C-power turbine J01	B	Wind turbine	94						BC							
Norther OHVS cable deck	B	OHVS	19										BC	BC	BC	BC
Norther WTG B01	B	Wind turbine	19											BC		
Norther OHVS 1st deck	B	OHVS	23													BC
Northwester II OHVS top deck	B	OHVS	36.5									BC	BC	BC	BC	
Northwester II cable deck	B	OHVS	18													BC
Scheurwielingen MOW 4	B	Mast	10									BC	BC			
Wandelaar MOW 0	B	Mast	10										BC	BC	BC	
Westhinder MOW 7	B	Mast	25													BC

Overall, the data collected in the Dutch EEZ from 2012 to 2020 generally meets the specified data requirements. All data were collected using high quality acoustic recorders (Batcorders or Avisoft recorders, see table 3.1).

Both the spring and autumn migration periods are important for data collection. According to Seebens Hoyer et al. (2020), monitoring should take place during the peak of migration, covering a duration of at least one month. For Germany, the authors state that data is only considered representative for spring migration if it includes the month of May, and for autumn migration, it should cover the period from mid-August to mid-September. For the southern North Sea these periods should be a little earlier in spring and a little later in autumn. Combining the phenology data available from offshore and coastal areas in the Netherlands (Lagerveld, 2017 and 2022, Jonge Poerink & Dekker, 2018) the peak of spring migration in the southern North Sea region is in April - May. For autumn migration the peak is form mid-August until late October (Lagerveld et al. 2023).

By applying the minimum monitoring period standards set by Seebens-Hoyer et al. (2020) to the dataset from the Netherlands and Belgium, approximately 80% of the location-year combinations monitored, specifically during the spring and autumn migration periods, are considered sufficiently representative.

The following remarks should be made regarding the use of the collision risk models to estimate the number of bat casualties at OWFs:

- The data used to validate are primarily based on onshore acoustic data.
- The algorithms are based on data collected at wind turbines with a maximum height of < 150m. Most wind turbines at sea are bigger than 150m.
- The correlation between acoustic activity and bat casualties found at onshore wind turbines (Behr *et al*., 2023; Runkel, 2020) cannot be validated by carcass searches at sea. However, it is a reasonable assumption that the measured acoustic bat activity at sea and the collision risk at offshore wind farms show a comparable correlation.
- The data collected at sea at nacelle height show far lower bat activity compared to the average bat activity recorded at onshore wind turbine in coastal areas. The bat activity at offshore windfarms might be so limited compared to the average bat activity at onshore windfarms that it is not sure whether the model can reliably estimate the number of bat casualties per wind turbine. In that case the number of bat casualties per offshore wind turbine is probably also significantly lower compared to the average onshore wind turbine. More research into the practical restrictions of the available models is needed.

Although models based on carcass searches cannot be validated for OWFs they could be useful tools to estimate the number of bat casualties at offshore wind farms. These models are available for a first estimate of offshore fatality numbers based on already existing acoustic surveys. It is likely that the measured acoustic bat activity at sea and the collision risk at offshore wind farms show a comparable correlation with onshore wind turbines situated close to the coast.

3.2 Cumulative risk assessment

To estimate the expected yearly cumulative number of bat casualties at OWFs within the Dutch North Sea the following steps should be taken:

1. Based on the measured bat activity at sea and the spatial migration ecology of bats a spatial analysis can be executed to establish areas of high and low bat activity. For the German part of the North Sea a similar spatial analysis based on acoustic data was already completed (Seebens-Hoyer *et al*., 2020). It should be noted that additional acoustic data will have to be collected first, before the spatial analysis for the Dutch part of the North Sea can be completed reliably.
2. For each wind farm an estimate of the number of bat casualties must be made using the collision risk model based on the local bat density according to the spatial analysis. Therefore, specifications of operational and planned wind farms (e.g. number of wind turbines, wind turbine dimensions, rotor speed, etc.) are needed.
3. Combining the estimated number of casualties for each wind farm renders the cumulative estimated number of bat casualties per year in the Dutch part of the North Sea.

The abovementioned steps are elaborated in the following paragraphs.

3.2.1 Spatial analysis bat activity distribution

Currently the number of Nathusius' pipistrelles migrating over the North Sea is unknown, as well as the spatial distribution and density of this species. The number and spatial distribution of bats flying over the North Sea is difficult to assess:

- Bats are primarily active at night, making visual observation only possible with thermal imaging or infrared (IR) cameras. However, these cameras can only capture bats over short distances, typically less than 50 to 100 meters.

- In the North Sea, bat observations are only feasible from offshore structures such as wind farms, oil platforms, measuring masts, and vessels.
- The density of bats over the North Sea is very low, even during the peak autumn migration period. As a result, the likelihood of observing an individual bat flying over the sea is extremely low. Therefore, relying on human observation from various points is not an effective method for mapping the spatial distribution and density of bats in this area.

On the positive side, the low density of bats over the North Sea allows for the estimation of the number of individuals by carefully analyzing acoustic data. The estimation of the number of bats flying offshore can be used for a more detailed assessment of the potential impact of offshore wind farms on the Dutch Nathusius' pipistrelle population (see §3.3.1). Since bat activity at sea is low, it is possible to distinguish sequences of recordings from individual bats. Typically, an individual bat is recorded for one or a few minutes before continuing its migratory flight. Seebens Hoyer et al. (2020) developed a separator for these recording sequences, based on statistical analysis of the German acoustic data set. It is important to note that the separator is not effective in determining whether two or more individuals are flying together during a (sequence of) recording(s). When multiple bats are flying simultaneously, this can be identified by analyzing the sonograms of the recordings.

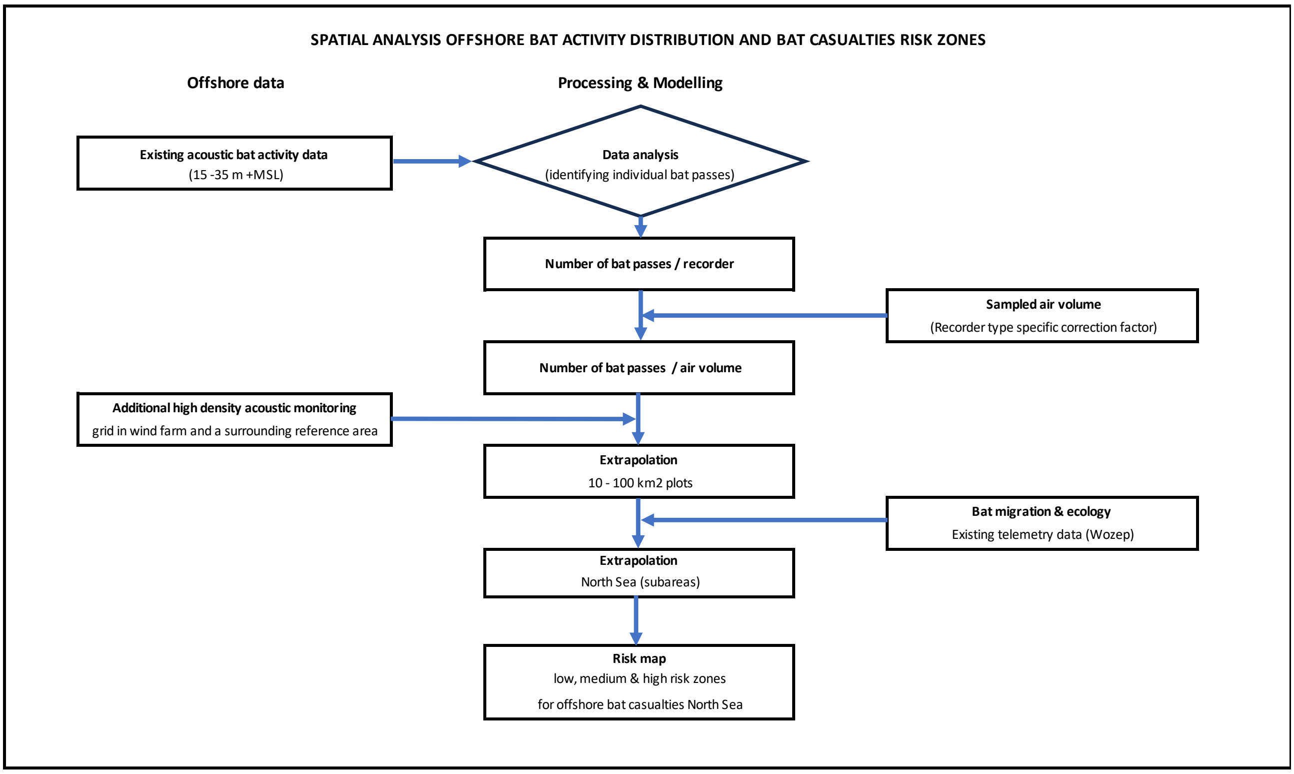
The acoustic data collected by an acoustic recorder reflect the acoustic activity of a specific air volume in front of the microphone. The recorder specific air volume is determined by the type of recorder, the recorder settings and the type of microphone used. Typically, a recorder is activated by the calls of Nathusius' pipistrelles at a distance of up to approximately 30 meters from the microphone (Simon et al. 2015, Voigt et al. 2021). Seebens Hoyer et al. (unpublished data, presented at the conference 'Evidenzbasierter Fledermausschutz bei Windkraftvorhaben'; 15 October 2024) developed a method to extrapolate the recorded number of Nathusius' pipistrelles within the monitored volume of the recorders to estimate species density per 10 km² in the North Sea and Baltic Sea. By combining these densities with knowledge of the species' migration ecology, Seebens Hoyer et al. created a heat map indicating low, medium, and high-risk areas for bat casualties in the German Exclusive Economic Zone (EEZ).

Given the fact that there are more Dutch and Belgian monitoring locations, which are also more evenly distributed over the North Sea compared to the German monitoring locations, applying the same methodology to the Dutch part of the North Sea could also be feasible.

A significant limitation of the method developed by Seebens Hoyer et al. is that it does not account for the attraction of bats to wind turbines and other structures at sea. These structures can draw bats from the surrounding area, which may result in a higher number of recordings. This higher number of recordings can lead to a higher calculated density of bats per 10 km², which could not represent the actual bat density. By monitoring bat activity with a dense network of passive recorders in a wind farm area, it is possible to investigate how much bats are attracted to wind turbines and other structures at sea. The recorders should not only be mounted on several wind turbines within a wind farm, but also on buoys at various distances from the wind turbines.

The spatial analysis of bat activity distributions is summarized in the flow diagram in figure 3.4.

Figure 3.4 Flow diagram of the spatial analysis of offshore bat activity to map offshore bat casualties risk zones.



3.2.2 Present and planned wind turbine inventory

In order to apply the collision risk model at the individual wind farm level, data of the location specific input variables are required. In tables 3.2 and 3.3 the necessary wind farm and turbine specifications are summarized.

Ideally, location specific turbine rotor speed data are also used in the collision risk model. These are currently lacking from the overview.

Table 3.2. Overview of existing and planned wind farms in the Dutch and Belgian EEZ showing the current status, year of start operational phase, total capacity, number of wind turbines, coordinates and area of the wind farm.

No	Name wind farm	Country	Status	Start operation Year	Capacity MW	N of turbines	Latitude WGS-84	Longitude WGS-84	Area km²
NL01	Offshore windpark Egmond aan Zee	NL	Existing wind farm	2007	108	36	52,606542	4,42136	27,0
NL02	Prinses Amalia Windparken	NL	Existing wind farm	2008	120	60	52,587865	4,223826	21,6
NL03	Luchterduinen	NL	Existing wind farm	2015	129	43	52,40509	4,163095	16,2
NL04	Gemini ZeeEnergie	NL	Existing wind farm	2017	300	75	54,0345	5,884242	34,8
NL05	Gemini Buitengaats	NL	Existing wind farm	2017	300	75	54,038334	6,041712	34,8
NL06	Borssele Kavel II	NL	Existing wind farm	2020	376	47	51,634978	3,069338	56,0
NL07	Borssele Kavel I	NL	Existing wind farm	2020	376	47	51,747253	3,06011	56,0
NL08	Borssele Kavel III	NL	Existing wind farm	2021	366	39	51,668879	2,969346	61,0
NL09	Borssele Kavel IV	NL	Existing wind farm	2021	366	39	51,736214	2,88212	61,0
NL10	Borssele Kavel V	NL	Existing wind farm	2021	19	2	51,709157	3,003306	0,6
NL11	Hollandse Kust Zuid Kavel IV	NL	Licensed wind farm	2023	374	34	52,330556	4,144927	54,0
NL12	Hollandse Kust Zuid Kavel III	NL	Licensed wind farm	2023	385	35	52,227635	4,014755	54,0
NL13	Hollandse Kust Zuid Kavel II	NL	Licensed wind farm	2023	385	35	52,291203	3,983368	52,0
NL14	Hollandse Kust Zuid Kavel I	NL	Licensed wind farm	2023	385	35	52,373173	4,0409	52,0
NL15	Hollandse Kust Noord Kavel V	NL	Licensed wind farm	2023	759	69	52,709669	4,259873	92,0
NL16	Hollandse Kust West Kavel VI & VII	NL	-	2026	1520	108	52,677723	3,763402	176,2
NL17	IJmuiden Ver Gamma	NL	Designated wind farm	2029	2295	153	53,028274	3,72945	192,9
NL18	IJmuiden Ver Alpha & Beta	NL	Designated wind farm	2029	4020	268	52,859551	3,528962	372,1
NL19	Nederwiek Noord	NL	-	2030	4600	306	53,408954	3,255527	418,0
NL20	Nederwiek Zuid	NL	-	2030	2295	153	53,099579	3,178079	156,0
NL21	Hollandse Kust West kavel VIII	NL	-	2031	760	38	52,556281	3,633218	69,1
NL22	Ten noorden van de Wadden west	NL	-	2031	795	53	54,022957	5,655941	70,0
NL23	Doordewind	NL	-	2031	2300	115	54,273738	5,657578	209,0
BE01	Belwind	BE	Existing wind farm	2011	165	55	51,670367	2,803114	17,0
BE02	C-Power	BE	Existing wind farm	2013	325	54	51,539111	2,921969	12,1
BE03	Northwind	BE	Existing wind farm	2014	216	72	51,619411	2,90185	13,8
BE04	Nobelwind	BE	Existing wind farm	2017	165	50	51,67848	2,78715	9,9
BE05	Rentel	BE	Existing wind farm	2018	309	42	51,591348	2,944563	23,3
BE06	Norther	BE	Existing wind farm	2019	369,6	44	51,526941	3,013164	44,0
BE07	Northwester 2	BE	Existing wind farm	2020	219	23	51,686538	2,75263	15,2
BE08	Seamade - Seastar	BE	Existing wind farm	2020	252	30	51,63418	2,861651	18,4
BE09	Seamade - Mermaid	BE	Existing wind farm	2020	235	28	51,718611	2,73949	16,3
BE10	Princess Elisabeth Zone - Area 1	BE	Designated wind farm	2029	700	32 - 54	51,62113	2,556757	46,0
BE11	Princess Elisabeth Zone - Area 2	BE	Designated wind farm	2030	1225 - 1400	64 - 105	51,45167	2,463333	103,0
BE12	Princess Elisabeth Zone - Area 3	BE	Designated wind farm	2030	1225 - 1400	64 - 117	51,488128	2,403131	106,8

Table 3.3 Overview of existing and planned wind farms in the Dutch and Belgian EEZ showing turbine types, turbine capacity, turbine height, hub height, rotor diameter and number of rotor blades

No	Name wind farm	Turbine type	Turbine capacity MW	Turbine height m	Hub height m	Rotor diameter m	N of rotorblades
NL01	Offshore windpark Egmond aan Zee	Vestas V90/3000	3	115	70	90	3
NL02	Prinses Amalia Windparken	Vestas V80	2	99	59	80	3
NL03	Luchterduinen	Vestas V112	3	137	81	112	3
NL04	Gemini ZeeEnergie	Siemens SWT-4.0 -130	4	154	89	130	3
NL05	Gemini Buitengaats	Siemens SWT-4.0 -130	4	154	89	130	3
NL06	Borssele Kavel II	Siemens Gamesa 8,0 MW-167 DD	8	192	108	167	3
NL07	Borssele Kavel I	Siemens Gamesa 8,0 MW-167 DD	8	192	108	167	3
NL08	Borssele Kavel III	V164 - 9.5 MW	9,5	190	108	164	3
NL09	Borssele Kavel IV	V164 - 9.5 MW	9,5	190	108	164	3
NL10	Borssele Kavel V	V164 - 9.5 MW	9,5	190	108	164	3
NL11	Hollandse Kust Zuid Kavel IV	SG 11.0-200 DD	11	225	125	200	3
NL12	Hollandse Kust Zuid Kavel III	SG 11.0-200 DD	11	225	125	200	3
NL13	Hollandse Kust Zuid Kavel II	SG 11.0-200 DD	11	225	125	200	3
NL14	Hollandse Kust Zuid Kavel I	SG 11.0-200 DD	11	225	125	200	3
NL15	Hollandse Kust Noord Kavel V	SG 11.0-200 DD	11	225	125	200	3
NL16	Hollandse Kust West Kavel VI & VII	Vestas , type 15 MW	15	261	143	236	3
NL17	IJmuiden Ver Gamma	15MW per turbine	15	261	143	236	3
NL18	IJmuiden Ver Alpha & Beta	15MW per turbine	15	261	143	236	3
NL19	Nederwiek Noord	15MW per turbine	15	261	143	236	3
NL20	Nederwiek Zuid	15MW per turbine	15	261	143	236	3
NL21	Hollandse Kust West kavel VIII	20MW per turbine	20	305	165	280	3
NL22	Ten noorden van de Wadden west	15MW per turbine	15	261	143	236	3
NL23	Doordewind	20MW per turbine	20	305	165	280	3
BE01	Belwind	v90 vestas - 3MW	3	117	72	90	3
BE02	C-Power	Repower 6,15MW	5 - 6,15	157	94	126	3
BE03	Northwind	MVOW v112-3.0 MW	3,3	127	71	112	3
BE04	Nobelwind	3.3MW	3,3	135	79	112	3
BE05	Rentel	Siemens 7.0-154	7,35	183	106	154	3
BE06	Norther	8.4MW	8,4	183	101	164	3
BE07	Northwester 2	vestas v164-9,525 kW	9,5	187	105	164	3
BE08	Seamade - Seastar	SG 8.0-167	8,4	192,5	109	167	3
BE09	Seamade - Mermaid	SG 8.0-167	8,4	192,5	109	167	3
BE10	Princess Elisabeth Zone - Area 1	tbd	12 - 22	245 - 325	135 - 175	220 - 300	3
BE11	Princess Elisabeth Zone - Area 2	tbd	12 - 22	245 - 325	135 - 175	220 - 300	3
BE12	Princess Elisabeth Zone - Area 3	tbd	12 - 22	245 - 325	135 - 175	220 - 300	3

3.2.3 Cumulative estimation number of bat casualties

The number of collision fatalities can be estimated per wind farm, based on the input variables presented in tables 3.2 and 3.3 and the location specific bat density from the spatial analysis (§3.2.1). Combining the estimated number of casualties for each individual wind farm renders the cumulative estimated number of bat casualties per year in the Dutch part of the North Sea.

3.3 Assess impact cumulative effects on population

3.3.1 Estimate Nathusius' pipistrelle population size

The legal framework is based on the impact of additional mortality (1% ORNIS criterion) on the population of Nathusius' pipistrelle due to offshore wind farms. The size of the population of Nathusius' pipistrelle in the Netherlands is estimated at 50.000 – 400.000 individuals during autumn migration (BIJ12, 2024). This estimate is based on an expert judgement. An accurate census was not carried out for the Nathusius' pipistrelle population in the Netherlands. As the estimate is a very broad range, it is currently not possible to accurately analyze the impact of the estimated number of bat casualties on the population of Nathusius' pipistrelle. The range can be improved by a systematic census of Nathusius' pipistrelles in the Netherlands.

A systematic census could be achieved by counting calling Nathusius' pipistrelle males during the mating and autumn migration period. This census should be carried out within a representative selection of square kilometers distributed over different regions in the Netherlands. By analyzing data from systematic surveys on Nathusius' pipistrelles mating group szes found in bat boxes it will be possible to establish an average number of individuals. In some of the selected square kilometers the actual number of occupied bat boxes and group sizes should be included in the census for validation purposes. In figure 3.5 a summary of the method to estimate the Nathusius' pipistrelle population size in the Netherlands is given.

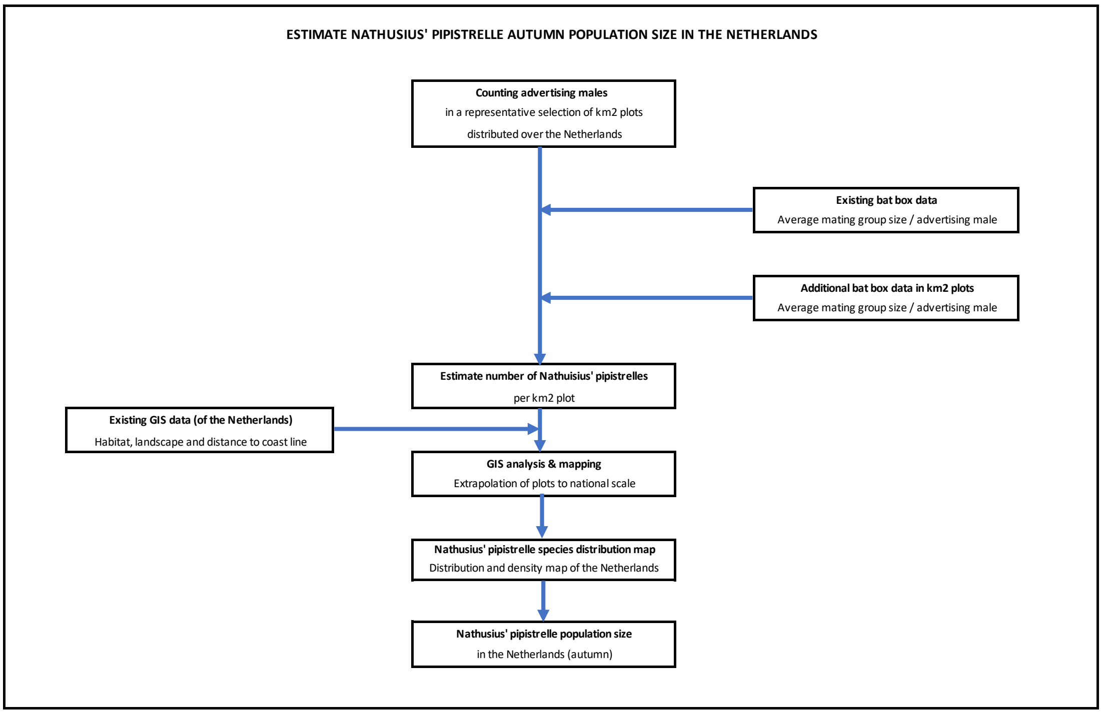


Figure 3.5 Flow diagram of the method to estimate the Nathusius' pipistrelle population size in the Netherlands

3.3.2 Relative comparison of bat activity on land versus at sea

An alternative approach to the estimate of the absolute population size of Nathusius' pipistrelle would be to compare their offshore and onshore acoustic activity in detail. Even without knowing the number of offshore casualties and without knowing the Dutch population size exactly , the relative impact on the population could be estimated by comparing onshore and offshore bat activity with each other. The larger the onshore population is compared to the number of Nathusius' pipistrelle flying offshore, the less impact of offshore wind farms can be expected. A certain number of offshore casualties would have less impact on a larger population compared to a smaller population. By comparing the relative acoustic activity of Nathusius' pipistrelle over the North Sea with the activity onshore, an assessment could be made on what fraction of the population is flying offshore and could be exposed to offshore wind farms. In this way, it can be assessed what fraction of the population is at risk within the OWFs and the relative impact of the additional mortality in OWFs on the total population of Nathusius' pipistrelle could be estimated. Recently an acoustic study was carried out in the coastal zone of the Wadden Sea in the North of the Netherlands to study the relative density of migrating bat species, what could be a feasible method to compare onshore and offshore bat activity as well (Jonge Poerink et al., 2024).

The available telemetry data can be used as an additional data source for this assessment, for instance by comparing the fraction of tagged animals flying offshore to those staying onshore. As this analysis should be done for the Dutch population of Nathusius' pipistrelle as a whole it would be representative to tag Nathusius' pipistrelles in the region where the majority of migrating bats are entering the Netherlands. This approach is reasonable as a considerable fraction of the total population will not even reach the west coast of the Netherlands and will certainly not be affected by offshore wind farms.

4. FURTHER RESEARCH

4.1 Short term assessments

The following assessments can be conducted in the short term:

- As a first step, a collision risk model can be applied to the existing dataset of bat activity collected at sea, along with the dimensions of the operational wind farms. This will allow gaining experience with the model and provide insights into additional data that should be collected in the near future, along with an initial assessment of the collision risk.
- Another practical analysis that can be performed in a relatively short term is to compare the offshore acoustic bat activity data collected at sea with existing onshore acoustic data. By comparing these datasets, we can estimate the proportion of the Nathusius' pipistrelle population that migrates over the sea and is exposed to offshore wind farms. This will give us a preliminary understanding of the part of the population that could potentially be affected by these wind farms.

4.2 Medium - long term research

To obtain a more accurate estimate of bat casualties at offshore wind farms in the southern North Sea and to assess the impact on the Dutch Nathusius' pipistrelle population, additional data collection is necessary. The following recommendations are made for this purpose:

Additional Data Collection for Collision Risk Modelling

- Vertical Distribution of Bat Activity: The current dataset primarily includes data collected at elevations between 10 and 35 meters above mean sea level. To improve understanding of the vertical stratification of bat activity at sea, recorders should be installed at various heights on offshore wind turbines and other marine structures. Data should be gathered simultaneously at both 10 to 35 meters above sea level and at nacelle height, with an additional monitoring point halfway up the turbine tower. In 2025-2026, the Wozep research program plans to include bat detectors at different heights (Wozep theme title VL.6).
- Continuation of Monitoring Year Series: There has been no data collected in the Dutch Exclusive Economic Zone (EEZ) by the Wozep research program over the past four years, creating a significant data gap for that period. Given ongoing climate change and its potential effects on bat migration behavior, it is recommended to continue monitoring at a selection of previous locations. These monitoring locations should be evenly distributed across areas of the North Sea where wind farms are currently located or planned. The northern part of the Dutch EEZ, north of the Wadden Islands, is currently underrepresented in the existing dataset. In 2025, the Wozep research program will begin data collection at offshore wind farms in this area (Wozep theme title VL.2a). A minimum of 15 to 20 monitoring sites should be established, ideally allowing for both low and high altitude monitoring, such as at wind turbines. Utilizing locations previously monitored can enhance long-term studies by providing insights into annual fluctuations. For this purpose, Batcorder and Batmode (by Avisoft) are recommended as suitable passive recording devices. The collected data may also be used to map the relative density of bats over the North Sea.

Additional data collection for impact assessment on Nathusius' pipistrelle population

- To accurately analyze the impact of the estimated number of bat casualties on the Nathusius' pipistrelle population, both absolute and relative approaches can be applied as described above. By combining offshore acoustic data collection with onshore data collection, the fraction of the population at risk within offshore wind farms can be estimated. For this purpose, a network of passive recorders is needed both onshore and offshore.
- To estimate the absolute population size of Nathusius' pipistrelle in the Netherlands, a systematic census should be conducted by counting calling males during the mating and autumn migration periods. This census should take place in a representative selection of square kilometers distributed across various regions of the Netherlands, with a minimum of 50 square kilometer plots recommended. By analyzing data from systematic surveys of Nathusius' pipistrelle mating group sizes observed in bat boxes, the average number of individuals can be estimated. This refined approach will enhance the assessment of the impact of offshore wind farms on the Nathusius' pipistrelle population more accurately.
- Tracking Nathusius' pipistrelles using telemetry can provide further insights into the portion of the population that migrates offshore. Additional tracking of bats is planned within the Wozep research program (VL 5). Future tracking efforts should focus on the entire Dutch population of Nathusius' pipistrelle, rather than just the western part of the Netherlands. The most effective method would involve tagging Nathusius' pipistrelles in the northeastern region of the Netherlands, where most migrating bats enter the country. This approach is crucial because a significant portion of the total population may not reach the western coast and could remain further east. As a result, these bats are likely not to be affected by offshore wind farms. MOTUS receivers located within the offshore wind farms could provide valuable additional data (Wozep theme VL5c).

Additional data collection for density mapping

- Spatial distribution of bat activity within a wind warm: The existing dataset primarily comprises monitoring data from locations that are relatively distant from one another. To evaluate the density of Nathusius' pipistrelles within offshore wind farms, it is essential to obtain detailed information on the spatial distribution of bat activity. This can be accomplished by deploying a high density of acoustic recorders in a specific area, such as within a wind farm and its immediate vicinity. This approach will help confirm whether bats are attracted to wind turbines and other structures at sea.

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Ecosensys
Hoofdweg 46
9966 VC Zuurdijk
Groningen

e-mail: info@ecosensys.nl
website: www.ecosensys.nl