Bureau Waardenburg
Ecology & Landscape

# Bat curtailment IJmuiden Ver

## Reducing bat mortality in offshore windfarms

Commissioned by: A. Potiek, F. van Vliet

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## Reducing bat mortality in offshore windfarms

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# Preface

In 2023 the Ministry of Economic Affairs and Climate Policy will initiate the tender for the first four sections of IJmuiden Ver. Offshore wind energy production is rapidly growing in the Dutch North Sea. On 11 February 2022, the Dutch Government raised the offshore wind energy target from 11,5 to about 21 GW around 2030. This also raises concerns about the effect of these developments on wildlife. Birds and bats can be killed by moving rotor blades. Wind turbines can be stopped during specific conditions to reduce this mortality rate: curtailment. RWS Zee en Delta asked Bureau Waardenburg to develop curtailment to reduce bat mortality in IJmuiden Ver. The work was carried out by Martijn Boonman en Maarten Japink. From RWS Zee en Delta Raoul Syrier supervised the project. Floris van Haarlem and Per Juul Østergaard (Ørsted) kindly provided us with data from the offshore windturbines of Kavel Borssele.

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# 1 Introduction

Bats are occasionally encountered on gas and oil rigs in the Dutch North Sea (Boshamer & Bekker 2008). A few decades ago it was often assumed that these animals accidentally got to these remote locations by wind drift. During a pilot study with bat detectors in two Dutch offshore windfarms it was discovered that bats regularly occur in the North Sea during the migration season (Jonge Poerink *et al.* 2013), later confirmed during monitoring of several locations in the Dutch and Belgium North Sea (Lagerveld *et al.* 2017). A North Sea crossing by Nathusius' pipistrelle was recorded for the first time in 2013. A bat ringed in the UK was rediscovered in the Netherlands. Up until now ten bats ringed in the UK have been rediscovered in continental Europe, mostly in the Baltic States but also Poland and Russia[1]. Nathusius' pipistrelles migrate to the UK in late summer and autumn and return in spring. Bats can be killed by moving rotor blades (Kunz *et al.* 2007), including the most common species at the Dutch North Sea: Nathusius' pipistrelle (Voigt *et al.* 2012). Bats are protected by EU law, mortality by wind farms should not exceed levels that are unsustainable by bat populations. Unfortunately, we currently do not have sufficient information to determine this critical mortality level. Both population size and the number of bats that are annually killed in the Dutch offshore windfarms are unknown. A common approach in impact assessments to deal with these knowledge gaps, is to use worst case estimates. In worst case scenario there is a small population, low recruitment and high mortality. If mortality is sustainable under these assumptions, effects are ruled out. In the environmental impact assessments (EIA) for the IJmuiden Ver wind farm zone, a cumulative effect of all the projected wind farms on the Nathusius' pipistrelle population cannot be ruled out by using such worst case estimates. Following the precautionary principle, bat mortality is now being reduced in many offshore windfarms. Up until now, curtailment is the most effective way to reduce bat mortality in wind farms (Baerwald *et al.* 2009; Adam *et al.* 2021). Because bats are mostly present during low wind speed, this can usually be done without a major effect on energy production. In Hollandse Kust Zuid curtailment consists of raising the cut in speed to 5 m/s at night between August 15$^{th}$ and October 1st. This curtailment was improved by using bat activity data measured in wind farms close to the Dutch coast (OWEZ, PAWP and LUD). This curtailment is taking into account that bat activity is far more likely to occur during wind from NE-E direction (Boonman 2018) and now being applied in the Borssele wind farms and soon in the Hollandse Kust Noord, Zuid and West wind farms.

Bat activity is measured at many locations in the North Sea including several platforms further offshore (Lagerveld *et al.* 2017; 2022). According to these studies bat activity at these remote locations is not identical to the activity measured closer to the coast. Animals are roosting more often at these remote locations as shown by records shortly after sunset. Therefore, it was recognized that constructing a new curtailment for locations further offshore would be needed. This report describes the development and application of this curtailment.

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1 https://www.bats.org.uk/our-work/national-bat-monitoring-programme/surveys/national-nathusius-pipistrelle-survey

# 2 Materials and methods

## 2.1 Method to construct curtailment

It is commonly accepted that acoustic monitoring data of bats can be used to construct curtailment since bat activity in the rotor swept area is related to bat mortality (Korner-Nievergelt *et al.* 2013). Several tools are available to construct a curtailment for bats by using acoustic monitoring data (ProBat, Chirotech). Unfortunately, these tools cannot be used for IJmuiden Ver because they require measurement of bat activity from the nacelle of wind turbines. Secondly, they are developed by using data from onshore wind farms and will not be suited to fit offshore wind farms which are generally much taller, have lower rotational speed and have a rotor swept area that is closer to ground/sea level than onshore wind turbines. It is also doubtful whether these tools will be applicable for bats that are only present during the migration season and under conditions favourable for migration. ProBat for instance does not include wind direction in the curtailment. Therefore the available tools were not used and curtailment was constructed independently. The aim was to construct a curtailment that reduces at least 40% bat mortality with lowest loss of energy production, in line with the curtailment for the Borssele and Hollandse Kust wind farms.

The method used to construct the curtailment for IJmuiden Ver consists of the following steps:

1. Relating bat presence to time and weather variables at nacelle height and construct a model.
2. Use a long term weather time series for IJmuiden Ver at nacelle height and estimate the probability of occurrence of bats for each hour according to model 1.
3. Determine relation between wind speed and rotor speed for offshore WTG and use this relation to estimate the risk of mortality for each wind speed.
4. Estimate bat mortality for each hour by multiplying the probability of bat occurrence (2) with mortality risk (3).
5. Estimate energy production of a wind turbine for each hour by using wind speed at nacelle height (2) and a power curve of a modern offshore wind turbine.
6. Divide bat mortality (4) by energy production (5) for every hour (bat / MWh). A high value indicates high bat mortality combined with low energy production.
7. Formulate optimal curtailment by stepwise including conditions with highest bat/MWh (6) until 40 % of bat mortality is reduced.

## 2.2 Construct a model to calculate the probability of occurrence of bats according to time and weather variables

**Bat activity data**

Bat activity data from 2018 to 2020 collected with Avisoft equipment were used in this study. These data were collected during the bat monitoring project which is part of the Dutch Governmental Offshore Wind Ecological Programme (Wozep). Data from (autumn) 2021 were not yet available and data prior to 2019 were mostly collected by using different equipment (batcorders, EcoObs) with lower sensitivity.

We used bat activity data from locations in de Dutch North Sea that are more than 50 km away from the coastline as they were expected to be more representative for the wind energy area IJmuiden Ver which is situated 63 km (center) from the coastline. Locations north of the Wadden Sea such as Gemini were excluded since animals that are detected there probably did not start their North Sea crossing from the Dutch coast but more likely from Germany or Denmark. These criteria lead to selecting five locations (figure 2.1). These locations and the monitoring equipment are described in detail in Lagerveld *et al.* (2022). Bat activity at these locations is measured at 20 – 35 m height above sea level.

From these five locations bat activity data were used from the autumn migration season August 15th to November first. Bat activity data from the spring migration period were not included. Bat activity is lower in spring (Lagerveld *et al.* 2017; 2022) making it difficult to detect patterns that can be used in curtailment. We decided against merging data from spring and autumn migration because in spring when bats are migrating in opposite direction, bats are likely to respond differently to weather conditions (e.g. winddirection) than in autumn. Curtailment described in this study, thus focuses on the autumn migration season which is in line with the curtailment for the Borssele and Hollandse Kust wind farms.

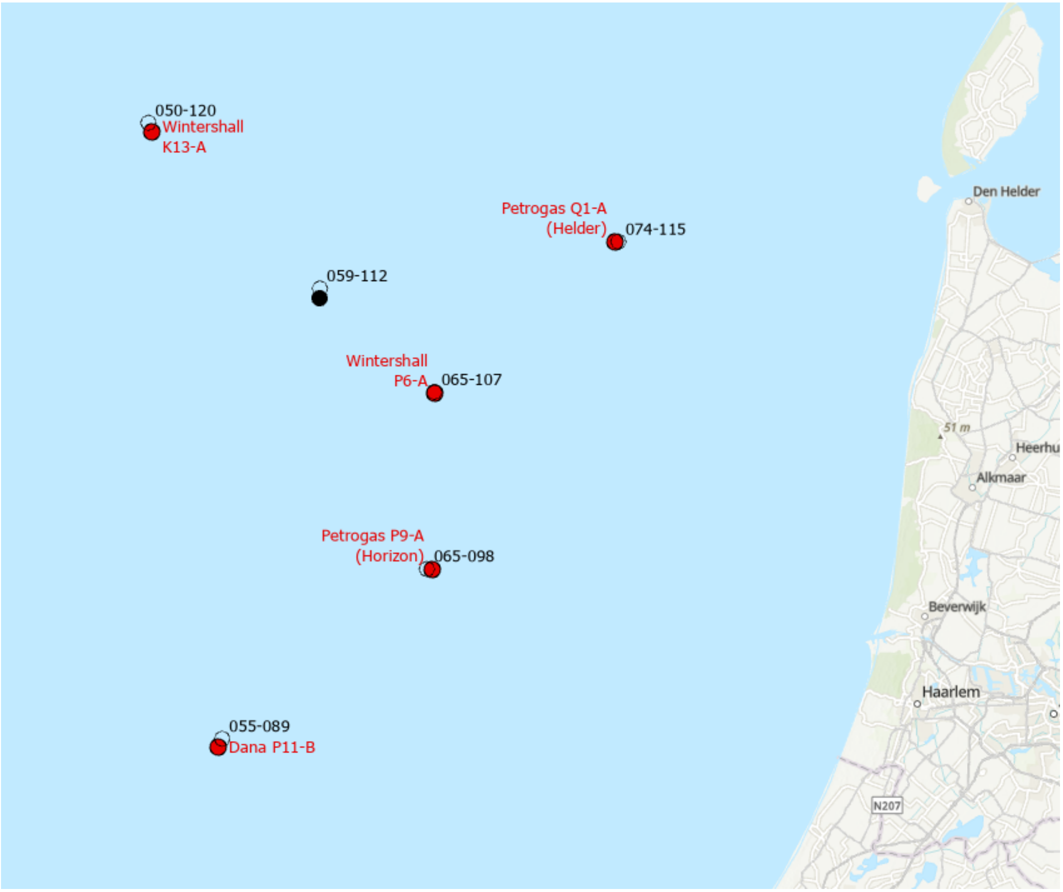


*Figure 2.1. Locations where bat activity was measured (red dots). The names of these oil/gas production platforms are given in red. Black solid dot indicates the middle of kavel IJmuiden Ver. Open dots show the location from where weather data was used with 6 digit labels referring to the WINS50 dataset (https://dataplatform.knmi.nl).*

**Weather data**

Wind direction, windspeed and temperature from the WINS50 dataset (KNMI Data Platform) were used. The database contains hourly values for 10 to 600 m height in high resolution without any shading effects. For each of the locations where bat activity was measured, the nearest grid cell of the WINS50 dataset was used (figure 2.1). Weather data were used from August 15th to November 1st if the bat detector was operational.

**Model**

Because the aim is to predict when wind turbines are best stopped to reduce bat mortality and establish the corresponding energy loss, wind speed at nacelle height is needed. Wind speed at low elevation will not allow calculating energy loss and if used in curtailment it would also be difficult to implement since wind speed is not easily measured at low elevation due to shading of the tower. Weather variables from 100 m height were therefore used. This height corresponds best to the height where wind is measured on wind turbines (nacelle roof top). Only a few bat observations were done during daytime. Daytime hours were excluded from the analysis to reduce zero inflation and improve the model fit.

For statistical analysis the program R was used with package Mass (R Core Team 2022). Model validation was carried out according to Zuur (2013). We used a logistic regression model (Binomial GLM with logit link) to predict presence or absence of bat activity for each hour and used windspeed, wind direction, temperature, nighttime and night number as covariates. We did not use the lunar phase to predict bat activity because there does not seem to be a conclusive effect (Lagerveld *et al.* 2017 reported a positive effect vs negative effect reported by Lagerveld *et al.* 2022). We used sinus wind direction because wind direction is a cyclic variable with 0 degrees being equal to 360 degrees. Nighttime is a value between 0 (sunset) and 1 (sunrise) that represents the portion of the night past sunset (0.2 = one fifth of the night after sunset; 0.5 = midnight). If a gradual increase or decrease during the entire season is to be expected, night number (the equivalent of day number in year for nights) is expected to fit well. As migration peaks mid September and is lower both at the start and end of the season, this is not the case. Therefore day number was converted to SINnight + 13. SINnight is the sinus of the night number. By adding 13, SINnight in the middle of September is exactly -1.

The probability of occurrence of bats within every hour was calculated by using the Logistic regression formula:

Probability of event = $P = 1/ (1+e^{-(B0+B1*X1+B2*X2)})$

## 2.3 Mortality risk

At onshore wind farms a large portion of bat activity takes place during very low wind speed when the rotor is not moving or only very slowly. At a rotor speed less than 1 rotation per minute (rpm), the tip of the blades is not moving fast enough to cause any mortality (Horn *et al.* 2008). If 50 % of bat activity takes place above 4 m/s windspeed and the cut-in speed is raised to 4 m/s, the effectiveness of this curtailment will be less than 50% because the lower wind speeds cause less mortality than higher wind speeds. To estimate the effectiveness of curtailment, a correction is thus needed for the difference in mortality risk for each windspeed.

Mortality risk is dependent on rotor speed. When rotor speed is zero, there is no mortality. With increasing rotor speed, the blades pass more frequently, making it less likely that a bat is able to fly through the rotor swept area (RSA) unharmed. The tip of the rotor blades has the largest speed because it travels the entire circumference of the RSA. With higher rotor speed there is also a larger portion of the RSA where mortality can take place because the parts closer to the nacelle also achieve a speed that bats cannot avoid.

The relation between mortality risk and windspeed was established by looking at the relation between wind speed and rotor speed in modern offshore wind turbines. We used data from Siemens Gamesa 8,0 MW-167 DD turbines from the windfarm Borssele provided by Ørsted.

## 2.4 Energy production

The power curve of a 15 MW offshore reference turbine was used (https://github.com/NREL/turbine-models/). The power curve shows the relation between wind speed and energy production.

## 2.5 Optimal curtailment

A 30 year weather time series (1992-2022) from the middle of IJmuiden Ver (figure 1) was used (KNMI North Sea Wind; KNW dataset; KNMI Data Platform). This time series is long enough to obtain a good picture of the weather conditions that can be expected at IJmuiden Ver (pers. com. I. Wijnandts, KNMI). Weather variables from 100 m height were used between sunset and sunrise between August 15$^{th}$ and November 1$^{st}$ (paragraph 2.2). In this dataset, the probability of bat presence was calculated for every hour by using the logistic regression formula (paragraph 2.2). Both mortality and energy production were calculated for every hour by using mortality risk (paragraph 2.3) and power curve (paragraph 2.4). Bat mortality was divided by energy production for every hour (bat / MWh). A high value indicates high bat mortality combined with low energy production. Optimal curtailment was achieved by stepwise including conditions with highest bat/MWh until bat mortality was reduced to 40 %.

# 3 Results

## 3.1 Bat activity

At the five selected locations, 1050 recordings of bats were made during 2-3 years. A bat can be recorded more than once, it is therefore not known how many individuals were recorded. The majority belonged to Nathusius' pipistrelle. Common pipistrelle and Nyctaloid (noctule or parti-coloured bat) were also detected. A thorough description of bat activity on the Dutch North Sea is available in Lagerveld *et al.* (2022). Bat activity at locations far offshore (>50 km from nearest coastline) does occur mostly during low wind speed but is still substantial at moderate (5,5 – 8 m/s) windspeed (figure 3.2). Most activity takes place during 8-23 September and is lower during the second part of October (figure 3.3). Bat activity at the five selected locations occurs mostly during SW wind, similar to the available wind (figure 3.1). A preference for NE or E wind such as described by Lagerveld *et al.* (2022) for all Nort Sea locations (including those close to the coast) is not present at these locations further offshore.

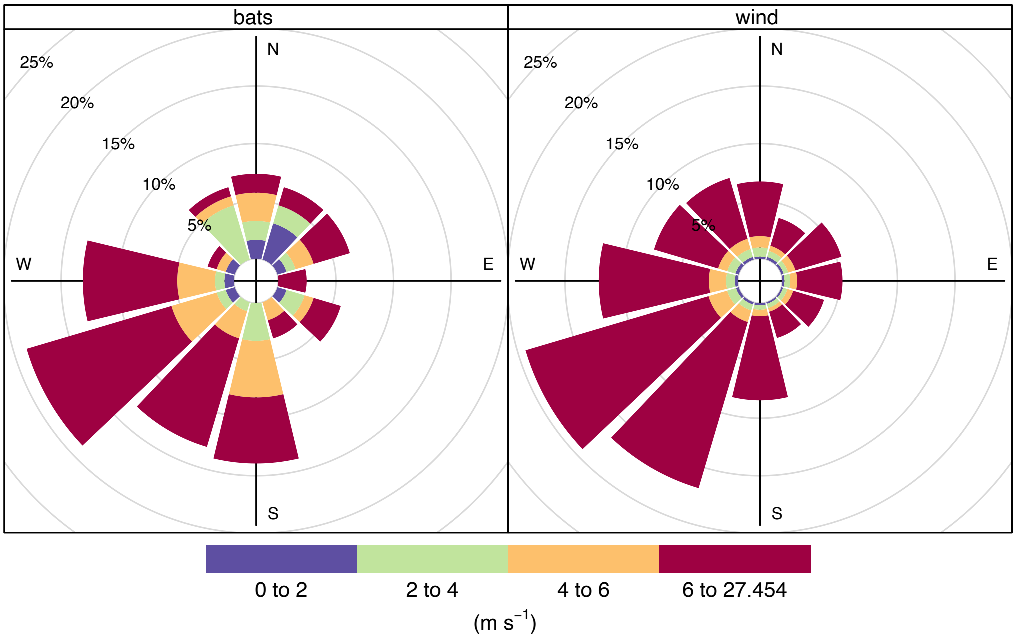


*Figure 3.1 Windrose for hours when bats are present (bats) compared to the available wind (wind).*

## 3.2 Logistic regression model

Both wind direction and the interaction between wind direction and windspeed were not significant and excluding them from the model resulted in lower AIC. Temperature was related to the time of the year (night number) and therefore excluded from the model. Nighttime was also not significant. The best model as shown by lowest AIC included only SINnight and windspeed (table 3.1).

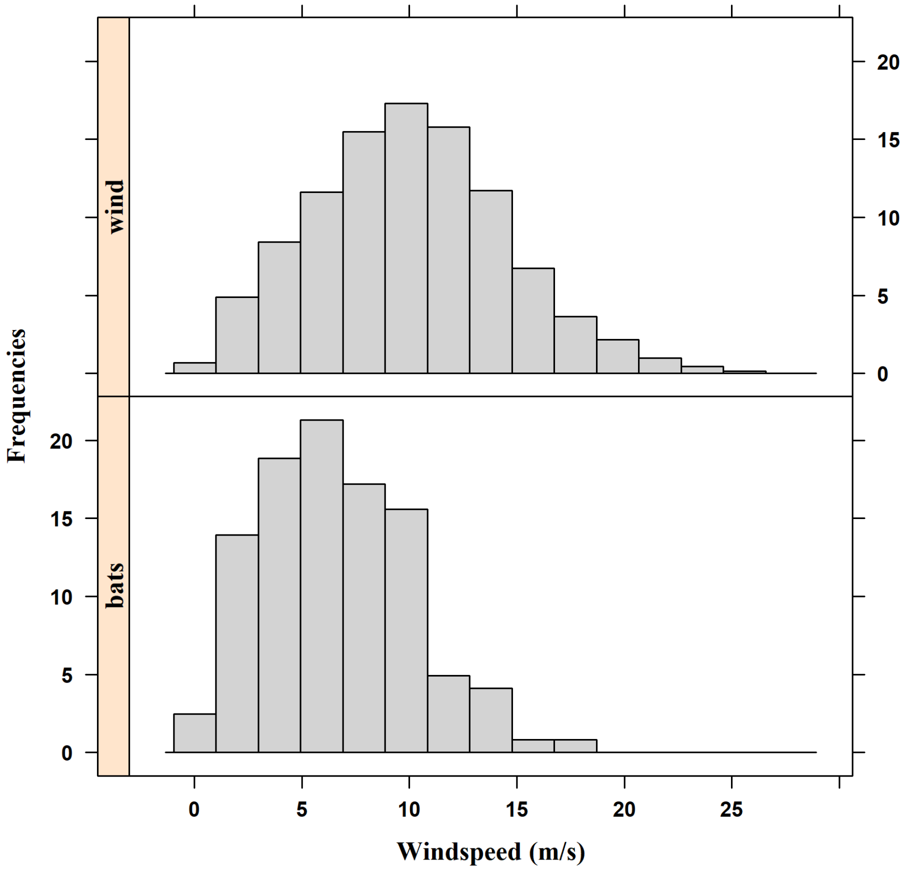


*Figure 3.2 Histogram of windspeed at 100 m height when bats were detected (bats; n=1050) compared to available wind speed (wind).*

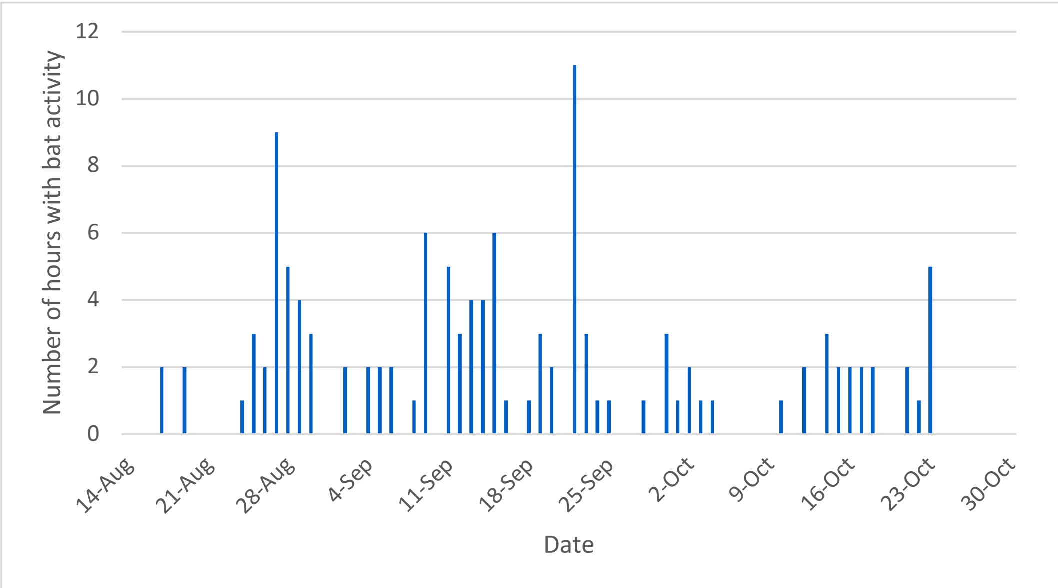


*Figure 3.3 Seasonality of bat activity during autumn migration.*

*Table 3.1 Results of the Logistic regression analysis*

| | Estimate of *B* | Probability |
|---|---|---|
| Intercept | -8,0 | 8,5 e-09 |
| SINnight | -5,7 | 7,7 e-05 |
| Windspeed | -0,2 | 5,4 e-16 |

Bats are often recorded shortly after sunset. These bats have most likely been roosting at the site. Bats are present on average 6 hours after sunset (Lagerveld *et al.* 2022). Nathusius' pipistrelles travel on average more than 100 km per night during migration (Bach *et al.* 2022) and are able to cross the North Sea in a single night (Lagerveld *et al.* 2021). It is therefore safe to assume that many bats recorded after midnight may have left the coast that evening. We tried relating bat activity that occurred within a few hours after sunset with weather conditions from the previous night and bat activity after midnight with weather conditions during the previous evening. Both resulted in a poor fit (results not shown).

## 3.3 Mortality risk

In Boonman (2018) a linear increase in mortality risk was assumed between 2 and 5 m/s based on a figure presented in Arnett *et al.* (2013). The offshore wind turbines we studied (Siemens Gamesa from Borssele) showed that rotor speed does increase with wind speed, but the relation is not linear. Even though these turbines have direct drive and are thus gearless, rotational speed is constant for certain low windspeed intervals, subsequently rising to another rpm level if wind speed increases. The exact relation is used to calculate mortality but cannot be presented here because the information is confidential.

## 3.4 Optimal curtailment

Figure 3.4 shows the mortality per MWh. A high value means high bat mortality accompanied by low energy loss. An efficient curtailment includes time intervals with highest mortality / MWh. During the idling phase (windspeed 1,5 – 3 m/s), approximately 10% of bat mortality occurs while no energy is being produced (indicated in purple in figure 3.4). Mortality / MWh cannot be calculated for this phase (dividing by zero leads to undefined values) but it is obvious that these are the most cost-efficient time intervals to be included in the curtailment. Every colour in figure 3.4 shows time intervals with similar bat mortality / MWh. Even very early and late in the season, curtailment can be efficient during the lowest windspeeds. At higher windspeed bat mortality / MWh decreases because energy production increases and probability of bat mortality decreases. During 8 – 23 September the probability of bat mortality is highest. Including time intervals with higher windspeed is more cost-efficient in this time of the year.
Time intervals with the highest mortality per MWh were included in the curtailment step by step until 40% reduction of bat mortality was achieved. The border between the light green and orange cells in figure 3.4 indicates 40% mortality reduction during autumn migration. The effect of every step on energy production loss is shown in figure 3.5. At 40% mortality reduction, the corresponding energy production loss (at night between August 15$^{th}$ and November 1$^{st}$) is 1,1 % (88 MWh energy loss / year for a 15 MW wind turbine). Energy loss

is approximately 6-7 times larger than estimated by Boonman (2018) for wind farms closer to the coast. The main reason for this difference is the fact that curtailment described by Boonman (2018) is mainly applied during winddirections (E and NE) that do not occur very often. A higher bat mortality reduction than 40% quickly becomes more costly as energy production loss increases exponentially with bat mortality reduction (figure 3.5).

| | 227 | 230 | 233 | 236 | 239 | 242 | 245 | 248 | 251 | 254 | 257 | 260 | 263 | 266 | 269 | 272 | 275 | 278 | 281 | 284 | 287 | 290 | 293 | 296 | 299 | 302 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0,2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0,3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0,4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0,5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0,6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0,7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0,8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0,9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1,1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1,2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1,3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1,4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1,5 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| 1,6 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| 1,7 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| 1,8 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| 1,9 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| 2 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| 2,1 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| 2,2 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| 2,3 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| 2,4 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| 2,5 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| 2,6 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| 2,7 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| 2,8 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| 2,9 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| 3 | 0,0266 | 0,029 | 0,0332 | 0,0383 | 0,0418 | 0,0454 | 0,0477 | 0,0502 | NA | 0,0535 | 0,0539 | 0,0534 | 0,0526 | 0,0504 | 0,0476 | 0,0445 | 0,0421 | 0,0378 | 0,0338 | 0,0294 | 0,0258 | 0,0217 | 0,0194 | 0,016 | 0,013 | 0,0106 |
| 3,1 | 0,0002 | 0,0002 | 0,0002 | 0,0003 | 0,0003 | 0,0003 | 0,0003 | 0,0003 | 0,0004 | 0,0004 | 0,0004 | 0,0004 | 0,0004 | 0,0003 | 0,0003 | 0,0003 | 0,0003 | 0,0003 | 0,0002 | 0,0002 | 0,0002 | 0,0002 | 0,0001 | NA | 9E-05 | 7E-05 |
| 3,2 | 1E-04 | 0,0001 | 0,0001 | 0,0001 | 0,0002 | 0,0002 | 0,0002 | 0,0002 | 0,0002 | 0,0002 | 0,0002 | 0,0002 | 0,0002 | 0,0002 | 0,0002 | 0,0002 | 0,0002 | 0,0001 | 0,0001 | 0,0001 | 0,0001 | 8E-05 | 7E-05 | 6E-05 | 5E-05 | 4E-05 |
| 3,3 | 7E-05 | 8E-05 | 9E-05 | 1E-04 | 0,0001 | 0,0001 | 0,0001 | 0,0001 | 0,0001 | 0,0001 | 0,0001 | 0,0001 | 0,0001 | 0,0001 | 0,0001 | 0,0001 | 0,0001 | 1E-04 | 9E-05 | 8E-05 | 7E-05 | 6E-05 | 5E-05 | NA | 3E-05 | 3E-05 |
| 3,4 | 6E-05 | 6E-05 | 7E-05 | 8E-05 | 9E-05 | 1E-04 | 1E-04 | 0,0001 | NA | 0,0001 | 0,0001 | 0,0001 | 0,0001 | 0,0001 | 1E-04 | 9E-05 | 9E-05 | 8E-05 | 7E-05 | 6E-05 | 5E-05 | 4E-05 | 4E-05 | 3E-05 | NA | 2E-05 |
| 3,5 | 5E-05 | 5E-05 | 6E-05 | 7E-05 | 7E-05 | 8E-05 | 8E-05 | 9E-05 | 9E-05 | 9E-05 | 1E-04 | 9E-05 | 9E-05 | 9E-05 | 8E-05 | 8E-05 | 7E-05 | 6E-05 | 6E-05 | 5E-05 | 5E-05 | 4E-05 | 3E-05 | 3E-05 | 2E-05 | 2E-05 |
| 3,6 | 4E-05 | 4E-05 | 5E-05 | 6E-05 | 6E-05 | 7E-05 | 7E-05 | 8E-05 | 8E-05 | 8E-05 | 8E-05 | 8E-05 | 8E-05 | 8E-05 | 7E-05 | 7E-05 | 6E-05 | 6E-05 | 5E-05 | 5E-05 | 4E-05 | 3E-05 | 3E-05 | 2E-05 | 2E-05 | 2E-05 |
| 3,7 | 4E-05 | 4E-05 | 5E-05 | 5E-05 | 6E-05 | 6E-05 | 7E-05 | 7E-05 | 7E-05 | 7E-05 | 7E-05 | 7E-05 | 7E-05 | 7E-05 | 7E-05 | 6E-05 | 6E-05 | 5E-05 | 5E-05 | 4E-05 | 4E-05 | 3E-05 | 3E-05 | 2E-05 | 2E-05 | 1E-05 |
| 3,8 | 3E-05 | NA | 4E-05 | 5E-05 | 5E-05 | 6E-05 | 6E-05 | 6E-05 | 7E-05 | 7E-05 | 7E-05 | 7E-05 | 7E-05 | 6E-05 | 6E-05 | 6E-05 | 5E-05 | 5E-05 | 4E-05 | 4E-05 | 3E-05 | 3E-05 | 2E-05 | 2E-05 | 2E-05 | 1E-05 |
| 3,9 | 3E-05 | 3E-05 | 4E-05 | 4E-05 | 5E-05 | 5E-05 | 5E-05 | 6E-05 | 6E-05 | 6E-05 | 6E-05 | 6E-05 | 6E-05 | 6E-05 | 6E-05 | 5E-05 | 5E-05 | 4E-05 | 4E-05 | 3E-05 | 3E-05 | 3E-05 | 2E-05 | 2E-05 | NA | 1E-05 |
| 4 | 3E-05 | 3E-05 | 3E-05 | 4E-05 | 4E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 6E-05 | 6E-05 | 6E-05 | 6E-05 | 5E-05 | 5E-05 | 5E-05 | 4E-05 | 4E-05 | 4E-05 | 3E-05 | 3E-05 | 2E-05 | 2E-05 | 2E-05 | 1E-05 | 1E-05 |
| 4,1 | 3E-05 | 3E-05 | 3E-05 | 4E-05 | 4E-05 | 4E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 4E-05 | 4E-05 | 4E-05 | 3E-05 | 3E-05 | 3E-05 | 2E-05 | 2E-05 | 2E-05 | 1E-05 | 1E-05 |
| 4,2 | 2E-05 | 3E-05 | 3E-05 | 3E-05 | 4E-05 | 4E-05 | 4E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 5E-05 | 4E-05 | 4E-05 | 4E-05 | 3E-05 | 3E-05 | 3E-05 | 2E-05 | 2E-05 | 2E-05 | 1E-05 | 1E-05 | 1E-05 |
| 4,3 | 2E-05 | 3E-05 | 3E-05 | 3E-05 | 4E-05 | 4E-05 | 4E-05 | 4E-05 | 4E-05 | 5E-05 | 5E-05 | 5E-05 | 4E-05 | 4E-05 | 4E-05 | 4E-05 | 4E-05 | 3E-05 | 3E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 1E-05 | 1E-05 | 9E-06 |
| 4,4 | 2E-05 | 2E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 4E-05 | 4E-05 | 4E-05 | 4E-05 | 4E-05 | 4E-05 | 4E-05 | 4E-05 | 4E-05 | 4E-05 | 3E-05 | 3E-05 | 3E-05 | 2E-05 | 2E-05 | 2E-05 | 1E-05 | 1E-05 | 1E-05 | 8E-06 |
| 4,5 | 2E-05 | 2E-05 | 2E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 4E-05 | 4E-05 | 4E-05 | 4E-05 | 4E-05 | 4E-05 | 4E-05 | 4E-05 | 3E-05 | 3E-05 | 3E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 1E-05 | 1E-05 | 1E-05 | 8E-06 |
| 4,6 | 2E-05 | 2E-05 | 2E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 4E-05 | 4E-05 | 4E-05 | 4E-05 | 4E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 1E-05 | 1E-05 | 9E-06 | 7E-06 |
| 4,7 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 1E-05 | 1E-05 | 1E-05 | 8E-06 | 7E-06 |
| 4,8 | 1E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 1E-05 | 1E-05 | 9E-06 | 8E-06 | 6E-06 |
| 4,9 | 1E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 1E-05 | 1E-05 | 1E-05 | 8E-06 | 7E-06 | 6E-06 |
| 5 | 1E-05 | 1E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 3E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 8E-06 | 7E-06 | 5E-06 |
| 5,1 | 1E-05 | 1E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 3E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 1E-05 | 1E-05 | 1E-05 | 8E-06 | 7E-06 | 6E-06 | 5E-06 |
| 5,2 | 1E-05 | 1E-05 | 1E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 1E-05 | 1E-05 | 1E-05 | 9E-06 | 8E-06 | 6E-06 | 5E-06 | 4E-06 |
| 5,3 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 9E-06 | 7E-06 | 6E-06 | 5E-06 | 4E-06 |
| 5,4 | 9E-06 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 1E-05 | 1E-05 | 1E-05 | 9E-06 | 8E-06 | 7E-06 | 6E-06 | 5E-06 | 4E-06 |
| 5,5 | 9E-06 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 9E-06 | 7E-06 | 6E-06 | 5E-06 | 4E-06 | 4E-06 |
| 5,6 | 8E-06 | 9E-06 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 9E-06 | 8E-06 | 7E-06 | 6E-06 | 5E-06 | 4E-06 | 3E-06 |
| 5,7 | NA | 9E-06 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 2E-05 | 2E-05 | 2E-05 | 2E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 9E-06 | 9E-06 | 7E-06 | 6E-06 | 5E-06 | 5E-06 | 4E-06 | 3E-06 |
| 5,8 | 7E-06 | 8E-06 | 9E-06 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 9E-06 | 8E-06 | 7E-06 | 6E-06 | 5E-06 | 4E-06 | 3E-06 | 3E-06 |
| 5,9 | 6E-06 | 7E-06 | 8E-06 | 9E-06 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 9E-06 | 8E-06 | 7E-06 | 6E-06 | 5E-06 | 5E-06 | 4E-06 | 3E-06 | 3E-06 |
| 6 | 6E-06 | 7E-06 | 8E-06 | 9E-06 | 9E-06 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 9E-06 | 9E-06 | 8E-06 | 7E-06 | 6E-06 | 5E-06 | 4E-06 | 4E-06 | 3E-06 | 2E-06 |
| 6,1 | 5E-06 | 6E-06 | 7E-06 | 8E-06 | 9E-06 | 9E-06 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 9E-06 | 9E-06 | 8E-06 | 7E-06 | 6E-06 | 5E-06 | 5E-06 | 4E-06 | 3E-06 | 3E-06 | 2E-06 |
| 6,2 | 5E-06 | 6E-06 | 7E-06 | 7E-06 | 8E-06 | 9E-06 | 9E-06 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 9E-06 | 9E-06 | 8E-06 | 7E-06 | 6E-06 | 6E-06 | 5E-06 | 4E-06 | 3E-06 | 3E-06 | 3E-06 | 2E-06 |
| 6,3 | 5E-06 | 5E-06 | 6E-06 | 7E-06 | 7E-06 | 8E-06 | 9E-06 | 9E-06 | 1E-05 | 1E-05 | 1E-05 | 1E-05 | 9E-06 | 9E-06 | 9E-06 | 8E-06 | 8E-06 | 7E-06 | 6E-06 | 5E-06 | 5E-06 | 4E-06 | 3E-06 | 3E-06 | 2E-06 | 2E-06 |
| 6,4 | 4E-06 | 5E-06 | 6E-06 | 6E-06 | 7E-06 | 8E-06 | 8E-06 | 8E-06 | 9E-06 | 9E-06 | 9E-06 | 9E-06 | 9E-06 | 8E-06 | 8E-06 | 8E-06 | 7E-06 | 6E-06 | 6E-06 | 5E-06 | 4E-06 | 4E-06 | 3E-06 | 3E-06 | 2E-06 | 2E-06 |
| 6,5 | 4E-06 | 5E-06 | 5E-06 | 6E-06 | 6E-06 | 7E-06 | 7E-06 | 8E-06 | 8E-06 | 8E-06 | 8E-06 | 8E-06 | 8E-06 | 8E-06 | 7E-06 | 7E-06 | 7E-06 | 6E-06 | 5E-06 | 5E-06 | 4E-06 | 3E-06 | 3E-06 | 2E-06 | 2E-06 | 2E-06 |
| 6,6 | 4E-06 | 4E-06 | 5E-06 | 5E-06 | 6E-06 | 6E-06 | 7E-06 | 7E-06 | 8E-06 | 8E-06 | 8E-06 | 8E-06 | 8E-06 | 7E-06 | 7E-06 | 7E-06 | 6E-06 | 5E-06 | 5E-06 | 4E-06 | 4E-06 | 3E-06 | 3E-06 | 2E-06 | 2E-06 | 2E-06 |
| 6,7 | 4E-06 | 4E-06 | 5E-06 | 5E-06 | 6E-06 | 6E-06 | 6E-06 | 7E-06 | 7E-06 | 7E-06 | 7E-06 | 7E-06 | 7E-06 | 7E-06 | 6E-06 | 6E-06 | 6E-06 | 5E-06 | 5E-06 | 4E-06 | 4E-06 | 3E-06 | 3E-06 | 2E-06 | 2E-06 | 1E-06 |
| 6,8 | 3E-06 | 4E-06 | 4E-06 | 5E-06 | 5E-06 | 6E-06 | 6E-06 | 6E-06 | 7E-06 | 7E-06 | 7E-06 | 7E-06 | 7E-06 | 6E-06 | 6E-06 | 6E-06 | 5E-06 | 5E-06 | 4E-06 | 4E-06 | 3E-06 | 3E-06 | 2E-06 | 2E-06 | 2E-06 | 1E-06 |
| 6,9 | 3E-06 | 3E-06 | 4E-06 | 4E-06 | 5E-06 | 5E-06 | 6E-06 | 6E-06 | 6E-06 | 6E-06 | 6E-06 | 6E-06 | 6E-06 | 6E-06 | 6E-06 | 5E-06 | 5E-06 | 4E-06 | 4E-06 | 3E-06 | 3E-06 | 3E-06 | 2E-06 | 2E-06 | 2E-06 | 1E-06 |

*Figure 3.4 Bat mortality per MWh. Rows show windspeed, columns show nightnumber (equivalent of daynumber in year for nights). When energy production is 0 while bat mortality occurs, bat /MWh could not be calculated (shown as x). NA means a certain windspeed never occurred at this time of the year in the 30-year weather time series. Each colour shows a category with similar bat mortality/MWh values. By including these categories in the curtailment, bat mortality is reduced as shown right below. 40% reduction is achieved when all categories except orange are included.*

| | mortality reduction (%) |
|---|---|
| (purple) | 10,0 |
| (dark blue) | 4,8 |
| (light blue) | 11,0 |
| (green) | 11,3 |
| (light green) | 3,4 |
| (orange) | 7,0 |

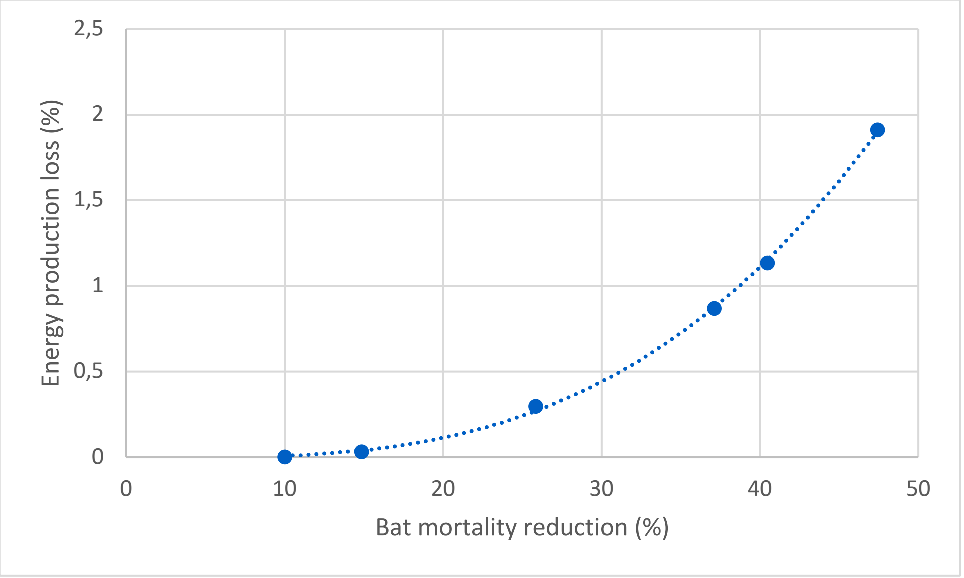


*Figure 3.5* *Bat mortality reduction during late summer and autumn as a result of curtailment and the corresponding effect on energy production. Note that energy production loss is only calculated for nights between August 15th and November 1st.*

# 4 Discussion

## 4.1 Limitations of this study

This study is a theoretical approach to reduce bat mortality at the IJmuiden Ver wind farm zone during autumn migration. Although the assumptions are plausible, the model has never been validated. Voigt (2022) recently pointed out that acoustic monitoring data may not accurately describe fatality risk when an area is sampled that isn't representative for the entire rotor swept area. This issue cannot be ruled out in this study. The dataset of bats occurring at the Dutch North Sea in the vicinity of IJmuiden Ver available for this study is collected from oil / gas production platforms. We assumed that bat activity at these locations is representative for future offshore windfarms in the vicinity of these platforms. The measured height corresponds to height of the lower part of the rotor swept area (measured height: 20-35 m above sea level vs tip low of wind turbines: 25 m). This is also where most mortality can be expected when looking at activity profile of Nathusius' pipistrelle (Wellig *et al.* 2018). But bats migrating over the North Sea might be flying at higher altitude and flight height might also be affected by the presence of wind turbines. So we do not know if the height that is sampled corresponds with the risk zone where most mortality takes place.

The oil and gas platforms differ from wind turbines both in shape and size, some of them are quite extensive (figure 4.1) and are likely to contain more options for roosting bats than wind turbines. Onshore work with thermal imaging cameras revealed that bats are attracted to wind turbines (Cryan *et al.* 2014). Compared to wind turbines, platforms may be more or less attractive to bats. Bats may also spend more time at platforms if they contain better options for roosting or foraging, in which case bat activity is overestimated for wind turbines. Once wind turbines are built in IJmuiden Ver, improving curtailment can be done by measuring bat activity within the rotor swept area. Bat activity measured from the nacelle and the tower will more accurately describe mortality risk of bats and can directly be related to wind parameters measured by the wind turbines.


*Figure 4.1 Wintershall P6-A*

During spring migration curtailment is not applied. Bat activity is much lower in spring (Lagerveld *et al.* 2017; 2021) but mortality might still occur. If the mortality is reduced by 40% in autumn, the yearly mortality is reduction is therefore slightly lower.
Wind energy production losses calculated in this study are overestimated because they assume that wind turbines are always operational according to their power curve and ignore shading from surrounding wind turbines. In absolute terms the presented energy losses are therefore unreliable, in relative terms (loss during curtailment compared to total yield) the results are reliable because there is no reason to assume that these above-mentioned shortcomings affect the curtailed situation more than the non-curtailed situation.

## 4.2 Bat presence further offshore is harder to predict

Bat activity at locations far offshore (>50 km from nearest coastline) differs in a number of ways to that closer to the coast. Close to the coast there is a strong preference for NE or E wind (Boonman 2018; Lagerveld *et al.* 2021). This may reflect bats that start their migration during preferable weather conditions (tailwind, low wind speed. Further offshore bat presence becomes harder to predict, as shown by this study. Most notably there is a complete lack of preference for NE or E wind. This may be due to the fact that after the onset of their crossing, weather conditions could deteriorate. Unfortunately, bat presence could not be predicted any better by using past weather conditions. A strong variation in the time between the onset of their crossing and the arrival at the offshore locations could explain this poor fit. Bats may have started the crossing a couple of hours ago, during the previous evening or the night before. Even when splitting nights, there isn't a single time frame in the past that fits all animals. There is another explanation for the relatively poor predictability of bats far offshore. Further offshore, roosting behavior becomes more prevalent than closer to the coast as shown by the more frequent occurrence of bats shortly after sunset (Lagerveld *et al.* 2022). During unfavourable conditions for crossing the North Sea (headwind) bats are more tempted to stay at a roost site and wait for better conditions, similar to small songbirds that are often encountered on ships during poor weather. These animals have a better chance of being recorded than animals with tailwind that may not interrupt their migration (often). Nathusius' pipistrelles are able to cross the North Sea (in spring) in a single night (Lagerveld & Leuverink 2021). It seems unlikely that these migrating bats spend much time at platforms or wind farms during their flight. Bat activity far offshore may thus be harder to predict because it occurs both during favourable ('migrating animals') and unfavourable conditions ('roosting animals') for crossing the North Sea. 'Roosting' animals may thus be overrepresented in acoustic activity data. This is not necessarily problematic since bats that spend more time around offshore structures also have a higher mortality risk. Ideally, curtailment protects healthy animals that exhibit normal behaviour. Although there is now no reason to assume otherwise, we recommend looking at future work on radio tagged bats followed by the MOTUS system (similar to Lagerveld & Leuverink 2021) to verify if roosting on offshore structures is regularly observed in animals during the autumn migration.

### 4.3 How much mortality reduction is needed?

The amount of mortality that can be sustained by the Nathusius' bat population is not known; in fact we don't even know the number of bats that are being killed in offshore windfarms. Therefore, it is impossible to say how much mortality reduction is needed to keep a sustainable Nathusius' bat population. Following the precautionary principle, reducing bat mortality is a good decision. As energy production loss rises exponentially with bat mortality reduction, reducing more than 40% (principle used in this study) of bat mortality quickly becomes expensive. It is therefore wise to explore other ways to reduce bat mortality. Reducing mortality is almost certainly cheaper by curtailing smaller onshore wind turbines and affects the same Nathusius' bat population as when wind farms along the north coast of Germany and the Netherlands are selected. Acoustic deterrents have shown promising results (Weaver *et al.* 2020) but do not seem to be effective in all bat species. Due to the limited range of ultrasound, deterrents may not be very effective in large wind turbines but it can be a valuable additional method nonetheless.

# 5 Recommendations for implementation

The curtailment presented in this study is based on wind speed at 100 m height and is therefore complementary to the wind speed at nacelle height of many offshore wind turbines. Windspeed is measured by every wind turbine on the roof of the nacelle and this is recorded for every 10 minute interval. The most logical and precise way to implement curtailment is by using this 10 minute average windspeed values from SCADA. Schirmacher *et al.* (2017) reported that using a 20 minute interval instead of 10 minute interval resulted in a lower bat mortality and lower number of on/off commands. We therefore recommend using a 20 minute interval. There is probably no need to predict when bat curtailment will be applied a few days in advance since it will not affect energy production in a major way.

In table 5.1 the curtailment is shown needed to achieve a 40% mortality reduction during the autumn migration period. The cut-in speed is given for every night. A value of 5,2 means that for this particular night, the rotational speed needs to be lowered to 1 rpm when the wind speed during the previous 20 minutes (as measured by a wind turbine at nacelle height) is below 5,2. If the wind speed increases to a 20 minute average above 5,2 m/s, normal operational can be resumed.

It is not known if there is a difference in mortality risk between a rotational speed of 1 and 2 rpm. If we assume a 200 m rotordiameter, the speed of the tip will be 75 km/h at 2 rpm instead of 38 km/h at 1 rpm. Bats killed by traffic are often found along provincial roads with a speed limit of 80 km/h (Kiefer *et al.*1995). We cannot rule out the possibility that bat are killed when 2 rpm is applied. We therefore recommend using 1 rpm when the turbines with rotordiameter of 200 m or more are curtailed.

*Table 5.1 Curtailment required to achieve 40% reduction in bat mortality during late summer and autumn. For every night the cut-in speed is given. Nightnumber is the equivalent of daynumber. Nightnumber 226 in 2022 is the time interval between sunset at August 14th and sunrise at August 15th 2022.*

| Nightnumber | Cut-in Speed | Nightnumber | Cut-in Speed |
|---|---|---|---|
| 226-228 | 4,7 | 274-276 | 5,3 |
| 229-231 | 4,8 | 277-279 | 5,1 |
| 232-234 | 5,0 | 280-282 | 5,0 |
| 235-237 | 5,2 | 283-285 | 4,9 |
| 238-240 | 5,3 | 286-288 | 4,7 |
| 241-243 | 5,4 | 289-291 | 4,4 |
| 244-246 | 5,5 | 292-294 | 4,2 |
| 247-249 | 5,5 | 295-297 | 4,0 |
| 250-252 | 5,6 | 298-300 | 3,8 |
| 253-255 | 5,6 | 301-303 | 3,6 |
| 256-258 | 5,6 | | |
| 259-261 | 5,6 | | |
| 262-264 | 5,6 | | |
| 265-267 | 5,5 | | |
| 268-270 | 5,5 | | |
| 271-273 | 5,4 | | |

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