CHAPTER 9

THE INFLUENCE OF METEOROLOGICAL CONDITIONS ON THE PRESENCE OF NATHUSIUS' PIPISTRELLE (*PIPISTRELLUS NATHUSII*) AT SEA

BRABANT Robin[1], LAURENT Yves[1], MUTETI Jane[1], JONGE POERINK Bob[2] & DEGRAER Steven[1]

[1] Royal Belgian Institute of Natural Sciences (RBINS), Operational Directorate Natural Environment (OD Nature), Aquatic and Terrestrial Ecology (ATECO), Marine Ecology and Management (MARECO), Vautierstraat 29, 1000 Brussels, Belgium

[2] Ecosensys, Hoofdweg 46, 9966 VC Zuurdijk, the Netherlands

Corresponding author: rbrabant@naturalsciences.be

Abstract

Bats undertaking seasonal migration between summer roosts and wintering areas can cross large areas of open sea. Given the known impact of onshore wind turbines on bats, concerns were raised on whether offshore wind farms pose risks to bats. Better comprehension of the phenology and associated weather conditions of offshore bat migration will provide a science base for mitigating the impact of offshore wind turbines on bats. This study investigated the weather conditions linked to the occurrence of bats in an offshore wind farm in the Belgian part of the North Sea during autumn 2017. We installed seven ultrasonic recorders, registering the echolocation calls of bats, on seven different wind turbines. A total of 142 bat recordings were registered during 23 nights throughout the entire study period. All echolocation calls were identified as calls from the species Nathusius' pipistrelle *Pipistrellus nathusii*. Wind speed seemed to have a large influence on the presence of bats during the study period, with 87% of the detections when the wind speed was maximally 5 m/s. The wind direction is also important for the recorded bat activity at sea, with a clear peak in occurrence when wind originated from the East and the South East. Bat activity was further positively related to temperature and barometric pressure. This study sheds light on the meteorological conditions that favor bat activity at sea. The collection of more data and multivariate analysis would allow to make statistically sound conclusions about the most important variables that explain offshore bat activity in the Southern North Sea.

1. Introduction

Bats undertaking seasonal migration between summer roosts and wintering areas can cross large areas of open sea (Rodrigues *et al.* 2015). This is also the case in the Southern North Sea, where bats have been frequently recorded in the last years (*e.g.* Walter *et al.* 2007; Boshamer & Bekker 2008; Skiba 2009; Leopold *et al.* 2014;

Brabant *et al.* 2016; Lagerveld *et al.* 2017). Nathusius' pipistrelle (*Pipistrellus nathusii*) is the species that is most frequently reported at sea (Hüppop & Hill 2016; Lagerveld *et al.* 2017; Brabant *et al.* 2018), but also common noctules (*Nyctalus noctula*), parti-coloured bats (*Vespertilio murinus*) and Leisler's bats (*Nyctalus leisleri*) have been observed.

Given the known impact of onshore wind farms on bats, offshore wind farms (OWFs) also pose risks to bats (*e.g.* Rodrigues *et al.* 2015; Baerwald & Barclay 2014; Rydell *et al.* 2010; Voigt *et al.* 2012; Lehnert *et al.* 2014; Brabant *et al.* 2018). Because most OWFs are out of the foraging range of local bats, particularly migratory bats may be at risk. Sightings of bats are regularly reported from OWFs (fig. 1; *e.g.* Lagerveld *et al.* 2014; Hüppop & Hill 2016; Brabant *et al.* 2017). Lagerveld *et al.* (2014) reported that these occurrences are generally limited to periods with calm weather suitable for long-distance migration. Also, Hüppop and Hill (2016) hinted towards a weather-dependency of the offshore presence of bats at a research platform 45 km of the German coast. A better comprehension of the phenology and associated weather conditions would provide a science base for mitigating the impact of wind turbines on bats at sea.

This study investigated the weather conditions linked to the occurrence of bats in an OWF in the Belgian part of the North Sea (BPNS) during an autumn migration period. We were particularly interested in shedding a light onto those weather conditions needed for offshore bat migration.

2. Material and methods

The C-Power wind farm is located on the Thornton Bank in the BPNS at approximately 27 km from the nearest point at the Belgian coastline (fig. 2). The wind farm consists of 54 wind turbines and one offshore transformer platform. Six turbines have a capacity of 5 MW; the other 48 are 6.15 MW turbines. The turbines have a cut-in wind speed of 3.5 m/s, a rotor diameter of 126 m, and the hub height is approximately 94 m above sea level.

We installed seven ultrasonic recorders (batcorder 3.0/3.1 EcoObs Ltd., Germany), registering the echolocation calls of bats, on

Figure 1. Bat specimens that were sighted on offshore wind farms (OWFs) in spring 2019. Left picture: bat sp. roosting in the grate floor of a turbine in the Belgian Nobelwind OWF (8 April 2019); right picture: bat sp. roosting on the foundation of a turbine in the Belgian C-Power OWF (30 April 2019).

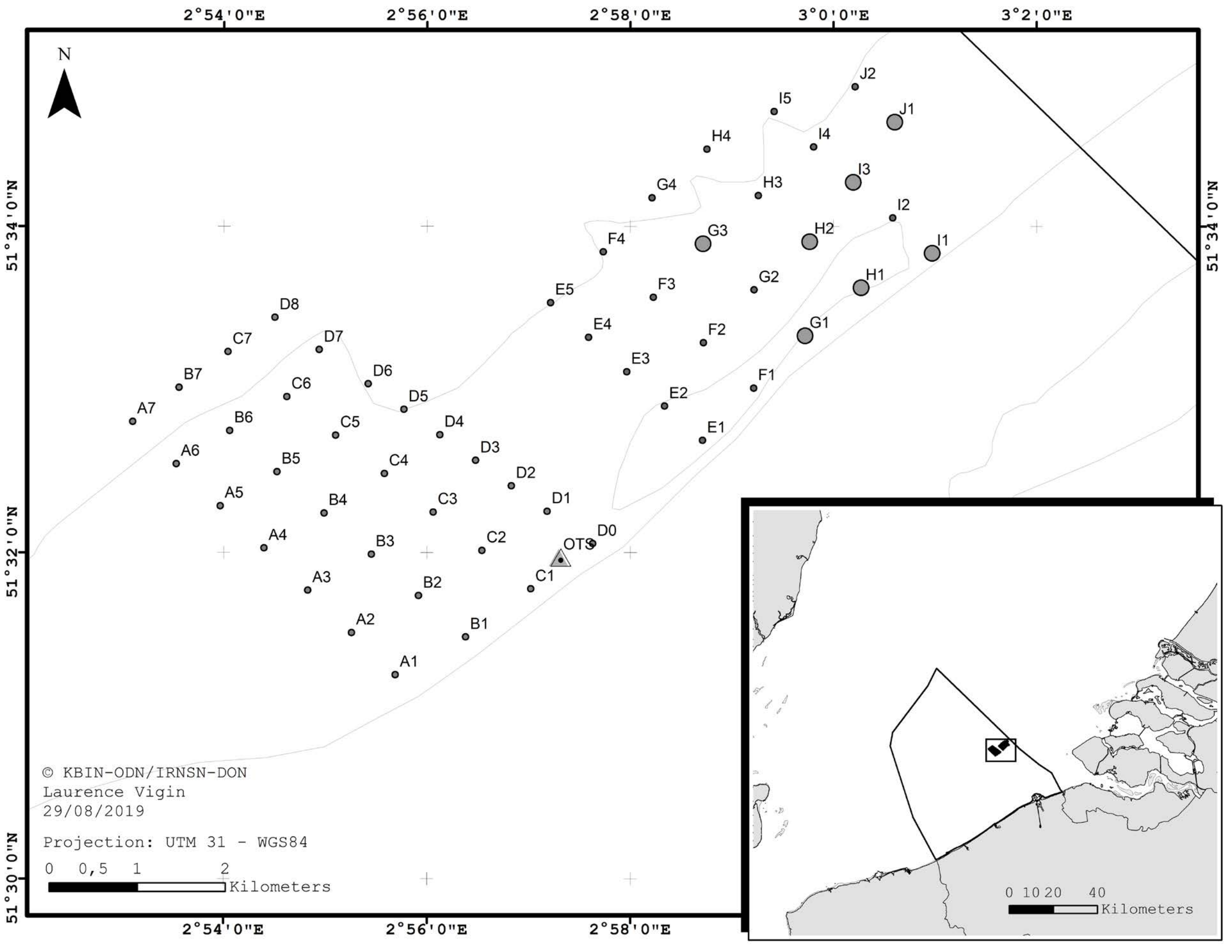

Figure 2. Lay-out of the C-Power wind farm on the Thornton Bank in the Belgian part of the North Sea. Each dot represents a wind turbine. Turbines G1, G3, H1, H2, I1, I3 and J1 (indicated by the large dots), in the North-East of the wind farm, were equipped with a batcorder on the transition piece (16 m amsl). Meteorological data were collected at the offshore transformation station (OTS).

seven different wind turbines in the C-Power wind farm (fig. 2). The batcorders were installed on the service platform of the turbines, at approximately 16 m above MSL. Each recorder was powered by a solar panel. The recorded data were locally stored on SD memory cards. The batcorders were installed on 8 August 2017 and were operational until 30 November 2017. We made full spectrum recordings in .RAW format (sampling rate: 500 kHz; record quality: 20; threshold amplitude (sensitivity): -36 dB; post trigger: 400 ms; threshold frequency (sensitivity): 30 kHz). A threshold frequency of 30 kHz was used to avoid wind turbine generated noise in the dataset. This setting does not allow to reliably sample Nyctaloid bats (*i.e.* a species group that includes genera *Nyctalus*, *Vespertilio*, *Eptesicus*) that have a frequency of maximum energy (FME) lower than 30 kHz (Barataud 2015). Therefore, this study focused on pipistrelle bats, which are most frequently recorded offshore (see above).

Detections were processed and visualised with the software program Sonochiro 3.3.3 (Biotope, France). Automated species identifications were verified by a bat expert. To level off high numbers of recordings caused by one individual residing near the recorder, the recordings were converted to detection positive ten minutes (DP10) meaning that a ten-minute period is considered as positive if it contains at least one bat call (*e.g.* a specimen producing 100 calls in 10 minutes and a specimen only calling once are valued in the same way and render one DP10).

The meteorological variables wind speed, wind direction, visibility and atmospheric pressure were collected by C-Power at their offshore transformation station (fig. 2), with a 1- to 10 minute resolution. Air temperature data were retrieved from the Scheur Wielingen measuring pile, which is part of the Flemish banks monitoring network of the Agency for Maritime Services and Coast. For further analysis, the meteorological values nearest to the time of a bat detection, were linked to that detection. The number of bat recordings were normalised by dividing the number of records (DP10) by the frequency of occurrence of that meteorological variable (*e.g.* wind direction) during the study period.

We calculated the tailwind component (TWC) and crosswind component (CWC) to assess the influence of the wind on the recorded bat activity. Calculations were done following the methodology of Hüppop and Hilgerloh (2012):

- TWC = cos (observed wind direction - tailwind direction) x wind speed;
- CWC = sin (observed wind direction - tailwind direction) x wind speed.

The tailwind direction is defined as the direction of migration minus 180°. Positive TWC values mean tailwind, negative values are headwind. Positive CWC are winds from the left of the bat migrating into the presumably preferred direction, winds from the right are negative CWC.

Hüppop and Hill (2016) assumed a WSW direction of bat migration in autumn for similar calculations with data from the FINO1 platform in the German Bight based on recoveries of ringed Nathusius' pipistrelles (Pētersons 2004; Vierhaus 2004). Reproduction areas of Nathusius' pipistrelle are located in North-Eastern Europe, whereas the wintering areas are in the South-West (Dietz & Kiefer 2016), this implies a SW migration during autumn. Therefore, we calculated TWC and CWC for two scenarios: (1) direction of flights to the WSW (*i.e.* bats crossing the North Sea towards the UK from the Dutch Zeeland coast, hereby passing the study site); and (2) SW direction of flight. Positive CWC mean in both cases offshore crosswinds.

3. Results

Bats were registered throughout the entire study period, from the end of August until the end of November, with a peak between the 23rd and 29th of September. A total of 142 bat recordings, equaling 68 DP10, were made by all seven batcorders. All echolocation calls were identified as calls from the species Nathusius' pipistrelle *Pipistrellus nathusii*. Bat activity was recorded during 22 nights (fig. 3).

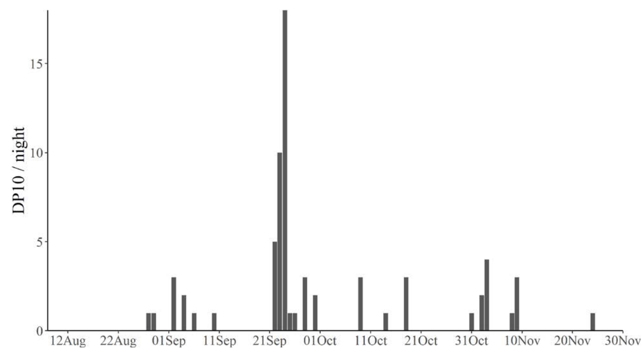

Figure 3. Detection positive 10 minutes (DP10) per night from 8 August until 30 November 2017.

The recorded wind speed at night was on average 7.6 ± 4.5 m/s during the study period, with a median value of 7.0 m/s and a maximum of 27.4 m/s. The mean wind speed at the time bats were recorded was 3.1 ± 1.9 m/s, with a median value of 2.4 m/s. 66% of the DP10 occurred when the wind speed was lower or equal to 3 m/s; 87% when wind speed was maximally 5 m/s (fig. 4). No bats were recorded when wind speed was higher than 11 m/s.

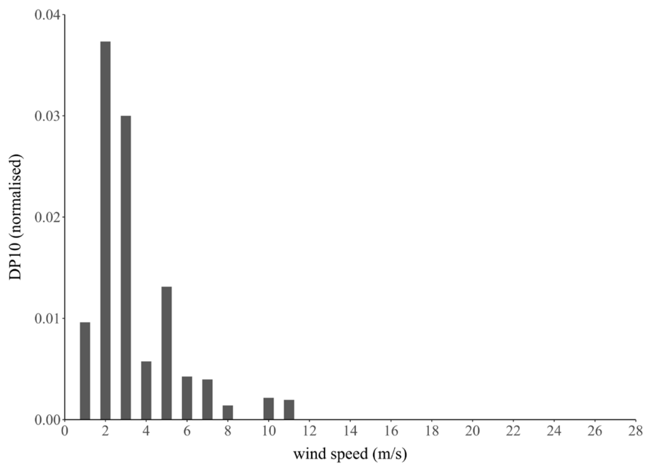

Figure 4. Normalised detection positive 10 minutes (DP10) of bat recordings in relation to wind speed. The range on the X-axis is the range of wind speed measured during the study period.

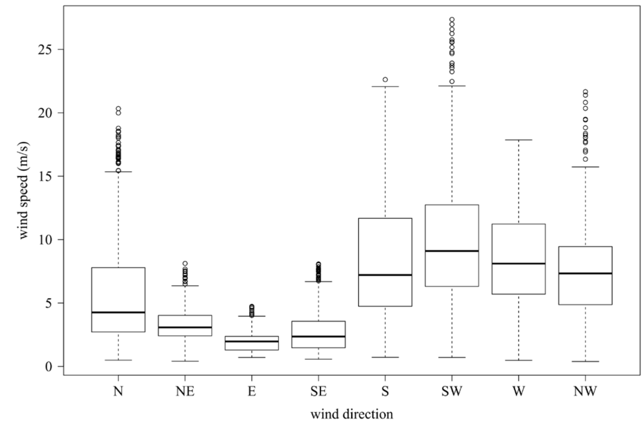

Figure 6. Boxplot of the wind direction and wind speed during the entire measurement period. Line in the box is the median value. Lower and upper limits of the box represent 25th and 75th percentile of the data, respectively. The upper whisker is defined as a 75th percentile + (1.5 x spread). The lower whisker is 25th percentile – (1.5 * spread), the spread being 75th – 25th percentile.

Most recordings were made during easterly (n = 16 DP10) and southeasterly (n = 18 DP10) wind and to a lesser extent wind from the south (n = 12 DP10). These are the wind directions that were the least frequently measured during the study period. Normalising the number of recordings per wind direction results in a clear peak in bat activity during easterly and southeasterly winds (fig. 5). These are the wind directions were the lowest wind speed was measured (fig. 6).

On average, bats were detected during a slight headwind (mean TWC = -0.53 ± 2.79) and offshore crosswind conditions (mean CWC = 1.19 ± 1.96), when we assume that the direction of migration is WSW (fig. 7). This is also the case when assuming a SW migration direction (mean TWC = -0.95 ± 2.74; mean CWC = 0.89 ± 2.02; fig. 8).

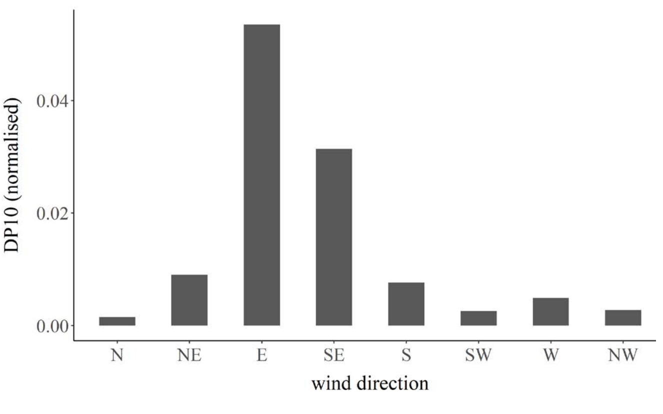

Figure 5. Normalised bat activity in relation to wind direction, *i.e.*, detection positive 10 minutes (DP10) of bat recordings divided by the frequency of occurrence of the wind direction during the study period.

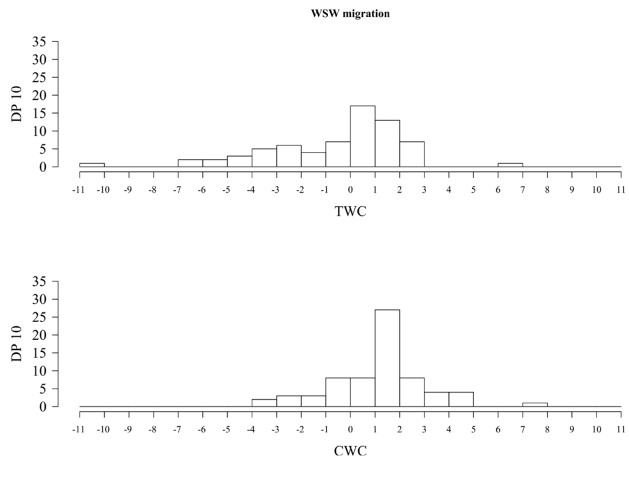

Figure 7. Detection positive 10 minutes (DP10) of bat recordings in relation to the tailwind and cross wind component, assuming a WSW migration direction. Positive TWC = tailwinds; negative TWC = headwinds. Positive CWC = offshore wind; negative CWC = onshore wind.

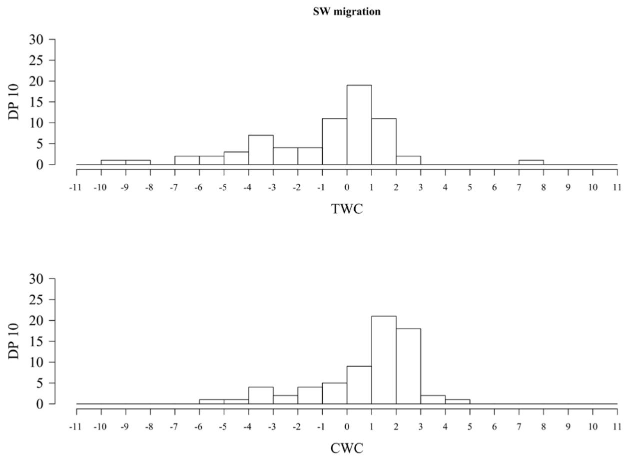

Figure 8. Detection positive 10 minutes (DP10) of bat recordings in relation to the tailwind component and cross wind component, assuming a SW migration direction. Positive TWC = tailwinds; negative TWC = headwinds. Positive CWC = offshore wind; negative CWC = onshore wind.

The mean atmospheric pressure during the study period was 1010.7 ± 7.7 hPa, with a median value of 1012.3 hPa. During bat recordings the atmospheric pressure was 1015.2 ± 4.0 hPa and a mean of 1017.0 hPa (fig. 9). Nighttime temperature was 13.6 ± 3.5°C on average during the study period. The mean temperature when bats were recorded was 13.8 ± 2.4°C (fig. 10).

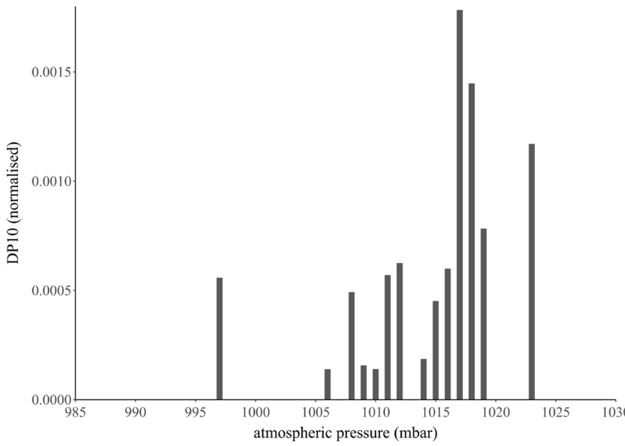

Figure 9. Normalised detection positive 10 minutes (DP10) of bat recordings in relation to atmospheric pressure (hPa). The range on the X-axis is the range of atmospheric pressure measured during the study period.

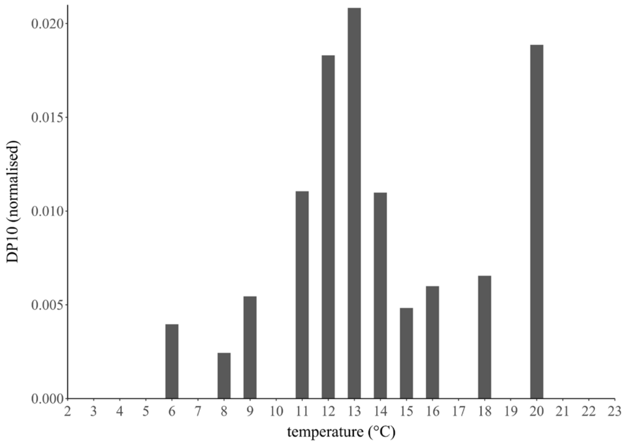

Figure 10. Detection positive 10 minutes (DP10) of bat recordings in relation to temperature (°C). The range on the X-axis is the range of temperature values measured during the study period.

4. Discussion

All recordings that were made were identified as Nathusius' pipistrelles. The threshold frequency used in this study (30 kHz, to avoid turbine generated noise), however, prevented to reliably detect Nyctaloid bats (genera *Eptesicus*, *Vespertilio* and *Nyctalus*). Therefore, our conclusions are only valid for pipistrellus bats. However, other studies showed that this is by far the most common species detected at the North Sea, with occurrence rates between 82 and 100% (Lagerveld *et al.* 2014; Hüppop & Hill 2016).

The highest number of detections were registered in the month of September (DP10 = 47) and, to a lesser extent, October (DP10 = 8) and November (DP10 = 11). This coincides with the known migration peak period for Nathusius' pipistrelle (*i.e.* mid-August to mid-October; Rydell *et al.* 2014; Barataud 2015). The relatively high number of detections in November is remarkable. Less detections than expected were recorded in August (study started August 8th), *i.e.* two DP10. As the weather in August 2017 was colder than average and with a lot of precipitations, we expect that the migration period of bats started later than on average.

Wind speed seemed to have a large influence on the presence of bats during the study period, with 66% of the DP10 recorded when the wind speed was lower or equal to 3 m/s, 72% when wind speed was lower or equal to 4 m/s and 87% when wind speed was not higher than 5 m/s. The cut-in wind speed, *i.e.* wind speed at which the wind turbine rotor starts rotating, of operational and planned wind turbines in the BPNS is between 3.0 and 4.0 m/s. This means that most of the bat activity took place when the turbines were not operational. Increasing the cut-in wind speed to 5 m/s would be an effective mitigation measure and is as such already imposed in the planned Dutch Borssele wind farms between August 15 and October 31 (Lagerveld *et al.* 2017).

The wind direction is also important for the recorded bat activity at sea, with a clear peak in occurrence when wind originated from the E and the SE. This coincides with the findings of Lagerveld *et al.* (2017) who report highest bat activity at sea during wind directions between NE and SE. However, the mean wind speed was lowest when the wind direction was NE, E and SE. Most likely, the low wind speed was a more important driver of the reported bat activity.

By calculating the TWC and CWC, the wind direction and wind speed at the time of bat recordings are combined. This results in, on average, slight headwind and crosswind conditions, both when assuming a WSW and SW migration direction. Hüppop and Hill (2016) reported that the highest bat activity at a research platform in the German Bight coincides with crosswind conditions, which suggests that wind drift is the main driver of bat occurrence at sea. Given the high number of recordings during low wind speed conditions, it seems unlikely that offshore drift explains the occurrence of bats in our study site. It might be the case for some recordings, but intentional migration across the North Sea channel seems more likely for most recordings.

Bender and Hartman (2015) showed that bat activity on land was positively related to average nightly temperature and average nightly barometric pressure. Our results suggest that this is also the case for bat activity across the North Sea.

This study sheds light on the meteorological conditions that favor bat activity at sea. Multivariate analysis would allow to make statistically sound conclusions about the most important variables that explain bat activity. At this point, however, we do not have enough data to perform reliable multivariate statistical analysis. Therefore, it is needed to continue to collect recordings of bats at sea. More data will then result in more robust conclusions about the drivers of the activity of bats at sea in order to support future policy decisions with regards to offshore wind farms.

References

Baerwald, E.F. & Barclay, R. 2014. Sciencebased strategies can save bats at wind farms. *Bats* 32 (2): 2-4.

Barataud, M. 2015. *Acoustic Ecology of European Bats. Species, Identification, Study of their Habitats and Foraging Behaviour*. Mèze: Biotope Éditions.

Bender, M.J. & Hartman, G.D. 2015. Bat activity increases with barometric pressure and temperature during autumn in central Georgia. *Southeastern naturalist* 14 (2): 231-243.

Brabant, R., Laurent, Y. & Jonge Poerink, B. 2018. First ever detections of bats made by an acoustic recorder installed on the nacelle of offshore wind turbines in the North Sea. In S. Degraer, R. Brabant, B. Rumes & L. Vigin (eds), *Environmental Impacts of Offshore Wind Farms in the*

Belgian Part of the North Sea: Assessing and Managing Effect Spheres of Influence. Memoirs on the Marine Environment. Brussels: Royal Belgian Institute of Natural Sciences, OD Natural Environment, Marine Ecology and Management Section, pp. 129-136.

Dietz, C. & Kiefer, A. 2016. *Bats of Britain and Europe*. London : Bloomsbury Publishing.

Hüppop, O. & Hilgerloh, G. 2012. Flight call rates of migrating thrushes: effects of wind conditions, humidity and time of day at an illuminated offshore platform. *Journal of Avian Biology* 43 (1): 85-90.

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

Lagerveld, S., Jonge Poerink, B., Haselager, R. & Verdaat, H. 2014. Bats in Dutch offshore wind farms in autumn 2012. *Lutra* 57 (2): 61-69.

Lagerveld, S., Gerla, D., Tjalling van der Wal, J., de Vries, P., Brabant, R., Stienen, E., Deneudt, K., Manshanden, J. & Scholl, M. 2017. *Spatial and temporal occurrence of bats in the southern North Sea area*. Wageningen Marine Research (University & Research centre), Wageningen Marine Research report C090/17, 52 p.

Lehnert, L.S., Kramer-Schadt, S., Schönborn, S. Lindecke, O., Niermann, I. & Voigt, C.C. 2014. Wind farm facilities in Germany kill noctule bats from near and far. *PloS ONE* 9 (8): e103106.

Leopold, M.F., Boonman, M., Collier, M.P., Davaasuren, N., Fijn, R.C., Gyimesi, A., de Jong, J., Jongbloed, R.H., Jonge Poerink, B., Kleyheeg-Hartman, J.C., Krijgsveld, K.L., Lagerveld, S., Lensink, R., Poot, M.J.M., van der Wal., J.T. & Scholl, M. 2014. *A first approach to deal with cumulative effects on birds and bats of offshore wind farms and other human activities in the Southern North Sea*. IMARES Report C166/14.

Pētersons, G. 2004. Seasonal migrations of northeastern populations of Nathusius' bat *Pipistrellus nathusii* (Chiroptera). *Myotis* 41/42: 29-56.

Rodrigues, L. *et al.* 2015. Guidelines for consideration of bats in wind farm projects: revision 2014. UNEP/EUROBATS.

Rydell, J., Bach, L., Dubourg-Savage, M.-J., Green, M., Rodrigues, L. & Hedenström, A.. 2010. Bat mortality at wind turbines in northwestern Europe. *Acta chiropterologica* 12 (2): 261-274.

Skiba, R., 2009. *Europäische Fledermäuse.* Hohenwarsleben: Verlagskg Wolf, 220 p.

Vierhaus, H. 2004. *Pipistrellus nathusii* (Keyserling und Blasius, 1839) – Rauhhautfledermaus. In F. Krapp (ed.), *Handbuch der Saugetiere Europas*. Wiebelsheim: Aula, pp. 825-873.

Voigt, C.C., Popa-Lisseanu, A.G., Niermann, I. & Kramer-Schadt, S. 2012. The catchment area of wind farms for European bats: a plea for international regulations. *Biological conservation* 153: 80-86.

Walter, G., Mathes, H. & Joost, M. 2007. Fledermauszug über Nord- und Ostsee – Ergebnisse aus Offshore-Untersuchungen und deren Einordnung in das bisher bekannte Bild zum Zuggeschehen. *Nyctalus* 12: 221-233.