Impact of wind speed on the activity of bats - at the coast and inland

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Introduction

In recent years nature conservation organizations and authorities in Germany became increasingly aware of bat fatalies at wind turbines and the legal implications of this. This led to the introduction of mitigation measurements in order to prevent bat fatalies as much as possible.In wind parks with high bat activity the only mitigation measures available are often site choice for individual turbines and switching off the turnbines during critical periods.
Additionally there is often an obligation to carry out bat monitoring after the turbines have been constructed to adjust the mitigation measurements, especially to define cut-in wind speed, and to identify seasonal patterns with high bat activity.
In this poster we present two of our monitoring studies, one at the coast and the other 200 km inland. We will concentrate on the influence of wind speed on bat activity. Our hypotheses are:

1. Different species show different tolerance to wind speed
2. Cut in wind speed cannot be defined countrywide but has to be assessed for each wind farm separately
3. In seasons with high wind speeds, such as autumn, the pattern of bat activity is different to other seasons and therefore curltailment can be adjusted according to seasons.

Study areas

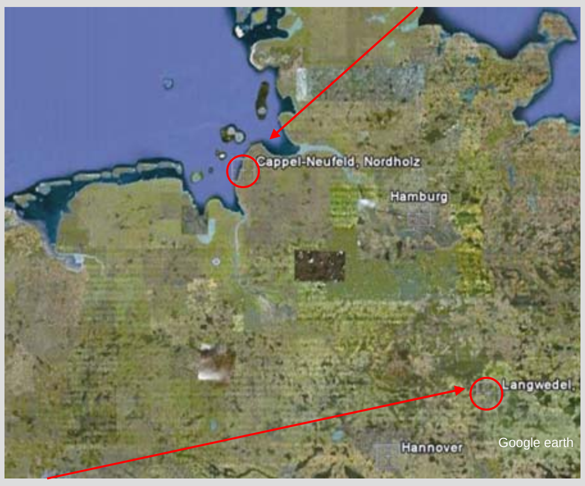
Inland (Langwedel)

Fig 1a: landscape and position of the microphone pointing downwards (red arrow, similar to it at a Vestas wind turbine)

Methods

The monitoring took place at five wind turbines between 1 April and 30 November 2009 and 2010. Bats were monitored acoustically and parallel carcass searches were carried out. The wind turbines (Vestas V100) were **125 m high** (nacelle) with a **blade diameter of 100 m**. Wind speed was measured at the height of the nacelle at one of the turbines. To assess the bat activity (acoustic monitoring) we used AnaBat SD1 (Titley, Ballina, Australia). The **microphone** was situated **at the nacelle** and pointed downwards between the rotor blades and the mast in 2009. In 2010 the microphone pointed downwards at the rear end of the nacelle.
We combined the wind speed and the contact data of both years for each species. The analysis was carried out in the statistic programme R.

Cappel (close to Cappel-Neufeld) is about 500m inland from the dike and about 1,5km from the coastline. It is situated between the estuaries of the rivers Weser and Elbe (Lower Saxony). The area itself consists mostly of pastures, meadows and arable fields. Hedgerows are rare.



Langwedel belongs also to the northgerman lowlands (Lower Saxony, Lüneburger Heide) but is situated 170 km from the coast. Agricultural land use is similar to the Cappel site but the site contains more hedgerows. A small woods is situated nearby.

Coast (Cappel)

Fig 1b: landscape and position of the microphone pointing downwards (red arrow) in combination with a mirror plate

Methods

The monitoring took place at four wind turbines (Enercon E-33) between 15 July and 30 October 2008 and 2009. Bats were monitored acoustically and parallel carcass searches were carried out. The wind turbines were **40 m high** (nacelle) with a **blade diameter of 34 m**. Wind speed was measured at one of the turbines at the height of the nacelle. To assess the bat activity (acoustic monitoring) we used AnaBat SD1 (Titley, Ballina, Australia). The **microphone** was installed outside at the mast **at a height of 20 m**. In order to record only these bats flying within the range of the blades we installed a reflector plate underneath the microphone, which pointed downwards.
We combined the wind speed and the contact data of both years for each species. The analysis was carried out in the statistic programme R.

Results (inland)

In total 1511 contacts of five species were registered. *Nyctalus noctula* (63%) was by far the most common species. Less common were *Pipistrellus pipistrellus* (12%) and *Pipistrellus nathusii* (5%). For *Pipistrellus pygmaeus* and *Eptesicus serotinus*, only five and four calls, respectively, were registered. Not included were 19% of contacts belonging to the genus *Nyctalus*, which could not be identified to species level
The whole data set or only the data of *Nyctalus noctula, Pipistrellus pipistrellus* and *Pipistrellus nathusii* were used in the following results.

Definition of bat contacts:
1 bat contact = 1 bat in an AnaBat-file of 15 sec
2 bats in an AnaBat-file of 15 sec. = 2 bat contacts

Results (coast)

In Cappel 2646 contacts of five species were registered. *Pipistrellus nathusii* was the most common species (48%) followed by *Pipistrellus pipistrellus, Nyctalus noctula* (18 and 17%, respectively) and *Eptesicus serotinus* (6%). Only 2 contacts were registered for *Pipistrellus pygmaeus*.
The whole data set or the data of *Nyctalus noctula, Pipistrellus pipistrellus* and *Pipistrellus nathusii* were used in the following results.

<u>Comparison between wind speeds in the total study period and during periods of bat activity</u>
The comaprison shows a significant difference between the wind speeds within the study period and the wind speeds that are used by bats. Bats at turbines were more abundant at lower relative to higher wind speeds.

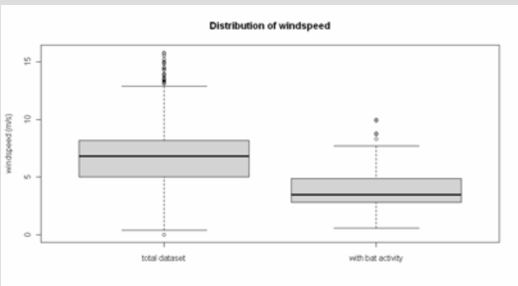


Fig 2a: distribution of wind speed in total and only with bat activity at Langwedel

Comparison of threshold activity levels for the most abundand species between the inland and coastal study site
According to mitigation measurements we estimated a threshold level of bat activity (95%) above which the chance of collision is reduced to the level of a random event. Table 1 gives the wind speed up to which 95% of each species were active. shows the highest wind speed up to 95 % of bat activity of a certain species.

	Inland 95 % activity	Coast 95 % activity
Nyctalus noctula	5,9 m/s	6,6 m/s
Pipistrellus pipistrellus	5,6 m/s	6,5 m/s
Pipistrellus nathusii	7,3 m/s	7,6 m/s
Eptesicus serotinus	too few data	6,8 m/s

Nyctalus noctula and *Pipistrellus pipistrellus* had their 95% activity level at a lower wind speed than *Pipistrellus nathusii*. The 95% acitivity levels for both species were considerably lower in Langwedel relative to Cappel. *Pipistrellus nathusii* showed quite similar results in both monitroing areas.

Comparison between wind speeds in the total study period and during periods of bat activity
The distribution of wind speeds during times of bat activity and during the whole study period showed a similar pattern for both study sites. However, no significant difference in wind speed between times with bat activity relative to the whole study period was found for Langwedel.

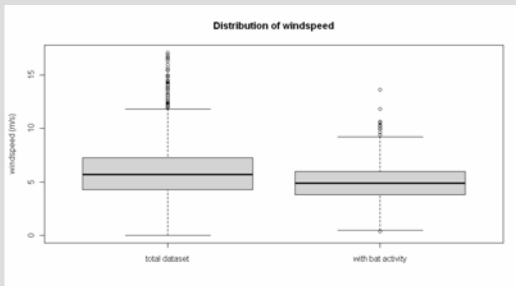


Fig 2b: distribution of wind speed in total and only with bat activity at Cappel

<u>Wind tolerance of the most common bat species in Langwedel:</u>
In total the bat activity occured within a statistical range interquartile range of between 0 and 8 m/s in Langwedel.
Although the differences are not significant, P. nathusii shows a slightly higher wind tolerance than the other species.

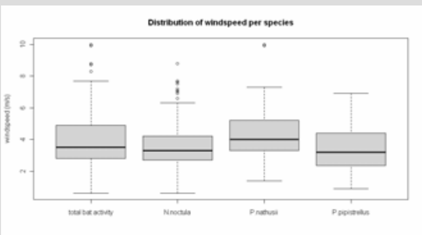


Fig 3a: distribution of wind speed per species at Langwedel

<u>Bat fatalities and wind speed</u>
The results indicate that the majority of bat fatalities occured at wind speeds of 4-7 m/s with a slight concentration at wind speeds around 5-6 m/s. However, it has to keep in mind that the excact time of death and the wind speed at that time was unknown.

<u>Inland</u>

Bat fatalities Species (number)	Average windspeed in the previous three nights
Pipistrellus nathusii(2)	5,3 m/s
Nyctalus leisleri (1)	5,0 m/s
Nyctalus noctula (7)	5,8-6,4 m/s

<u>Coast</u>

Bat fatalities Species (number)	Average windspeed in the previous three nights
Pipistrellus nathusii(5)	3,9 – 7,0 m/s
Pipistrellus pipstrellus (2)	5,3; 6,6 m/s

<u>Wind tolerance of the most common bat species in Cappel:</u>
At the coast the interquartile range of bat activity lies up to 9 m/s and again the boxes reveal borders of activity at about 6,5 m/s. *Pipistrellus nathusii* show the same pattern as at the inland: again, this species is most tolerant against higher windspeed, although the data are not significant.

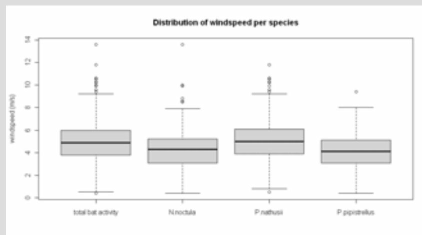


Fig 3b: distribution of wind speed per species at Cappel

<u>Adjustment of curltailment according to the season</u>
In Langwedel the wind speed rose slightly in September and October.
Nyctalus noctula and Pipistrellus nathusii occured in lower wind speeds than the median of the total dataset. The data indicate that both species tolerated higher wind speeds in September. Pipistrellus pipistrellus showed the highest wind tolerance in August.

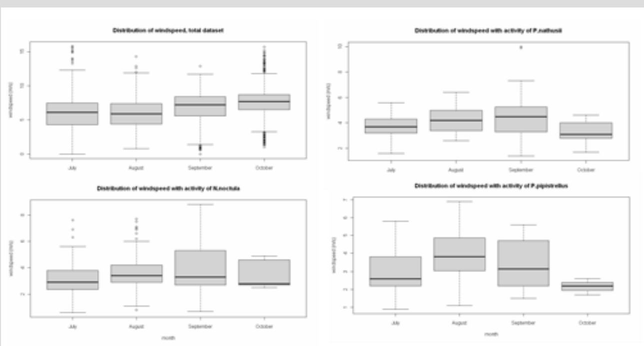


Fig 4a: distribution of wind speed per month and of the three most abundant species at Langwedel

<u>Adjustment of curltailment according to the season</u>
At the coast the average wind speed did not change with season. As with wind speed, the activity of each species did not change with season.

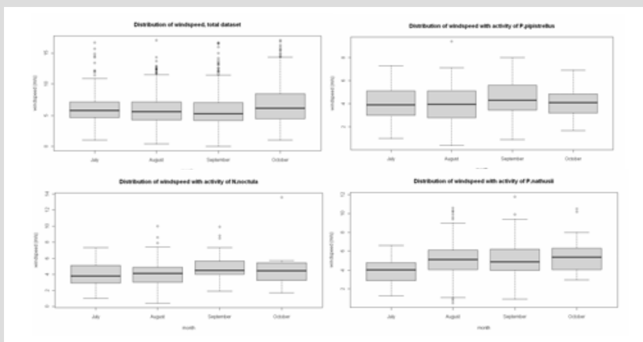


Fig 4b: distribution of wind speed per month and of the three most abundant species at Cappel

Discussion

According to German and European law (e.g. Habitate directive) it is illegal to kill bats on purpose. However, some bat species collide with wind turbines regularly (Rodriguez et al. 2008, Rydell et al 2010). Consequently, whenever wind turbines are build in areas with a high amount of activity of these species mitigation measures are required to reduce the risk of collisions to below a certain level. According to German law, mitigation measures are required when there is a "significant increase in collision risk", or in other words, when regular collisions are probable. Since the probability of collisions increases with the activity of bats, a threshold level of activity has to be defined, below which the bat activity is so low that the probability of collisions is random. That means that mitigation measures should cover a defined level of the bat activity (here 90-95%) to comply with German law. The most common mitigation measure is a curtailment concept including the factors seasonal and diurnal pattern, temperature and especially wind speed (Arnett et al. 2010, Baerwald et.al 2009).
Wind tolerance of different species
Although the results are not significant in both study sites, *Pipistrellus nathusii* appears to be the most windtolerant species. This might not be asthonishing since *Pipistrellus nathusii* is a long distant migrant. In contrast, *Nyctalus noctula* is also a migratory species and is a big bat and strong flyer which regularly hunts in open areas (Bach & Bach 2009, Behr et al 2011).But in both study sites it appeared to be less wind tolerant than *Pipistrellus nathusii*.
It is necessary to know the species composition and their abundance at each site to refine mitigation measures. For example, in the absence of a *Pipistrellus nathusii* population 'cut in wind speeds' can be set to a lower level.
It appears that bat fatalities occur at higher wind speeds. It has to take into account that there is a range between low wind speed (when the windtrubines are shut down) and high wind speed (when only very few bats fly) Nevertheless collisions happened mostly in average wind speed up to 7,0 m/s.
Regional and seasonal differences
The comparion of these two study sites might suggest that there are suprisingly small differences in the wind speed situation. Nevertheless the bat activity inland was significantly lower in higher wind speeds wheras at the coast wind speed did not seem to affect the occurence of bats. However, this might be due to an effect of the wind turbine height. One factor that might explain the differences in wind tolerance is the height at which the bat activity was recorded. Bat activity decreases with increasing altitude (e.g. Collins & Jones 2009). This decrease might be partly due to an increase in wind speed and a possible decrease of insect abundance (given that wind speed is held constant) with altitude. Another explanation could be differences in landscape structure. Whereas the site at Langwedel contains many hedgerows and small woods, the site at Cappel does not. Bats in Langwedel had the opportunity to avoid high wind speeds by hunting in the wind shadow of hedges. In Cappel the bats did not have this opportunity.
It was possible to refine curltailment according to the seasonal patterns of the species in Langwedel but this was not the case in Cappel at the coast where the seasonal wind patterns of species showed no differences.
In conclusion, although the sites showed similarities such as the distribution of wind speeds, they also showed differences such as in species composition and abundances or in different level of wind tolerance of species (see *Nyctaus noctula* and *Pipistrellus pipistrellus* at the 95% level). Therefore, it is advisable to treat every site separately.

Acknowledgements

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