Bat fatalities at different wind facilities in Northwest Germany

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Introduction

Due to the climate change discussion several governments aim to increase the production of renewable energy. Especially wind power is increasing in Germany and Europe. BRINKMANN et al. (2011) stated that the collision rate of bats with wind turbines (WT) in Germany is about 9-10 bats/WT/year. However, there is a huge variation between landscapes and geographical areas (NIERMANN et al. 2011, RYDELL et al. 2010). The reasons for this are that habitat types the distribution of bats and an area's importance for bat migration varies between landscapes. These factors influence the overall number of collisions and the species which are most affected. Our aim here is to present data on bat collisions for different wind farms in several landscapes in north-western Germany and to identify variables that might predict bat mortality in north-western Germany (see AMORIM et al. 2012, SANTOS et al 2013).

Methods

We did post construction monitoring studies at five different wind farms (19 wind turbines of different turbine types) in north-western Germany. The types and technical parameters are described in table 1. Bats were monitored acoustically and parallel carcass searches were carried out.

To assess the bat activity (acoustic monitoring) we used AnaBat SD1 (Titley, Ballina, Australia) or Avisoft-Detectors (Avisoft Bioacoustics, Berlin, Germany). In most cases the **microphone** was situated **at the nacelle** and pointed downwards at the rear end of the nacelle. In one case, the wind farm **Cappel**, the AnaBat-**microphone** was installed outside at the mast **at a height of 20 m**. In order to record only bats flying within the range of the blades we installed a reflector plate underneath the microphone, which pointed downwards. Wind speed and temperature was measured at the height of the nacelle at one of the turbines.

The carcass searches were carried out every third day at a radius of 40 - 50 m around the turbines and we carried out carcass removal trials to estimate the scavenging rate and search efficiency (after RODRIGUES et al. 2008, BRINKMANN et al. 2011). To estimate the mortality rate we used the following formula:

H = T x S x A x F

H = estimation of mortality rate

T = number of fatalities

S = search efficiency (estimated for each visibility class resp. searcher and weighted according to the percentage of the visibility classes at each site)

A = carcass removal (average accumulated percentage of removal, in our case over three days)

F = an area factor, which includes the area that was impossible to search

To identify driving factors of bat fatalities, we performed a general linear model analysis (GLM). Bat fatalities were specified as dependent variable of the model; bat activity (contacts), wind-turbine dimensions, weather data and location parameters were specified as independent variables of the model. The dependent variable was log-transformed $x' = \ln(x+1)$ prior to analysis. Bat fatalities represented 3-day measurements, and therefore weather data and bat contacts were averaged over three days to match the same time-resolution. Non-linear terms of weather data were included to allow for representation of a hump-shaped relationship between weather and bat fatalities in the model. Backward selection of variables was applied to ensure that the final model was exclusively built from significant variables. The analysis was performed using the Statistica for Windows package (StatSoft Inc., Tulsa, OK, USA).

Definition of bat contacts:

1 bat contact = 1 bat in an AnaBat-file or Avisoft-file of about 15 sec

2 bats in an AnaBat-file or Avisoft-file of 15 sec. = 2 bat contacts

Table 1: study areas, study design and characterisation of the studied wind turbines

	Cappel	Langwedel	Aurich	Friesland	Cuxhaven
type of WT	ENERCON E33	Vestas V90	ENERCON E82	Nordex	AN Bonus
nacelle height	40 m	125 m	108 m	90 m	60 m
free height°	23 m	80 m	67 m	45 m	22 m
blade radius	17 m	45 m	41 m	45 m	38 m
airspace cut through	2752.5 m^3	19985.9 m^3	16590.8 m^3	19985.9 m^3	14251.7 m^3
Distance to structures	500 m	100 m	75 m	130 m	450 m
Distance to coastline	800 m	190 km	35 km	3,7 km	4,5 km
study year	2008 + 2009	2009 + 2010	2011 + 2012	2012	2012
number of WT	7	5	6	5	2
acoustic monitoring	4	5	6	2	2
Carcass search	7	5	6	5	2

° = free space between rotor blade tip and ground

Results

Species distribution and amount of estimated fatalities

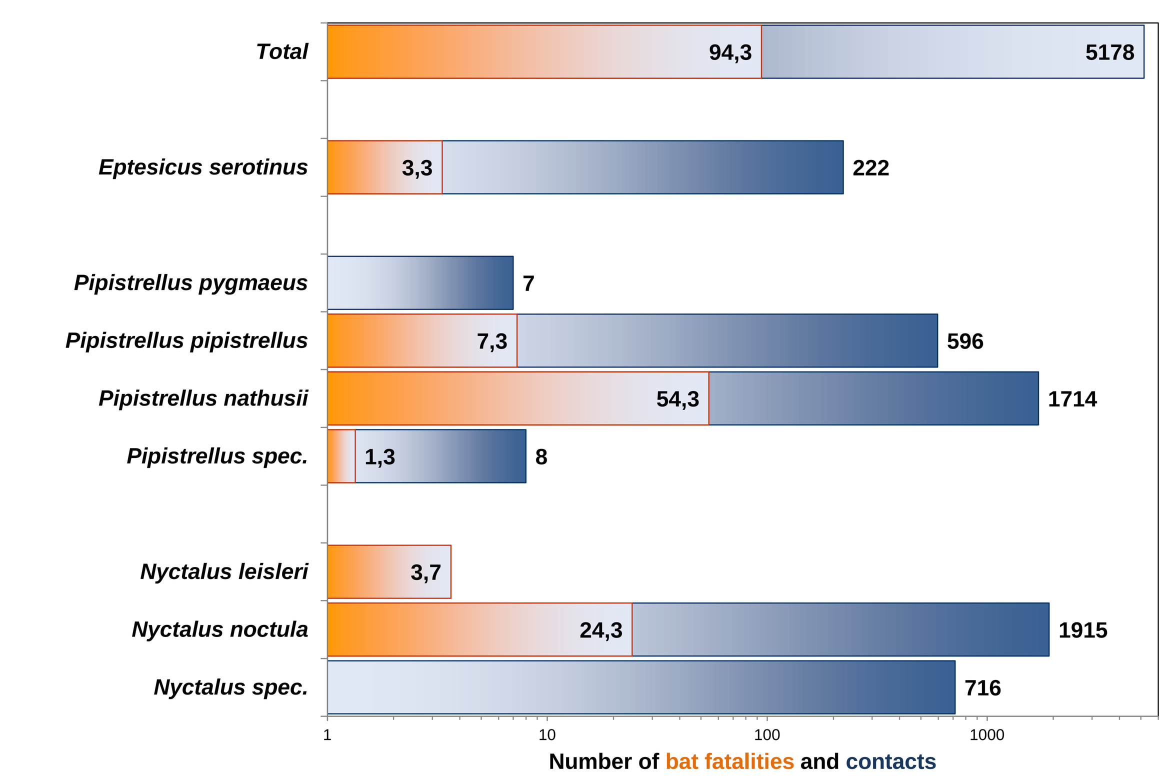

Fig.1: overview of the species, number of contacts and estimated fatalities of each species in five investigated wind facilities in NW- Germany

In our five investigated wind facilities *Pipistrellus nathusii* was the species with the most estimated (and real) fatalities by far, whereas *Nyctalus noctula* was the species with the most contacts. According to DÜRR 2012, *Nyctalus noctula* is the bat species with the highest mortality rate at wind farms in Germany, followed by *Pipistrellus nathusii*. On average, one bat is killed every 45 contacts (*P. nathusii* every 29 contacts, *P. pipistrellus* every 81 contacts, *N. noctula* every 79 contacts, *E. serotinus* every 27 contacts). All these species are known to have summer colonies in the surrounding of the wind facilities. *P nathusii* and *N. noctula* are also known migrant species.

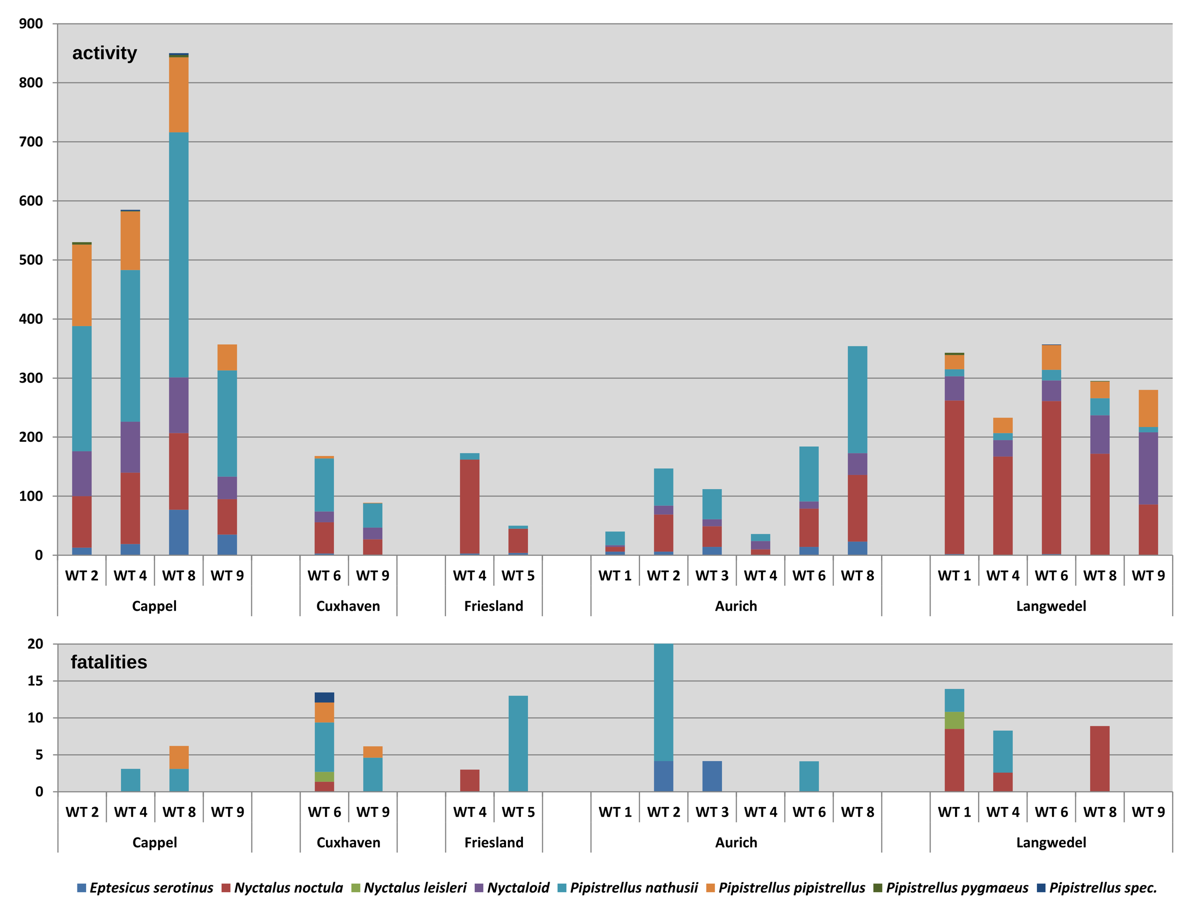

Fig. 2: bat activity (above) and estimated bat fatalities (below) per species at each monitored WT

Figure 2 is an example of the great variability of the data if we compare each wind turbine (WT) in each project and year. The number of contacts at nacelle height varies from 36 contacts (WT 4 in Aurich) to 850 contacts (WT 8 in Cappel). Estimated bat fatalities vary from 0 (at 7 of 19 WT) to 20.1 (WT 2 in Aurich) in two years of investigation. It is interesting that the number of bat fatalities can differ considerably between turbines within one wind farm (see Aurich). The fatalities and the recorded species reflect the typical species found in NW-Germany, but abundances differ between areas: Whereas in Langwedel and Friesland *Nyctalus noctula* was the most abundant species, *Pipistrellus nathusii* was the most recorded species in all other wind facilities. The mortality rate of a species does not seem to be proportionate to its abundance. Especially in Friesland considerably more *Pipistrellus nathusii* than *Nyctalus noctula* carcasses were recovered.

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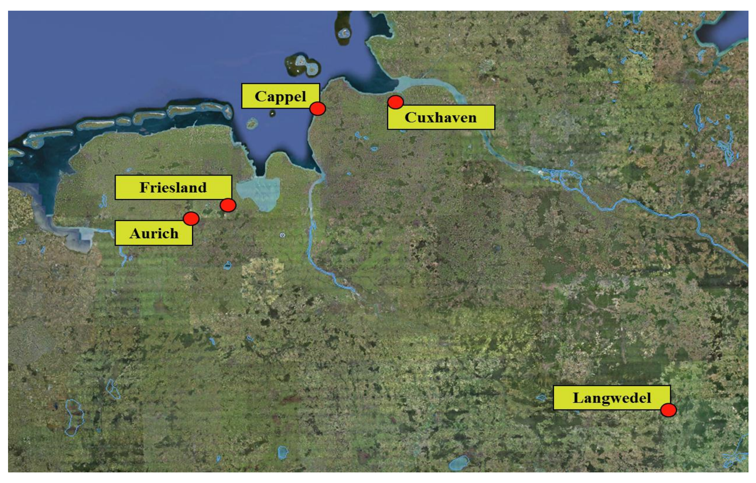

Map of the investigated area, diameter east-west: ca.100km, north-south 200 km

Results

Bat fatalities and parameters of the wind facilities

As the most affected species in our investigation was *Pipistrellus nathusii* we present results for this species only.

Table 2: Analysis of *P. nathusii* fatalities
General Linear Model (GLM) with backward stepwise selection of variables
SS: sum of square errors, p: error probability, R^2: explained variance

	Fatalities		
Predictor Variable	SS	p	Remark
Intercept	0,36	0,0868	
Contacts		n.s.	Activity
Month of the Year	2,31	0,0064	Season
Free Height		n.s.	WT data
Rotor Radius		n.s.	
Height of Nacelle		n.s.	
Wind		n.s.	Weather
Wind²	0,93	0,0065	
Temperature	0,53	0,0382	
Temperature²	0,51	0,0429	
Wind x Temperature		n.s.	
Distance to Coast		n.s.	Location
Distance to Wood		n.s.	
Error	12,66		
Model R²	0,20		Model Quality
Model p		0,0042	

Explained variance was relatively low (R^2= 0.20), which implies that fatalities were to a large part driven by other factors than those present in the analysis. Statistical power was limited by the low (from a purely statistical viewpoint) number of non-zero values in the dependent variable and would clearly profit from a compilation of relevantly more data.

Activity and seasonality

According to the model, *P. nathusii* fatalities were not explained by the specie's activity as measured by the contacts. Seasonality had a significant effect on both, *P. nathusii* fatalities and *P. nathusii* activity (see neighbouring poster). This is not surprising since it has been shown that the majority of fatalities occur in late August/September (migration period, high insect density) (NIERMANN et al. 2011, RYDELL et al. 2010). This period is also the peak activity season of all species (fig.3). It shows that fatalities of all species occurred not only in the narrow peak activity period around day 240 (end of august) but in a period of about 4 month (mid of May, day 140, to end of October, day 300) The majority of the fatalities occur after the peak of activity at day 240.

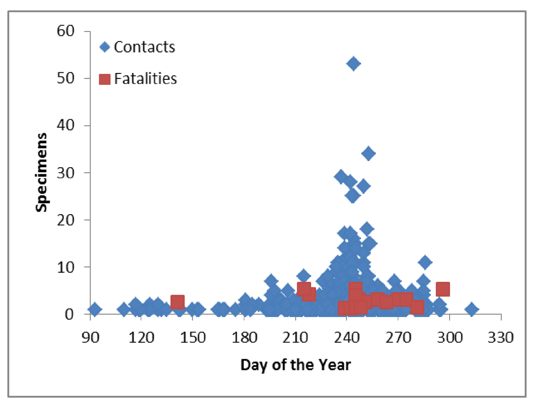

Fig 3.: Seasonality in activity and fatalities

Dimensions of the wind turbines

Dimension parameters of the wind turbines such as rotor radius and space between the bottom and the rotor blade tip had no significant effect on *P. nathusii* fatalities. Here it would be useful to compare bat activity and fatalitiy data from differently shaped WT such as from those with very low free space between rotor blade and ground and with a high rotor radius.

Weather conditions

Wind and Temperature exhibited a combined and non-linear effect on *P. nathusii* fatalities.
Fig. 4 illustrates that fatalities occurred in a narrow window of 3.4 - 6.9 m/s wind and were not related to wind or temperature extremes.

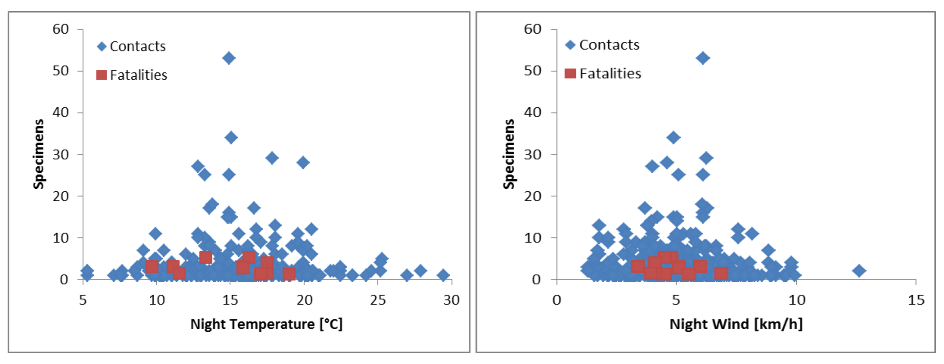

Fig 4.: Night temperature and wind speed in activity and fatality

Site parameters

There was no significant effect of distance to hedgerow structures or of distance to the coast on *P. nathusii* fatalities, although there was an effect on *P. nathusii* activity (see neighbouring poster).

Conclusion

NW Germany is known to be a quite uniform, flat landscape which often leads to the expectation that all wind facility sites can be treated just the same with respect to mitigation measurements. However, even within a wind facility the number of bat fatalities differs between single WT. For example there is no explanation why so many fatalities occurred at WT 2 whereas WT 8 had none although bat activity was higher at WT 8. These randomly distribution pattern is also known from Northamerica (ARNETT et al. 2008)

Concerning the proportion of fatalities on contacts we would have expected that the proportion would be the same for the two species *Pipstrellus nathusii* and *P. pipistrellus*. These species are quite similar in their acoustic range. It might be that estimation of the fatalities for each wind facility can distort the data set but a more comfortable data basis set is needed

The technical designs of WT show no correlation with the number of fatalities of *P. nathusii* in this study. A correlation between bat fatality and rotor swept area was reported from other studies (ARNETT et al. 2008, BARCLAY et al. 2007,) seasonality and wind speed influence the number of bat fatalities, but with a very low explanatory value. Usually in other studies these parameters have a much higher explanatory value (ARNETT et al. 2008, GEORGIAKAKIS et al. 2012

The subject needs further investigation and a greater sample size. According to the latest figure there are ca. 5.300 WT in Northwest Germany (BWI 2013). In some of these wind facilities monitoring studies were obligatory but the results are unavailable. So these posters are also an appeal to colleagues to combine the available data in order to have a larger sample size and to identify factors affecting bats negatively.

Aknowledgements

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Literature:

Amorim, F. H. Rebelo &Rodrigues, L (2012) : Factors influencing bat activity and mortality at a wind farmin the Mediterranean region Acta Chiropterologica, 14(2): 439–457

Arnett, E., W.K. Brown, W.P. Erickson, J.K. Fiedler, B.L. Hamilton, T.H. Henry, A. Jain, G.D. Johnson, J. Kerns, R.R. Koford, C.P. Nicholson, T.J. O´Connel, M.D. Piorkowski & R.D. Tankersley (2008): Patterns of bat fatalities at wind energy facilities in North America. – J. Wildl. Manag. 72(1): 61-78.

Baerwald, E.F.& R. M. R. Barclay (2009): Geographic variation in activity and fataliy of migratory bats at wind energy facilities. - Journal of Mammalogy, 90(6):1341–1349

Barclay, R. M. R., E. F. Baerwald, and J. C. Gruver. (2007): Variation in bat and bird fatalities at wind energy facilities: assessing the effects of rotor size and tower height. Canadian Journal of Zoology 85:381–387.

Brinkmann, R., O. Behr, I. Niermann & M. Reich (Hrsg.) (2011): Entwicklung von Methoden zur Untersuchung und Reduktion des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen. - Umwelt und Raum Bd. 4, Cuvillier Verlag, Göttingen.

BWI 2013: http://www.wind-energie.de/verband/landes-und-regionalverbaende/niedersachsen-bremen **29.01.2013**

Dürr (2012): Auswirkungen von Windenergieanlage auf Vögel und Fledermäuse http://www.lugv.brandenburg.de/cms/detail.php/bb1.c.312579.de (18.12.2012)

Georgiakakis, P. E. Kret, B. Carcamo, B. Doutau, A. Kafkaletou-Diez, D. Vasilakis & E. Papadatou (2012): Bat fatalities at wind farms in north-eastern Greece. - Acta Chiropterologica, 14(2): 459–468

Niermann, I., R. Brinkmann, F. Korner-Nievergelt & O. Behr (2011): Systematische Schlagopfersuche - Methodische Rahmenbedingungen, statistische Analyseverfahren und Ergebnisse. – In: Brinkmann, R., Behr, O., Niermann, I. & Reich, M. (Hrsg.): Entwicklung von Methoden zur Untersuchung und Reduktion des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen. - Umwelt und Raum Bd. 4, 40-115, Cuvillier Verlag, Göttingen.

Rodrigues, L., L. Bach, M.-J. Duborg-Savage, J. Goodwin, and C. Harbusch. (2008): Guidelines for consideration of bats in wind farm projects. Eurobats publication series No. 3. UNEP/Eurobats Secretariat, Bonn.

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

Santos, H., Rodrigues, L., Jones G., H. Rebelo (2013): Using species distribution modelling to predict bat fatality risk at wind farms. - Biological Conservation 157: 178–186