How bats are affected by wind turbines

Maja Jonholm

Supervisor University of Lund: Prof. Anders Hedenström

Supervisors Triventus Consulting: Malin Johansson and Stefan Johansson

Department of Biology, Lund University, Sölvegatan 35, SE-233 62 Lund

Abstract

In this study a wind power park of five turbines, Gummaråsen, in the south west of Sweden have been investigated to find out if bats fly in the height of the rotor blades, what species are present and the abundance of bats, at the site. The result showed that no bats was flying close to the wind power turbine, at the height of the nacelle (machine housing) and rotor blades, but bats were present closer to the ground. On warm nights with no precipitation and low wind speed, bats were especially abundant at Gummaråsen. Bats are most abundant close to wind power turbines in late summer and early autumn, the conclusion of this study shows that bats were present at the site of Gummaråsen from September the 13th to October the 5th at ground level. At the height of the rotor blades no bats were detected from September the 12th to November the 21th. Further investigations performed earlier in the season, and investigations with automatic acoustic detectors, at each site, could give an additional picture of the bat abundance and species composition at Gummaråsen.

Introduction

At present in Sweden, 2,4% of the electrical power production comes from wind turbines. which corresponds to 3,5 Twh/year. The Swedish government have targeted that in 2020, 30 Twh of the electrical power production should come from wind power (Naturvårdsverket 2012). An expansion of this dimension means that 3000-4000 new wind turbines will be up and running in Sweden in eight years (Energimyndigheten). Bats are known to be at risk of being injured and killed by wind power turbines, either by collision with the rotor blades or by pulmonary barotrauma, caused by the fast change in air pressure close to the moving turbine blades. The changed air pressure causes haemorrhage to the lungs of the bats because of the air that expand causes them to collapse (Baerwald, E, F. et al. 2008). Bats detect their targets at close range and if they move towards operating rotor blades they will have 1/100 second to avoid the blade (Rydell et al. 2010) since all bat species are protected by law in Sweden and Europe it is important to know how they are affected by wind power when planning for the expansion.

In this study two automatic and one manual acoustic detectors were used to collect information about bat activity at the site Gummaråsen. One automatic acoustic detector was placed in the Nacelle of a wind power turbine for more than two months, recording. The other automatic acoustic detector was placed on the ground level, close to the same wind power turbine, the detector was placed on different spots during the nights of the investigation. The manual acoustic detector was used mainly on the four sites where no automatic acoustic detector was used. The five sites of the wind power turbines was also searched in the mornings for killed and injured bats.

Ecology of bats

In Sweden today the presence of nineteen bat species have been documented (Ahlén 2011). All bat species are protected in *The Habitat Directive* of the European Union (92/43 EEG), which has been ratified in Swedish law in *Jaktlagen* (SFS 1987:259), *Jaktförordningen* (SFS 1987:905) and *Artskyddsförordningen* (SFS 2007:845). According to the *Agreement on the Conservation of bats in Europe* (EUROBATS 1991), which was signed by Sweden in 1992 and implemented in Swedish law in 1994 (SÖ 1993:30), it is prohibited to deliberately capture, keep or kill bats except under permission from the responsible authority, Naturvårdsverket (Ahlén 2006). Seven of the nineteen species are on the Swedish red list (Artdatabanken 2010), which means that they are threatened or rare, and three of them are considered *near threatened* on the international red list of the International Union for Conservation of nature (IUCN 2011) (see appendix 1). The first findings in Sweden of bats killed by wind turbines, was collected in 1999 (Ahlén 2002). Ahlén (2010) states that in January 2010, a total of six different bat species had been found dead underneath wind turbines and that most of the bats was killed at wind turbines placed near the coast. Bats reproduce slowly, females most often gives birth to only one offspring a year, which makes the population of bats vulnerable to extensive killing. Bats sometimes hunt close to wind turbines because of the insects that are attracted to it, and this is when the bats get injured (Rydell et.al. 2010), (Rydell et. al. 2011). High objects like wind turbines attract insects mostly on warm nights with low wind speeds, during late summer and early autumn, leading to most kills (Ahlén 2010) and (Rydell et. al. 2010) from July to September (Rydell et al. 2011). In Sweden, bats have been observed hunting at altitudes up to 1200m (Ahlén 2010). Both migratory and stationary bats have been found dead underneath wind turbines. Species that hunt at the height of the rotor blades are called high risk species (Rydell et. al. 2011). Identified high risk species in Europe includes the Common Noctule (*Nyctalus noctula*), the Parti-colored bat (*Vespertilia murinus*), the Northern bat (*Eptesicus nilssonii*) the Soprano Pipistrelle (*Pipistrellus pygmaeus),* the Leisler´s bat (*Nyctalus leisleri),* the Common Pipistrelle (*Pipistrellus pipistrellus*) Nathusius Pipistrelle (*Pipistrellus Nathusii*) (Rydell et al. 2011). On the European continent, research has shown that wind turbines placed at the coast and in forested areas kill more bats than those placed in agricultural landscapes (Ahlén 2010) and (Rydell et. al. 2010). Rydell et al (2011) states that distinct heights in the landscape is also places of high risk but that no investigations on how bats react to wind turbines placed on hills have been performed in Sweden which has to be further examined before drawing conclusions in the matter. Bats prefer to hunt close to their resting sites. Resting sites are therefore often situated in areas with great insect abundance, letting the bats save energy when moving between resting site and hunting site (de Jong 2006).

Important biotopes

According to to the agreement EUROBATS, important habitats for bats must be taken into account when deciding about changes and operations in these biotopes (Ahlén 2010). Bats prefer to hunt in half open environments and is most abundant at the border region of forests and agricultural land (de Jong 2000). The most important biotopes for bats are deciduous broad leaved forests with partly open and varied vegetation structure, combined with shallow lakes and watercourses. These kinds of habitats are especially important early in the bats active season, when the insect abundance in these environments is high, and are therefore pointed out as key habitats that requires protection from a conservational point of view. Further forest habitats that attract bats is other kinds of deciduous forests close to watercourses and lakes, older less dense coniferous forests, coniferous swamp forests and wetlands in general. Agricultural land use with small patches of differing biotopes, like forest edges, patches of trees and parkways can also function as good habitats. Open seashores and mountain steeps are also proved be good places for hunting (Ahlén 2010). Early and late in the season, bats tend to gather at smaller areas where large amounts of insects are available. These key habitats are likely to be the most important factor in determining the species variation and distribution of bats in an area. Identification of this environments is therefore of great interest (Ahlén et. al. 2006).

Maternity colonies and day resting places can be found in structures like houses, hollow trees, old mines, caves and bridges (Ahlén 2010). Winter roost sites needs to be well protected, cool, but above freezing temperatures and have high air humidity, like underground storehouses, old mines, caves and non heated stone houses (de Jong 2000).

Aim of the study

Background and aim

In this study the aim was to find out if bats fly at the height of the rotor blades of wind turbines, which species that occupy areas close to wind turbines, and the activity at five sites where wind turbines were located. The study area was five sites, at Gummaråsen in the province of Halland, see fig. 1 and fig. 2. The information gathered in this study will also be applied to a discussion in the making of a control program for the not yet constructed wind turbine park at Björnåsen, also located in the province of Halland.

The five wind power turbines at Gummaråsen have each a total height of 150 meters, including the rotor blades that have a span of 90 meters and a sweep area of 6358 m^2. The calculated energy production is 29 500 Mwh/ year in total, for the five turbines (Varbergs energi).

Method

Acoustic monitoring

Most bats can not be heard without help from acoustic monitors that detect ultrasound, because of their high frequency sounds that are inaudible to the human ear. Acoustic monitoring is an effective way of studying bats, and is used to detect different bat species and their activity. Monitoring individuals is not achievable this way, because it is not possible to know if recorded sounds comes from one bat passing several times or several bats passing once. (Strickland, M.D et. al. 2011). The acoustic detectors used in this study were D500X (Pettersson elektronik), and D240X (Pettersson elektronik). D500X (Pettersson elektronik) is a so called autobox, that records automatically when triggered by ultrasounds. The sound is passively recorded as WAV-files on to Compact Flash cards. The files can be analysed using computer programs that visualize sound files graphically and also allows analysing by listening to them. In this study the computer program Batsound 4(Pettersson elektronik) was used. The manually used detector, the D240X (Pettersson elektronik) directly transforms the ultra sound to audible sound, making it possible to analyse bat sounds in the field. The audible sound was recorded by connecting the D240x to a recorder.

At Gummaråsen turbine 4 an automatic acoustic detector was placed in the nacelle and another at ground level. Manual detecting was also planned, but was only performed during two nights, see table 1. Gummaråsen 1,2,3 and 5 were investigated using a manual detector. An automatic acoustic detector record all sounds from bats that fly close enough, during the night, according to the settings made, and is not time consuming like the manual detecting. The budget of this study was not big enough to supply five automatic acoustic detectors. The amount of information was supposed to be more substantial from the site where an automatic acoustic detector was used than at the other four sites.

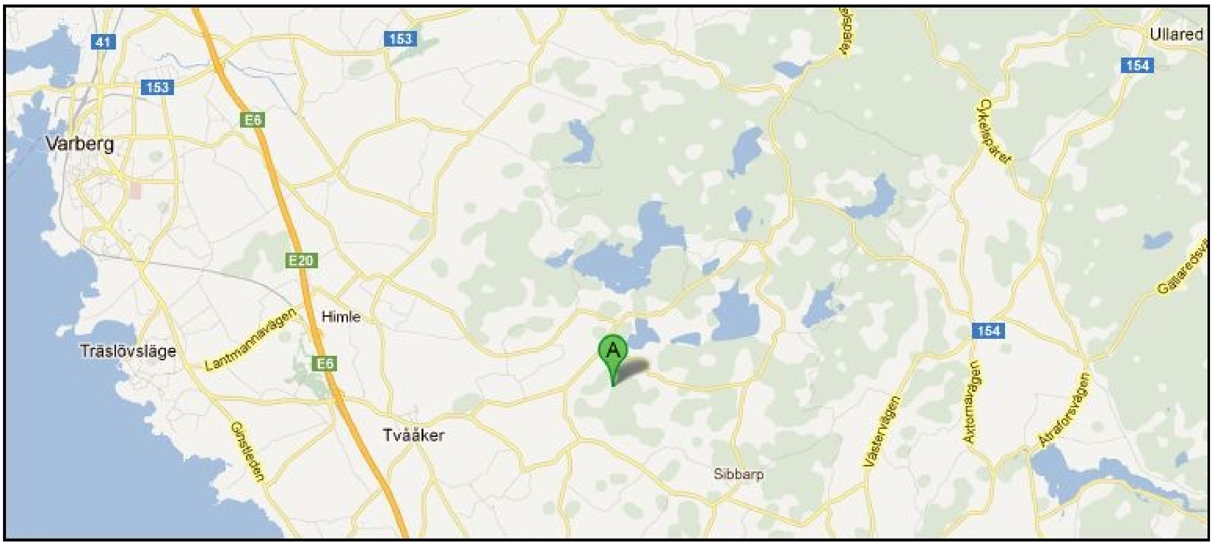


Figure 1. Shows the location of Gummaråsen in the Halland province (Google Maps 2012).

Figure 2. The image shows the five wind turbines at Gummaråsen, named 1-5 (Google Maps 2012).

Design of the field work

Automatic acoustic detector, nacelle, Gummaråsen turbine 4.
The field work was performed during September to November 2011 at Gummaråsen, see figure 1 and 2. An acoustic detector (D500X, Pettersson elektronik) was placed inside the nacelle of the wind turbine Gummaråsen 4. An external microphone was placed hanging down through a door underneath the nacelle, see figure 3. The placement of the acoustic detector was determined after consultation with C Hein (Personal communication) who had performed a pilot study in the US. Experiences from the pilot study showed that when placing the microphone of the acoustic detector facing away from the blades, most of the noise from the nacelle was reduced.

Figure 3. The wind turbine with the acoustic detector D500X. The red circle shows the back of the nacelle, from where a microphone connected to the acoustic detector D500X is hanging out through an opening underneath the nacelle.

(*Fotography, Johan Walberg*)

The timer of the autobox was set to start recording around sunset, 21:30, and stop around sunrise, 06:30. The time of the sunset and sunrise was determined by using the SMHI (Sveriges Meterologiska och Hydrologiska Institut) website. The profile settings are shown in figure 4 and the recording settings are shown in figure 5. The autobox was equipped with two external 6V alkaline batteries coupled in parallel, connected to the autobox with an extension cord for D500X (Pettersson elektronik). The construction of the power supply and the settings of the acoustic detector was consulted with Pettersson elektronik (L. Petterson, personal communication). The power supply was calculated to last for two month, but had not been tested before as far as what could be found in the literature or from personal conversations. The D500X records in real time. Four Compact Flash cards with 4 GB memory was used to record the audio files. The autobox inside the nacelle of the wind turbine Gummaråsen 4 was in place and recording from the 12th of September until the 21th of November. The audio files recorded by the acoustic detector was later analysed with the computer program Batsound by listening through them one at the time, manually deciding if the file contained bat calls.

Figure 4. Profile settings for the acoustic detector D500X. SAMP. FREQ is the sampling frequency. PRETRIG will store audio from before the trigger. REC. LEN is the length of the recording, in seconds. HP-FILTER is a high-pass filter that only let signals above 20 kHz to get through. AUTOREC is the automatic recording mode . T. SENSE determines the duration of the signal at which the recording will be triggered.

Figure 5. Recording settings for the acoustic detector D500X. INPUT GAIN is the gain added to the recording. The TRIG LEV is the trigger level, the level at which recording starts. INTERVAL is the minimum time between recordings, in seconds.

Automatic acoustic detector, ground level, Gummaråsen turbine 4.

Another autobox was placed at ground level by the wind turbine Gummaråsen 4. This autobox was also set to record from sunset until sunrise. The recordings made during the night was collected in the morning when search for killed bats was conducted. This autobox was placed in a tree behind the wind turbine, see appendix 2, at the edge of the forest on the 13, 15 and the 22nd of September. On these nights the area around Gummaråsen 4 was also searched manually with an acoustic detector (D240X, Pettersson elektronik), see table 1. During week 39, the landowner closed the big road to the wind turbine when letting his cattle out, and the only way to drive there was a small road that got flooded. It was decided not safe to drive there after sunset. Instead of manually searching at Gummaråsen 4, the position of the autobox was changed every morning to get information from three different positions at the site, similarly to the manual search at the other four sites. The autobox was never placed close to the stairs of the wind turbine because it was thought to be to visible by people passing by. The autobox at ground level of Gummaråsen 4 was in place and recording from the 13th of September until the 6th of October.

Manual acoustic detector

The sites Gummaråsen 1, 2, 3, and 5 was searched manually, using an acoustic detector (D240X, Pettersson elektronik) each night of the field work, see table 1. The manual searches took place just after sunset, approximately from 07:30 until 10:00. Three spots per site, see table 1 and appendix 2, were investigated by listening for bats during ten minutes using the ultrasound detector D240x.

The settings for the D240x

The mode *MANUAL TRIGGING* was used. *TIME EXPANSION* was set to 10. The recordings were made in the *NORMAL* mode. The real time sound was listened to in *HET (heterodyne)* mode and when the looped sound was replayed the settings was changed from *HET* to *TIME EXP* and was recorded with a separate recorder.

The D240x (Pettersson elektronik) uses a heterodyne system to transform ultrasound to audible sound. The incoming sound is mixed with an internal high frequency, and the product is a sound that is the difference between the incoming and the internal frequency. Ultrasounds from bats processed this way are audible to the human ear (Bat conservation trust). When a bat was detected this way the *record* button was pushed and the previous 1.7 seconds were recorded. A loop of 1.7 seconds is continuously saved and then replaced in the detector. After pushing the *record* button, the switch for *HETERODYNE/TIME EXPANSION* was moved to *TIME EXPANSION* and the previous 1.7 seconds was played 10 times slower. Time expansion was set to 10 times instead of the other alternative, 20 times, so that the time it took to record the sound was 17 seconds instead of 34 seconds. This decision was made to minimize the time when no bats could be detected, since detection is impossible during replay. The 17 seconds of sounds were recorded to a hand held recorder as WAV-files. The WAV-files were 96,000 Hz and 24 bits large. The frequency at which the bat was recorded was also written down.

Manual searches were planned on the 13th, 14th, 15th, 21st, 22nd, 27th, 28th and 29th of September and 3rd, 4th, 5th and 6th of October 2011. The planned searches on the 14th of September and the 6th October were cancelled and the searches on the 13th and 15th of September were interrupted by bad weather. Three abiotic factors that control the occurrence of bats were taken into account. Bats do not usually hunt when (1) the temperature is below +10°C and (2) wind speeds are above 6 m/s. (3) Precipitation is also negatively correlated to bat occurrence (Gerell. et. al. 1984). On several occasions the weather was not favourable to find bats, according to Gerell (1984). On nights with low temperature, heavy rain and wind the inventory was cancelled for the rest of that day. But if conditions was close to Gerells (1984) three factors or if not all of them were achieved, the sites were investigated even though the chance of detecting bats was assumed to be small (see table 1).

Table 1. The sites manually searched and weather conditions. Dates when the sites at Gummaråsen was searched manually for bats, during the night, and the weather and temperature which affects the presence of bats. The numbers 1 to 5 refers to the sites of the wind turbines. The letter NE is for North East, E is for East, SW is for West, NW is for North West, S is for South, Es is for East and stairs because two of the three sites at number 3 was located east and Es is the site at the stairs of the wind turbine.

Date	Sites	Weather	Temperature (°C)
13/09/11	4 (NW, N, NE) 1 (W)	Cloudy, high wind speed. Began to rain heavily and the inventory had to be interrupted.	13
14/09/11	No inventory.	Heavy rain and high wind speed.	No measures.
15/09/11	4 (NW, N, NE) 5 (NE, E, SW)	At first light rain and low wind speed, later thunderstorm, high wind speed and hail. The inventory had to be interrupted.	11 to 12
22/09/11	4 (NW, N, NE) 5 (NE, E, SW) 1 (NW, W, S) 3 (E, Es, S) 2 (S, W, SW)	Light rain and moderate to medium wind speed.	11
27/09/11	5 (NE, E, SW) 1 (NW, W, S) 3 (E, Es, S) 2 (S, W, SW)	Moderate wind speed, clear weather.	11 to 13
28/09/11	5 (NE, E, SW) 1 (NW, W, S) 3 (E, Es, S) 2 (S, W, SW)	Very moderate wind speed.	12 to 14
29/09/11	5 (NE, E, SW) 1 (NW, W, S) 3 (E, Es, S) 2 (S, W, SW)	Foggy, very moderate wind speed.	12 to 13
03/10/11	5 (NE, E, SW) 1 (NW, W, S) 3 (E, Es, S) 2 (S, W, SW)	Foggy, medium wind speed.	15 to 16
04/10/11	5 (NE, E, SW) 1 (NW, W, S) 3 (E, Es, S) 2 (S, W, SW)	Light rain and medium wind speed.	10 to 12
05/10/11	5 (NE, E, SW) 1 (NW, W, S) 3 (E, Es, S) 2 (S, W, SW)	High wind speed.	14
06/10/11	No inventory	Heavy rain and high wind speed.	No measures.

Where bats were expected

Most bat species prefer to hunt at forest edges (Ahlén 2010), but some species also hunt in open air and others prefer forest (de Jong 2006). In this study the aim was to find out if bats were present near the wind turbines. The research was conducted in cleared areas around the wind turbines, see Appendix 2. Two spots at each site were chosen where it was assumed to be the most probable to find bats. Spots near the edge of the forest, and primarily forest containing broadleaved trees, were preferred. The third spot investigated at all four sites was the stairs of the wind turbine.

Search for killed bats

Detecting killed bats could lead to a better understanding of which species are present in the area of Gummaråsen and if they fly at the height of the rotor blades. The areas around the five wind turbines at Gummaråsen were searched for killed bats at sunrise, see Table 2 and Appendix 2. The searches for dead bats were performed even if the weather conditions had been unfavourable the previous night.

Table 2. Dates and sites, searched for killed bats. The dates and sites that was searched for killed bats at sunrise, and the temperatures at the sites.

Date	Site	Temperature (ºC)
13/09/11	1,2,3,4,5	14 to 15
14/09/11	1,2,3,4,5	12 to 13
15/09/11	1,2,3,4,5	10
16/09/11	1,2,3,4,5	6 to 7
23/09/11	1,2,3,4,5	11 to 12
28/09/11	1,2,3,4,5	12 to 13
29/09/11	1,2,3,4,5	13
30/09/11	1,2,3,4,5	11 to 12
04/09/11	1,2,3,4,5	01/12/14
05/09/11	1,2,3,4,5	12
06/09/11	1,2,3,4,5	14
07/09/11	1,2,3,4,5	9

Area

The sizes of the sites that were searched for dead bats varied between the sites, (see Table 3). The cleared areas around the wind turbines was searched by foot, looking thoroughly at the ground. Areas outside the cleared areas, with too compromising environment such as, streams and wetlands with dense vegetation, was not searched. Ahlén (2002) found killed bats between 3 and 25 metres from the wind turbine tower in a study where 160 sites with wind turbines was searched. If dead bats are most often found in this range around a wind turbine, the areas searched in this study would have been large enough, with the exception of Gummaråsen 4, where there was much compromising vegetation also close to the turbine.

Table 3. The sites at Gummaråsen that were searched for killed bats. The sites of the wind turbines, the area around them that was searched for killed bats at sunrise, and the type of vegetation at the sites.

Site	Area	Vegetation (surroundings)
1	2600 m2	The area around the wind turbine is limited to the closest surroundings. High spruce forest closest to the turbine, shrubberies and birch trees along the road and a little stream.
2	5625 m2	Open terrain, larch seedlings, beech trees on the other side of the road, and some high spruce behind the turbine.
3	2550 m2	Rather young spruce and birch forest, slopes with scarce vegetation
4	1000 m2	Wetland on one side, mixed coniferous and deciduous forest on the other sides.
5	1980 m2	Mostly spruce forest, with some young birch trees. An open street down the hill west of the wind turbine towards the coast

Result

Automatic acoustic detector, nacelle, Gummaråsen 4.

The acoustic detector was recording sound from the 12th of September to the 21st of November. During this time 26,075 files were recorded. Each file was manually analysed in the computer program Batsound 4, but none of them contained any sounds recognizable as bat calls. The acoustic detector continuously recorded, in the frequency range of 0 to 150 kHz. The power supply of two

6V alkaline batteries, coupled in parallel, and the four 4 GB Compact Flash cards that was used to record the audio files proved to be sufficient. Only two of the Compact Flash cards was in fact used. The first of them was filled but not the second. A total of 6, 38 GB of the memory was used.

Automatic acoustic detector, ground level, Gummaråsen 4.
As shown in table 3, the automatic acoustic detector was recording ultrasounds at three different places at the site Gummaråsen 4. The sites are also shown in more detail in Appendix 2. Because of malfunctioning equipment, some of the nights the autobox did not record at all. Sounds in a total of 10 nights were recorded.

Table 3. Recordings and place of the automatic acoustic detector at Gummaråsen 4. Dates when recordings were made, the position in were the detector was placed relative to the wind turbine, W- west, NW- north west and NE- north east. Total number of recorded files and files containing bat sounds. (M) is for Malfunctioning, when no sound was recorded at all, due to malfunctioning equipment.

Date	Place	Number of files	Number of files with bat sounds	Species
13/9-14/9	W	8	0	
14/9-15/9	W	11	2	*Pipistrellus pygmaeus*
15/9-16/9	W	225	2	*Pipistrellus pygmaeus*
17/9-18/9	W	0	0 (M)	
18/9-19/9	W	0	0 (M)	
19/9-20/9	W	235	1	*Pipistrellus pygmaeus*
20/9-21/9	W	985	0	
21/9-22/9	W	1939	10	*Pipistrellus pygmaeus*
22/9-23/9	W	0	0 (M)	
23/9-24/9	W	0	0 (M)	
24/9-25/9	W	0	0 (M)	
25/9-26/9	W	0	0 (M)	
26/9-27/9	W	0	0 (M)	
27/9-28/9	W	0	0 (M)	
28/9-29/9	NW	137	105	*Pipistrellus pygmaeus*
29/9-30/9	NW	147	23	*Pipistrellus pygmaeus, Myotis spp.*
30/9-31/9	NE	0	0 (M)	

4/10-5/10	NE	57	0
5/10-6/10	W	0	0 (M)
			Total: 143

A total of 143 files contained sounds from bats. Of these, 142 were recognized as the Soprano pipistrelle (*pipistrellus pygmaeus)* and one as myotis spp., either Brandt´s bat (*Myotis brandtii*) or the Whiskered bat (*Myotis mystacinus).*The two myotis species are difficult to distinguish , according to Ahlén (2006) The species are so hard to tell apart that their teeth needs to be examined for accurate species recognition (de Jong 2000).

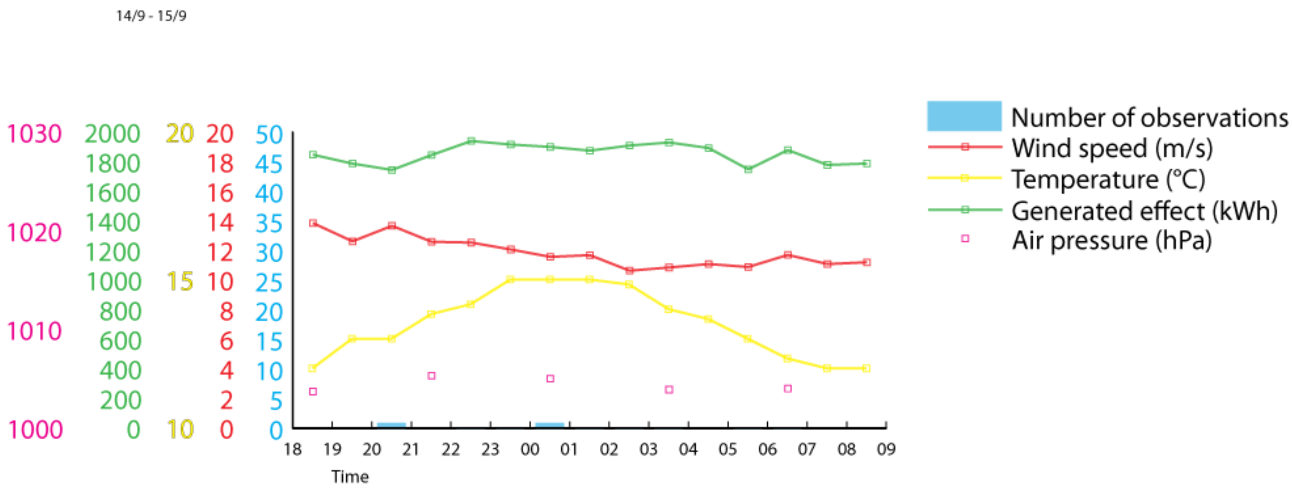


Figure 6. Gummaråsen 4, automatic acoustic detector, at ground level. 14/9-15/9. Observations per hour, during the night of 14/9-15/9, recorded by automatic acoustic detector D500X. Wind speed (m/s), temperature (C°), generated effect (kWh) and the air pressure (hPa). Two bats were detected, one between 20:00 and 21:00 and one between 00:00 and 01:00.

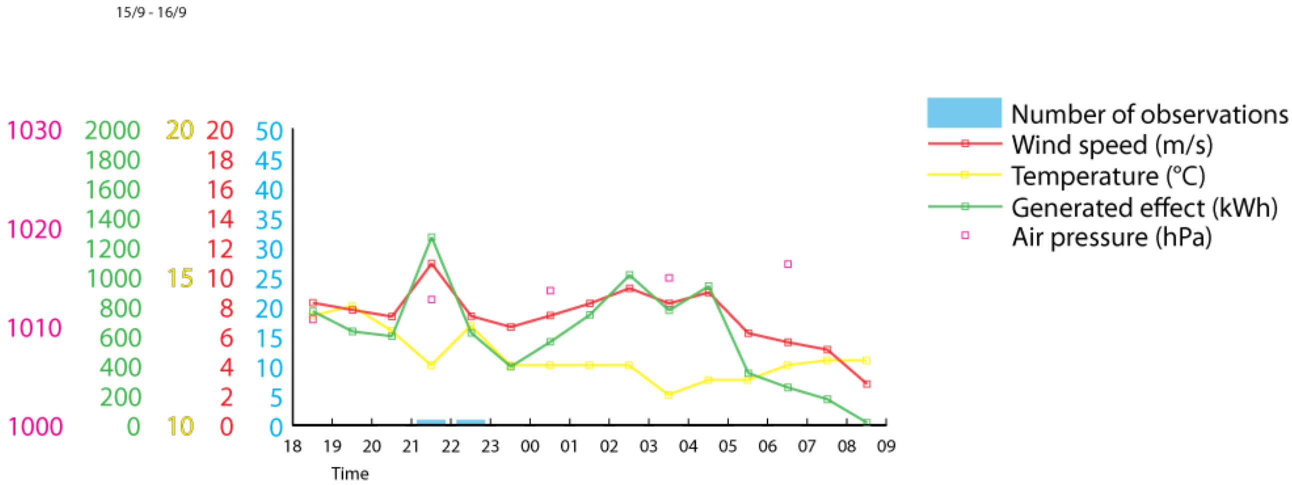


Figure 7. Gummaråsen 4, automatic acoustic detector, at ground level. 15/9-16/9.Observations per hour, during the night of 15/9-16/9, recorded by automatic acoustic detector D500X. Wind speed (m/s), temperature (C°), generated effect (kWh) and the air pressure (hPa). Two bats were detected, one between 21:00 and 22:00 and one between 22:00 and 23:00.

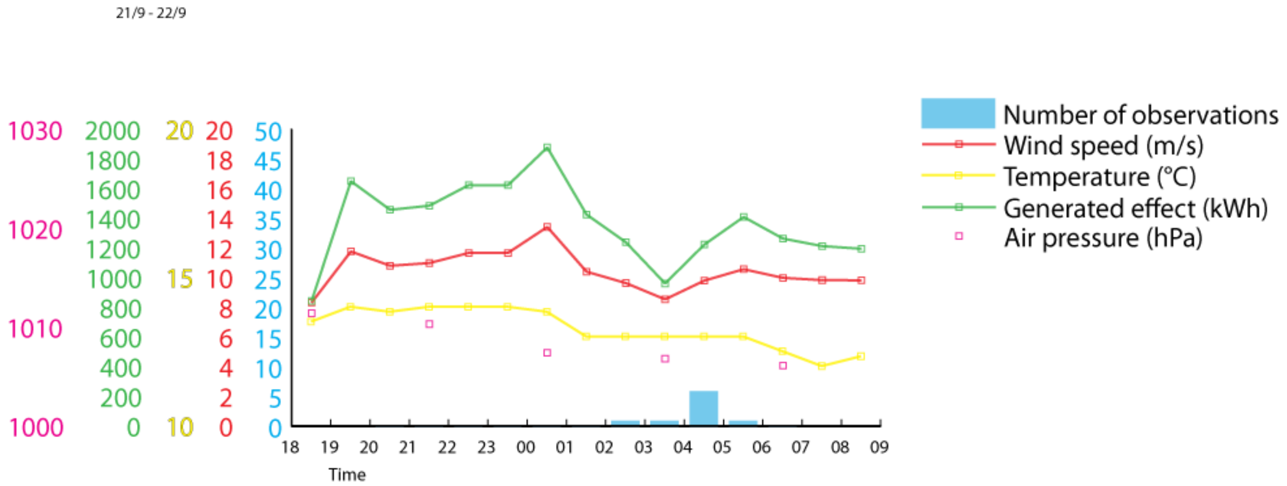


Figure 8. Gummaråsen 4, automatic acoustic detector, at ground level. 21/9-22/9. Observations per hour, during the night of 21/9-22/9. Number of observations recorded by an automatic acoustic detector (D500X) placed on the ground and Wind speed (m/s), temperature (C°), generated effect (kWh) and air pressure (hPa) collected from the nacelle of wind power turbine Gummaråsen 4. A total of 11 bats were detected.

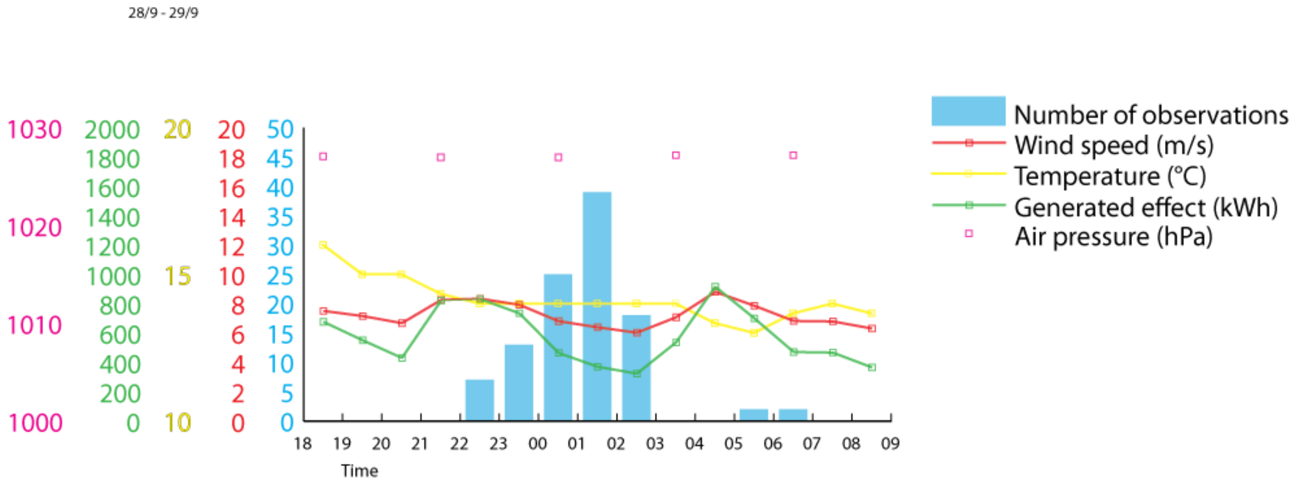
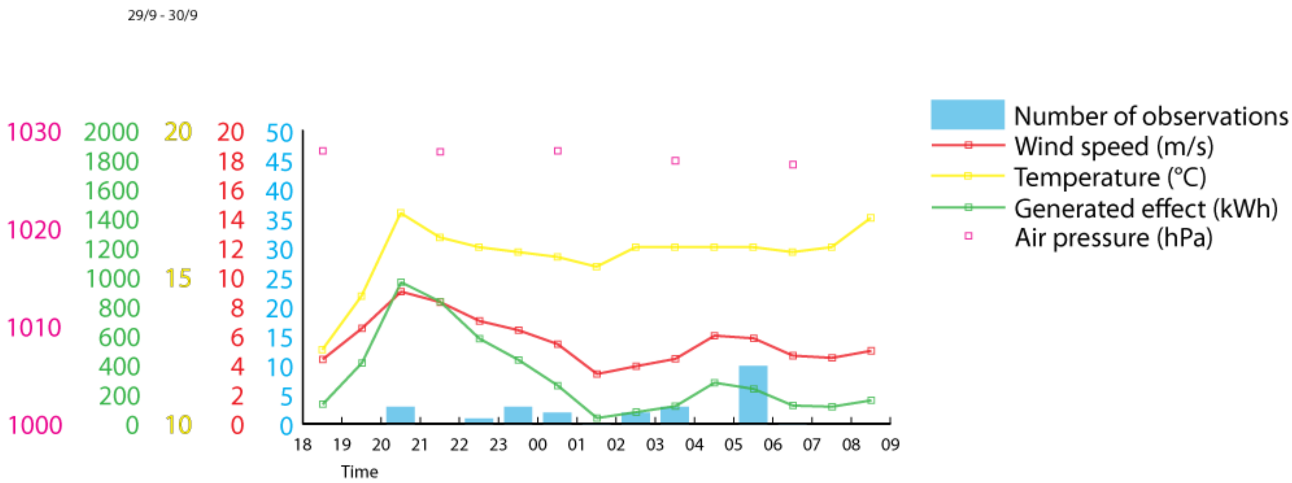


Figure 9. Gummaråsen 4, automatic acoustic detector, at ground level. 28/9-29/9. Observations per hour, during the night of 28/9-29/9. Number of observations recorded by an automatic acoustic detector (D500X) placed on the ground and Wind speed (m/s), temperature (C°), generated effect (kWh) and air pressure (hPa) collected from the nacelle of wind power turbine Gummaråsen 4. A total of 105 files containing bat sounds were recorded during this night. 7 files between 22:00 and 23:00, 13 files between 23:00 and 00:00, 25 files between 00:00 and 01:00, 39 files between 01:00 and 02:00, 18 files between 02:00 and 03:00, 2 files between 05:00 and 06:00, 2 files between 06:00 and 07:00.

Figure 10. *Gummaråsen 4, automatic acoustic detector, at ground level. 29/9-30/9.*



Observations per hour, during the night of 29/9-30/. Number of observations recorded by an automatic acoustic detector (D500X) placed on the ground and Wind speed (m/s), temperature (C°), generated effect (kWh) and air pressure (hPa) collected from the nacelle of wind power turbine Gummaråsen 4. 23 files containing bat sounds were recorded during this night. 3 files between 20:00 and 21:00, 1 file between 22:00 and 23:00, 3 files between 23:00 and 00:00, 2 files between 00:00 and 01:00, 2 files between 02:00 and 03:00, 3 files between 03:00 and 04:00, 10 files between 05:00 and 06:00.

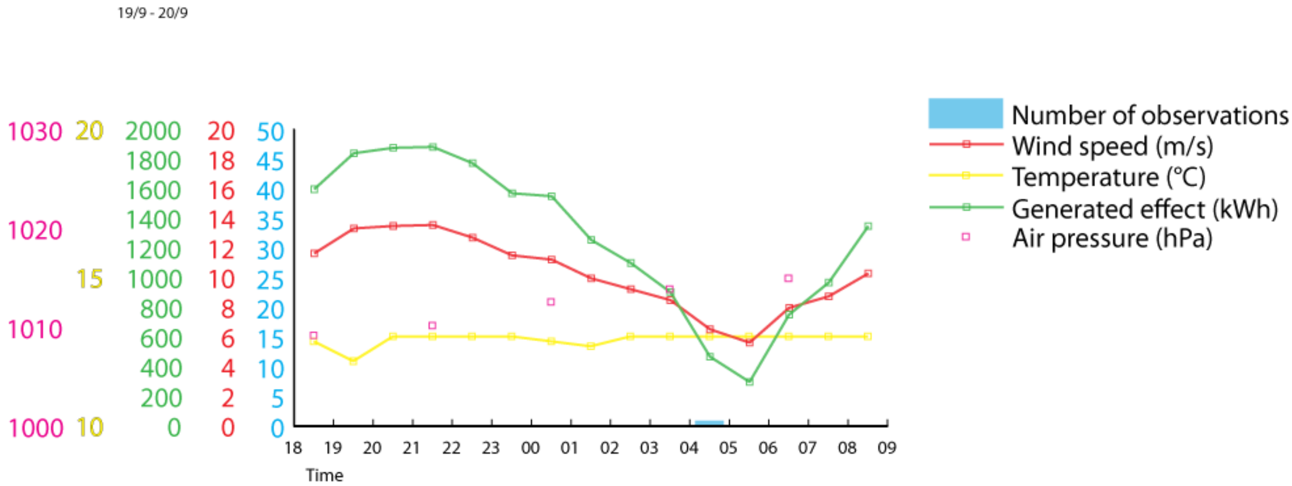


Figure 11. Gummaråsen 4, automatic acoustic detector, at ground level. 19/9-20/9. Observations per hour, during the night of 19/9-20/9. Number of observations recorded by an automatic acoustic detector (D500X) placed on the ground and Wind speed (m/s), temperature (C°), generated effect (kWh) and air pressure (hPa) collected from the nacelle of wind power turbine Gummaråsen 4. One file containing bat sounds was recorded between 04:00 and 05:00.

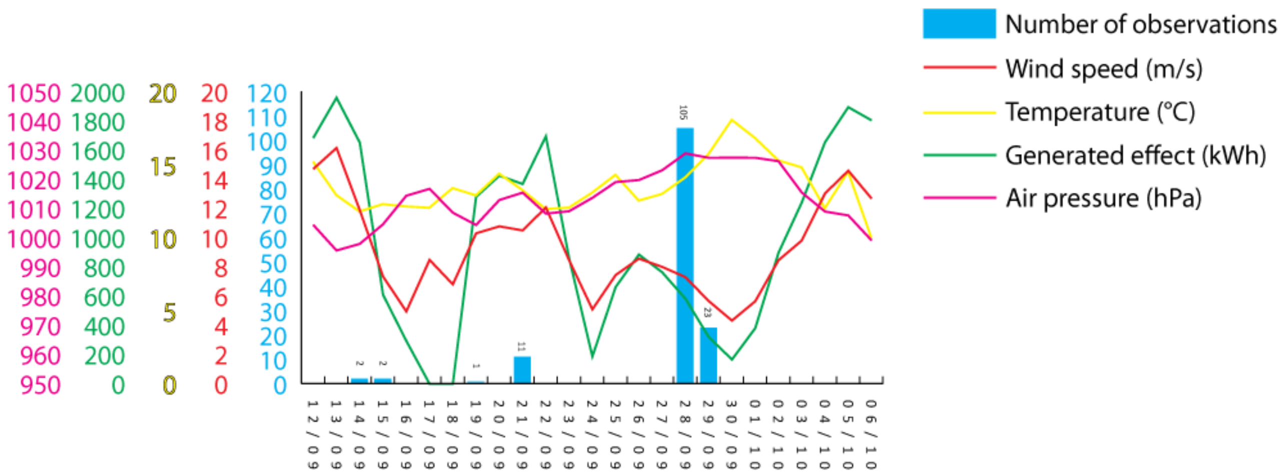


Figure 12. Gummaråsen 4, automatic acoustic detector, at ground level. 12/9-6/10.Observations per night from 12/9 - 6/10 2011. Number of observations recorded by an automatic acoustic detector (D500X) placed on the ground and Wind speed (m/s), temperature (C°), generated effect (kWh) and air pressure (hPa) collected from the nacelle of wind power turbine Gummaråsen 4. On the nights of 17/9-18/9, 18/9-19/9, 22/9-23/9, 23/9-24/9, 24/9-25/9, 25/9-26/9, 26/9-27/9, 27/9-28/9, 30/9-31/9 and 5/10-6/10, the automatic acoustic detector malfunctioned and no files were recorded.

Manual acoustic detector

The manual search was conducted as shown in Table 1 (see also Appendix 3. The files could not be analysed in the computer program Batsound, probably because something went wrong when the sounds were recorded with the hand held recorder. The frequency of all the manual recordings were documented and all of them were higher than 55 kHz. All detected bats were assumed to be Soprano Pipistrelle (*Pipistrellus pygmaeus*), since that is the only Swedish species with calls exceeding 55kHz (Gerell & Gerell 1995).

Table 4. Number of observations at each spot. Spots where the manual searches for bats were performed and the number of observations at each site.

Spots	Number of observations	Species
1 NW	3	Pipistrellus pygmaeus
1 W	3	Pipistrellus pygmaeus
1 S	1	Pipistrellus pygmaeus
2 S	-	
2 W	-	
2 SW	2	Pipistrellus pygmaeus
3 E	-	
3 Es	1	Pipistrellus pygmaeus
3 S	3	Pipistrellus pygmaeus
4 NW	-	
4 N	-	
4 NE	-	
5 NE	2	Pipistrellus pygmaeus
5 E	7	Pipistrellus pygmaeus
5 SW	1	Pipistrellus pygmaeus

Table 5. Observations at each site. Site of the wind turbines where manual searches for bats were performed. The three spots per site together and the total number of observations.

Site of wind turbine	Total number of observations	Species
1	7	*Pipistrellus pygmaeus*
2	2	*Pipistrellus pygmaeus*

3	4	*Pipistrellus pygmaeus*
4	-	
5	10	*Pipistrellus pygmaeus*
Total	**23**	

Discussion

The area of Gummaråsen is a place of diverse nature, containing deciduous and coniferous forest, pastures, lakes, some wetlands and farms and groups of buildings. This environment could be good habitats for several bat species. The wind turbines at Gummaråsen is located on a hill. Since there is no published studies showing the knowledge of how wind turbines, placed on hilltops in Sweden affect bats (Rydell et. al. 2011), no conclusion that the wind turbines at Gummaråsen do affect bats negatively can be drawn. The affect on bats still needs to be examined since it has been shown that wind turbines placed on heights can affect bats negatively on the European continent (Ahlén 2010), (Rydell et. al. 2010).

Manual acoustic detector

The manual acoustic detection and the automatic acoustic detection shows that bats are present in the area of Gummaråsen. The only species detected manually was the Soprano Pipistrelle. All 23 recordings of bats proved to be the Soprano Pipistrelle. On some occasions more than one bat was seen, and recorded, at the same time, otherwise no proof was found if the recordings was from one, or several different bats. If the search had been conducted using automatic acoustic detectors at the sites, instead of using manual detectors more information could have been collected. The budget of this study could not cover the cost of that kind of equipment.

Automatic acoustic detector, ground level, Gummaråsen 4

The recorded files from the automatic acoustic detector at Gummaråsen 4 showed that the Soprano Pipistrelle was common at the site, but since the automatic acoustic detector did not record any sounds on several nights (Figure 12), the information gathered by it was rather sparse.

The most common species at the time of the field study was the Soprano Pipistrelle, all 166 recordings of bats except one proved to be Soprano Pipistrelle, the one other species was a myotis spp.

The automatic acoustic detector placed at Gummaråsen turbine 4 was recording all trough the night and gathered, as supposed, much more information at this site compared to the other four sites that was investigated manually.

Automatic acoustic detector, nacelle, Gummaråsen 4

The acoustic detector placed in the nacelle on the wind turbine called Gummaråsen 4 continuously recorded sounds in a range from 0 to 150 kHz. The recorded sounds were all excess noises. If bats had been present, hunting at the height of the nacelle, their calls should also have been recorded. Even if no bats was detected, the method was not thought to be insufficient because sounds was recorded during the whole period, the power supply did not run out and the Compact Flash cards was not filled.

When deciding where to locate the construction of wind turbines, Ahlén (2010) suggests a simplified model for determining if an area is suitable for construction or not. Three different divisions can be selected from:
1) High risk. Not suitable for construction. No research of the area is necessary.
2) Uncertain. Research necessary to be able to put the area in either division 1 or 3.
3) No risk. Suitable for construction. No further research of the area is necessary.

The choice of division requires extensive knowledge in the ecology of bats and that the ecology at the location is well documented. If these criteria are filled, choosing one of Ahléns (2010) divisions can be a time and resource saving way of determining if an area is suitable for construction.

The Soprano Pipistrelle is a *high risk* species according to Rydell et. al. 2010. This means that the species is known to hunt at the height of the rotor blades of wind turbines, and have been observed doing so both when the rotor blades were moving and when the turbine was inactive, implying that the bats have no strategy for avoiding the dangers of moving rotor blades. The high risk species have also been observed feeding on insects on the surface of wind turbines. The automatic acoustic detector placed in the nacelle of the wind turbine did record excess noise continuously, but did not collect any information of bats hunting at the height of the rotor blades, conclusions can be drawn that at the place of Gummaråsen no bats were hunting at the height of rotor blades during the period from the12th of September until the 21th of November, at the currant climatic conditions, (see Table 1 and Figure 6 to 12 for climatic records). Since the Soprano Pipistrelle was the most abundant species at Gummaråsen, (see Table 3-5), and also is classified as a high risk species, it would have been likely to hunt at the height of the rotor blades if the conditions was right. Since bats prefer to hunt when the wind speeds are lower than 6 m/s and wind turbines are placed at spots where it is likely to be higher wind speeds during most of the year, it could be that hunting at the height of rotor blades is not preferable for bats at Gummaråsen. Hunting at the edges of the forest gives protection from the wind and may therefore attract more bats then the higher altitudes around the nacelle.

About a program of control

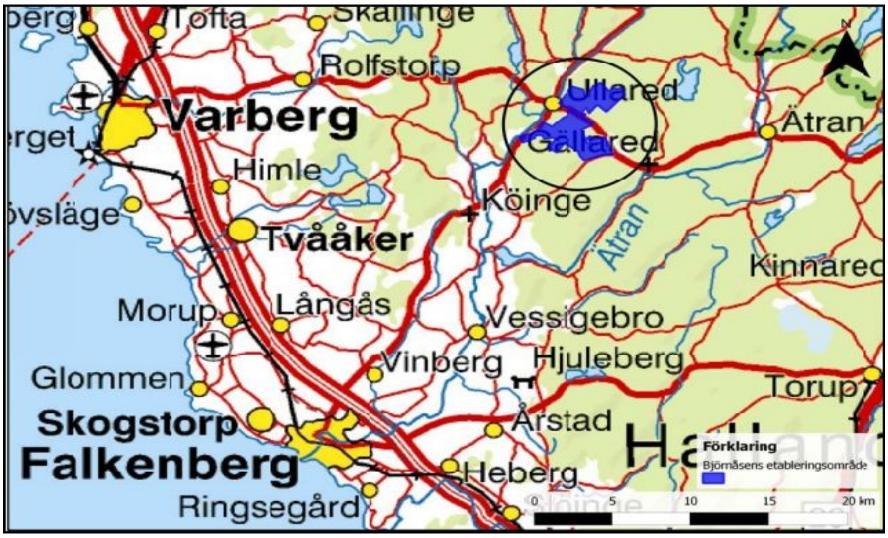


Figure 12. Björnåsen, community of Falkenberg, province of Halland.

A wind power farm of 12 turbines is planned to be constructed in the community of Falkenberg in the province of Halland (figure 12). The park is planned to be put in to operation in 2014. The turbines will reach a total height of 190 meters and will be placed east and south of the town Ullared. When planning a construction of this size, the environmental impact must be taken into account. Investigating how protected species, like bats, will be affected is a part of this concern. A demand from Länsstyrelsen in the province of Halland is that a program of control will be conducted some time after the construction of this wind power park.

According to Rydell et al (2011), on account of Naturvårdsverket, the reason for a controlling program is to see if and in what range, bats actually get affected by the establishment of wind power turbines at the site. The knowledge from this kind of investigations contributes to the total state of knowledge about wind power and bats. Information gained from already existing establishments can be important when planning for, new establishments elsewhere, and be able to adjust the operation to the prevailing conditions at the site.

Gerell (2011) conducted a survey on bats in the area of Björnåsen to see if this site was eligible for the construction. Gerell (2011) came to the conclusions that the area contained few species and also few individuals. The surroundings was considered trivial from a bats point of view. No distinctive routes that could be used for migration by migrating bats from other sites, could be identified in the environment close to the planned construction either. What could be a problem was that the barbastelle (*Barbastella barbastellus)* was found in the investigation of the area. The species is classified as endangered in the Swedish red list and is subject for a conservational program in Sweden. The Barbastelle was hunting along small forest paths where their primary food source of moths gathered during the dark hours. These paths are therefore recommended to be spared and not broadened in the construction.

In a controlling program, once again searching the small forest roads for bats, primarily to find out if the barbastelle still inhabits the area would be appropriate. Doing a similar investigation to the one done before the construction of the wind power park seems like a good way to proceed to gather results that can easily be compared. According to Naturvårdsverkets “guiding of the Swedish species in the habitat directive appendix 2” (Naturvårdsverket 2011) no wind power turbines should be constructed in areas where the barbastelle has been sighted, in the aim of conserving the species, before more investigation has been conducted to find out if the barbastelle hunts at the height of the rotor blade. Since it is presumed by Gerell (2011) that the wind power park will be situated in the perifery of the hunting grounds of the barbastelle, the park is therefore deemed not to affect the species negatively. Never the less, investigating the actual activity at the height of the rotor blades can ensure clarity to whether or not the barbastelle actually hunt at this height. Such information can be usable when planning for other wind power farms and bring some more information about the fairly unknown behaviour of the species. The barbastelle is active and hunts from early spring until late autumn. Collecting information a little earlier in the season, than in this study, is recommended since no sound from bats was collected at the height of the rotor blades. The barbastelle is not known to migrate far distances but in the autumn some individuals move to the coasts since the insect abundance is more substantial there.

Conclusion

Table 6. Recordings. Number of files containing bat sounds at the different sites and with the different ways to collect the information.

Investigations	Number of recordings containing bats
Manual detection, Gummaråsen 1, 2, 3, 5	23
Automatic detection, nacelle, Gummaråsen 4	0
Automatic detection ground level, Gummaråsen 4	143
	Total: 166

No bats could be proved to fly at the height of the rotor blades at Gummaråsen turbine 4 between the 12th of September and 21th of November, since no recordings of bats was made by the acoustic detector in the nacelle and no dead bats were found underneath any of the five wind turbines at Gummaråsen. The most abundant species at Gummaråsen was the Soprano Pipistrelle, which is known to be a high risk species. The species that hunt close to the rotor blades and therefore are in risk of getting injured, almost always belongs to one of the classified high risk species (Rydell et. al. 2011). Research during the rest of the season could show if bats were present at other times of the year at the site. Bats tend to fly at higher altitudes when migrating and therefore at this occasions the risk of getting injured is elevated at sites with wind power turbines. It is most optimal for bats to migrate when the the food abundance is substantial and the nights are long, since they need to both forage and migrate by night. This leaves an optimal timing for migration in the spring and autumn

(Hedenström 2009). The peak of migration may have occurred earlier in the season, before the study was conducted. There is little published knowledge about the phenology of migrating in bats. A species that seams to be present in larger areas of Sweden then known before recently and have been spotted close to the site of investigation (Ahlén 2011), is the pipistrellus nathusii. A study performed in Latvia showed that the peak of autumn migration for the pipistrellus nathusii occurred during the second half of August and beginning of September. But migrating bats were also spotted, at a sight in Germany as late as in the beginning of november (Petersons 2004). The soprano pipistrelle was the species mostly detected at Gummaråsen. This species consist of both residential individuals and individuals migrating south to winter roosts in continental Europe (Ahlén 2011). Research using automatic acoustic detectors at each site is preferable to get as much information as possible. In this study there were not enough resources to be able to use automatic acoustic detectors at each of the five sites.

Since bats are protected by Swedish law, investigations on how they might be affected by windpower constructions is necessary before the construction. When the wind power plant has been operating for a while, a control program is often requested by the authority at hand. In the case of Gummaråsen it is Länsstyrelsen in Halland that is the authority. A control program will give the information needed to evaluate the impact of the construction. The information gathered in such programs can be of great value when planning for constructions in the future and is hopefully something that will be conducted at most, if not every, sites of wind power constructions and other constructions that can affect bats or other species that require protection. The knowledge from these studies can also contribute greatly to the common knowledge about bats.

References

Ahlén, I. (2011) Fladdermusfaunan I Sverige, arternas utbredning och status. Kunskapsläget 2011. *Fauna & Flora.* 106:2, 2011

Ahlén, I. (2010) Vindkraft kräver hänsyn till fauna och känslig natur. *Kungl. Skogs- och Lantbruksakademiens tidskrift nr 3 2010:22–27*

Ahlén, I. Gerell, R. Gerell Lundberg, K. de Jong, J. Larsson, T. Nedinge, M. and Rydell, J. (2006) Handlingsprogram för skydd av fladdermusfaunan.
Naturvårdsverket, Rapport 5546

Artdatabanken (2010). Rödlistade arter i Sverige 2010.
http://www.slu.se/sv/centrumbildningar-och-projekt/artdatabanken/rodlistan/om-rodlistan1/
Collected 2012-03-08

Artskyddsförordningen (SFS 2007:845) *Regeringskansliet, Miljödepartementet. coming into effect 2008-01-01.*

Baerwald EF, D'Amours GH, Klug BJ, Barclay RMR (2008)
Barotrauma is a significant cause of bat fatalities at wind

turbines. *Curr Biol 18:R695–R696*

Bat conservation trust

(Collected 2012-01-31)

http://www.bats.org.uk/pages/bat_detectors.html#Het

De Jong, J. (2000) *Fladdermössen I landskapet*. Jordbruksverket, Skogsstyrelsen

Energimyndigheten, *Främjande av vindkraft, planeringsram för 2020.*
http/:www.energimyndigheten.se
Collected 2012-04-10.

EUROBATS (1991). Agreement on the Conservation of Populations of European Bats. *United Nations Environment Programme*.
http://www.eurobats.org/documents/pdf/Agreementtexts/FCO_Agreement_Text_engl.pdf

Gerell, R. & Gerell Lundberg, K. (1998). Inventering av fladdermöss inom Malmö stad. *Rapport. 6 sid.*

Naturvårdskonsult Gerell (2011) Planerad vindkraftspark mellan Okome - Björnåsen, Falkenbergs kommun- En analys av effekterna på fladdermusfaunan. *Bilaga 4, miljökonsekvensbeskrivning, för vindkraftpark Björnåsen.*
http://www.triventus.com/windpower/files/2012/02/Bilaga-4-MKB.pdf
(Collected 2012-11-14)

Hedenström, A.(2009) *Optimal migration strategies in bats. Journal of mammalogy, 90(6):1298-1309.*

IUCN 2011. *IUCN Red List of Threatened Species. Version 2011.2*.
http://www.iucnredlist.org
Collected 2012-03-08.

Jaktförordningen (SFS 1987:905) *Regeringskansliet, Jordbruksdepartementet.*

Jaktlagen (SFS 1987:259) *Regeringskansliet, Jordbruksdepartementet.*

Natuvårdsverket 2011. Barbastell- barbastella barbastellus. *Vägledning för svenska arter i habitatdirektivets bilaga 2*
NV-01162-10
http://www.naturvardsverket.se/upload/04_arbete_med_naturvard/vagledning/arter/vl-ryggradsdjur/vl_barbastell.pdf
(collected 2012-11-14)

Naturvårdsverket, Vindkraft, w*ww.naturvårdsverket.se*

(collected 2012-03-23)

Petersons, G. (2004) "*Seasonal migrations of north-eastern populations of* Nathusius' bat Pipistrellus nathusii (Chiroptera)" Myotis vol. 41-42: 29-56.

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

Rydell, J. Engström, H. Hedenström, A. Larsen, J, K. Pettersson, J. and Green, M. (2011) Vindkraftens effekter på fåglar och fladdermöss. *Rapport 6467, Naturvårdsverket.*

SMHI
Swedish Meteorological and hydrological institute
http://www.smhi.se

Strickland, M.D., Arnett, E.B., Erickson, W.P., Johnson, D.H., Johnson, G.D., Morrison, M.L., Shaffer, J.A., and Warren-Hicks, W. (2011) Comprehensive Guide to Studying Wind Energy/Wildlife
Interactions. *Prepared for the National Wind Coordinating Collaborative, Washington, D.C., USA.*

SÖ 1993:30, Sveriges internationella överenskommelser (SÖ) (1994). *Utrikesdepartementet.*
http://www.regeringen.se/content/1/c6/11/30/54/af823af5.pdf
Collected 2012-03-08

The Habitat directive. (1992). *Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.*

Varbergs energi
http://www.varbergsenergi.se/?id=3893
Collected 2012-11-07

Appendix

Appendix 1. Swedish species that are considered rare or threatened and therefore are on the Swedish red list and/or on the IUCN red list.

Scientific name	Category Swedish red list, 2010	Type of landscape, important	Type of landscape, present	Category, IUCN red list (for Sweden)
Myotis bechstenii	CR	JSU		NT
Myotis dasycneme	EN	VLSU	JHB	NT
Myotis natterei	VU	SU	V	LC
Pipistrellus pipistrellus	CR	JS	VU	LC
Nyctalus leisleri	EN	SJ	V	LC
Eptesicus serotinus	EN	JU	S	LC
Barbastella barbastellus	EN	JSU	V	NT

Categories: CR-Critically endangered, NT- Near threatened, LC- Least concern, EN- Endangered, VU-vulnerable. **Type of landscape:** J- Agricultural, S- forest, U- urban, L- limnic biotope, H-Seashore, B- Brackish water, V- wetland.

Appendix 2, Inventeringspunkterna och omr.

Appendix 3. Manual search protocol

Manual