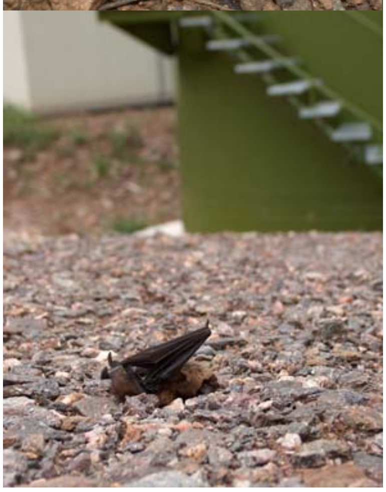

Survey of possible operational impacts on bats by wind facilities in Southern Germany

Ordered by: **Administrative District of Freiburg – Department 56 Conservation and Landscape Management**
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Summary

On authority of the administrative district government of Freiburg and supported by the foundation "Stiftung Naturschutzfond Baden Württemberg", a study on the possible operating-based effects of wind turbines on bats were conducted between August 2004 and October 2005. The main purpose of this study was to answer the question whether, in the administrative district of Freiburg, Southern Germany, bats collide with wind turbines and to what extent, as reported in other areas nationally and internationally. The study consisted of three different types of complementary surveys: searching for collision fatalities under working turbines, the examination of collision fatalities to determine the cause of death, and observations of bat behaviour at turbines using a thermal imaging camera.

Between the end of July and the end of October 2005, searches for collision fatalities were conducted every five days at 16 selected, representative turbines located mainly in the Black Forest and its foothills of Southern Germany (altitudes between 470 and 1100 m above sea level). Additionally, two to three extra searches were conducted at 16 other turbines in the same area during the same time period. Between the beginning of April and mid-May, as well as between mid-July until mid-October 2005, eight of the turbines that had been checked in 2004 were searched again with the same search interval. Furthermore, specific experiments to determine the searcher efficiency and the carcass removal rate were carried out at selected turbines. Taking into account these error factors, the actual number of collision fatalities was projected. The following results were gained:

- A total of 50 bat carcasses were found, 45 during the systematic fatality searches and five more during extra searches. When comparing the results from the eight turbines that were searched in both years, the numbers differ significantly between the years: in 2004, 31 carcasses were found whereas in 2005, with the same search intensity, only 10 were documented.
- The species found were Common Pipistrelle *Pipistrellus pipistrellus* (39 spec.), Leisler's Bat *Nyctalus leisleri* (8 spec.), Parti-coloured Bat *Vespertilio murinus* (2 spec.) and one Serotine Bat *Eptesicus serotinus*.
- Apart from bats, only nine bird carcasses were found: three House Martins *Delichon urbic*), three Swifts *Apus apus*, one Alpine Swift *A. melba*, one Goldcrest *Regulus regulus* and one Melodious Warbler *Hippolais polyglotta*. Overall, five times as many bats were found.
- Average searcher efficiency in the different ground coverage classes was: 84% in open areas, 77% in overgrown areas and 40% in heavily overgrown areas. The carcass removal rate differed between the sites; the average though for all experiments was rather high. For a five-day interval the average was 58.8%.
- Considering the searcher efficiency, the carcass removal rate and an area factor describing the relation of searchable to non-searchable area in a 40 m radius, it is possible to estimate the actual number of dead bats from the number of bat carcasses found. This projection results in 335 bats for the 16 turbines regularly checked in 2004 with a variation of the carcass removal rate from a minimum of 269 to a maximum of 446 bats. This equals 20.9 bats (16.6 - 27.9) per turbine. For the turbines surveyed in 2005, a total of 95 collision fatalities (75 - 125) were projected, which equals 11.8 bats (9.4 - 15.6) on average per turbine.

- Most bats were found between the end of July and mid-August and at the beginning of September. Between the beginning of April and mid-May 2005, no bat carcasses were found at any of the eight surveyed turbines.
- The Common Pipistrelle *Pipistrellus pipistrellus*, the species which was mainly affected, is not a migratory species.
- All the fatalities were found at turbines either in forests or in wind throw areas, none were found in open areas.

The **examination of the bat carcasses** showed that some of the bats had broken wings or obvious head injuries. Other bats showed signs of skull fractures. The dissection proved that most bats had internal injuries which were beyond doubt of traumatic origin. The results of these examinations lead to the only plausible conclusion, that the bat fatalities are in causal relationship to wind turbines.

Using a **thermal imaging camera,** bat activity was observed at two turbine sites (one in forest, one in open area) and at a third site without a turbine (wind throw) as reference, for four half-nightly observations. Highest bat activity was recorded at the reference site. At both turbine locations, bat activity was similar at an altitude > 40 m. This is contrary to the search results, where a large number of bat carcasses were found at the forest site but none at the open area site.

Approximately 25% of the bats approaching a rotor showed evasive behaviour. A bat colliding with a rotor could not be observed with certainty. At an altitude > 40 m with wind speeds between 3.5 and 7.5 ms^{-1}, slightly more bats – and at wind speeds higher than 7.5 ms^{-1} slightly fewer bats – were observed than would have been expected for the distribution of wind speeds. Bat activity could be observed near turbines at higher wind speeds of up to 10.9 ms^{-1}.

Because of strict protection regulations for bats in the Habitats Directive (European Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora) and also in the German Federal Nature Conservation Act (Bundesnaturschutzgesetz), and due to the potentially high impact risk, it is recommended to carefully review the bat conservation issues during the planning and approval procedures for wind facilities. Especially important is impact avoidance, achieved most likely through site selection. According to current knowledge, turbine sites in forests and/or on ridges should be considered as potentially very problematic.

Another possibility for mitigation is restricting the operating times of the facility when bat activity is especially high. But current data is not specific enough and at times contradictory, so that generally valid guidelines to restrict operating times in specific seasons or at certain wind speeds cannot be established. Accordingly, the only solution at the moment is to carefully examine each location during the planning process and once approved, to monitor the effectiveness of the mitigation measures.

Index

Page

This paper is the translation of a report originally released in German for the Conservation and Landscape Management Department 56, Administrative District of Freiburg, Germany under the title “Untersuchungen zu möglichen betriebsbedingten Auswirkungen von Windkraftanlagen auf Fledermäuse im Regierungsbezirk Freiburg”. (http://www.rp-freiburg.de/servlet/PB/show/1158478/rpf-windkraft-fledermaeuse.pdf)

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1 Introduction and Objectives

Findings of dead bats under various wind turbines in Germany have recently directed the public interest to a new area of conflict between the use of wind energy and nature conservation. Especially the collections of dead bats at wind farms in Brandenburg, Germany showed the possible connection of bat fatalities and wind turbines (DÜRR 2002). First systematic studies in Saxony even lead to the conclusion that comparatively large numbers of bat fatalities can occur in individual cases (TRAPP et al. 2002). This results in increasing levels of bat conservation issues that need addressing in approval procedures for wind farms, additionally to the issues of bird conservation.

Recent studies are showing more and more clearly what effects the construction and operation of wind farms can have on bats and their habitats (see ARNETT 2005). Current knowledge suggests that fatal effects, especially due to collisions[1] of bats with wind turbines, can have a very high impact on populations. These are likely to be even greater than non-fatal effects such as disturbance, displacement or habitat loss which usually accompany the construction or operation of wind farms (see BACH & RAHMEL 2004, BRINKAMNN 2004, HÖTTKER et al. 2005). This report therefore deals solely with the collision risk of bats with wind turbines and its effects.

All systematic studies on the collision risk of bats with wind turbines that have been conducted before the start of this study in July 2004 relate mainly to wind farm sites in agriculturally characterized areas in northern and eastern Germany. In the administrative district of Freiburg, Southern Germany, wind farms are mostly located on forested, rounded hill tops in elevated areas of the Black Forest and its foothills, due to preferable wind conditions. It is questionable if the results from northern and eastern Germany can be transferred to the local conditions of the Black Forest.

The aim of this study is therefore to examine whether collisions occur at the existing wind turbines in the administrative district of Freiburg. If so, the extent and reason for these collisions shall be identified as best as possible.

Firstly, an extensive carcass searching project was conducted at a total of 32 turbines in the administrative district of Freiburg during late summer and autumn of 2004. The results of this carcass search have already been presented in detail as an interim report in November 2004 (BRINKMANN & SCHAUER-WEISSHAHN 2004). A summary of this interim report has been published by the DISTRICT ADMINISTRATION OF FREIBURG 2005.

In 2005, the search was continued from the beginning of April until mid-May and from mid-July until mid-October. Additionally, tests were carried out to determine the searcher efficiency as well as the loss of carcasses due to natural causes. This will allow an estimate of the number of actual collision fatalities. In both years, all bat carcasses were examined in the laboratory by Dr. Häußler to obtain precise information on the status of the animals and the cause of death.

The behaviour of bats was observed by means of a thermal imaging camera at certain wind turbines. This was done to gather additional information on where and why bats collide with turbines. These observations also supported and secured the results gained from the collection of carcasses in relation to varying collision rates at different locations and with varying climate conditions.

[1] It has been proven that dead bats found at wind turbines can die after collision with turbine blades or due to turbulences in the immediate vicinity. In this report, the term collision or collision fatality will be used for both causes of death as they often cannot be clearly identified.

Based on the results of this study, the second part of this report assesses the risk of disturbance to bats, which are placed under exceptional species protection laws, caused by the construction and operation of wind farms in the administrative district of Freiburg, (Habitats directive). Furthermore, recommendations will be made for the avoidance or reduction of the possible negative effects on bats. We will also compile advice on conservation issues that could arise during approval procedures.

2 Bat fatality searches at wind turbines

2.1 Introduction and formulation of questions

The first investigations beginning in the mid 1990's aimed to examine possible disturbances of bats in their foraging habitats or on their flight paths (BACH et al. 1999, 2001). Although observations in Australia (HALL & RICHARDS 1972) and the USA (OSBORN et al. 1996) proved that bats can collide with wind turbines, carcass searches have been carried out in Germany roughly since the year 2000. The results of the previous searches for bat carcasses published to date mostly deal with randomly found bats (e.g. VIERHAUS 2000, DÜRR 2002, 2004) and do not allow interpretations about the type and extent of collisions.

Throughout the whole of southern Germany (Bavaria, Baden-Württemberg) there have been no systematic studies nor records of random findings of dead bats underneath wind turbines (see DÜRR 2004). A few studies were carried out systematically but they relate nearly exclusively to wind farm sites on arable land in the Northeast and central Germany (e.g. Brandenburg DÜRR 2004, Saxony ENDL 2004). Apart from one study at the wind farm Puschnitz (pre-forest stages of arable land near the Oberlausitzer Gefilders, see TRAPP et al. 2002) no studies have been conducted in wooded or forested areas.

At the beginning of this study it was completely unknown if and to which extent the phenomenon of bat collision with wind turbines occurred in the administrative district of Freiburg. The composition of bat species found in the landscapes of southwestern Germany and particularly in the elevated regions of the Black Forest as well as the significance of these landscapes for the long-distance migrating species vary to the composition and the significance in the arable land of northern and central Germany. Therefore the results of previous studies conducted in northern and central Germany can not be applied to the Freiburg district.

The easiest and clearest way to prove collisions is a systematic search for collision fatalities under operating wind turbines. This method was chosen to answer the following questions:

- Do collisions happen in the administrative district of Freiburg, Southern Germany? Can dead bats be found under the existing wind turbines?
- Which bat species are affected?
- Can the results be linked to time, spatial distribution or different turbine types?
- To what extent do bats collide with turbines?

2.2 Methods

2.2.1 Selection of study sites and sampling intervals

Survey year 2004

The aim of the first survey period in late summer and autumn 2004 was to gain an initial broad overview of the occurrence of collisions in the administrative district of Freiburg. 16 turbines were selected for systematic fatality searches in the survey period. Additionally, another 16 turbine sites were searched on 2 to 3 extra dates[2]. Altogether the sites represented various habitats (foothills; Baar; higher altitudes of the Black Forest) and different types of turbines (hub height, diameter of rotor). Refer to Table 1 for an overview on the regularly checked turbines. Details on the additional turbines and the search dates are compiled in Table A-2 in the annex. The locations of all examined turbines are shown in Figure 1.

Table 1: Data of regularly checked turbines (fatality searches conducted at all 16 turbines in 2004 between August and October. In 2005, fatality searches conducted at 8 selected turbines (marked bold in table) from beginning of April until mid-May and from mid-July until Mid-October.)

Location/ Name of turbines	Type	Hub height m	Rotor Ø m	Habitat	Altitude above sea level m
Ettenheim Mahlberg 1	Nordex N 80	80	80	Clearing	470
Ettenheim Mahlberg 2	Nordex N 80	80	80	Forest	470
Ettenheim Mahlberg 3	Südwind S 77	90	77	Forest	500
Ettenheim Brudergarten 1	Nordex N 62	69	62	Forest	470
Ettenheim Brudergarten 2	Nordex N 62	69	62	Forest	470
Ettenheim Brudergarten 3	Nordex N 62	69	62	Forest/Clearing	470
Freiamt Hohe Eck	Enercon E 66	86	70	Forest	600
Freiamt Schillinger Berg 1	Enercon E 66	86	70	Forest	720
Freiamt Schillinger Berg 2	Enercon E 66	86	70	Pasture	710
St. Peter Plattenhöfe 1	Enercon E 40	78	44	Pasture/Forest	1000
Simonswald Plattenhöfe 2	NEG Micon 60/1000	70	60	Pasture/Forest	1000
Simonswald Plattenhöfe 3	NEG Micon 60/1000	70	60	Pasture/Forest	1000
Simonswald Plattenhöfe 4	NEG Micon 60/1000	70	60	Pasture	1000
Horben Holzschlägermatte 1	Enercon E 66	98	70	Forest	920
Horben Holzschlägermatte 2	Enercon E 66	98	70	Forest	920
Fürstenberg	REpower MD 77	90	77	Pasture	920

The fatality searches took place regularly every 5th day from August until October 2004 at the 16 sites selected for the systematic checks. The searches were conducted on two consecutive days[3]. On the first day (Tour 1) the following sites were inspected: Schillinger Berg 1+2, Hohe Eck, Brudergarten 1-3 and Mahlberg 1-3;.on the second day (Tour 2)[4] Plattenhöfe 1-4, Fürstenberg and Holzschlägermatte 1+2. The first searches were carried out August 03. and 04. 2004, the last search on October 28, 2004. This results in a total of 18 inspections of the turbines on Tour 1 and 17 inspections of the

[2] Hornberg 1+2, Schweighausen 1+2, Herbolzheim, Reichenbach-Windkampf 1-3, Schonach 1+2, Rohrhardsberg, Neueck 1+2 and Gütenbach-Kaiserebene 1-3
[3] Search days for Tour 1+2 had to be delayed by one day to the 02.and 03.09.2004 and for Tour 1 to the 27.10.2004
[4] Plattenhöfe 1-4, Tour 2, were not searched on 04.09.2004.. Instead Neueck 1+2 and Gütenbach-Kaiserebene 1-3 were inspected. The last search day for Tour 2 had to be cancelled due to persistent poor weather conditions.

turbines on Tour 2. A few times searches were conducted at certain turbines on extra days. (Brudergarten 1: 01.08.04; Schillinger Berg 1: 21.09. + 24.10.04; Hohe Eck: 24.10.04).

Survey year 2005

The results from 2004 showed clearly that the phenomenon of bat collisions with wind turbines also happened in the administrative district of Freiburg. The studies in the second year should therefore help to answer the following questions:

- ► Do collisions at wind turbines also occur in other seasons, especially during migration periods of bats in spring and early summer?
- ► Does the number of collisions vary between years?

Other investigations indicated that collisions in spring and early summer would occur less frequently (see DÜRR 2004). To test the seasonal hypothesis, those wind turbines were selected where bat carcasses had been found in 2004. These sites were also suitable for the second question, as they are all located in wooded areas, which allow for easy and systematic searches, in comparison to pastures.

When analysing the results of 2005, it has to take into account that the chosen wind turbines are not representative for all the wind farms in the administrative district of Freiburg. Instead, the selected turbines are those with the highest collision rates in 2004. They were chosen for methodical reasons and only to answer the questions posed.

The following eight wind turbines were selected for the investigations in 2005: Holzschlägermatte 1+2, Schillinger Berg 1, Hohe Eck, Brudergarten 1-3 und Mahlberg 3 (Table. 1). The turbines were searched for collision fatalities from the beginning of April until mid-May and from mid-July until mid-October on every 5th day. Three additional searches were carried out on May 28th, June 20th and June 30th. The first search took place on April 2, 2005, the last on October 16, 2005. This results in a total of 30 searches for those eight turbines in 2005.

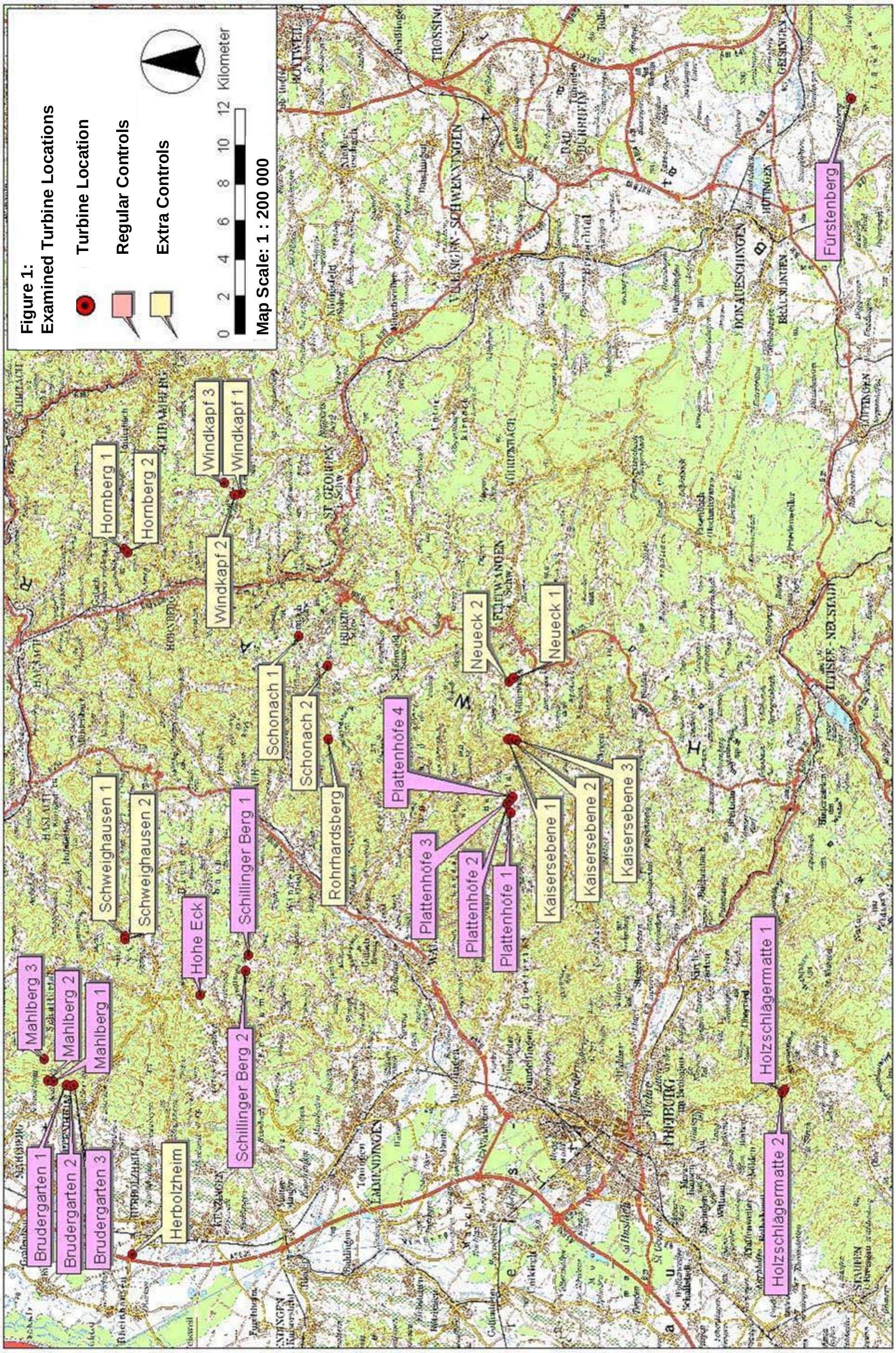
Figure 1:
Examined Turbine Locations
Turbine Location
Regular Controls
Extra Controls
0 2 4 6 8 10 12 Kilometer
Map Scale: 1 : 200 000
Brudergarten 1
Brudergarten 2
Brudergarten 3
Mahlberg 1
Mahlberg 2
Mahlberg 3
Herbolzheim
Hohe Eck
Schweighausen 1
Schweighausen 2
Schillinger Berg 1
Schillinger Berg 2
Hornberg 1
Hornberg 2
Windkapf 1
Windkapf 2
Windkapf 3
Schonach 1
Schonach 2
Rohrhardsberg
Plattenhöfe 1
Plattenhöfe 2
Plattenhöfe 3
Plattenhöfe 4
Kaisersebene 1
Kaisersebene 2
Kaisersebene 3
Neueck 1
Neueck 2
Holzschlägermatte 1
Holzschlägermatte 2
Fürstenberg

2.2.2 Definition of size and structural composition of the search areas

The search was conducted in a radius of 50 m around the turbines base. TRAPP et al. (2002) had found bat carcasses under comparable turbines up to this distance during their investigations. For those turbines located in forests, it was not always possible to search the whole area. Searching the forest or dense stands of bramble and gorse was considered not practical. The vegetation and structural composition of the 50 m radius was classified according to the degree of ground coverage. This was done to calculate the area of the site that could actually be searched and also to document the location setting where dead bats were found (see report of dead bat findings in the annex). Five different classes of ground coverage were used and their proportion of the 50m radius was recorded on site.

- Open: areas without vegetation, mostly tracks and gravel
- Overgrown: areas lightly overgrown with grass
- Heavily overgrown: dense stands of grasses and sedges
- Very heavily overgrown: stands of bramble or gorse
- Forest

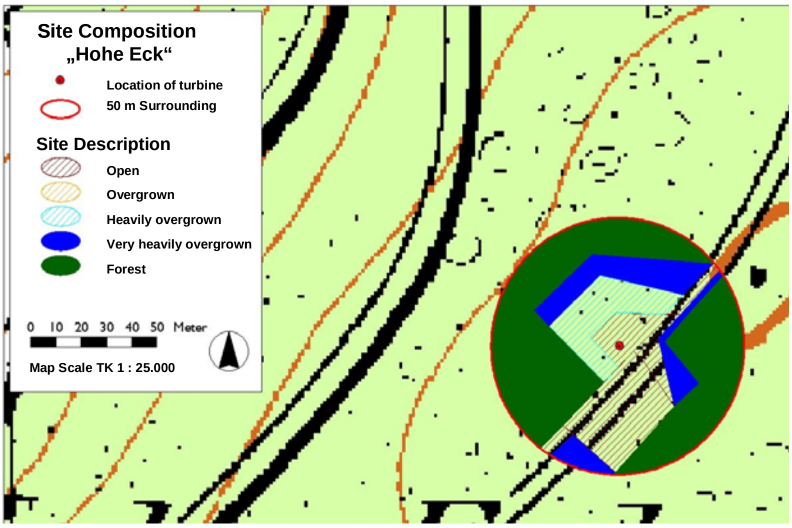

Figure 2: Calculation of searched areas beneath the turbines shown for the wind turbine “Hohe Eck”

The search for collision fatalities was conducted only in the first three classes (open to heavily overgrown). The proportion of each coverage class in the 50 m radius was mapped on site and their size of the area was calculated using GIS software (ArcView 3.2a, Figure 2). Turbines located in open areas of pastures, which were examined in 2004, were not searched when the vegetation exceeded a certain height, to avoid damage to the vegetation. Due to overall high levels of ground coverage on those pastures, they were all classified as “heavily overgrown”.

2.2.3 Searching and data recording on site

Those areas that could be searched were walked systematically in rows of up to 6 m apart (less than that according to vegetation coverage and denseness) so that a searching corridor of up to 3 m on either side was covered. Depending on the size and character of the searchable areas, the searching time varied between 30 and 50 minutes per turbine.

When a carcass was found, the following procedure took place: Firstly, the animal was photographed where found for documentation purposes. To record the precise location where the bat was found, the distance to the turbine base was measured and the bearing taken with a compass. On site, the species was identified and the condition of the carcass was described (e.g. visible injuries, degree of mummification, etc.). All details of the finding were recorded in a protocol (see report of dead bat findings in the annex). The carcasses were then frozen for a later and more detailed examination. The same procedure was applied when dead birds were found. The birds however were left on site. (Exception: One bird found on 27.08.05 at Holzschlägermatte 1 was sent to the "Staatliche Museum für Naturkunde Karlsruhe" (Museum of Natural History in Karlsruhe) for identification.)

2.2.4 Determining the carcass removal rate

From August 17 - 27, 2005, experiments were conducted at five of the eight regularly checked turbines to estimate the length of time that the carcasses remained on site. Ten dead laboratory mice were laid out at each turbine, distributed proportionately in open, overgrown and heavily overgrown areas. The mice were checked on ten consecutive days. If the carcass was missing, the date was recorded. Sometimes traces allowed conclusions about the reasons for its disappearance. When scavenging insects (mostly Burying Beetles) were involved, the inspections continued until the carcass was no longer visible and could be found only by means of transect marking. It was then classified as missing.

The carcasses were placed along linear transects (mostly two transects to take into account the varying classes of vegetation coverage) with distances between 2 and 40 m from the turbine base. A string was placed over the transect with tags in varying colours representing the different turbines. The tags were fitted with a number of knots (1-10) representing the 10 carcasses. This allowed a quick and effective check without having to permanently mark the position of the carcass on the ground.

The laboratory mice used were deep frozen carcasses. Their body size (head and body length: up to 80 mm) was slightly larger than that of a Leisler's Bat *Nyctalus leisleri* (head and body length: 50-65 mm). The coloration was similar to that of bats. The carcasses were handled with gloves to minimise the effect of human odour on the behaviour of scavengers.

2.2.5 Determining the searcher efficiency

On 11.05.2005, bat dummies were laid out at six of the eight regularly checked turbines[5]. They dummies were made from dark brown artificial fur and were roughly of the size of the medium-sized Leisler's Bat *Nyctalus leisleri*. They were placed in the same areas under the turbines that were usually searched. The dummies were evenly distributed in open, overgrown and heavily overgrown areas (20 dummies in each area).

The fakes were dropped from hip height during dispersal to achieve a positioning similar to that of collision fatalities. This trial was carried out during the regular checks of the sites. After the dummies

[5] The turbines at Schillinger Berg 1, Hohe Eck, Brudergarten 1-3 and Mahlberg 3 were chosen.

had been brought out by an assistant, the search was carried out as usual. The usual time spent searching was not exceeded.

2.2.6 Statistics

The sample size in this investigation was usually too small to allow statistical evaluation of the results. Where possible, statistics were used and detailed information about the applied methods is provided in the corresponding chapters. The employed software is SPSS 11 and JMP 5.1 as well as Actus 2.0 for randomizations.

2.3 Results

2.3.1 Numbers, species and status of found bat carcasses

In total, 45 bats of three species were found heavily injured[6] or dead under the turbines during 18 fatality searches at 16 turbines in 2004 and 30 fatality searches at eight turbines in 2005. Five more bats, including a fourth species, were found during two or three extra searches at 16 other turbines in 2004.

The number of bats found differs distinctly for each year as well as for each seasonal period (i.e. spring, late summer, or autumn months, Table 2). The majority of carcasses (35) were registered during late summer until autumn 2004 at the 16 sites which were regularly inspected. Another five specimens were discovered during the extra inspections at 16 other sites (Table A-2 in the annex), making a total of 40 specimens in 2004.

The searches were continued at eight selected turbines in 2005. During the twelve inspections spaced 5 days apart from mid-April until mid-May 2005, no carcasses were found (Table 2). The search period between mid-July and mid-October 2005 was slightly earlier than that in late summer and autumn 2004. Conducted with the same intensity, only ten dead bats were found. This is roughly a third of the numbers found at these particular turbines in 2004, which amounted to 31.

Table 2: Search intensity and number of carcasses found under the regularly searched turbines in late summer / autumn 2004, spring 2005 and late summer, autumn 2005 (2005: twelve searches between April and May and 18 searches between July and October)

Location/ Name of turbines	Type	2004		2005	
		Number of Searches	Number of Carcasses	Number of Searches	Number of Carcasses
Ettenheim Mahlberg 1	Nordex N 80	18	1	-	-
Ettenheim Mahlberg 2	Nordex N 80	18	1	-	-
Ettenheim Mahlberg 3	Südwind S 77	18	2	12/18	0/0
Ettenheim Brudergarten 1	Nordex N 62	18	3	12/18	0/1
Ettenheim Brudergarten 2	Nordex N 62	18	2	12/18	0/0
Ettenheim Brudergarten 3	Nordex N 62	18	2	12/18	0/2
Freiamt Hohe Eck	Enercon E 66	18	7	12/18	0/4
Freiamt Schillinger Berg 1	Enercon E 66	18	9	12/18	0/2
Freiamt Schillinger Berg 2	Enercon E 66	18	0	-	-
St. Peter Plattenhöfe 1	Enercon E 40	16	0	-	-
Simonswald Plattenhöfe 2	NEG Micon 60/1000	16	1	-	-
Simonswald Plattenhöfe 3	NEG Micon 60/1000	16	1	-	-
Simonswald Plattenhöfe 4	NEG Micon 60/1000	9	0	-	-
Horben Holzschlägermatte 1	Enercon E 66	17	5	12/18	0/1
Horben Holzschlägermatte 2	Enercon E 66	17	1	12/18	0/0
Fürstenberg	REpower MD 77	17	0	-	-
Sum			**35**[7]		**10**

[6] A very seriously injured Common Pipistrelle was taken into care but died the next day.
[7] Five more carcasses were found during the searches at Neueck 1 (1 *Pipistrellus pipistrellus*) and Rohrhardsberg (1 *Eptesicus serotinus*, 3 *Pipistrellus pipistrellus*).

The species most commonly found was the Common Pipistrelle *Pipistrellus pipistrellus* with 39 samples. 15 were identified as adults and 21 as subadults. In 2004, more subadult bats born that year were found than adults (11 adults compared to 17 subadults, three carcasses could not be aged). In 2005, the distribution of adults and subadults of the eight individuals was even. (see Table 3). The sex ratio of 31 Common Pipistrelle found in 2004 was even with 11 males and females each (nine carcasses could not be sexed). In 2005, six males were found in contrast to only one female (one carcass could not be sexed.)

Looking at the data of both years together, males and females as well as adults and subadults of the Common Pipistrelle are affected to a similar degree. Due to the overall small number of samples, no statements can be made on significant differences of the collision risk in relation to sex or age.

Figure 3: Female Leisler's Bat *Nyctalus leisleri* with double fractures of the wings. The animal was found freshly dead under a turbine during nocturnal observations with a thermal imaging camera. Right: Dead Serotine Bat *Eptesicus serotinus* under a turbine in South Baden. All photos were taken during the study.

With 8 individuals, the second most common species was the Leisler's Bat *Nyctalus leisleri*. No significant differences concerning the distribution of fatalities between sex and age could be found here either (Table 3). Being such a small sample, the limited expressiveness of these results must be considered.

Apart from the Common Pipistrelle and the Leisler's Bat, only two other species were found: Two Parti-coloured bats *Vespertilio murinus*, one in 2004 and one in 2005 as well as one Serotine Bat *Eptesicus serotinus* in 2004. Two were adult males; one of the Parti-coloured bats could not be sexed or aged as the abdomen was missing.

Table 3: Overview on number, species, sex and age of all dead bats found

Species		**Number of carcasses**		**Sex**			**Age**		
		abs.	**in %**	♂	♀	**?**	**ad**	**sub**	**?**
Parti-coloured Bat *Vespertilio murinus*	2004	1	2,5			1	1		
	2005	1	10,0	1			1		
Serotine Bat *Eptesicus serotinus*	2004	1*	2,5	1			1		
	2005								
Leisler's Bat *Nyctalus leisleri*	2004	7	17,5	3	4		4	3	
	2005	1	10,0		1		1		
Common Pipistrelle *Pipistrellus pipistrellus*	2004	31*	77,5	11	11	9	11	17	3
	2005	8	80,0	1	6	1	4	4	
Sum	2004	40*	100	15	15	10	17	20	3
		(% n=40)		37,5	37,5	25,0	42,5	52,5	5,0
Sum	2005	10	100	2	7	1	6	4	
		(% n=10)		20,0	70,0	10,0	60,0	40,0	
Total		**50**	**100**	**17**	**22**	**11**	**23**	**24**	**3**
		In % (n=50)		**34,0**	**44,0**	**22,0**	**46,0**	**48,0**	**6,0**

* Includes the carcasses found at the additionally searched turbines (Rohrhardsberg and Neueck)

2.3.2 Seasonal distribution of found bat carcasses

In both study periods, bat carcasses were only found between mid-July and mid-October. No carcasses were found at the eight selected turbines during the searches conducted in 5 day intervals from the beginning of April to mid-May 2005. Statements cannot be made for the periods from end of October to beginning of April and from mid-May until mid-July, as no searches took place during those times. Figures 4 and 5 show an overview of the seasonal distribution of the found carcasses.

In both years, most of the bats were found between the end of July and the beginning of September. In 2005, the dead bats were distributed rather evenly throughout the survey period. In contrast, the findings of dead bats in 2004 varied significantly. This correlates to specific weather conditions.

In 2004, 70% of all the carcasses were found under wind turbines between the end of July and mid-August (31.07 until 18.08.2004) (Figure 4). Especially at the beginning of August the nights were very warm with very low winds. In the second half of August, nights were mostly cooler and often very windy and rainy. At the beginning of September, another period with relatively warm nights and also usually low winds occurred. In this period (03. until 06.09.2004), another 20% of all carcasses were found. During the remainder of the survey period, only single specimens were found under the turbines.

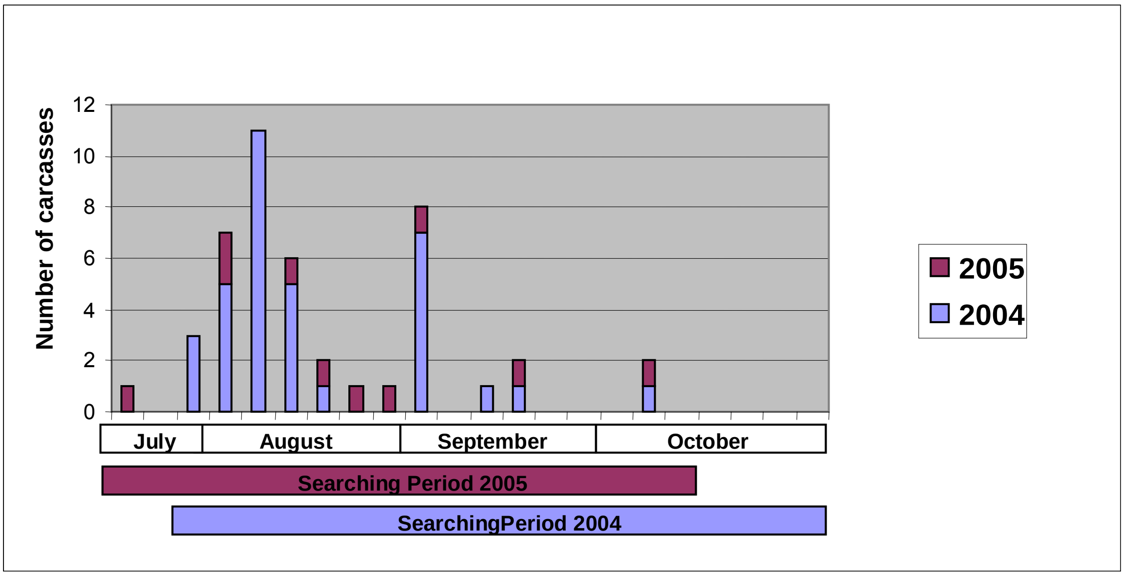

Figure 4: Seasonal distribution of dead bats found at the turbines searched in 5 day intervals 2004: n = 16, in 2005: n = 8)

The presented results of the survey period cannot be further analysed in regard to single species (see Figure 5). The Common Pipistrelle bats found during the searches (n = 35) were mainly found between the end of July and mid-September. This also applies for the Leisler's Bats as the second most common species (n = 8). The Parti-coloured Bats were found mid-June and at the beginning of August. The Serotine Bat was found on 06.08.2004 at Rohrhardsberg during one of the extra searches in 2004. Therefore, this species is not shown in Figure 5. See Tables A-1 and A-2 and the carcass record sheets in the annex for detailed records of all bats found.

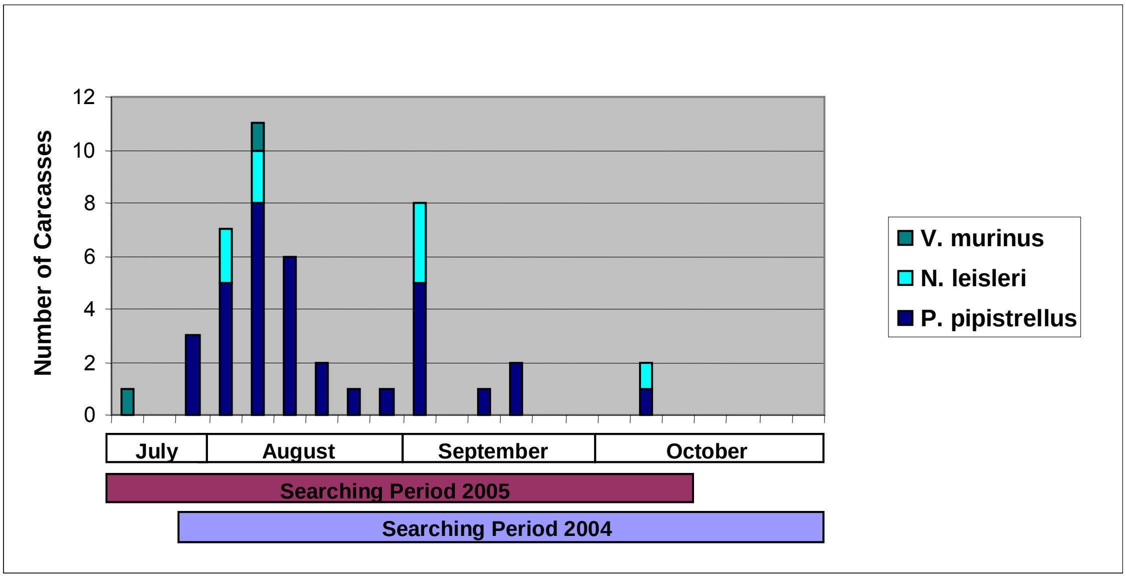

Figure 5: Seasonal distribution of all carcasses found at the turbines searched in 5 day intervals, according to species (2004: n = 16, 2005: n = 8)

2.3.3 Impact of turbine location and turbine type

According to the present results there are no differences in the number of dead bats when related to different turbine types or to the location of turbines in different habitats or altitudes. Dead bats were found at turbines in the foothills, e.g. at Ettenheim Mahlberg 1-3 (470 m above sea level) as well as in the higher altitudes of the Black Forest e.g. at Holzschlägermatte (920 m above sea level) or at Rohrhardsberg (1100 m above sea level) (Figure 6). Differences in the number of fatalities in relation to the size of the turbines couldn't be detected either. Carcasses were found under smaller turbines e.g. the Nordex 62 (hub height 69 m, rotor diameter 62 m) at Ettenheim / Brudergarten as well as at larger turbines of the type Enercon E 66 (hub height 86 or 98 m respectively, rotor diameter 70 m) at Schillinger Berg or at Holzschlägermatte (Figure 7).

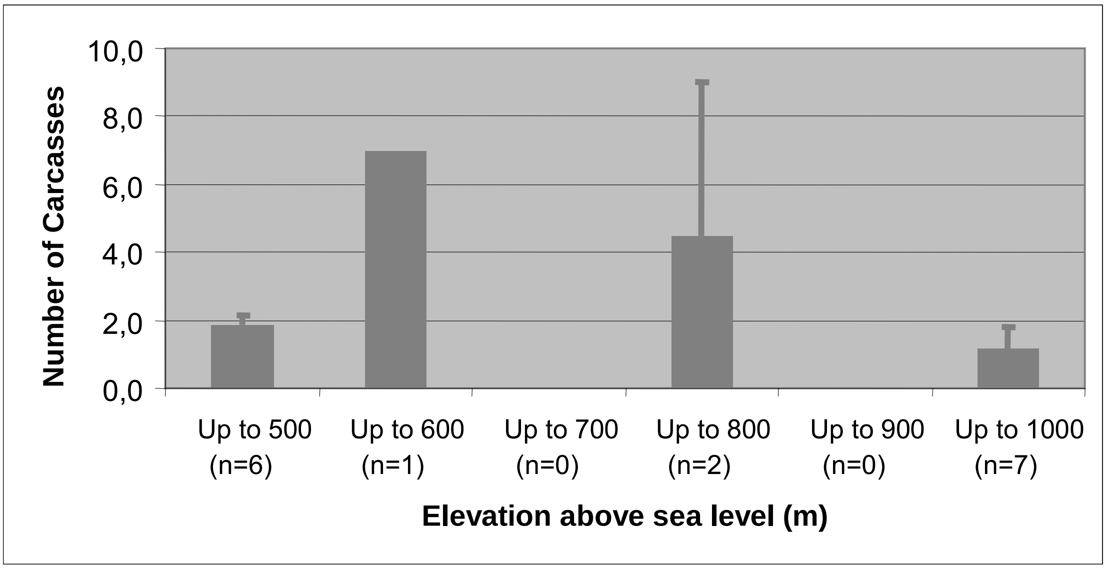

Figure 6: Distribution of carcasses at turbines at different altitudes (data of the 16 turbines searched in 5 day intervals in 2004, figure shows mean and standard error)

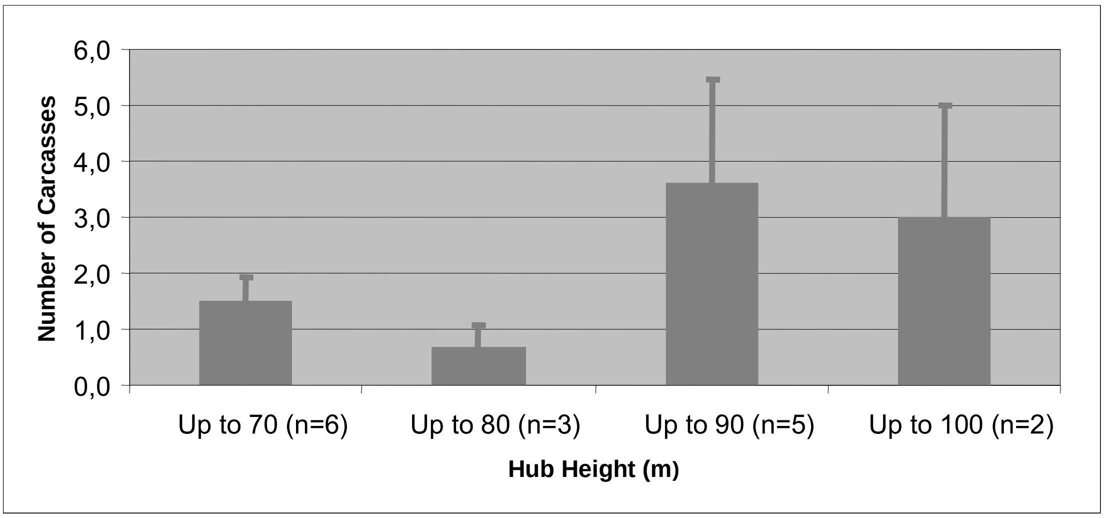

Figure 7: Distribution of carcasses at turbines with different hub heights (data of the 16 turbines searched in 5 day intervals in 2004, figure shows mean and standard error)

Nevertheless, the results do show a difference in relation to the immediate surroundings of the turbines. Significantly more carcasses were found under turbines located in forests compared to those in pastures in the Black Forest (Figure 8).

Despite the much smaller sample size, a similar result was also found for the 16 turbines that were only searched two or three times during the extra checks in 2004. Of these turbines, five were located in forests, six at the border between forests and open area and five in open area. All six carcasses were found below two turbines in the forest.

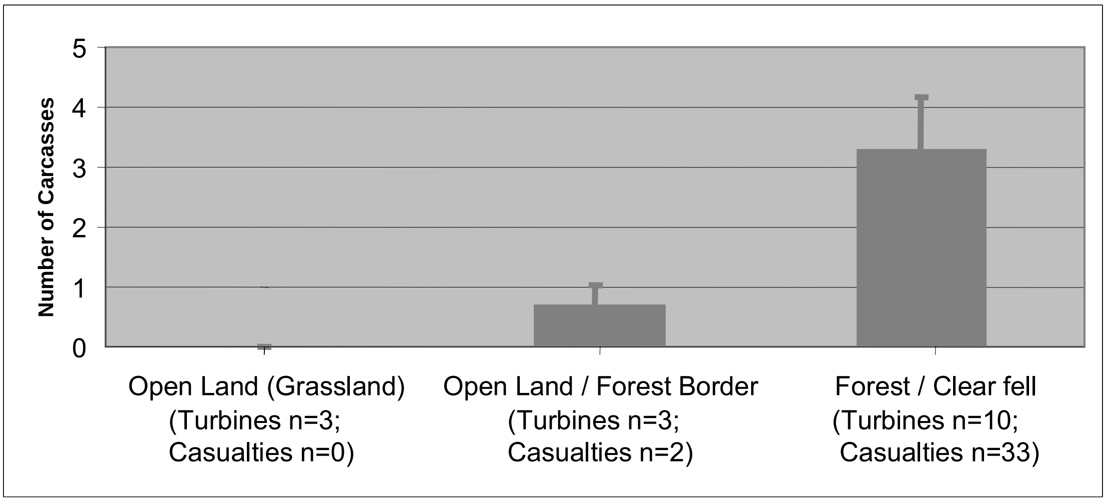

Figure 8: Distribution of carcasses at turbines searched regularly between the end of July and the end of October in 2004 in relation to the different turbine surroundings (figure shows mean and standard error)

This result was also confirmed by comparing the results of two neighbouring turbines of the same type (Enercon E 66, Hub height 86 m, rotor diameter 70 m) at Schillinger Berg. At Schilinger Berg 1, located in forest on a rounded hilltop, nine dead bats were found during the survey whereas at Schillinger Berg 2, only a few hundred meters away, but in grassland, no carcasses were recorded. Nevertheless, it must be taken into account that the grassland was searched less frequently and with a lesser searcher efficiency due to its use and the vegetation structure (see chapter 2.2.2).

2.3.4 Carcass location in relation to turbine base

For the eight turbines searched in both years of the study, the structural composition of the 50 m radius around the turbine base was recorded. The data (n = 41) will be used to analyse the distance and bearing of the locations where dead bats were found in relation to the turbine bases. Furthermore, it will be analysed how the locations of found carcasses relate to how well the area could be searched, depending on the vegetation cover. The ground coverage classes “open”, “overgrown” and “heavily overgrown” are classified as searchable. Areas classified as “very heavily overgrown” and “forest” are classified as not searchable.

The bearing of the carcass locations from the turbine base shows no clear tendency. Relations to further factors such as predominant wind direction cannot be made due to very low resolution of the data on a timely scale and the small sample size.

Most carcasses were found in an area up to 30 m from the turbine base. Although the area was searched in a 50 m radius, the furthermost carcass was located 37 m away from the turbine base (Figure 9).

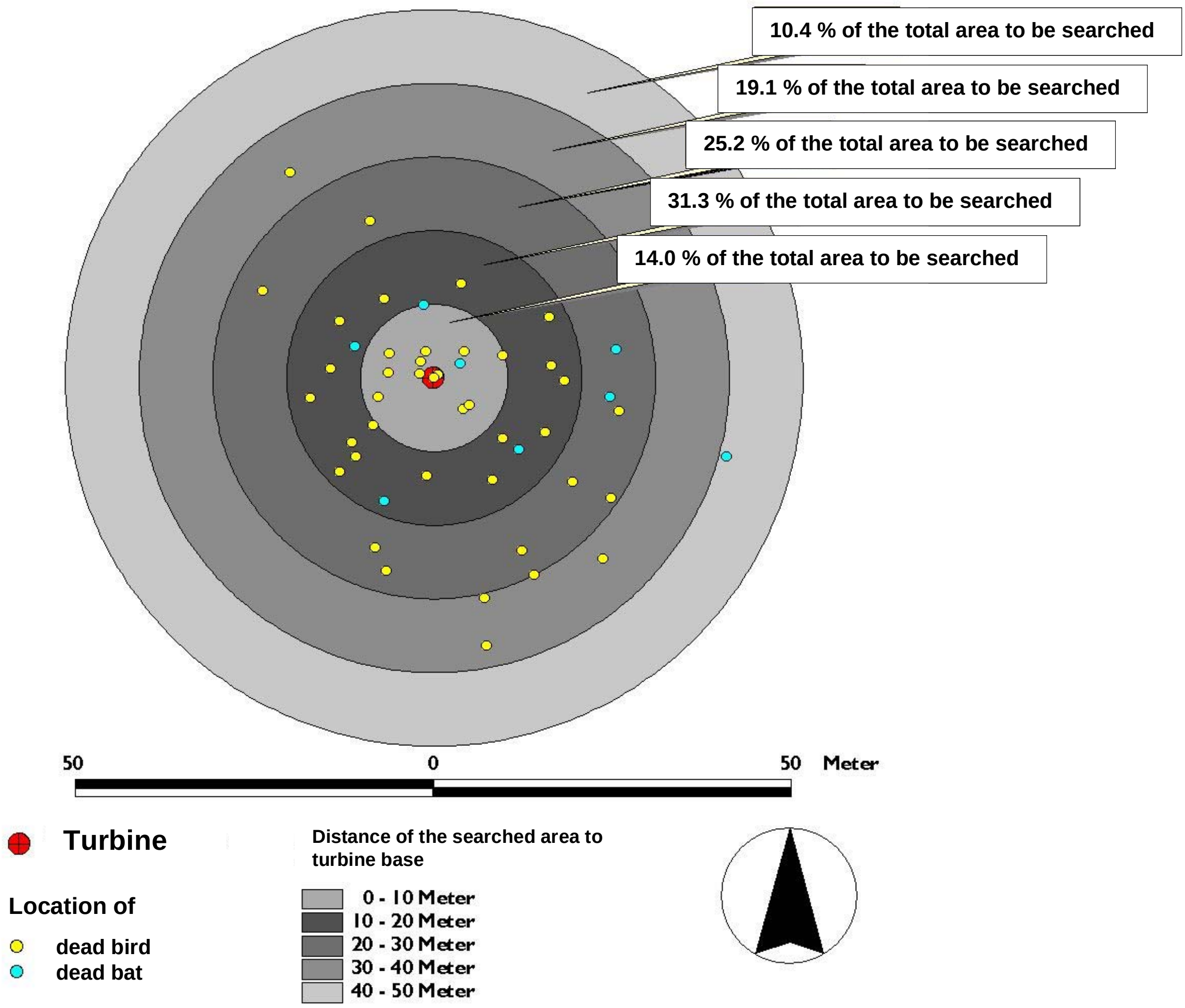

Figure 9: Distance and bearing of locations where dead birds and bats were found in relation to the turbine base and illustration of the proportion of searchable area in 10 m intervals (Data of 8 regularly searched turbines in 2004 and 2005, bats n=41, birds n=8)

When analysing these results, the structure of the searchable area beneath the turbines must be considered. The area that could actually be searched increased initially with the distance from the turbine base but then it decreased rapidly. This is due to the fact that former construction areas such as location of cranes and access tracks are mostly located in distances of up to 20 or 25 m around the turbines base (see red columns in Figure 10). Those areas could be searched very efficiently as vegetation was usually very low or absent. But even when considering the varying habitats at different distances to the turbine bases, one does find that a slightly larger proportion of bats were found in the area of up to 20 m from the turbine base. In the area between 20 and 50 m from the turbine base, fewer bats were found (Figure 11). Nevertheless, the two curves do not differ significantly in the area of up to 40 m from the turbine base.

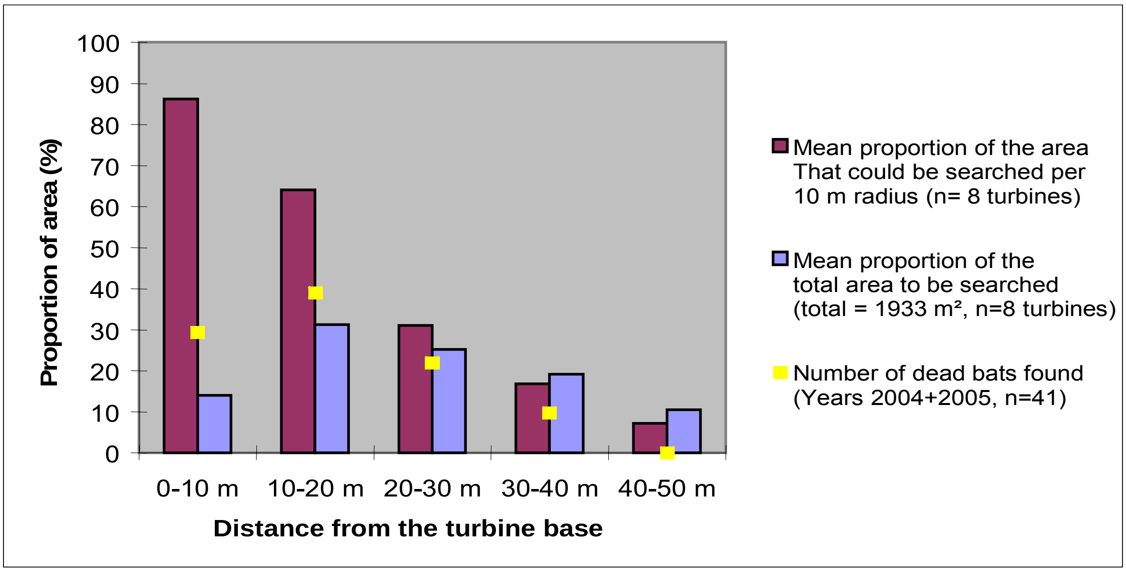

Figure 10: Percentage of dead bats found in the five 10 m radius areas around the turbine base in relation to the area that actually could be searched (red columns) and in relation to the total area to be searched (light blue).

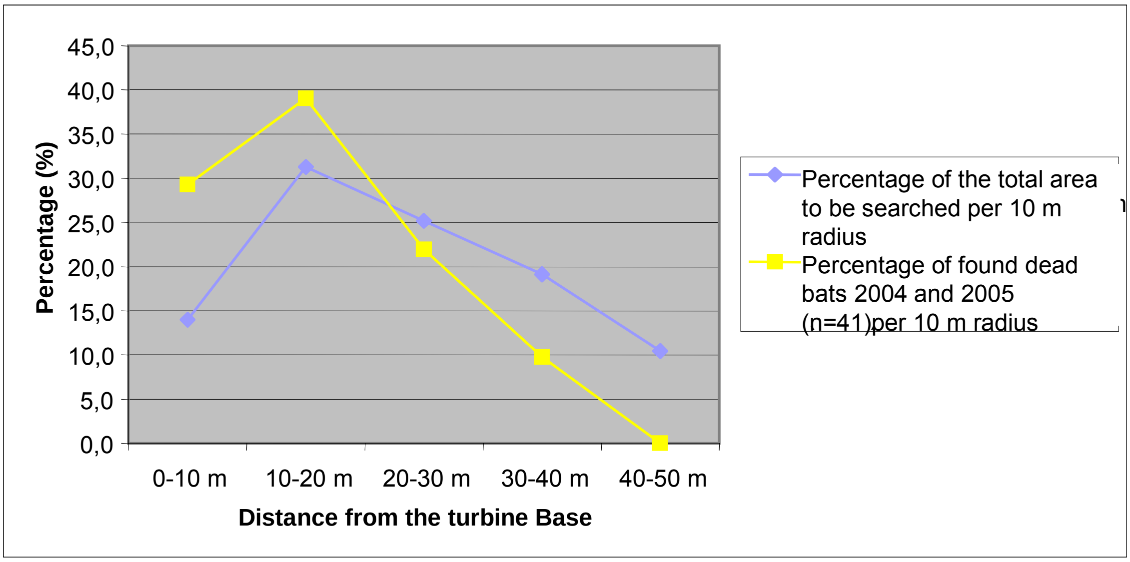

Figure 11: Percentage of dead bat findings and total area to be searched in the five 10 m radius groups from the turbine base. The curves are not significantly different for those areas where bats were found (up to 40 m). (Randomised X^2 test, $X^2 = 6.75$, df = 3, p= 0.076).

Figure 12: The bats are quite visible on the gravel beneath the turbines and can therefore easily be found (here a Common Pipistrelle *Pipistrellus pipistrellus*)

2.3.5 Searcher efficiency

Ten dummies each were placed under six turbines in the three vegetation classes that were searched. The number of dummies in one vegetation class represented the proportion of the total area covered by that particular vegetation class. (Per vegetation class n = 20 dummies, total n = 60). In open vegetation 16 dummies were found, in overgrown vegetation 14 and in the heavily overgrown six. This results in an average searcher efficiency of 85% for open vegetation, 77% for the overgrown areas and 40% for the heavily overgrown habitats for those six turbines (Figure 13).

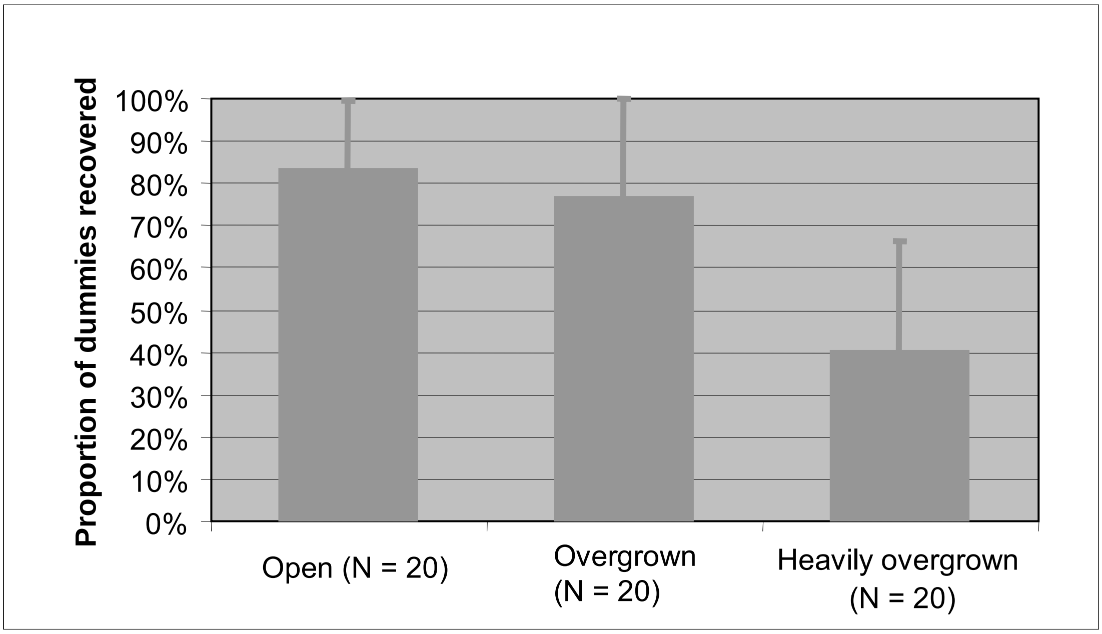

Figure 13: Mean searcher efficiency in the searchable areas in relation to class of vegetation coverage. (Shown are means plus standard error).

2.3.6 Carcass removal

The dead laboratory mice that were laid out to experimentally determine carcass removal rate disappeared relatively quickly from the sites. Only six days after bringing out the carcasses, on average more than 90% could no longer be traced (Figure 14). The rate of removal varied strongly between the sites after the first days. In one case, for example, all carcasses had completely disappeared on the second survey day, whereas they remained considerably longer at other turbines.

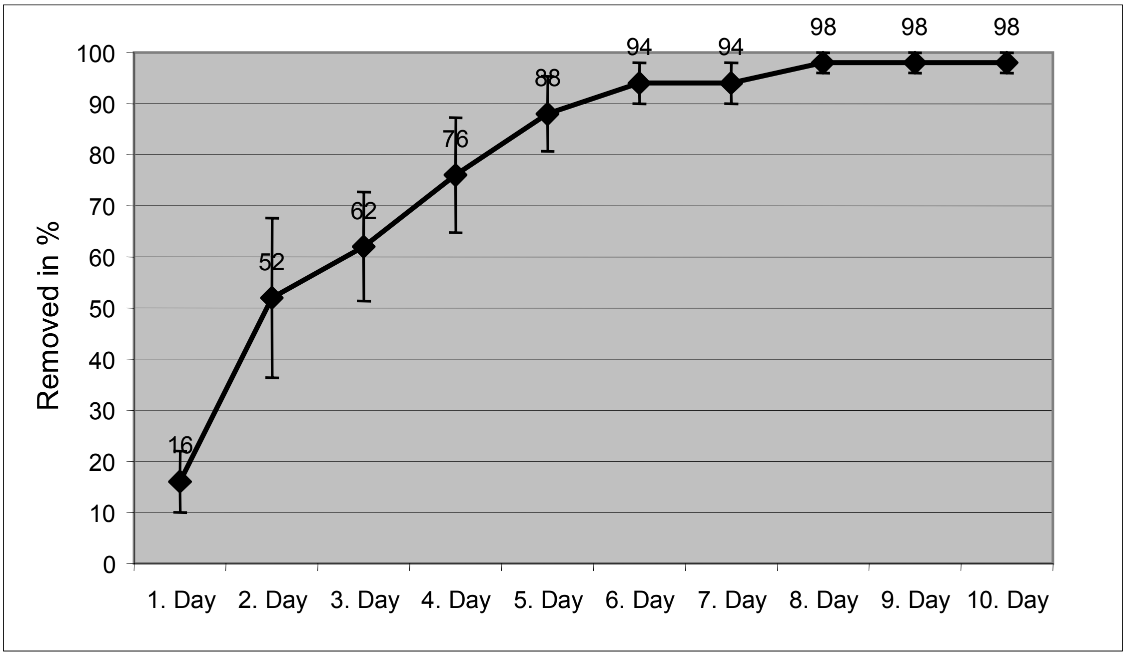

Figure 14: Carcass removal of ten laboratory mice each, deposited in five experiments, analysed daily for 10 consecutive days (mean values for all five sites, presentation of mean value and the standard error)

To evaluate the carcass removal rate of collision fatalities within the search interval of five days, the carcass removal rate shown in Figure 14 was averaged over the first five days. The mean carcass removal rate after five days is 58.8%. Therefore, only 41.2 % of the collision fatalities could be found during the carcass searches conducted every fifth day. When the maximum and minimum values (as shown in Figure 14: maximum and minimum standard error, respectively) of all experiments are considered, the maximum carcass removal rate after five days could vary between 69% and 48.6%.

In several cases during the experiments, burying beetles were observed burying the carcasses. Wasps had left only skeletons, and bottle flies also fed on the carcasses. In one case, fresh wild boar tracks indicated that the remaining carcasses had been consumed by wild boars.

The observations made during the laboratory mouse experiment concerning the carcass removal rate coincide with those observations made during the carcass searches in the two years of the study. Burying beetles were also observed working on bat carcasses and wasps were seen feeding on dead bats (Figure 15). The laboratory examination of the bat carcasses (see chapter 3) confirmed that post mortal feeding had occurred in most cases. Insects were very often responsible but shrews as well as probably *Apodemus* species and other small carnivores also fed on the carcasses. Fox droppings were found frequently and indicated that this species was probably also responsible for large numbers of removed carcasses. Carcass removal was never observed by diurnal birds of prey or corvids. Removal by these birds seems to play a minor role at examined sites in wood habitats.

Figure 15: A Common Pipistrelle *Pipistrellus pipistrellus* is buried by a burying beetle. It takes on average half a day or less for the beetles to locate a carcass, especially when flies have already found it. Burying takes, depending on the soil, between two to five hours. Right: Wasps feeding on a dead Parti-coloured Bat *Vespertilio murinus* at a wind turbine in South Baden.

2.3.7 Estimate of the number of actual collision fatalities

Considering the searcher efficiency, the carcass removal rate and the proportion of searched area in relation to the whole area surrounding the turbine base within a given radius, an approximate value for the actual number of collision fatalities can be determined using the following formula:

$$H = (T-2\%) * S * A * F$$

H	=	Approximate value / Estimate of the actual number of collision fatalities
T	=	Number of carcasses found. According to our calculations, 2 % of the carcasses found may have been missed in previous searches.
S	=	Factor searcher efficiency, calculated as 1/searcher efficiency for each of the three searched vegetation classes and the proportion of each vegetation class of total area searched beneath the turbine
A	=	Factor carcass removal, differentiated between mean removal rate (58.8%, resulting in factor 2.43) and upper and lower threshold levels (lower 48.6%, factor 1.95 and upper 69%, factor 3.23)
F	=	Area factor, calculated from the relation of searched to not-searched area in a 40 m radius around the turbine base

The carcass removal rate only represents an approximate value due to methodological limitations (use of laboratory mice as carcasses, no consideration of seasonal variances, mean values of the study results). Therefore, the approximate value for the actual number of fatalities is calculated using the mean value as well as the upper and lower threshold levels. The results will therefore give a range of possible fatality numbers. A 40 m radius is calculated for the area factor as dead bats were found only within this area (see discussion chapter 2.4.2).

For the 16 turbines regularly checked in 2004, the approximate value amounts to 335 dead bats (ranging between 269 to 446) with an average of 20.9 (ranging 16.8 to 27.9) dead bats per turbine (Table 4).

Taking into account that in 2004 only very few or no carcasses at all were found at turbines located in open areas, the average number for those turbines located in woodland habitats rises considerably. For the eight turbines in woodland habitat that were also examined in 2005, their approximate values are the following: a total of 297 (range 238 to 394) dead bats with an average of 37.1 (range 29.8 to 49.3) dead bats per turbine.

For 2005, these eight turbines result in a total of 94 dead bats (range 75 to 125) with an average of 11.8 (range 9.4 to 15.6) per turbine (Table 5).

For the individual turbines, the ratio of actually found dad bats to estimated approximate value varies between 1:6 (Holzschlägermatte), 1:7 (Freiamt Hohes Eck) up to 1:11 (e.g. Schillinger Berg 1 or Brudergarten). (These values apply for the survey period with a five-day carcass search interval.)

Table 4: Approximate numbers of actual collision fatalities based on the number of found dead bats at the 16 turbines in 2004 with consideration of searcher efficiency, carcass removal rate and the area factor (presented with the upper and lower threshold levels of the carcass removal rate)

Location / Name of turbine	Carcasses found	Increase factor caused by searcher efficiency (Ø according to searchability)	No. of carcasses after accounting for searcher efficiency and varying carcass removal rates			Area factor referring to 40 m radius	No. of carcasses after accounting for area factor and varying carcass removal rates		
			high	medium	low		high	medium	low
Ettenheim Mahlberg 1 Windschlag	1	1,19	3,76	**2,83**	2,27	4,6	17,30	**13,02**	10,44
Ettenheim Mahlberg 2 Wald	1	1,19	3,76	**2,83**	2,27	3,4	12,78	**9,62**	7,72
Ettenheim Mahlberg 3 Wald	2	1,28	8,11	**6,10**	4,89	2,4	19,46	**14,64**	11,74
Ettenheim Brudergarten 1 Wald	3	1,41	13,36	**10,05**	8,06	3,5	46,76	**35,18**	28,21
Ettenheim Brudergarten 2 Wald	2	1,41	8,91	**6,70**	5,37	3,6	32,08	**24,12**	19,33
Ettenheim Brudergarten 3 Wald/Windschlag	2	1,22	7,71	**5,80**	4,65	3,8	29,30	**22,04**	17,67
Freiamt Hohe Eck Wald	7	1,43	31,61	**23,79**	19,07	2,2	69,54	**52,34**	41,95
Freiamt Schillinger Berg 1 Wald	9	1,20	34,28	**25,79**	20,67	4,0	137,12	**103,16**	82,68
Freiamt Schillinger Berg 2 Wiese	0	2,17	0,00	**0,00**	0,00	1,0	0,00	**0,00**	0,00
St. Peter Plattenhöfe 1 Wiese/Wald	0	2,17	0,00	**0,00**	0,00	1,4	0,00	**0,00**	0,00
Simonswald Plattenhöfe 2 Wiese/Wald	1	2,13	6,73	**5,06**	4,06	1,5	10,10	**7,59**	6,09
Simonswald Plattenhöfe 3 Wiese/Wald	1	2,22	7,03	**5,29**	4,24	1,5	10,55	**7,94**	6,36
Simonswald Plattenhöfe 4 Wiese	0	2,50	0,00	**0,00**	0,00	1,2	0,00	**0,00**	0,00
Horben Holzschlägermatte 1 Wald	5	1,32	20,80	**15,65**	12,54	2,4	49,92	**37,56**	30,10
Horben Holzschlägermatte 2 Wald	1	1,25	3,95	**2,97**	2,38	2,7	10,67	**8,02**	6,43
Fürstenberg Wiese	0	2,00	0,00	**0,00**	0,00	1,0	0,00	**0,00**	0,00
	35						445,58	**335,23**	268,72

Table 5: Approximate numbers of actual collision fatalities based on the number of found dead bats at the eight turbines in 2005, accounting for searcher efficiency, carcass removal rate and the area factor (presented with the upper and lower threshold levels of the carcass removal rate)

Location / Name of turbine	Carcasses found	Increase factor caused by searcher efficiency (Ø according to searchability)	No. of carcasses after accounting for searcher efficiency and varying carcass removal rates			Area factor referring to 40 m radius	No. of carcasses after accounting for area factor and varying carcass removal rates		
			high	medium	low		high	medium	low
Ettenheim Mahlberg 3 Wald	0	1,28	0,00	**0,00**	0,00	2,4	0,00	**0,00**	0,00
Ettenheim Brudergarten 1 Wald	1	1,41	4,45	**3,35**	2,69	3,5	15,58	**11,73**	9,42
Ettenheim Brudergarten 2 Wald	0	1,41	0,00	**0,00**	0,00	3,6	0,00	**0,00**	0,00
Ettenheim Brudergarten 3 Wald/Windschlag	2	1,22	7,71	**5,80**	4,65	3,8	29,30	**22,04**	17,67
Freiamt Hohe Eck Wald	4	1,43	18,06	**13,59**	10,89	2,2	39,73	**29,90**	23,96
Freiamt Schillinger Berg 1 Wald	2	1,20	7,62	**5,73**	4,59	4,0	30,48	**22,92**	18,36
Horben Holzschlägermatte 1 Wald	1	1,32	4,16	**3,13**	2,51	2,4	9,98	**7,51**	6,02
Horben Holzschlägermatte 2 Wald	0	1,25	0,00	**0,00**	0,00	2,7	0,00	**0,00**	0,00
	10						125,07	**94,10**	75,43

2.3.8 Number and diversity of found birds

Apart from the bats, in total nine bird carcasses were found below the turbines (Table 6). The most common birds were swifts and house martins (three individuals of each species). Remarkable is the finding of an Alpine swift below one of the turbines at Holzschlägermatte. The bird had been ringed in the same year in a breeding colony in Freiburg (W. FIEDLER, pers. Communication). During the searches, large flocks of swallows and swifts were observed foraging at daytime in the immediate vicinity of the blades (e.g. on 06.09.2005 at the turbine Schillinger Berg 1).

In 2004, dead bats were found eight times more frequently than dead birds (ratio of 40:5). In 2005, this ratio was reduced to 2.5 times (ratio 10:4). Overall, the number of dead bats was much higher than that of dead birds. On average for both years the ratio of bats to birds is 5:1 (50:9).

Table 6: Species, number and location of dead birds found below turbines

Location / Date	Species	Comments
Plattenhöfe 1, 04.08.04	House Martin (*Delichon urbica*)	
Holzschlägermatte 2, 14.08.04	Alpine Swift (*Apus melba*)	Ring FL 19261 Radolfzell Germania
Hohe Eck, 12.09.04	House Martin (*Delichon urbica*)	
Hohe Eck, 17.09.04	House Martin (*Delichon urbica*)	
Brudergarten 1, 17.10.04	Crest (*Regulus cf regulus*)	Probably Goldcrest
Hohe Eck, 28.07.05	Swift (*Apus apus*)	
Holzschlägermatte 1, 07.08.05	probably Swift (*Apus sp. cf apus*)	Only primaries found
Holzschlägermatte 1, 17.08.05	Swift (*Apus apus*)	
Holzschlägermatte 1, 27.08.05	Melodious Warbler (*Hippolais polyglotta*)	Identified by Staatliches Museum für Naturkunde Karlsruhe

2.4 Discussion

2.4.1 Species diversity and status of bat fatalities

The carcass search for dead bats beneath wind turbines in the administrative district of Freiburg, Southern Germany, produced fundamentally new information about the species composition affected by wind turbines. The two most frequently found species, the common Pipistrelle *Pipistrellus pipistrellus* and Leisler's Bat *Nyctalus leisleri*, had been found significantly less often in other studies conducted thus far (Dürr & Bach 2004). In this study, species such as Nathusius' Pipistrelle *Pipistrellus nathusii* or the Noctule *Nyctalus noctula,* that had been found dead most frequently beneath turbines in central and northern Germany, have not been found at all. Both species hibernate in the forests of the Rhine river valley and in the foothills of the Black Forest, i.e. in the vicinity of the examined turbine sites, and pass through these areas during their spring and autumn migrations.

Our results correspond well with those of another study that was conducted at the same time in the same region, at Rosskopf near Freiburg by BEHR & HELVERSEN (2005). In their study, the Common Pipistrelle *Pippstrellus pipistrellus* also represented the largest proportion of bats killed by turbines (n=39) followed by the much rarer Leisler's Bat *Nyctalus leisleri* (n=4).

Our results support the impression that in the area of South Baden, primarily bats foraging in open spaces are colliding with turbines. Other species, such as the Greater Mouse-eared Bat *Myotis myotis*, the Natterer's Bat *Myotis nattereri*, the Whiskered Bat *Myotis mystacinus* or the species of Long-eared Bats *Plecotus sp.,* that forage and fly close to structures, and can be expected, in the author's opinion, within the surrounding area of the search sites, seem to collide very rarely if at all with wind turbines (see chapter 5.2). A single incident of a Grey Long-eared Bat *Plecotus austriacus* found below a turbine in Saxony (ENDL 2004) shows it can't be ruled out absolutely.

Our survey results lead to substantially new insights regarding assessing the collision risk for the native bat species. Until now the assumption was that the collisions occur mainly during the autumn migration to the hibernacula areas (BACH & RAHMEL 2004 and others). However, our results show that, especially for the Common Pipistrelle, collisions can happen in the wider vicinity of maternity roost areas. The Common Pipistrelle has numerous maternity roosts near the turbine locations and there is a large winter roost known in the Freiburg Minster. Remarkably, most carcasses were found from mid-July onwards after the majority of the maternity roosts had been vacated. Probably the bats have a wider range, since their attachment to the maternity roosts is no longer necessary, and use more distant foraging habitats or make short nightly visits to swarming sites and hibernacula. SIMON et al. (2004) showed that the Common Pipistrelle from maternity roosts about 20-25 km away, flew to the Marburg Castle to swarm and investigate this winter roost. The peak swarming activity was observed by the authors in August (ibid.), the month in which the greatest number of collision fatalities was found beneath the wind turbines.

2.4.2 Number of bat fatalities

Absolute numbers found

The number of bats found beneath the turbines was surprisingly high. The absolute numbers of bat carcasses found in this study are some of the highest that have been documented in Germany to date. Only BEHR & HELVERSEN (2005) found more at Rosskopf near Freiburg. When comparing the absolute carcass numbers, the search intensity must always be considered.

The total number of bats (n=40) found in 2004 at all examined turbines can be well compared with the numbers of BEHR & HELVERSEN (2005), who in 2004 found a total of 44 Common Pipistrelle and Leisler's Bats at the four turbines at Rosskopf, but with a higher search intensity. Their numbers are similar to those of the turbines at Schillinger Berg 1, Hohe Eck and Holzschläger Matte 1 at which high numbers of bats were found during the same time.

Determining correction factors for the projection of collision fatalities

To determine the number of bats that actually collided with the turbines, the number of found bats was used in a formula taking into account the searcher efficiency, the carcass removal rate and the area that had been searched. Searcher efficiency might have been slightly overestimated as the searching person was aware of the fact that dummies had been brought out. Nevertheless, the determined searcher efficiency is comparable to that of other experiments (e.g. KOFORD et al. 2005, KERNS et al. 2005).

The carcass removal rate was determined by experiments conducted in the second half of August 2005. With this limited period of time for this experiment, it is possible that during other search periods e.g. in July or October, slightly different carcass removal rates should be used. Especially the biological activity should decrease in autumn, e.g. the activity of the burying beetles, so that carcasses should not disappear as quickly from the sites as they did in August. This effect on the projection is qualified by the fact that most of the carcasses were found in August. According to current knowledge, strong variances in the carcass removal rates depending on different locations must be assumed, as we were also able to show in our experiments. Therefore we picked those turbines with the highest number of fatalities for the carcass removal experiments. The average carcass removal rate of our study is very similar to that of KERNS et al. (2005), which they gained from a very detailed study in the

USA where they used bats instead of laboratory mice for their experiments. They also showed that fresh bats disappeared much quicker than bats that had been temporarily frozen.

Since the carcass removal rate has a large impact on the calculation, we used the average value as well as the upper and lower threshold values to provide a range in which the number of actual collision fatalities is most probably included. When interpreting the presented data, keep in mind that the numbers merely represent a projection.

In connection with the carcass removal rate, the length of the search intervals must also be considered. According to current knowledge, collision fatalities do not occur evenly over a period of time, but rather clustered. Hence it is important to know how recently the collisions occurred before the next search. If a search has just been conducted, it can be expected that a large number of carcasses will have disappeared by the time the next search takes place. This would result in an underestimate of the number of fatalities. If a cluster of collisions occurred shortly before the next search, the number of fatalities would be overestimated, since a mean value for the carcass removal rate in reference to the search interval is used in the projection.. This was demonstrated by ARNETT et al. (2005) in an exemplary evaluation for a weekly search interval using data from daily searches. In their case, a weekly search would have led to an underestimate of fatalities by a factor of 3, despite using correction factors for the carcass removal rate. The highest numbers of fatalities had always, by chance, occurred just one or two days after a search. On the other hand, an overestimate would be expected roughly to the same degree if the greatest number of fatalities would occur by chance just prior to the next search. This leads to the conclusion that the intervals between carcass searches should be as short as possible in order to determine accurate numbers of the collision fatalities. By using upper and lower threshold levels, it is then possible to show in which range the actual number of fatalities might be.

To determine the area factor, only the area within 40 m from the turbine base was considered, since in this study the farthest carcass was found 37 m away. Nevertheless it is likely that animals can drift beyond the 40 m distance and probably even further than the 50 m radius that was searched. In other studies numerous animals were found at distances of up to ca. 60 m (KERNS et al. 2005, TRAXLER et al. 2004, Trapp et al. 2002 and others). BEHR & HELVERSEN (2005) even found a carcass 95 m away from the nearest turbine. Accordingly, the number of fatalities will tend to be underestimated when a radius of 40 m around the turbine is chosen to determine the area factor.

Since in this study the various distance areas showed no significant difference in the distribution of the found carcasses in relation to the searchable area, the projection was calculated uniformly for the searchable area of the 40 m range. (see chapter 2.3.4 and Figure 11).

Not taken into account is the fact that most probably not all collision fatalities had been found due to the limited search periods, April – May (only in 2005) and August – October. This leads to an underestimate of the projected numbers.

Projection results

The projection of the fatalities for the turbines surveyed in the administrative district of Freiburg shows for the first time realistically which collision rate in total as well as for each individual turbine can be expected: 335 collision fatalities (range 269 to 446) at the 16 turbines examined in 2004 and 94 collision fatalities (range 75 to 125) at the eight turbines examined again in 2005.

This study shows that the extent of the impact can be greatly underestimated when only the number of actually found carcasses is used. Therefore the searcher efficiency rate and the carcass removal rate of the specific area should always be included in all studies of collision fatalities.

If these correction factors had been determined and used in other studies in Germany e.g. at TRAPP et al. (2002) or BEHR & HELVERSEN (2005), their results would have been just as high or even higher. A number of studies from the USA and Austria were conducted very systematically and in great detail. Their results can be compared to those of this study (see Table 7). The highest number of incidents was always recorded at turbines located in woodlands. KERNS et al. (2005) found per turbine surveyed, on average 25 and 38 collision fatalities respectively at two wind farms in the woodlands of Pennsylvania and West Virginia. These values are similar to those that we determined for all the turbines as well as for just the eight turbines in woodland areas studied in 2004. By contrast, in open field (arable land), e.g. wind farm Top of Iowa, only 5.9 carcasses in 2003 and 10.2 in 2004 were registered (KOFORD 2005). TRAXLER et al. (2004) also found on average 8 and 5.3 carcasses per turbine respectively for two wind farms in eastern Austria, whereas we did not find any fatalities beneath turbines in open areas in our study. These results support the theory that significantly more bats collide with turbines in woodland locations (see also chapter 4.4.3).

Table 7: Mortality of bats caused by wind turbines at different wind farms in the USA, Spain, Austria and Germany

Location	Habitat structures at wind farm	Survey period (SP)	Fatalities/ turbine/SP	Consideration of **S**earcher efficiency, **C**arcass removal rate and **A**rea factor
Buffalo Ridge, MN P1	Arable land and pastures	1999	0,07	Yes (ERICKSON et al. 2002)
Buffalo Ridge, MN P2		1998-2001	2,02	Yes (ERICKSON et al. 2002)
Buffalo Ridge, MN P3		1999-2001	2,32	Yes (ERICKSON et al. 2002)
Foot Creek Rim, WY	Prairie, Aspen, Shrubs	1998-2001	1,04	Yes (ERICKSON et al. 2002)
Vansycle, OR	Arable land and pastures	1999	0,74	Yes (ERICKSON et al. 2002)
Wisconsin	Arable land and pastures	1999	1,10	Yes (ERICKSON et al. 2002)
Buffalo Mtn., TN	Deciduous woodland on mountaintop	2001	10	No (ERICKSON et al. 2002)
Mountaineer, West Virginia	Woodland on hilltop	31.07.-11.09.2004	38	Yes (KERNS et al. 2005)
Meyersdale, Pennsylvania	Woodland on hilltop	31.07.-11.09.2004	25	Yes (KERNS et al. 2005)
Top of Iowa	Arable land in vicinity to wetlands	15.04.-15.12.2003	5,91	Yes (KOFORD et al. 2005)
		24.03.-15.12.2004	10,17	
Navarre NO Spain	Willows and dwarf shrubs	1999-2001	2,6	**S + C** partly considered, consideration of **A** not certain (ALCALDE & SÁENZ 2004)
Prellenkirchen East Austria	Arable land	09.2003 - 09.2004	8,00	Yes (Traxler et al. 2004)
Steinberg East Austria	Arable land	09.2003 - 09.2004	5,33	Yes (Traxler et al. 2004)
Puschwitz, Saxony	Pre-forest state, Pine woods	18.08.-10.10. 2002	3,40	No (TRAPP et al. 2002)
Rosskopf Freiburg	Wind throw areas in woodland	08-10.2004	21,5	**A** only, **C+S** not considered (BEHR & HELVERSEN 2005)

2.4.3 Differences in fatality numbers for each year

In 2004, a total of 31 fatalities was counted, whereas in 2005 only 10 dead bats had been found. This shows clearly that the collision rate of bats with wind turbines fluctuates strongly between the years and at different sites.

One reason for the much lower numbers in 2005 could have been the weather. In 2005, the summer was much cooler. Warm nights with low winds in which collisions are more likely to occur were much rarer than in 2004. As long as the real reasons for bats coming into the vicinity of wind turbines are unknown, it will be difficult to correctly interpret the differences in numbers.

2.4.4 Seasonal distribution of collision fatalities

Concerning the seasonal distribution of bat collision fatalities, the results from this survey for the administrative district of Freiburg lead to no considerably new insights. The recorded seasonal distribution of bat collisions fits well into the already known pattern where most collisions occur between July and September (compare overview at DÜRR & BACH 2004). The absence of carcasses between the beginning of April and mid-May also coincides with published results of literature in which carcasses are described to be rarely and irregularly found in spring. It has to be taken into account however, that only few studies haven been conducted during this particular time of the year.

The temporal occurrence of the collisions in 2004 is very similar to that described by BEHR & HELLVERSEN (2005) for 2004 at Rosskopf. Here, most carcasses were registered at the beginning of August. In their study they also observed the largest number of fatalities after warm and relatively low wind nights. Using acoustic recordings, they showed that the highest activity of the Common Pipistrelle at the examined turbines and nacelles took place at wind speeds of less than 6 ms^{-1} (ibid).

The phenomenon of finding the largest number of fatalities after warm and low wind nights has been observed in all studies conducted thus far (e.g. ARNETT 2005. JOHNSON et al. 2003, TRAPP et al. 2002 and others). That the collision risk would be greater with increased prey and bat activity in such weather conditions seems to be at first sight a plausible explanation. This, as well as the theory that collision fatalities drift merely further away with higher wind speeds and thus cannot be found, have not been proven.

A reason for absence of carcasses from the searches between April and May, is that single or few fatalities can easily be overlooked with a five-day search interval. To obtain a more accurate picture of the circumstances, carcass searches with shorter intervals are necessary. Principally, one can assume that the number of fatalities during this period will be much lower than during late summer, which is also supported by the few publications available. Statements cannot be made regarding a possible additional mortality for the periods during the year where no data has been collected.

2.4.5 Impact of turbine location and turbine type

The results of this study showed no trends regarding the altitude of turbine location or turbine type. Collisions occurred at all turbine types and at all altitudes. The sample size of this study however is too small to evaluate it in relation to single location parameters. DÜRR & BACH (2004) evaluated all recorded bat collision fatalities in Germany available up to date and could not find a trend in relation to hub height or rotor diameter either.

The often discussed impact of the turbines' aviation lights was not examined any closer in this study. In principle, it seems possible that insects, as potential prey for bats, and consequently bats could be attracted to those lights. In a comparison study from the USA, where five lit and five unlit turbines were studied each for a night at a wind farm using thermal imaging cameras, HORN & ARNETT (2005) found no significant differences in bat activity.

3 Examination of collision fatalities

3.1 Introduction and objectives

To date no systematic veterinary examinations and dissections of collision fatalities were conducted in Germany. This is puzzling, as these procedures would possibly produce additional information on the cause of death or on the behaviour of the bats in the vicinity of the turbines. The following questions were of main concern when the collected carcasses were examined:

- What is the cause of death? Is there a connection between the use of wind energy or what other causes could be taken into account?
- What was the bats reproductive status?
- What is the feeding condition of the bats? Were they foraging before their death?

3.2 Methods

The frozen carcasses were handed over to the Staatliches Museum für Naturkunde Karlsruhe (Federal museum of natural history in Karlsruhe) to be added to their scientific collection. Apart from the usual basic data for inventory, Dr. Ursel Häußler carried out further examinations to investigate the cause of death. The methods and results presented here are taken from the examination reports available (HÄUSSLER 2004 and written communications 2005).[8]

The examinations by Dr. U. Häußler included:

- Verification and, if possible, completion of the animal status (species, sex, age, reproductive state). In difficult cases, the development of the gonads was examined. Production of sperm or insemination was checked microscopically with tissue samples.
- Level of preservation was checked and external injuries were recorded (the skull was examined thoroughly for haemorrhages or fractures. In two cases, a dissection of the skull was conducted.)
- Recording of all biometric data (initially, only the length of the forearm and the fifth finger was recorded.)
- Dissection of fresh dead bats:

  A, to check the overall feeding condition (clues to last food intake, digestive tract, faeces in rectum)

  B, to record internal injuries in thorax and abdomen.

Sixteen bats[9] (12 *P. pippistrellus* and 4 *N. leisleri*) were dissected. What was seen with the naked eye was verified using a stereomicroscope (up to 50x magnification). Any damage to the organs or haemorrhages was recorded. Seven[10] bats were frozen after the dissection for further examinations.

[8] All examinations were carried out by Dr. Ursel Häußler additionally to her work at the museum and voluntarily out of interest for the cause, for which we are very grateful.
[9] 12 bats (8 *P.pippistrellus*, 4 *N. leisleri*) from 2004 and 4 *P.pippstrellus* from 2005
[10] 3 bats (1 *P.pipistrellus*, 2 *N. leisleri*) from 2004 and 4 *P.pipistrellus* from 2005

All other carcasses, including those that had not been dissected, were placed into 75% alcohol for conservation.

Figure 16: Rarely is the cause of death so obvious as with this Common Pipistrelle (*Pipistrellus pipisstrellus*), found fresh dead with a split skull under a turbine.

3.3 Results

3.3.1 External injuries and skull fractures

Of the bats found in 2004, only 4 had external injuries such as broken wings and obvious head injuries which were clearly in causal relationship to their fatality (see reports in the annex). Yet, in all but two of the well preserved bats (n=14), blood was found in the nose and usually also in the mouth. Sometimes the oral mucous membrane of the upper jaw was suffused with blood. When inspecting the auditory canal with a stereo microscope, in five cases blood was found behind the tympanum, indicating a fractured skull. The preparation and dissection of a skull of one common Pipistrelle and one Leislers Bat showed fractures of the zygomatic arch and deformations of the Bullae tympani, respectively fractures of the skull base.

In 2005, six bats had broken wings and head injuries in causal relationship to their fatality. As in the previous year, fractures of the forearm (2 spec.), gums suffused with blood (1 spec.), blood in the auditory canal (2 spec.) or the Bullae tympani (1 spec.) or in the mouth (1 spec.), fractures of the lower (1 spec.) and upper jaw (1 spec.) and fractures of the rear base of the skull (1 spec.) were found.

Typical injuries to the flight membranes or bodies caused by (attempted) attack of raptors were not found. It can be concluded that the areas where the bats were found were neither preferred raptor foraging habitats nor feeding sites.

3.3.2 Results of dissections

Well preserved and externally undamaged specimens of both the Common Pipistrelle and the Leisler's Bat showed a severe hemothorax. All four Common Pipistrelle dissected in 2004 had a hemothorax as well. Massive haematomas into the pectoral cavity such as these indicate ruptured vessels caused by the impact of a blunt force. To support this assumption, fine anatomical preparation would have been necessary, but was not included in these examinations.

The lung tissue looked intact. Yet barotraumatic impact on the alveoli (relative underpressure or overpressure) could have led to the observed hemothorax. The abdominal organs were, as a result of the hemothorax, ischaemic. Ruptures of the abdominal wall with unknown causes were found in several cases, they may have occurred post-mortem. No internal rupture of the abdomen as a result of the impact of high pressure was found, which is sometimes discussed as a possible cause for the fatality.

All dissected bats were in good physical condition at the time of death. They all had stored body fat. With one exception, they had food pulp in their guts and were close to defecation. Completely full stomachs were not found. To identify the type of food and the time of last food intake, systematic examinations would have to be conducted.

3.4 Discussion and preliminary conclusion of the cause of death

With the current findings, natural causes of death as well as diseases can be excluded.

- The fatalities, many of them born the current year, were well nourished.
- There are no indications whatsoever for a causal disease (infections, heavy parasitic infestation, chemical noxa).
- A critical impairment to their physical fitness, resulting from toxin mobilisation after long distant flights or energetically costly swarming behaviour, cannot be considered as a relevant factor since the bats had fat reserves and were feeding shortly before their death.
- Attacks by birds of prey would have caused typical injuries.

The internal injuries are clearly of traumatic origins. The only possible conclusion therefore, is that the death of the found bats is in causal relationship to the wind turbines.

4 Observations of bat activity at wind turbines with thermal imaging cameras

4.1 Introduction and tasks

Only few studies have been carried out on the behaviour of bats in the rotor swept area.. This might be due to the methodological difficulties. The standard method for detecting bat activity is the use of bat detectors from the ground. This cannot be used for these particular observations as the bat calls at rotor height are outside the range of most bat detectors, apart from a few exceptions. It is also discussed that bats might orientate without echolocation in open airspace while migrating. If so, the bats would not be detected using this method (RAHMEL et al. 2004).

For the observation of bats above 100 m, it has been suggested to use thermal imaging cameras (ibid). Since this technique had never before been used to observe bats at wind turbines, detailed tests were conducted to develop suitable observation methods. Furthermore, a classification system for the data was created.

Parallel to this study, the first bat observations at wind turbines using thermal imaging cameras were conducted in the USA. In 2004, HORN & ARNETT (2005) observed 10 turbines, each for a night, at the Mountaineer Wind Energy Center, Pennsylvania. Contemporaneously BEHR & HELVERSEN (2005) established densities of bat activity in the rotor swept area at the wind farm Rosskopf/Freiburg for the first time using automatic recordings of bat calls. With this method, bat calls are registered by a microphone positioned above the nacelle. The calls are then recorded via a computer located inside the nacelle. During two nights it was possible to use both methods simultaneously, registering the acoustic and the optical bat activity at one turbine, thereby testing them against one another (see chapter 4.2.3).

Thermal imaging was used to address the following basic questions about bat behaviour at wind turbines:

- Do bats show swarming or investigative behaviour at the turbines, which might indicate the potential use of the turbine as a roost?
- Can collisions or evasive movements be observed?
- Can differences in bat activity depending on site location, time or season be recorded?

In 2004, the thermal imaging camera was mainly used for testing and all-night observations at selected turbines to answer the above questions. In 2005, two more hypotheses were tested, which were developed from the results of 2004 and the newly published data from other activity studies. This verification is highly relevant for the planning process.

- The number of carcasses collected (see chapter 2) showed that less bats collide at turbines in open areas than at turbines in woodlands. Accordingly, the activity of bats at turbines in open areas should be lower than at turbines in woodlands.
- BEHR & HELVERSON (2005) showed with their acoustic activity examinations that 95% of all calls of the Common Pipistrelle were recorded at wind speeds less than 6 ms^{-1}.

Therefore a reduction of bat activity with increasing wind speeds was also expected for the thermal imaging observations.

Thermal imaging observations and their evaluations are very work-intensive. Only a limited number of observations could be conducted. We decided to use these observations for a location comparison, even though this meant that only a small sample size could be processed. The results cannot be statistically analysed and show only a trend that needs further detailed examination.

4.2 Methods

4.2.1 Selection of study areas and observation period

Apart from numerous tests on the methodology, two whole-night observations with the thermal imaging camera were conducted in 2004 at the turbines Schillinger Berg 1 (02./03.09.04) and Holzschlägermatte 1 (07./08.09.04).

Comparison observations were conducted in 2005 at one turbine located in woodland (Schillinger Berg 1), one turbine in open land (Schillinger Berg 2) and also at a reference site without a wind turbine. All three study sites are located at the foothills of the western Black Forest with an altitude of 710 m above sea level. The reference site was a wind throw area northeast of the Schillinger Berg. All three study sites are located relatively close to each other. Assuming turbine Schillinger Berg 1 to be the centre, both other locations are roughly 850 m away and any interference between them can be ruled out. The distance between Schillinger Berg 2 and reference site is roughly 1450 m.

Between mid-July and mid-October each of the three locations was observed four times for half a night with three to four weeks between each observation. The lot decided in which order the three sites were observed during three consecutive nights[11]. The observations were carried out during stable high pressure periods with clear skies in order to have comparable weather conditions for three consecutive nights. The observation period started at sunset and lasted for four hours.

4.2.2 Technical equipment and procedures

The position of the camera was set once for every location and did not vary between the four observations dates. At the turbine sites, the camera was positioned on a tripod 30 m from the turbine base. The camera was set up to fully show the nacelle and, depending on the wind direction, parts of the downward blade movement (see Figure 17). The nacelle was included in the observation to record possible swarming or inspecting behaviour of bats. The incline of the camera was documented to allow the observation of a comparable area at the reference site.

For the observations, the Mitsubishi Thermal Imager IR-5120AII was used[12]. This instrument can record infrared radiation of objects with 3 to 5 µm wavelength and transform these into real time

[11] The following observations dates were chosen: 26.-28.07.05, 16.-18.08.05, 01.-03.09.05 and 08.-10.10.05.
[12] The thermal imaging camera was put at our disposal by the research institute „Forschungsinstitut für Optronik und Mustererkennung“, Director. Dr. Ebert of the research society “Forschungsgesellschaft für angewandte Naturwissenschaften e.V.” in Ettlingen. We are very grateful for this technical support and would like to thank Mr. Willutzki especially for a large amount of technical and scientific support.

images. The radiation detector consists of 512 x 512 pixels and can produce a clear image with 1/60 sec field time. The images show temperature differences of 0.2 °C.

The infrared lens (f : 50 mm, F 1.2) has a field of view of 14° x 11° which results in a 20.5 m x 16.1 m area covered in 84 m distance (see Figure 17). Each pixel represents the area of 4.0 x 3.1 cm. This is sufficient to show a Common Pipstrelle as one pixel.

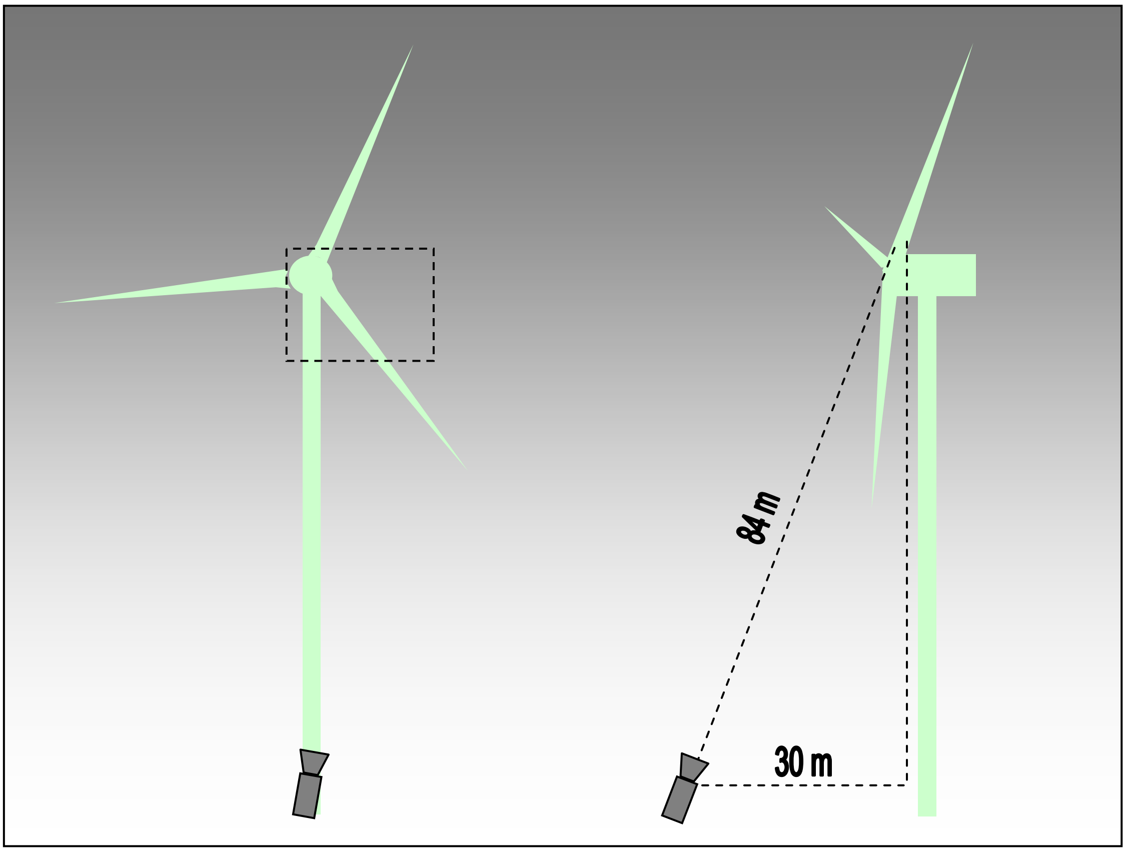

Figure 17: Schematic portrayal of the experimental design for the thermal imaging camera observations

The images recorded by the camera were transformed from NTSC into PAL format and digitally recorded. Date and time appear in the image and allow analysis of the recorded events accurate to the second. The observation took place on site with a 9” monochrome monitor.

The recording started at sunset which was determined by means of a GPS (Garmin) and lasted for four hours. During that time, the events were observed on the monitor. Flying objects were identified as best as possible and their flight direction and height were recorded with the corresponding time. All registered flying movements were double checked later, classified and a protocol was written. Breaks during observation were evaluated later on.

4.2.3 Tests to determine the observation depth, the type of observed objects and development of a system for the classification of observations

Prior to the actual observations, preliminary tests were conducted to determine the depth of the observation and the type of observed objects. These were supplemented and verified by further tests during the actual observations. The results were used to develop a classification system that would ensure an identification of the observed objects as objectively as possible.

The following tests were conducted:

- Medium-sized bats (Nathusius' Pipistrelle, Natterer's Bat and Bechstein's bat) that were trapped with mist nets during other projects were released in defined distances of 100 and 140 m from the camera. The bats were released at head height by a person standing on the ground in front of a forest. The conditions were rather unfavourable as the temperature differences between bats and forest was rather low. Nevertheless, the bats could be identified at a distance of a 100 m very well and at distances of 140 m quite well as pixels on the monitor showing a characteristic flight pattern.

- Several test observations at wind turbines were double-checked by a second observer, who observed optically the same area as the camera (initially during dusk without any aid, later by using a night vision device, Leica BIG 25) and acoustically (using a bat detector Petterson D 240x). Parallel observations of insects and bats produced further information on the imaging of these objects at close range (< 20-30 meters) of the camera.

- Comparable parallel observations were conducted at the Freiburg Minster. The Minster is a well known year-round roost for Common Pipistrelle, but it is also used by the Great Noctule and Parti-coloured Bats. These bats use the lit area around and above the cathedral as a foraging area. One observer was positioned on the west tower at 70 m height, who observed bat activity with a bat detector (for identification) and a night vision device. The camera was positioned on the ground with the same incline that was used for the turbine observation. Using walky-talkies, the two observers defined their observation area and started their parallel observations. The known height of the cathedral tower allowed concrete estimates of the flight altitude of the bats.

- Two half-nightly observations using the thermal imaging camera were conducted parallel to the acoustic observations by the University of Erlangen at wind turbines at Rosskopf near Freiburg (see BEHR & HELVERSEN 2005) and near Fröhnd in the administrative district of Lörrach. A microphone was attached to the top of the nacelle and connected to a recorder within the nacelle. The calls of passing bats were registered and recorded with the time accurate to the second. In two cases, the optical observations coincided exactly with the recorded calls of Common Pipistrelle. In 13 cases matches were not possible. It remains unclear whether the optical identification was incorrect, or the bats did not call or only called sporadically. It is also possible that the bats were too far away from the microphone for their calls to be recorded. The two Common Pipistrelle bats, where optical and acoustical recordings matched, flew extremely close to the nacelle, according to the optical perception. The irregular jagged flight pattern was clearly visible, which is the determinant criteria for the classification of visually observed bats.

Our tests showed that the distance between a flying object and the camera cannot be determined accurately to the meter. For this reason, only two classes of distances were chosen (< 40 m, > 40 m). The definition of greater than 40 m includes, in the case of the turbines, the rotor-swept area. We estimated distances up to which objects of a certain size would still appear on the camera. A common Pipistrelle should still be seen at distances between 150 to 180 m whereas a Leisler's bat would still appear up to distances between 200 to 250 m. Larger objects such as birds or planes are visible at far greater distances.

Based on the results of all tests, a system to classify the observations was developed and verified (see Table 8). The main objective was to be able to identify bats from other flying objects. Only objects with a high probability of being a bat were classified as "bats". Unambiguous observations of planes, insects and birds formed a separate category each. The "unknown" category comprised all other observations that either could not be identified at all or were too ambiguous. As observations even with the slightest doubt where classified as unknown, it is very likely that this category also includes bats. The number of insects, birds and planes observed were not counted as no separate evaluation was conducted, nor was the differentiation in distance classes noted.

Table 8: System for classification of observations with the thermal imaging camera on the basis of various criteria

Category	Criteria for identification of observed objects
Insects	Small objects, appearing very blurry and moving very fast across the screen (mostly larger insects such as nocturnal moths).
Birds	Objects in typical linear or v-shaped formations, moving steadily in the same direction, only definite identifications.
Planes	Small objects, crossing the picture very slowly and in straight lines, always easily recognized by their navigational lights when parallel observed.
Bats < 40 m	Rather large objects at close distance, body and wings of bats are easily recognizable. Due to closeness of the objects, images often very blurry. Fast passage across the screen.
Bats > 40 m	Small objects with typical bat flight pattern, jagged, with changes of direction and gliding. Straight flight for short distances also possible. Sometimes typical fast wingbeat visible. Objects pass across the screen with intermediate speed.
Unknown < 40 m	All other objects in close range that could not be identified.
Unknown > 40 m	Smaller to larger objects, passing across the screen with intermediate speed and in straight lines (probably mostly **birds**; at times, during beginning autumnal migration, numerous). All other small objects, passing across the screen with intermediate speed and mostly in straight lines (apart from **birds** this probably also includes bats, possibly individuals at great height during migration).

For those objects that were definitely identified as bats according to our classification system, the behaviour in relation to the usually turning blades was analysed in more detail. If a bat flying towards a blade suddenly changed flight direction, this was interpreted as evasive behaviour. A collision was identified when a bat approached a blade with the typical jagged flight pattern but after passing it, moved in a straight line (i.e. without typical jagged flight pattern) to the ground. Due to the technical adjustments of the camera, the depiction on the screen of the heat radiation from the blades obscure the objects in their immediate vicinity.

4.3 Results

4.3.1 Number and distribution of observed objects during the observation period

During the twelve half-nightly observations at the three selected locations in 2005, a total of 590 objects were observed. Roughly a third of them were identified as bats and two thirds were most likely birds or could not be clearly discriminated (see Table 9).

At the two locations with turbines, 22 bats were observed at the forest site and 26 in the open area (viewing field approx. 20 x 16 m). At each site, six bats were observed avoiding the blades by quickly changing their flight direction. This represents roughly 25 % of all observations. 75 % of the observed bats showed no change in flight direction, whereas it's possible that some of the bats may have been flying above or behind the blades, which was not possible to determine since the observation depth could not be accurately defined.

In two observations it appeared as if the bat might have been hit by the blade and consequently dropped to the ground. Due to the limited technical observation conditions we were not able to absolutely verify this.

Table 9: Number of all observed objects per location and category during the half-nightly observations at three selected locations in 2005 (Total observation time: 48h)

Location	Date	Number of Objects	Bats < 40 m	Bats > 40 m	Unknown < 40 m	Unknown > 40 m	Evasive behaviour
Wood	26./27.07.05	37	23	9	1	4	1
Wood	17./18.08.05	8	0	4	4	0	3
Wood	03./04.09.05	11	2	4	4	1	2
Wood	08./09.10.05	17	1	5	0	11	0
Wood		**73**	**26**	**22**	**9**	**16**	**6**
Open	27./28.07.05	9	7	0	1	1	0
Open	16./17.08.05	16	3	7	1	5	0
Open	01./02.09.05	13	1	9	0	3	3
Open	10./11.10.05	153	2	10	0	141	3
Open		**191**	**13**	**26**	**2**	**150**	**6**
Reference	28./29.07.05	85	24	24	16	21	0
Reference	18./19.08.05	34	16	6	9	3	0
Reference	02./03.09.05	33	9	3	8	13	0
Reference	09./10.09.05	174	10	14	5	145	0
Reference		**326**	**59**	**47**	**38**	**182**	**0**
	Sums	**590**	**98**	**95**	**49**	**348**	**12**

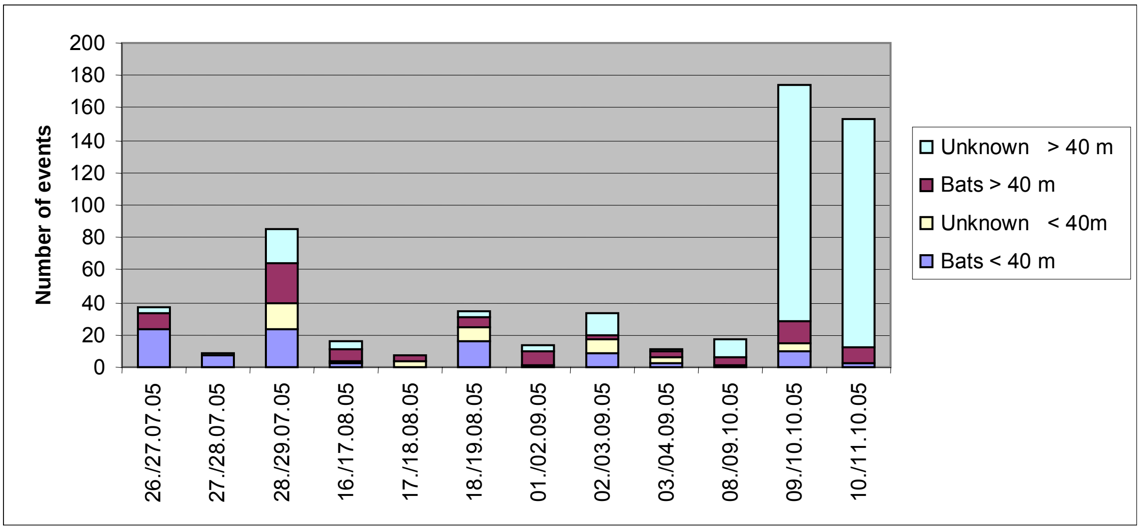

Figure 18: Distribution of observed objects during the four examination periods in July, August, September and October 2005

Figure 18 shows a conspicuous accumulation of unknown objects that were recorded on the last two observation days at the turbine in open area and at the reference site. The objects moved very steadily and probably in great altitude (significantly higher than turbine height) mostly from Northeast towards Southwest. These were most likely, in our opinion, migrating birds (see chapter 4.4.1). The observation at the turbine in the woodland location took place one night prior and although the turbine is only 850 m away from the two other sites, this phenomenon was not observed.

4.3.2 Swarming and investigative behaviour of bats

During all the observations using the thermal imaging camera, distinct swarming behaviour, as it is known by all bat species at used roosts, was not observed near the nacelle. But the total observation time was limited and only two systematic observations took place during the early morning hours. Several bats did, though, repeatedly pass closely near the nacelle within short intervals (continually visible on the screen). This could be interpreted as investigative behaviour.

4.3.3 Activity at the different locations

Bat activity was comparable at both turbine locations, but it was nearly twice as high at the reference site (see Table 9 and Figure 19). These considerable differences occurred during bat observations in both distance classes. Especially relevant for the collision risk are the observations of bats in the class > 40 m. The mean numbers in this class differed very little between the turbines at the forest site and the turbine in open area (see Figure 20). These observations strongly contradict the results of the carcass searches beneath turbines in 2004. Very many carcasses had been found beneath the turbine at the forest location (Schillinger Berg 1) but none at all at the turbine in the open area (Schillinger Berg 2) (see chapter 2.3.1).

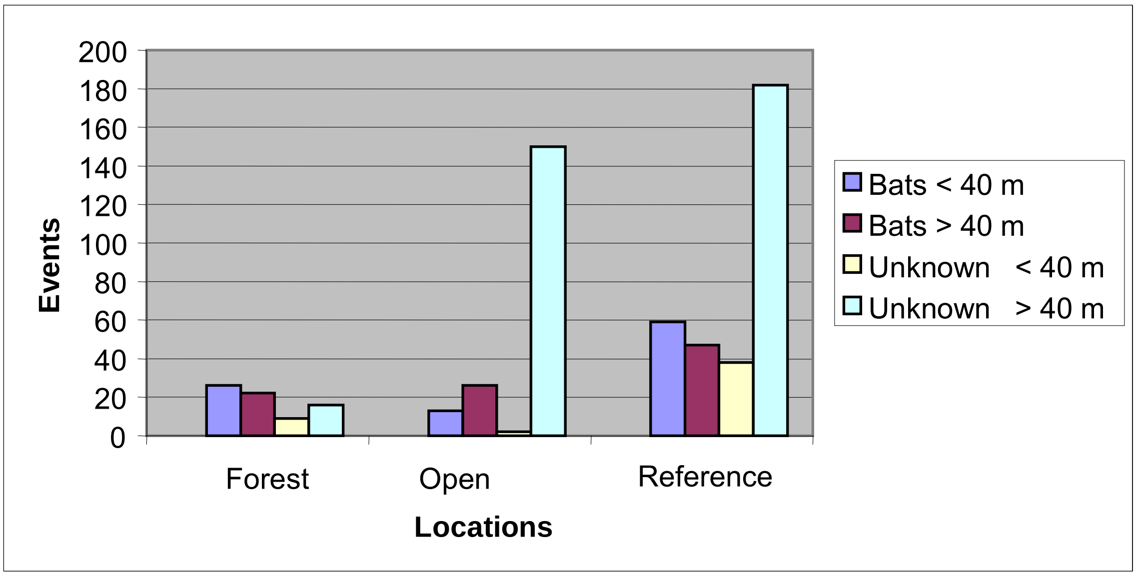

Figure 19: Total number of sightings during all observations split into the different locations (n=4, observation time: 16h/location)

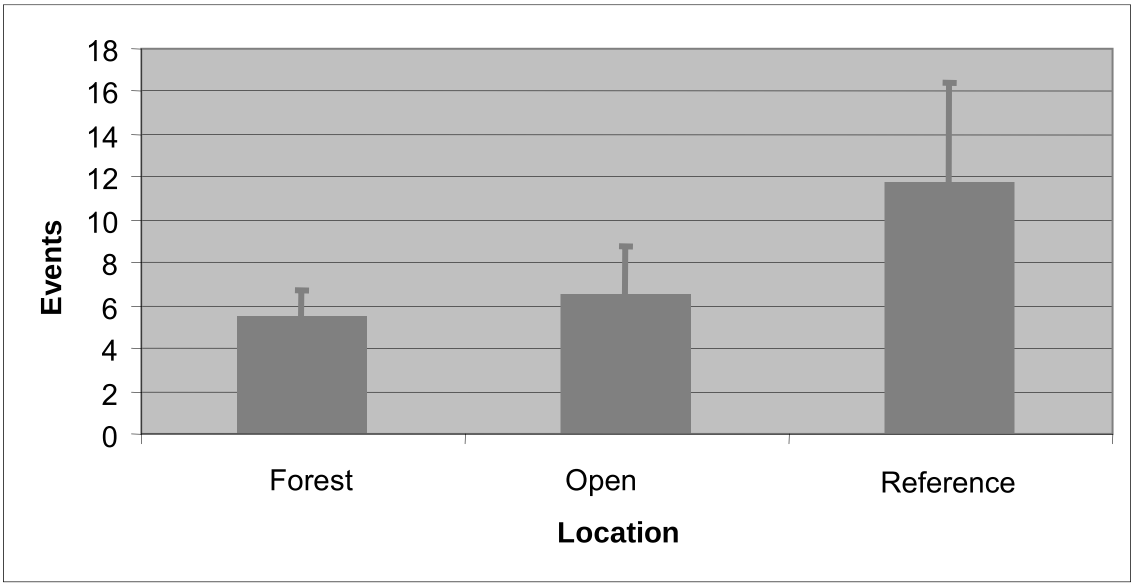

Figure 20: Average number of bat sightings > 40 m per observation split into the different locations (n=4, Observation time: 16h/location, presentation of mean and standard deviation.

The category "bats < 40 m" shows a significant difference between the two turbine locations. Random samples with bat detectors conducted parallel to the camera observations showed that bats in this category were mainly Common Pipistrelle. This corresponds with the expectation for the clearing at "Schillinger Berg 1", to find more Common Pipistrelle, as they prefer foraging at forest edges and above the trees. Still, it is remarkable that at the turbine "Schillinger Berg 2" in open area, a relatively high number of sightings were documented in the same category.

When interpreting these results, the small sample size must be considered. It is so small that no statistical analysis of the results is possible. Random, or specific for each location yet unknown factors, would have a great influence on the results.

4.3.4 Distribution of activity during the nightly observation

During the half-nightly location comparison observations, the bat activity remained relatively constant for the whole duration of four hours. Only in the first 30 minutes after sunset were hardly any bats observed in the area near the rotors (see Figure 21). In contrast, the activity of unknown objects increased continually from 30 minutes after sunset, reaching a maximum between 120 and 180 minutes after sunset. This result was mainly caused by the data from the last two observation days in October, which could be another strong indicator of migrating birds (see chapter 4.4.1).

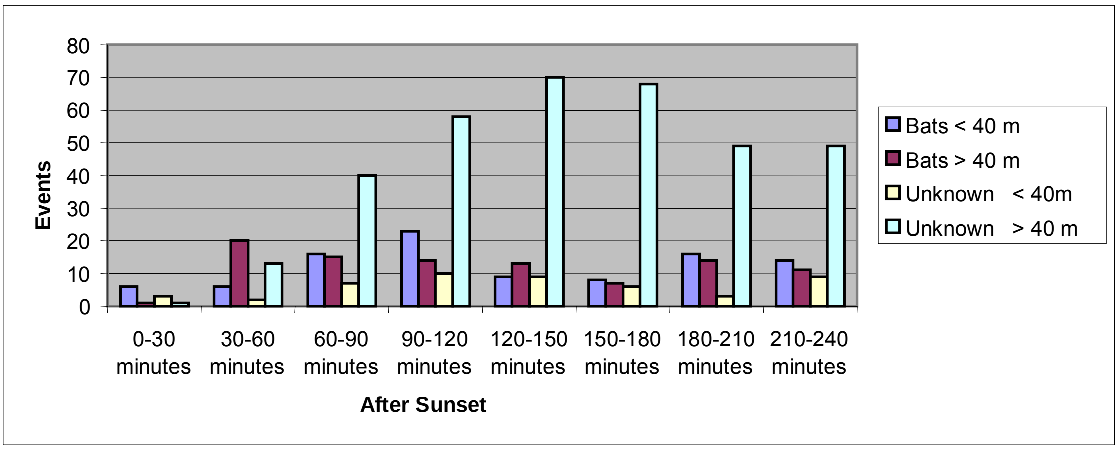

Figure 21: Number of sightings split into 30 minute intervals up to four hours after sunset (data of all three locations, total observation time 48 h)

Apart from the half-nightly observation in 2005, two full-night observations took place beginning of September 2004 at the locations “Holzschlägermatte 1” and “Schillinger Berg1”. Here also bat activity was evenly distributed over the entire night (see Figures 22 and 23). The absence of bats at “Holzschlägermatte 1” during the early morning hours was due to high winds with strong gusts. At the location “Schillinger Berg 1”,weather conditions were favourable for bat observations throughout the whole night. During the observation at “Schillinger Berg1”, two bats per chance were found: at approx. 21:50 a Common Pipstrelle, still alive and at approx. 0:30 a Leisler’s Bat with multiple broken forearms, still bleeding. They were found right in front of the camera on the gravel beneath the turbine. This showed that bats were colliding with the blades during the observations, but were not observed due to the small area that the camera was focused on.

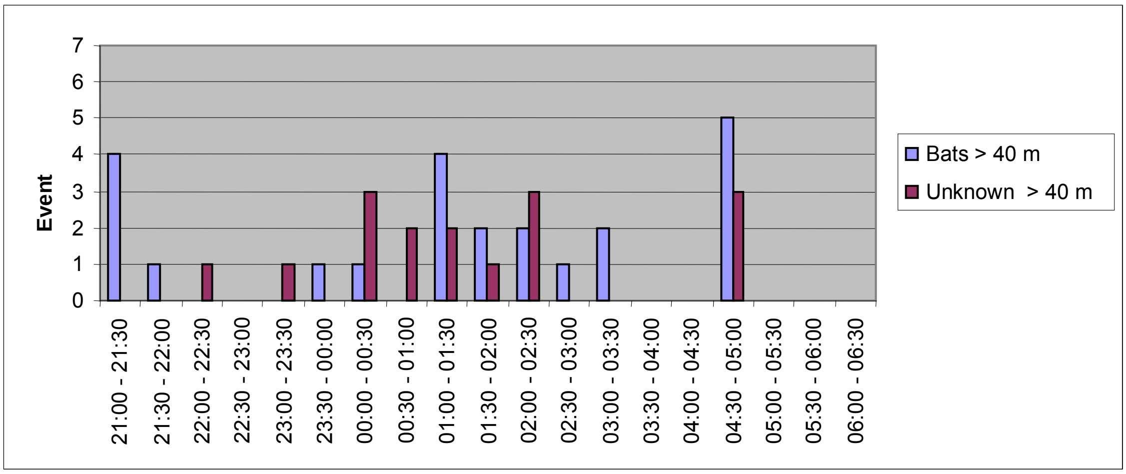

Figure 22: Sightings in the categories "Bats" and "Unknown" in 30 minute intervals during a full-night observation at location "Holzschlägermatte 1" on 07./08.09.04

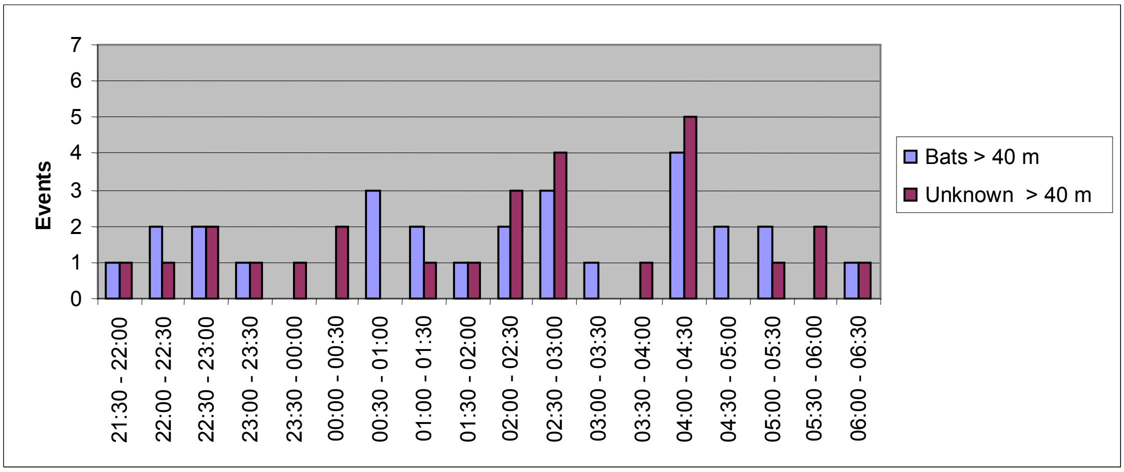

Figure 23: Sightings in the categories "Bats" and "Unknown" in 30 minute intervals during a full-night observation at location "Schillinger Berg 1" on 02./03.09.04

4.3.5 Bat activity in relation to wind speed

The half-nightly bat observations at the turbine locations "Schillinger Berg 1 & 2" can be put in relation to the actual wind speed at that time. The wind speeds (mean values for each 10-minute interval), recorded at the turbines, were provided by the wind farm management[13] for the observation nights. The bat observations, recorded accurate to the second by means of the thermal imaging camera (category "bats > 40 m"), were correlated to the wind speeds. For these results, all bat sightings at a height of over 40 m are included, although the wind speed data was recorded at height of 80 m at the turbine nacelle.

The wind speeds recorded during the eight half-nightly observations at the turbines (observation time: 32h) reached a maximum of 12 ms^{-1} per 10 minute interval. Figure 24 shows that bat activity was recorded at nearly all wind speeds to a maximum of 10.9 ms^{-1}.

[13] We would like to thank the company Regiowind, especially Mr. Markowsky and Mr. Strohmeier for providing the wind data and for general information on the turbines.

In Figure 24, two curves compare the 10 minute wind speed intervals with and without bat activity. They show that bat activity is not evenly distributed between them. At wind speeds between 3.5 and 7.5 ms^{-1}, a higher bat activity was recorded per interval than at wind speeds of less than 3.5 or more than 7.5 ms^{-1}, when compared to the intervals without any bat activity.

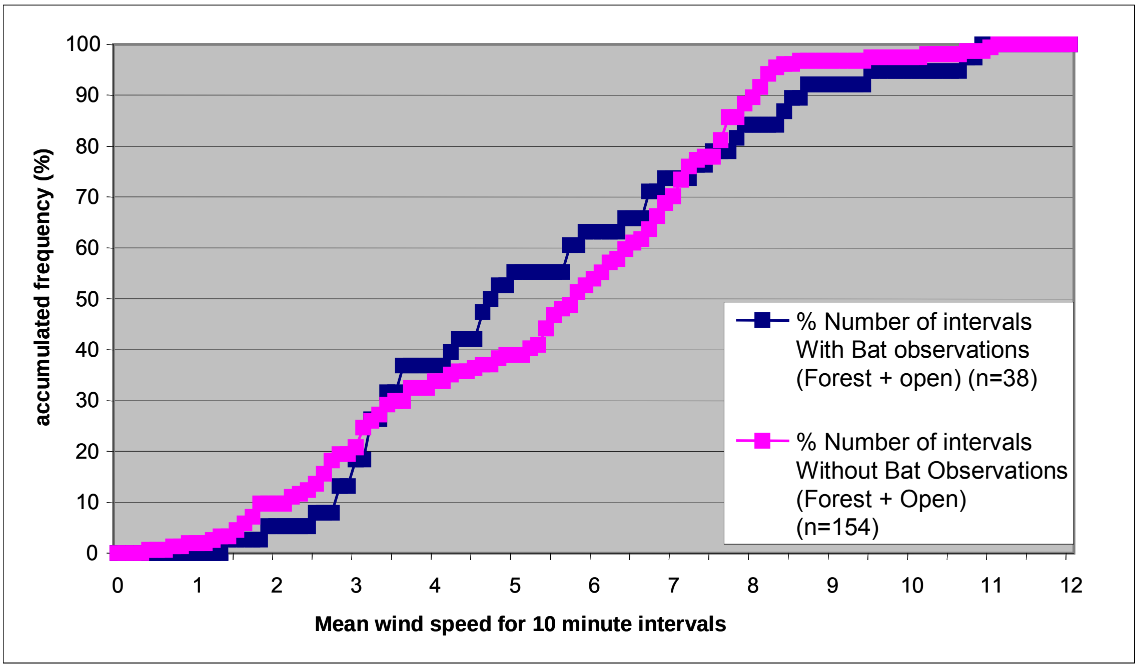

Figure 24: Accumulated frequency (in %) of 10 minute intervals with and without bat activity in relation to recorded wind speeds at the turbines "Schillinger Berg 1 & 2" (four half-nightly observations each, total observation time: 32 h). The wind speeds differed significantly for intervals with and without bat activity (Wilcoxon Test, N = 24, W = 109.5, p <= 0.021).

4.4 Discussion

4.4.1 Identification of flying objects and observation depth

When identifying the flying objects, bats might have been confused with songbirds of roughly the same size or with other birds of much larger size flying in higher altitude. The nocturnal bird migration in Southwest Germany mainly occurs between the beginning of August and the end of October. This nocturnal migration usually happens during favourable weather periods (warm, stable high pressure conditions), which we also chose for our observations. However, the flight altitude of these migrating birds is usually much higher. According to BRUDERER & LIECHTI (1998), the mean flight altitude for heavy bird migration over Southwest Germany is well above 600 m. Nocturnal migration consists mostly of passerine birds (proportion of waders is less than 10 %), which according to our tests should not be visible on the camera when flying over 200 m due to their small body size. Exemptions might occur with larger passerine birds. It is not unlikely that the objects moving Southwest in October were Nordic thrushes (e.g. *Turdus torquatus*, *Turdus pilaris*, *Turdus philomeols*), which reach their migratory peak in Baden-Württemberg round mid-October (see HÖLZINGER 1999). Due to their large size, they may still have been within the range of what our system is able to detect. Flight speed (see BRUDERER & BOLDT 2001) and flight pattern of these objects were completely different than all the observations that were classified as bats as well as numerous objects that were classified as unknown.

Due to their migration in high altitudes, birds are probably found less frequently as collision victims beneath turbines than bats. In 2004, Swifts were the only birds to be found in numbers worth mentioning (three birds between the end of July and mid-August, see chapter 2.3.8). They represented roughly 20% of the nocturnally migrating birds in the first three pentads of August (BRUDERER & LIECHTI 1998). However, Swifts are also likely to collide during daytime when foraging. This can also be assumed for the House Martins which are frequently found below turbines. We observed them foraging often during the day, at times in large numbers in the vicinity of the turbine blades.

Furthermore, very large moths might have been falsely identified as bats when they passed very closely to the camera, showing jagged flight patterns, resembling bats flying further away. But, objects flying closely past the camera cause a technical blurring, as many receptors are activated very quickly one after another. For moths flying in intermediate distances we cannot fully exclude misidentification with bats. On this particular matter more tests should be conducted in future studies.

4.4.2 Behavioural observations at wind turbines

In 25 % of all flight observations we saw evasive behaviour of bats towards the blades. The total number of sightings, however, was rather small (n=48). HORN & ARNETT (2005) registered evasive behaviour in only 7 % of their observations (n=998).

Although we did not observe a single collision of bats with the rotor, HORN & ARNETT 2005 documented eight collisions, which seems a rather small number in relation to their total flight observations (n=998). However, in both studies the camera only allowed the observation of a very small part of the rotor-swept area that the rotor passes.

Despite our vague observations of investigative behaviour, in contrast to the observed evasive behaviour, HORN & ARNETT (2005) recorded investigative behaviour frequently in individual bats. They describe (ibid.) how individual bats inspect the turbine tower as well as the slowly turning blades by repeatedly passing very closely to them or by hunting the tips. This investigative behaviour could explain why probably more bats die at turbines than one would expect considering the usual densities of foraging or migrating bats. Especially in this period, after abandoning their maternity roosts between mid-July and mid-September, the investigative behaviour of the species affected here should be particularly pronounced. This coincides with the period in which the highest numbers of collision fatalities were found.

4.4.3 Comparison of bat activity at different locations

The hypothesis that bat activity should be less at the turbine in open area than at the turbine in the forest is not supported by our data. There were 26 bat sightings in the category “bats > 40 m” in open area, i.e. more sightings than in the forest (n=22), although this wasn’t expected from the considerably higher number of dead bats found at the forest site the year before. One reason for this discrepancy might be the carcass search method. The meadows and grassland under the turbines at the open area site were very difficult and sometimes impossible to search due to vegetation height. Additionally the carcass removal rate might be very different here than at forest locations. The statement made in the comparison of locations (see chapter 2.3.3) that fewer bats collide at turbines in open areas must be regarded in the context of the behavioural observations and with the methodological limitations of the searching possibilities of the habitat.

The unexpected high activity of bats at the open area site might also be due to the bordering forest only a few hundred meters away and that it is enclosed on a larger scale by the forest habitat of the Black Forest. Accordingly, the turbine is within reach of bats foraging over the forest and along forest edges. This is different to the wide open areas of arable land with few structures. At these locations, the number of found dead bats has been comparatively low (see also Table 7 in Chapter 2.4.2).

By far, the highest bat activity was surprisingly found at the reference site, a wind throw area, and not at either of the two turbine locations. The high activity of bats at the reference site was mainly caused by a relatively large number of sightings in both height classes on the first observation night at the end of July. This might have been caused e.g. by a mass hatching of insects, which used the thermal to rise into higher altitudes. If so, this would have been a single occurrence which would have quite a strong impact on the total results due to the small sample size. The foraging of the Common Pipistrelle in the vicinity of the nacelle, i.e in high altitudes, has been proven by BEHR & HELVERSEN (2005), who recorded several feeding buzzes near the nacelle. The dissection results also indicate that the bats had been feeding until shortly before their deaths (see chapter 3.3).

4.4.4 Bat activity and wind speeds

The observations with thermal imaging cameras support the hypothesis that bat activity decreases with increasing wind speeds. Our observations showed a slight accumulation at wind speeds between 3.5 to 7.5 ms^{-1}. At wind speeds higher than 7.5 ms^{-1}, the recorded bat activity was lower than expected for the wind conditions.

During their acoustical studies at Rosskopf near Freiburg, BEHR & HELVERSEN (2005) registered 95 % of all bat calls (recorded at the nacelle) at wind speeds < 6 ms^{-1}. The majority of the recorded calls were identified as the here quite numerous Common Pipistrelle. On the other hand, 38% of all our sightings were registered at wind speeds > 6 ms^{-1}.

HORN & ARNETT (2005) recorded six of a total of eight registered collisions of bats with rotor blades also at wind speeds above 6 ms^{-1} (exact: 6.1; 6.5; 6.9; 9.0; 9.6 and 10.2 ms^{-1}). Flight behaviour and the wing shapes of Noctule, Leisler’s Bat or the Parti-coloured Bat, which forage in open airspace and perform long-distance transfer flights, lead to the assumption that these species are active at wind speeds higher than 6 ms^{-1}.

This study and numerous others (see BEHR & HELVERSEN 2005, TRAPP et al. 2002 etc.) showed that most collision fatalities were found under wind turbines after warm and low-wind nights. Therefore it seems unlikely that collisions would occur in large numbers at higher wind speeds. Nonetheless, it is possible that at higher wind speeds, when bats are hit by rotor blades in the upper swept area or caught in the whirls caused by the rotating blades, they are carried beyond the 50 m radius of searched ground by the strong winds, and remain undetected. BEHR & HELVERSEN (2005) for example, found one bat 95 m from the turbine base, far outside the actually searched area. This fact requires urgent attention in further studies.

5 Evaluation of the study results from a nature conservation point of view

5.1 Regulations for protected species

All bats species found in Baden Württemberg, Germany are listed in Annex IV of the Habitats directive (European Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora) and are therefore subject to the protective guidelines of Article 12*ff* of the Habitats directive and furthermore of the regulations of § 42 of the BNatSchG (Bundesnaturschutzgesetz: German Federal Nature Conservation Act).

The protective guidelines of Article 12*ff* of the Habitats directive are valid immediately for all species listed in Annex IV, regardless whether the species is found in a Natura 2000 site or not. Apart from other protection measures, Article 12a of the Habitats directive prohibits deliberate capture or killing of specimens and Article 12b any deliberate disturbance of these species, especially during their breeding, rearing, hibernation or migration periods.

Exemptions can only be granted if one of the exceptional circumstances, as described in Article 16 of the Habitats directive, is given. Prerequisite for enacting the exemption regulation is that there is no satisfactory alternative for the interfering action and that the populations of the species concerned remain in favourable conservation status in their natural range.

The species protection regulations of Article 12 of the Habitats directive are enacted in the directly prevailing §§ 42, 43 of the BNatSchG. According to verdict C 98/03 from 10.1.2006 of the European Court of Justice, this application is not sufficient. Certain, non-intentional interferences of protected species are excluded from the purview of the species protection regulations and the exemption regulations of Article 16 of the Habitats directive are not always guaranteed. Therefore, there is a current need for an amendment of BNatSchG.

According to the situation of the regulations for species protection described above, it is undoubtedly of particular importance to extensively consider bat populations listed as species in Annex IV of the Habitats directive and, at the same time, as especially and strictly protected species according to the BNatSchG, as well as possible impacts on the bat populations during the approval proceedings for wind farms.

5.2 Evaluation of the species-specific impacts of wind turbines on bats

Apart form the collision risk of bats with wind turbines, discussed above in detail, other impacts caused by the construction of turbines and the wind facility must be considered during the approval procedure. Such impacts include the building of access roads, maintenance and construction areas which can significantly interfere with the habitats of bats when located in forests in which bats roost and forage (see BRINKMANN 2004). A summary of possible impacts by the construction of wind farms, especially in forests, is given in Table 10.

There is very little knowledge about non-fatal impacts of operating wind turbines, such as disturbances caused by ultrasound or infrasound emissions or visual disturbances and resulting displacement or barrier effects (about displacement effects see BACH 2001). Accordingly, knowledge about the potential chain reactions linked with these effects is so slight, that a deduction of other possible risks cannot be made at this time (see BACH & RAHMEL 2004, HÖTKER et al. 2005). Undoubtedly, there is a high demand for further studies.

There is a high collision risk and therefore a very high conflict potential in the administrative district of Freiburg especially for the Common Pipistrelle and the Leisler's Bat, which could collide in greater numbers with the turbines. The Parti-coloured Bat and the Serotine Bat also have a high conflict potential. Those species were found less frequently but they probably occur in considerably lower densities in the vicinity of the turbines than e.g. the Common Pipistrelle. The Parti-coloured Bat, for example, is very rare in Baden-Württemberg. It is considered to be a migratory species which presumably mostly hibernates in Baden-Württemberg. Theses bats use crevices in one of the towers of the Freiburg Minster (the "Hahnenturm") as a hibernacula, and also for mating. The songflight of this species can be observed at great heights over the houses (see HELVERSEN et al. 1987). Due to their migratory behaviour as well as songflight in great altitudes near distinctive land marks, Parti-coloured Bats are extremely threatened by wind turbines – this is also shown by the comparatively large number of carcasses found under turbines (see DÜRR & BACH 2004) in correlation to their rare status.

In the administrative district of Freiburg, Serotine Bats are mainly found in lower altitudes, like the Upper Rhine area where several maternity roosts and foraging areas have been documented. This species forages in open areas in altitudes up to 50 m (own observations) and is therefore potentially endangered by wind turbines.

Due to the foraging strategies and migration behaviour of species such as the Noctule or Nathusius' Pipistrelle, a high conflict potential for these species has still to be expected. That no carcasses of these species were found in this survey, might be due to the fact that the search sites possibly were not located in areas used as preferred foraging habitats or as migratory routes by these species.

Although the Nathusius' Pipistrelle is found mainly in the Rhine valley where it also hibernates, a few areas in the Upper Black Forest are known where this species is found especially during migration in September for a short period in relatively high numbers (personal data). At these locations, a very high conflict potential exists by the construction of new wind farms. Nathusius' Pipistrelle do collide with turbines, proven by the fact that this species is the second most common species after the Noctule to be found under turbines throughout Germany.

Table 10 presents an overview of the impact of wind turbines on bats. For a more detailed description of the conflict risk, especially in relation to the operation of wind turbines, refer to BRINKMANN (2004).

Table 10: Possible impact of wind farms on bats in Baden Württemberg and assessment of potential conflict risk (+++ very high, ++ high, + existing conflict potential, -possibly no conflict potential, ? data insufficient, according to BRINKMANN 2004, altered and supplemented)

Species	Constructional &facility caused impact in forests		Operational Impact	
	Roosts	**Foraging-habitats**	**Transfer-flights**	**Forages flights**
Greater Horseshoe Bat *Rh.ferrumequinum*	-	+	-	-
Greater Mouse-eared Bat *Myotis myotis*	+	+	+	-
Bechstein's *Myotis bechsteinii*	++	+	-	-
Geoffry's Bat *Myotis emarginatus*	+	+	-	-
Natterer's Bat *Myotis nattereri*	++	+	-	-
Whiskered Bat *Myotis mystacinus*	++	+	-	-
Brandt's Bat *Myotis brandti*	+	+	-	-
Myotis alcathoe	?	+	?	?
Daubenton's Bat *Myotis daubentonii*	++	+	-	-
Noctule *Nyctalus noctula*	++	-	++	++
Leisler's Bat *Nyctalus leisleri*	++	-	+++	+++
Parti-coloured Bat *Vespertilio murinus*	-	-	++	++
Northern Bat *Eptesicus nilssonii*	-	-	++	++
Serotine *Eptesicus serotinus*	-	-	++	++
Soprano Pipistrelle *Pipistrellus pygmaeus*	-	-	?	+
Common Pipistrelle *Pipistrellus pipistrellus*	+	-	+++	+++
Nathusius' Pipistrelle *Pipistrellus nathusii*	++	-	++	++
Kuhl's Pipistrelle *Pipistrellus kuhli*	-	-	++	++
Barbastelle Bat *Barb. barbastellus*	++	+	+	+
Brown Long-eared Bat *Plecotus auritus*	++	+	-	-
Grey Long-eared Bat *Plecotus austriacus*	-	+	+	-

5.3 Standards for evaluating the degree of interference from collisions with wind turbines in bat populations

When applying the species conservation regulations as stated in Article 12 of the Habitats directive and in § 42 of the BNatSchG for a single specimen (see chapter 5.1), inevitably any and every disturbance to bats, but especially the killing of a bat by collision with a turbine, must be regarded as severe, yet the interpretation of the laws is ambiguous in this context (see ROLL et al. 2005). Final proposals of lawyer Kokott at the European Court of Justice on 15.12.2005 in a lawsuit Commission/Spain 221/04 indicate that it is more likely seen in the context of populations than individuals (particularly Nr. 77).

When applying the species conservation regulations to local populations, it is necessary to define a threshold level between significant and insignificant impact. The intervention would be insignificant when the higher mortality of juveniles and adults caused by the operation of the wind farm would not cause any changes in the long-term survival chances of the local population. The intervention would be significant when the mortality increased so drastically that even a higher reproduction rate could not even out the losses, so that the long term survival chances of the local population would decrease. If the necessary ecological population data were known, various simulation models could be employed to analyse the population risk (see HÖTKER et al. 2005).

For the here relevant bat species and local populations, the necessary data on population ecology is not available. Therefore a scientifically-based calculation of threshold levels is not possible to date. A fundamental problem is the appropriate spatial definition of a population. For the Common Pipistrelle in the region of Freiburg, should only those individuals that breed in the local colonies be included, or also those that seasonally migrate from the surrounding areas to e.g. hibernate in the Freiburg Minster? How large is the population of breeding Leisler's Bats in the Upper Rhine Valley and how large is the proportion of individuals only passing through? Additionally there is no current data on the natural mortality of these bats, which is one of the most important factors in a simulation model. To gain the necessary basic data for a population risk assessment for each of the mentioned bat species, an extensive research project including intensive data gathering over the course of several years and methods such as ringing and radio telemetry would be required.

The accumulating effects pose another problem that must be considered. Taking into account all the factors for threshold levels, it is necessary to include the influence of already existing wind farms into the calculations. In the final analysis, a maximum limit of collision fatalities for the entire distribution area of a particular population has to be determined.

Until reliable data on population ecology for the calculation is available, it is recommended to develop standards for the evaluation of the significance within a scientific convention. The threshold levels should be set rather low to support the conservation issues. Bats show particularly low reproductive rates; large losses of individuals can only be compensated over long periods of time.

Additionally it has to be kept in mind that for rare species with presumably smaller populations such as the Parti-coloured Bat, the Northern Bat, and also to some degree the Leisler's Bat, the loss of individuals has a larger impact than for example the Common Pipistrelle, which apparently belongs to the more common species in the administrative district of Freiburg.

6 Recommendations for acknowledging species protection regulations in the planning and approval procedure.

6.1 Situation in the administrative district of Freiburg

The results of this study and numerous other national and international studies show that bats can collide with wind turbines in considerable numbers. The number of bat fatalities at specific sites documented and projected in this study for the administrative district of Freiburg is the highest for Germany ever found, although to date only few detailed studies have been conducted in Germany.

The conflict potential in individual cases in the administrative district of Freiburg is possibly very high. Therefore the planning procedures for wind farms here require an adherence to and a careful handling of the species protection regulations in bat conservation.[14].

The conflict situation in the administrative district of Freiburg however is not homogeneous. Particular problems are to be expected in forest locations at the western foothills and at the western border of the Black Forest. In open areas the conflicts in connection with bats are probably fewer, but still remain to be checked in each case. Since there is still little knowledge about the distribution of bat species in the area, a precise prediction of conflict locations and especially a detailed assessment of particular sites is only possible when based on detailed field study data obtained at each location.

6.2 Preliminary examinations on site for determining possible impacts

Preliminary ecological field studies serve the purpose of identifying the conflict potential for each location. They should be designed in such a way as to result in concrete recommendations: e.g. for the approval of a project without any restrictions, or if necessary with specific operating restrictions, or maybe also a renunciation of a particular location.

Preliminary examinations to assess possible construction and facility based impacts differ from those to assess possible operational impact. The methodological standards for these examinations have already been published and are currently applied in numerous projects.

[14] After large numbers of collision fatalities were found at the wind farm Puschwitz, Saxony (see TRAPP et al. 2002), the construction of further turbines in the area was prohibited by authorities due to the proven danger for the especially and strictly protected bats. This decision was later confirmed by court decision (Administrative Court DRESDEN, Verdict from 02.06.2003, 7K 2583/02).

Methodological standards for the assessment of possible construction and facility based impacts

(For a detailed description please refer to BRINKMANN 1996, 1998 and DENSE & RAHMEL 1998 and others)

- several surveys with bat detectors between April and September to find foraging habitats, flight paths and roosts,
- bat capturing using mist nets to identify species that cannot be identified with certainty by the use of bat detectors, such as Bechstein's Bat (usually several nettings per study site between May and September),
- surveys of roosts in buildings and nest boxes, if applicable.

If the study site is so large that it cannot be surveyed in a single night, several surveys are necessary. If the Bechstein's Bat, for example, is anticipated in several parts of the area, the number of locations for mist netting has to be increased accordingly.

Methodological standards for the assessment for the operational impact

(For a detailed description, refer to RAHMEL et al. 2004, BACH & DIETZ 2003 and others)

- surveys with bat detectors to identify migrating bats or temporary gathering locations during migration, one survey per week during the relevant period of time,
- additional use of remote recording (analogue or digital recording of bat calls during the entire night) at every proposed turbine location simultaneously and in the same rhythm as the above surveys,
- observation of diurnally migrating Noctules between mid-September and the end of October (observation time roughly two to three hours before sunset),
- search for mating roosts of Leisler's Bat, Noctule and Nathusius' Pipistrelle (August to September) and areas with songflights of Parti-coloured Bats.

To identify various habitats and their function in the affected area, the study site has to be of a sufficient size. For single turbine locations, an area of at least 150 ha should be selected. For wind farms, the area of up to one kilometre around the outermost turbine locations should be examined.

6.3 Means to avoid operational impact

6.3.1 Site selection

The most effective way to avoid potential conflicts is to carefully select the turbine location. As shown in this study, turbines in forests in the administrative district of Freiburg have a very high collision risk. This trend is confirmed by nearly all other studies that have been published to date (see DÜRR & BACH 2004, ENDL 2004 and others). Therefore all current recommendations for the selection of sites suggest avoiding forests and their vicinity to reduce risks (HÖTKER et al. 2005, RODRIGUES et al. 2005 and others).

However, the comparative surveys with the thermal imaging camera did not support the fundamental thesis that the collision risk in open areas should be lower due to lower bat activity. Possibly other reasons are responsible that fewer carcasses are found in open areas, especially in pastures and meadows (searchability, carcass removal rate).

Therefore it cannot be generally recommended to choose open areas over forest locations. For each case, a study of the bat populations is necessary at every potential turbine location.

Even for turbines located in forests, there are specific differences between locations, as this study showed. At the turbines in Ettenheim Mahlberg significantly fewer collision fatalities were documented than at turbines at Schillinger Berg or Hohe Eck, which seem especially problematic due to the very high numbers of found bats. These two can be compared to the location Rosskopf (see BEHR & HELVERSEN 2005), where the numbers also were very high. The authors suggest that the large numbers of especially Common Pipistrelle fatalities at this wind farm are a result of its vicinity to the Freiburg Minster, which represents the largest winter and swarming roost of this species in the entire district of Freiburg. It is also conceivable, that mountain passes and saddles can cause accumulations of bats migrating closer to the ground. This same phenomenon is known from migrating passerines. This example shows that, apart from forest locations, other regional factors can be responsible for the accumulation of bats at single locations.

For every potential turbine location, the assessment needs to include the particular local and regional characteristics of the site and also of the further vicinity, such as particular topographic features, known flight paths, used roosts, swarming or foraging habitats, etc.

6.3.2 Avoidance of impact by restricting operating times

An effective method of mitigation is to stop the operation of a turbine during specific periods of time. That a bat would collide with a non-rotating turbine is highly unlikely. During an intensively and systematically conducted study in the USA, 398 dead bats were found at a wind farm with 40 turbines over a six weeks study period. Only beneath the one turbine that was not operating during that time due to a technical defect, not a single bat was found (Mountaineer Wind Energy Center, West Virginia, see KERNS et al. 2005).

Restricting the operating time is recommendable when bats are active in the vicinity of the turbines and hence, are likely to collide with the rotors. According to current knowledge, this is only the case in certain seasons and with certain weather conditions. Larger numbers of collision fatalities have so far only been found in July, August and September. Smaller numbers were found in April and May. For the months June and October only very few results are documented, therefore the necessity of limited operation during these months cannot be assessed with certainty.

In the months July until September, most collision fatalities were found after warm and low-wind nights, and especially those in which the rotor blades rotated at low wind speeds. No or only very few bats were found after cool, rainy and windy nights. However, this does not necessarily imply a lower collision risk, as collision fatalities might drift in the strong winds and would therefore unlikely be found.

The results of this and other studies indicate that bat activity in the vicinity of the nacelle correlates with certain weather parameters, such as wind speed and temperature. If these correlations could be definitely identified, wind turbines could be automatically controlled and switched off when bat activity could be expected near the nacelle. Current knowledge, however, is still insufficient to identify general and transferable threshold levels.

If restrictions on the operating time are correlated with wind speeds, it would be necessary to verify the effectiveness of the mitigation procedure during monitoring studies, since current knowledge is insufficient. This would, in any case, require fatality searches under turbines. They could be supplemented by acoustical monitoring at the nacelle, if this method would produce utilizable data at higher wind speeds. Results of these studies would contribute to the reduction in knowledge deficits and enable better prognosis for future projects.

All surveys must be conducted throughout the entire period in which bats are likely to collide with turbines. Furthermore, the searches must be conducted very frequently, best would be daily. Even then, only a fraction of the actual collision fatalities will be found due to factors such as searcher efficiency, carcass removal rate and the limited search area.

To validate the prognoses and assessments regarding the established mitigation procedures, the fatality searches and acoustical monitoring should be conducted for at least two years once the turbine has been put into operation. This serves the purpose of compensating for exceptional influences caused by weather conditions.

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ANNEX

Table A-1: Data, search intensity and results of all regularly searched turbines
(Fatality searches 2004 between end of July and end of October at all 16 turbines, fatality searches 2005 only at eight selected turbines, marked bold in the table, between the beginning of April and mid-May and between mid-July until mid-October).

Name of turbine	**Type**	**Hub-Height m**	**Rotor Ø m**	**Location**	**Altitude above sea level**	**Number of searches**	**Data on found carcasses (bats and birds)**
Ettenheim Mahlberg 1	Nordex N 80	80,0	80,0	Wind throw	470	18	03.08.04: 1 P. pipistrellus;
Ettenheim Mahlberg 2	Nordex N 80	80,0	80,0	Forest	470	18	08.08.04: 1 N. leisleri;
Ettenheim Mahlberg 3	Südwind S 77	90,0	77,0	Forest	500	48	31.07.04: 1 P. pipistrellus;07.10.04: 1 N. leisleri;
Ettenheim Brudergarten 1	Nordex N 62	69,0	62,0	Forest	470	49*	31.07.04: 1 P. pipistrellus; 01.08.04: 1 P. pipistrellus; 08.08.04: 1 P. pipistrellus; 17.10.04: 1 Regulus spec.; 17.08.05: 1 P. pipistrellus;
Ettenheim Brudergarten 2	Nordex N 62	69,0	62,0	Forest	470	48	03.08.04: 2 P. pipistrellus;
Ettenheim Brudergarten 3	Nordex N 62	69,0	62,0	Forest, wind throw	470	48	13.08.04: 2 P. pipistrellus; 12.07.05: 1 V. murinus; 02.08.05: 1 N. leisleri
Freiamt Hohe Eck	Enercon E 66	86,0	70,0	Forest	600	49*	03.08.04: 1 P. pipistrellus; 08.08.04: 3 P. pipistrellus; 13.08.04: 2 P. pipistrellus; 03.09.04: 1 N. leisleri; 12.09.04: 1 D. urbica; 17.09.04: 1 D. urbica; 28.07.05: 1 A. apus; 02.08.05: 1 P. pipistrellus; 22.08.05: 1 P. pipistrellus; 16.09.05: 1 P. pipistrellus; 06.10.05: 1 P. pipistrellus;
Freiamt Schillinger Berg 1	Enercon E 66	86,0	70,0	Forest	720	50*	03.08.04: 1 N. leisleri; 08.08.04: 2 P. pipistrellus, 1 N. leisleri, 1 V. murinus; 13.08.04 1 P. pipistrellus; 18.08.04: 1 P. pipistrellus; 03.09.04: 1 P. pipistrellus, 1 N. leisleri; 12.08.05: 1 P. pipistrellus; 01.09.05: 1 P. pipistrellus;
Freiamt Schillinger Berg 2	Enercon E 66	86,0	70,0	Pasture	710	18	None
St. Peter Plattenhöfe 1	Enercon E 40	78,0	44,0	Pasture, forest	1000	16	04.08.04: 1 D. urbica;
Simonswald Plattenhöfe 2	NEG Micon 60/1000	70,0	60,0	Pasture, forest	1000	16	18.09.04: 1 P. pipistrellus;

Name of turbine	Type	Hub-Height m	Rotor Ø m	Location	Altitude above sea level	Number of searches	Data on found carcasses (bats and birds)
Simonswald Plattenhöfe 3	NEG Micon 60/1000	70,0	60,0	Pasture, forest	1000	16	13.09.04: 1 P. pipistrellus
Simonswald Plattenhöfe 4	NEG Micon 60/1000	70,0	60,0	Pasture	1000	9	None
Freiburg Holzschlägermatte 1	Enercon E 66	98,0	70,0	Forest	920	48	09.08.04: 1 P. pipistrellus; 04.09.04: 3 P. pipistrellus, 1 N. leisleri; 07.08.05: 1 A. spec. cf apus; 17.08.05: 1 A. apus; 27.08.05: 1 P. pipistrellus, 1 H. polyglotta;
Freiburg Holzschlägermatte 2	Enercon E 66	98,0	70,0	Forest	920	48	09.08.04: 1 P. pipistrellus; 14.08.04: 1 A. melba;
Fürstenberg	REpower MD 77	90,0	77,0	Pasture	920	17	None

Tab. A-2: Data, search intensity and results from all turbines irregularly searched between August and October 2004.

Name of turbine	Type	Hub Height m	Rotor Ø m	Location	Altitude above sea level	Number of searches	Data on found carcasses (bats and birds)
Hornberg 1	Fuhrländer	70,0	54,0	Forest, Pasture	830	2	None
Hornberg 2	Fuhrländer	70,0	54,0	Forest	830	2	None
Schweighausen 1	Seewind	65,0	52,0	Arable Land, Pasture	590	3	None
Schweighausen 2	Seewind	33,0	20,0	Arable Land, Pasture, Forest	590	3	None
Herbolzheim	Tacke	77,0	46,0	Car Park of service station	170	2	None
Reichenbach Windkapf 1	REpower MD 77	100,0	77,0	Forest, Pasture	890	2	None
Reichenbach Windkapf 2	Enercon E 66	98,0	70,0	Forest, Pasture	890	2	None
Reichenbach Windkapf 3	REpower MD 77	100,0	77,0	Forest	890	2	None
Schonach 1	Südwind S 77	96,5	77,0	Forest	990	2	None
Schonach 2	Südwind S 77	90,0	77,0	Forest	1020	2	None
Rohrhardsberg	Enercon E 66	78,0	70,.0	Forest	1100	2	06.08.04: 2 P. pipistrellus, 1 E. serotinus; 06.09.04: 1 P. pipistrellus
Neueck 1	Enercon E 40	78,0	44,0	Forest, Pasture	990	2	04.09.04: 1 P. pipistrellus;
Neueck 2	Enercon E 40	78,0	44,0	Forest, Pasture	990	2	None
Gütenbach Kaisersebene 1	Enercon E 40	65,0	44,0	Pasture	1000	2	None
Gütenbach Kaisersebene 2	Enercon E 66	65,0	70,0	Pasture, Arable Land	1000	2	None
Gütenbach Kaisersebene 3	Enercon E 40	65,0	44,0	Pasture	990	2	None