Birds of Prey and Wind Farms: Analysis of Problems and Possible Solutions

Documentation of an international workshop in Berlin, 21st and 22nd October 2008

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Introduction

Birds of prey fall victim to collisions with wind turbines relatively more often than other bird species. In Germany, some species of raptors are among the most frequently reported collision victims on a national level. In order to understand the reasons underlying this phenomenon, the Michael-Otto-Institute within NABU, the consultancy BioConsult SH and the Leibniz Institute for Zoo and Wildlife Research started a research project on birds of prey and wind farms. The German Ministry of the Environment, Nature Conservation and Nuclear Safety financed the project in full. An important part of the project was to hold an international workshop about half way through the project period. International input to the project was desirable because other countries have also produced evidence for relatively high collision risk for birds of prey, over a number of years. Research projects have been set up in (for example) the USA, Canada, the UK and Norway. Colleagues from these countries were invited to a workshop in Berlin, which had several aims:

- Discussion of the project results in an international audience,
- exchange of information on ongoing research projects,
- learning from experiences in different countries,
- exchange of ideas about mitigation measures.

The workshop took place in the NABU building on October 21st and 22nd. About 50 delegates from seven countries attended the workshop.

The authors of the talks were asked to provide extended abstracts of their presentations for a documentation of the workshop. These abstracts and a concise summary of the discussion are presented in this document. The authors are responsible for the contents of their contributions. We have summarised the discussions to the best of our knowledge and belief, but we cannot guarantee the completeness of our records.

With great sadness we had to notice the death of Mike Madders, one of the speakers at the workshop, on 23rd Aug. 2009.

Acknowledgements

I would like to thank the German Ministry for the Environment, Nature Conservation and Nuclear Safety and the *Projektträger* Jülich for their support. In particular, Stefanie Hofmann and Gert Heider contributed to the success of the project and the workshop. I also would like to thank my colleagues within NABU for their help in organizing the workshop in Berlin. Many thanks also go to Richard Evans for language editing of this report.

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Workshop Programme

International workshop on Birds of Prey and Wind Farms

NABU Federal Office, Charitéstr. 3, Berlin

– programme –

Tuesday, 21st October

13:00 – 13:30 *Opening Addresses*

Stefanie Hofmann (German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety)

Olaf Tschimpke (President NABU)

13:30 – 18:45 *Results of the project "birds of prey and wind turbines: analysis of problems solutions"*

13:30 – 13:45 **Hermann Hötker (NABU):** Scope of the project „Birds of prey and wind farms: analysis of problems & solutions

13:45 – 14:30 **Ubbo Mammen (Ökotop), Lukas Kratzsch, Kerstin Mammen, Thomas Müller, Alexander Resetaritz, Ralf Sinao (NABU und Ökotop):** Interactions of Red Kites and wind farms: results of radio telemetry and field observations

14:30 – 15:00 **Leonid Rasran, Hermann Hötker (NABU), Ubbo Mammen (Monitoring Greifvögel):** Effect of wind farms on population trends and breeding success of Red Kites and other birds of prey

15:00 – 15:30 **Leonid Rasran, Hermann Hötker (NABU), Tobias Dürr (Staatl. Vogelschutzwarte Brandenburg):** Analysis of collision victims in Germany

15:30 – 15:45 *Coffee/Tea*

15:45 – 16:30 **Bodo Grajetzki, Malte Hoffmann, Georg Nehls (BioConsult SH):** Montagu's Harriers and wind farms: results of radio telemetry and observational studies

16:30 – 17:00 **Ralf Joest (ABU), Kai-Michael Thomsen (NABU):** Are Montagu's Harriers displaced by wind farms?

17:00 – 17:30 **Oliver Krone, Mirjam Gippert (IZW), Thomas Grünkorn (BioConsult SH):** White-tailed Eagles and wind farms.

17:30 – 18:45 *General Discussion*

19:00 *Workshop Dinner (Café Lina, within the NABU building)*

later: informal discussions at the bar

Wednesday, 22nd October

8:30 – 13:30 *Results of relevant studies in other countries*

8:30 – 10:00 **Torgeir Nygård, Roel May, Pernille Lund Hoel (NINA, Norway):**

Using GPS satellite telemetry to study movements of young White-tailed Sea Eagles at Smøla windfarm, Norway.

Radar studies on White-tailed Sea Eagle at an onshore wind farm on the island of Smøla, Norway.

10:00 – 10:45 **Charles Maisonneuve (Ministère des Ressources naturelles et de la Faune, Quebec, Canada):** Studies on threatened species of Birds of Prey and wind farms in eastern North America.

10:45 – 11:00 *Coffee*

11:00 –11:45 **Mike Madders (Natural Research, United Kingdom):** Assessing collision risks in Hen Harriers in the UK

11:45 – 12:30 **Shawn Smallwood (USA):** Methods to reduce raptor mortality at wind farms in the USA

12:30 – 13:30 General discussion on measures to avoid or to mitigation conflicts between birds of prey and wind farms

13:30 *Conference Close*

13:30 – 14:30 *Lunch (in Café Lina in the same building)*

Extended abstracts of talks and brief summaries of discussions

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Birds of Prey and Wind Farms: Analysis of Problems and Possible Solutions – A brief introduction to the project and the workshop

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Introduction

Generating electricity from wind is one of the most developed ways of producing renewable energy. In order to reduce the emission of greenhouse gases, Germany like other countries has ambitious plans to increase the proportion of national energy production generated from wind power in the coming years. Wind farms, however, can have adverse effects on birds, either by disturbance and displacement, or by mortality due to collisions of birds with wind turbines. Birds of prey predominate among collision victims. The most recent list of victims for Germany (Figure 1) shows that out of the top four most frequently reported species, three are birds of prey. Raptors and vultures also rank among the most commonly found victims in other countries (LANGSTON & PULLAN 2003, LUCAS et al. 2004, HÖTKER et al. 2006, LUCAS et al. 2008).

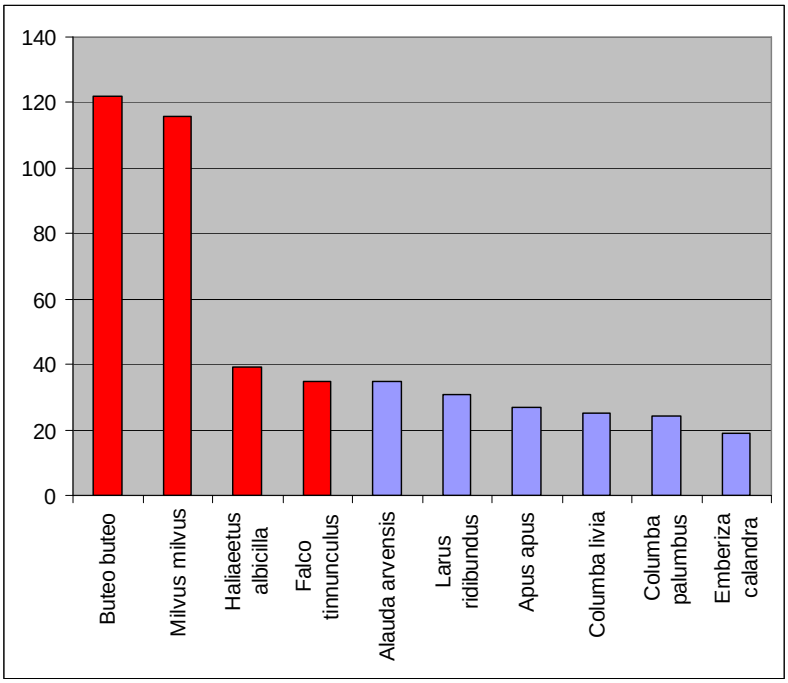

Fig. 1: Number of collision victims of the 10 most reported species at wind farms in Germany, as at 3 July 2009 (T. DÜRR in lit.). Raptors are indicated by red columns.

The reasons why raptors in particular should fall victim to wind turbines so often are not fully understood. Raptors are highly manoeuvrable birds, their eyesight is very good and they generally do not fly during the night. Thus, collisions obviously occur when turbines are fully visible to raptors. In Germany White-tailed Eagles (*Haliaeetus albicilla*) and Red Kites (*Milvus milvus*) are the most "prominent" victims. White-tailed Eagles have been subject to successful protection programmes in the past years (HAUFF 1998, SUDFELDT et al. 2007). Red Kites receive a special attention because more than half of the world population of this species breeds in Germany (BirdLife International 2004).

The occurrence of birds of prey next to potential sites for wind farms has often led to court cases about refusals of permissions to erect wind farms. In particular White-tailed Eagles and Red Kites but also Montagu's Harriers (*Circus pygargus*) have been involved.

In order to shed more light on the reasons for the collisions, a new research project has been set up: Birds of prey and wind farms: analysis of problems and possible solutions. The project is financed by the German Ministry for the Environment, Nature Conservation and Nuclear Safety (FKZ 0327684). The work for the project started on 11.4.2007. The project will end on 31.12.2010.

The main aim of the project is to understand when, where and why birds of prey are at risk of collision with wind turbines. Better knowledge of the underlying factors causing collisions will hopefully help to solve the conflict between the occurrence of birds of prey and wind farms. A further aim of the project is to develop measures to minimize collision frequencies. Practical guidance for wind farm developers and local and federal authorities will be developed at the end of the project.

Methods

The scientific work of the project consists of the analysis of available data sets and the acquisition of new field data. Existing data sets are the register of collision victims compiled by the *Staatliche Vogelschutzwarte Brandenburg*, data on monitoring birds of prey in Germany supplied by the *Förderverein Greifvogelmonitoring*, detailed data sets on the breeding distribution of Montagu's Harriers in two regions. In addition, data on the geographical distribution of wind farms including time of erection and technical specifications were collected. Habitat data were taken from the CORINE landcover.

The main activities of the project were behavioural studies of three species of birds of prey in the vicinity of wind turbines. Red Kites and White-tailed Eagles were in focus because of the relatively high number of victims. Montagu's Harrier was taken as a third target species

because it is very rare in Germany, it is red listed and listed on Annex 1 of the EU Birds' Directive, and it often occurs in places where wind farms are planned. Data collection for Red Kites takes place in two study sites in Sachsen-Anhalt, Montagu's Harriers are studied in Schleswig-Holstein, and White-tailed Eagles will be studied at several sites in north and eastern Germany. The observational protocol was standardized as much as possible across the species. For all focal species, individuals were equipped with transmitters in order to study their home ranges in relation to the position of wind farms.

Mitigation measures will be explored for Red Kite. Red Kites often use the vicinity of turbine tower bases for foraging and thus approach the hazardous zone of the turbine. Tower bases are attractive to Red Kites because they are frequently surrounded by some open strips of fallow land. These uncultivated patches often offer the very few areas of open ground where potential prey (small mammals) is easily visible. In the surrounding arable fields the crops are two dense and too high to allow successful hunting by Red Kites or other birds of prey. As an experiment, some tower bases will be made unattractive to Red Kites, by covering their surroundings with a layer of black polythene sheeting. Activity of Red Kites at covered and uncovered sites will be compared.

Structure of the project

The project is a co-operative partnership between seven partner bodies. Three partners receive direct financial support by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. The remaining four partners are included by means of contracts with the Michael-Otto-Institute of NABU, which is the coordinating body for the whole project (Fig. 2). The project is split into several subprojects, each of which is carried out by one or two project partners.

Sub-project Red Kite (ÖKOTOP, Michael-Otto-Inst. NABU)

- Radio telemetry, analysis of use of space
- Identification of risky situations
- Experimental covering of ground around the turbine bases

Sub-project lattice towers (Staatl. Vogelschutzw. Brandenb.)

- Search for victims in a wind park with lattice towers

Sub-project Montagu‘s Harrier telemetry (BioConsult SH)

- Radio telemetry, analysis of use of space
- Identification of risky situations

Sub-project Montagu‘s Harrier spacing (Arbeitsgem. Biol. Umweltschutz, Michael-Otto-Institut im NABU)

- Analysis of population trends and spacing of nests in relation to wind farms in two regions of Germany (Hellwegbörde and Nordfriesland)

Sub-project White-tailed Eagle (Institut für Zoo-und Wildtierforschung, BioConsult SH)

- Radio telemetry and GPS-loggers, analysis of use of space
- Focal animal sampling for identifying risky situations

Sub-project victim register (Staatl. Vogelschutzwarte Brandenburg, Michael-Otto-Inst. NABU)

- Analysis of all large bird turbine victims in Germany, search for explanatory variables

Sub-project monitoring of birds of prey (Förderverein Greifvogelmonitoring, Michael-Otto-Inst. NABU)

- Analysis of temporal variation in density and breeding success of birds of prey in relation to wind farms

The project has a homepage (http://bergenhusen.nabu.de/forschung/greifvoegel/) where more details of the project are available

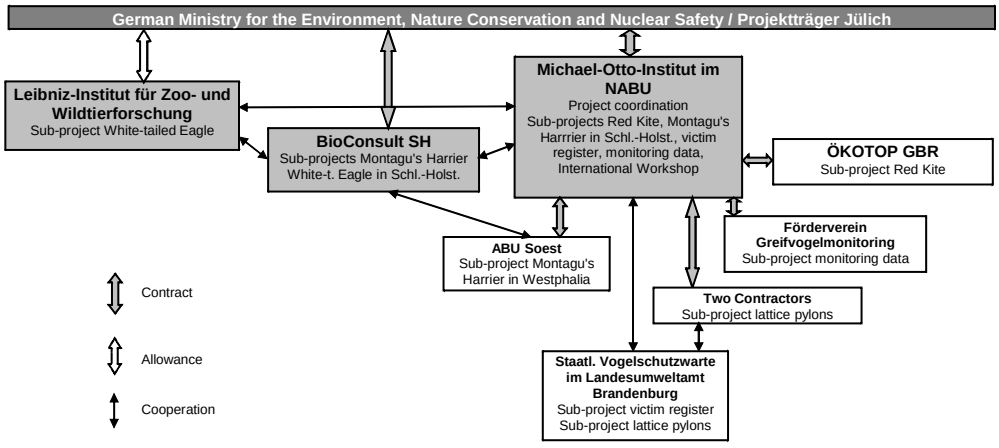

Fig. 2: Project partners and project structure.

International workshop

The international workshop is an integral part of the project. The workshop has several aims:

- Discussion of the project results in an international audience
- Exchange of information on ongoing research projects
- Learning from experiences in different countries
- Exchange of ideas about mitigation measures

Acknowledgements

I would like to thank the German Ministry for the Environment, Nature Conservation and Nuclear Safety and the Projektträger Jülich for providing the necessary funds for the project. In particular, Gert Heider (PTJ) and Stefanie Hofmann (BMU) helped substantially with initiating the project. I also would like to thank the members of the Project Steering Group and all of my colleagues for their support of the project. My particular thanks go to the foreign colleagues who accepted our workshop invitation.

References

BirdLife International (2004): Birds in Europe: population estimates, trends and conservation status. BirdLife International, Cambridge.

HAUFF, P. (1998): Bestandsentwicklung des Seeadlers *Haliaeetus albicilla* in Deutschland seit 1980 mit einem Rückblick auf die vergangenen 100 Jahre. Vogelwelt 119: 47-63.

HÖTKER, H., THOMSEN, K.-M. & JEROMIN, H. (2006): Impacts on biodiversity of exploitation of renewable energy sources: the example of birds and bats. Michael-Otto-Institut im NABU, Bergenhusen. 1-66 pp.

LANGSTON, R. W. H. & PULLAN, J. D. (2003): Wind farms and birds: an analysis of the effects of wind farms on birds, and guidance on environmental assessment criteria and site selection issues. Report written by BirdLife International on behalf of the Bern Convention, Sandy.

LUCAS, M. D., JANSS, G. F. E. & FERRER, M. (2004): The effects of a wind farm on birds in a migration point: the Strait of Gibraltar. Biodiversity and Conservation 13: 395-407.

LUCAS, M. D., JANSS, G. F. E., WHITFIELD, D. P. & FERRER, M. (2008): Collision fatality of raptors in wind farms does not depend on raptor abundance. Journal of Applied Ecology 45: 1695-1703.

SUDFELDT, C., DRÖSCHMEISTER, R., GRÜNEBERG, C., MITSCHKE, A., SCHÖPF, H. & WAHL, J. (2007): Vögel in Deutschland. Dachverband Deutscher Avifaunisten, Bundesamt für Naturschutz, Länderarbeitsgemeinschaft der Vogelschutzwarten, Münster.

Preface: NABU' position on wind energy

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Nature conservation and the struggle against the man induced climate change are important issues in the work of NABU. I, therefore, was very glad to hear that (aided by the German Ministry for the Environment, Nature Conservation and Nuclear Safety) a workshop tackling both themes could be organized in our house, and I was very pleased to see that so many experts from all over the world followed our invitation to this international workshop.
NABU – the Nature and Biodiversity Conservation Union - is the German partner of Birdlife International. As a NGO, NABU is right in the middle of many discussions around wind energy. Please let me briefly explain our approach to wind energy. It may be described as mitigating climate change and reducing impacts on biodiversity.

The key questions we are working upon are:

What are the perspectives for wind energy development now and in the future? Why should we as NABU advocate not only for avoiding and reducing impacts on biodiversity?

Which role has wind energy to play in an ambitious climate change mitigation policy in Germany? What is NABU's position on that?

What are our requirements for strategic planning to regulate the choice for the right location?

Once a location is legally fixed as designated area for wind farm projects, how can you avoid and reduce possible impacts on birds and bats?

Industrialized countries are responsible for the historic greenhouse gas emissions which have caused the human induced temperature rise we are facing already today. Thus we have to take stronger ambitions in climate change mitigation policies. Within the UNFCCC negotiations reductions of minimum 80% by 2050 compared to 1990 levels for regions like the EU are reasonable and fair. This is why we support our German government´s goal of 40% reduction by 2020 to path our way into a low carbon economy.

To achieve this you cannot say "safe energy first and later we deal with the switch to renewables". We need to follow both strategies at the same time, but of course the share of renewables will be even greater if we succeed in reducing our energy consumption. In many

parts of the developing and economically fast growing countries energy demand will rapidly be increasing instead of decreasing. But in Germany we have scientific projections that say energy efficiency has to play an important role as well as advanced deployment of renewables to achieve our CO_2 reduction goal.

Fortunately wind energy is not the only option within a future renewable energy mix. But today it offers in Germany the lowest cost for avoiding CO_2-emissions compared to solar energy for instance. We are a country with a high population density, so land consumption for agriculture is quite high. The energy yield from wind energy is much higher than from the utilization of biomass on fields. This is why NABU believes at least until 2020 wind energy has to offer the biggest contribution to the exploitation of renewable energy sources in the electricity sector.

However, we do not accept wind farm developments everywhere in the landscape. Our spatial planning system applies the system of designated areas for wind energy, excluding projects outside these areas. We would like to see the same approach legally implemented for offshore wind farms as soon as possible.

We should therefore engage in defining suitable locations for wind farms with careful assessments of the possible impacts on birds and bats. Our own research work gave us indications which sites should be kept free from wind energy development:

- IBA and SPA,
- well known migration routes and flight corridors,
- important roosting areas for waders and water birds,
- wetlands and woods, and
- places with high occurrences of birds of prey.

The last point has been very much in public dispute in Germany over the last years. We are therefore very grateful to our German Ministry for the Environment, Nature Conservation and Nuclear Safety for financing a project that should answer at least some of the open questions.

I hope that the first results presented in this workshop will help to ensure that we reach both, our aims for the future development of wind energy and a good conservation status for our birds of prey.

Interactions of Red Kites and wind farms: results of radio telemetry and field observations

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Red Kites as victims of wind turbines

At the time of writing of this article exactly 100 Red Kites *Milvus milvus* were registered In the central database of collision victims at wind turbines in Germany (T. DÜRR, „Staatliche Vogelschutzwarte in Brandenburg“). The months of death (known for 70 of these birds) were mainly April and August (Fig. 1). It has to be taken into account that most of the collision victims were found accidentally. Only few systematic studies took place, and even with a systematic search approach it would be hard to detect really all of the collision victims, because a systematically search for collision victims would mean that the vicinity of the wind turbine (100 m radius around the tower) can be completely checked. But in fact, the visibility within the field crops changes seasonally. For instance in February the visibility is excellent. In April, however, only 10 % of the investigated area still has a very good visibility. Searching for carcasses in the remaining area still is possible but requires more time and care. In June the visibility of the whole 100 m radius is very bad because only fallow vegetation around the wind turbine, the roads and other open areas can be checked, but not the arable crops.

Thus, in May, June and July up to harvesting, the probability of finding collision victims is very low. The seasonal pattern of recorded victims (Fig. 1) obviously is skewed by the limited visibility in spring and early summer. Additionally it has to be taken into account that a lot of carcasses disappear soon after collision (carried off by predators). It thus seems clear, that even with regular and systematic searches only a part of the collision victims can be found and the number of unreported cases remains very high. On the other hand, only a small part of accidental findings made by walkers or hunters are reported.

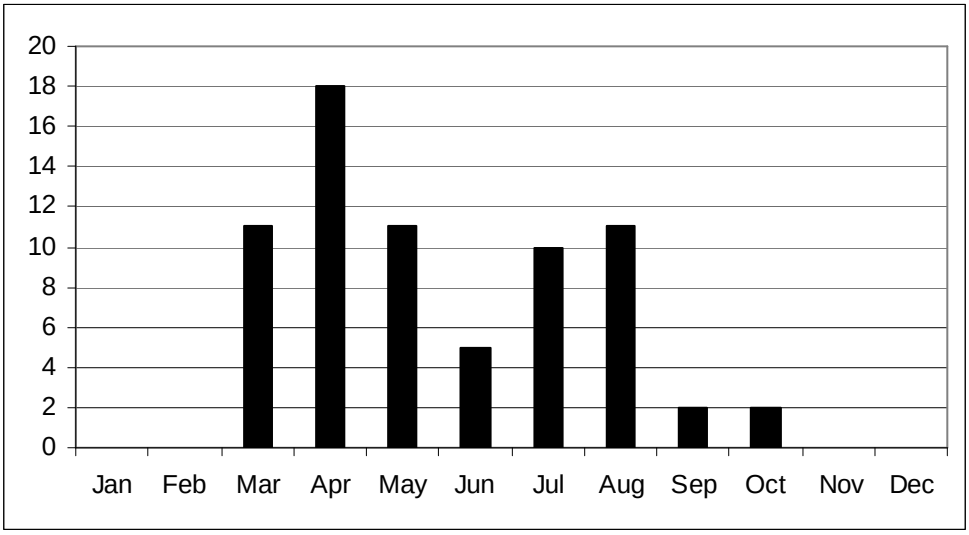

Fig. 1: Seasonal pattern of recorded collision victims of Red Kites in wind farms (n = 70 Red Kites with known month of death, data from 1995 to 2008).

Study sites and methods

The four study areas are situated in Saxony-Anhalt, the area with the highest breeding density of Red Kites within Germany and worldwide. All study sites consist of intensively used agricultural landscapes with at least of one wind farm in each of them. There are two main investigation sites and two additional sites. In the years 2007 and 2008 we mapped the breeding population of raptors within a 3-km-circle around the wind turbines. In order to collect collision victims we checked the wind turbines every two weeks on average (altogether 2.671 searches around a turbine). Within the wind farms we used standardized observation sessions of 45 minutes each. Within the sessions we noticed occurrence and behaviour of all raptors in the site. Additionally, we recorded flight sequences of Red Kites in more detail (flight height, distance to wind turbine etc.). Finally, we radio-tracked adult Red Kites in the main investigation sites.

Summary of first results

Within the observation sessions 540 observations of Red Kites were recorded. With reference to the total observation time this equals to 1 Kite per 89 minutes. In total 23 percent of all recorded Red Kites approached the wind turbines closer than 50 m. The variability between the study areas was high (Tab. 1). Nevertheless, the high proportion of flights near the turbines indicated clearly that Red Kites did not avoide operating turbines. A few Red Kites even flew through the inner danger zone (that means the rotor sphere and the rotor disk.). In 0,6 % of the observed flights Red Kites crossed the rotor disk. In a preceding study in the study site Querfurt STRAßER (2006) had found that 5,2 % of recorded flights crossed the rotor disk.

Table 1: Numbers of Red Kite records within a 50 m-circle around wind turbines in different study sites in both study years. The figures in brackets give the percentages of these observations in relation to all observations.

Study site	**2007**	**2008**	**Total**
Druiberg	66 (41%)	17 (61%)	83 (44%)
Dessau	7 (24%)	6 (32%)	13 (27%)
Querfurt	16 (12%)	7 (18%)	23 (13%)
Speckberg	1 (1%)	3 (6%)	4 (3%)
total	90 (22%)	33 (24%)	123 (23%)

Crossing a wind farm is dangerous for a Red Kite if it flies in reach of the rotor blades. Due to the presence of different types of wind turbines, rotor blades operate between 50 m and 150 m in our study sites. Consequently we recorded the percentage of time Red Kites spent in different altitudes. From March to June we recorded flying height all in all in 15.822 seconds (4,4 hours). In approx. 29 % of the observed time the Red Kites flew in the dangerous height between 50 and 150 meters (see Fig. 2). From July to October the flying height was recorded in 14.620 seconds (4 hours), and approx. 22 % of the Red Kites flew in the dangerous height of 50 and 150 meters.

The preceding results suggest that Red Kites often run into dangerous situations as soon as they enter a wind farm. An important question, therefore, is why Red Kites fly into wind farms? For this purpose we investigated which field crops were present in the study area and how they were used by foraging Red Kites. In order to distinguish between avoidance and preference of habitats we calculated the Jacobs-Index.

The habitat preference of Red Kites changed through the year. In May and June Red Kites preferred boundary structures, maize-fields and fields with fodder crops, which had been harvested early. In July the birds preferred boundary structures, harvested alfalfa fields and rape stubbles. In August Red kites mostly foraged on fields with harvested crops or alfalfa.

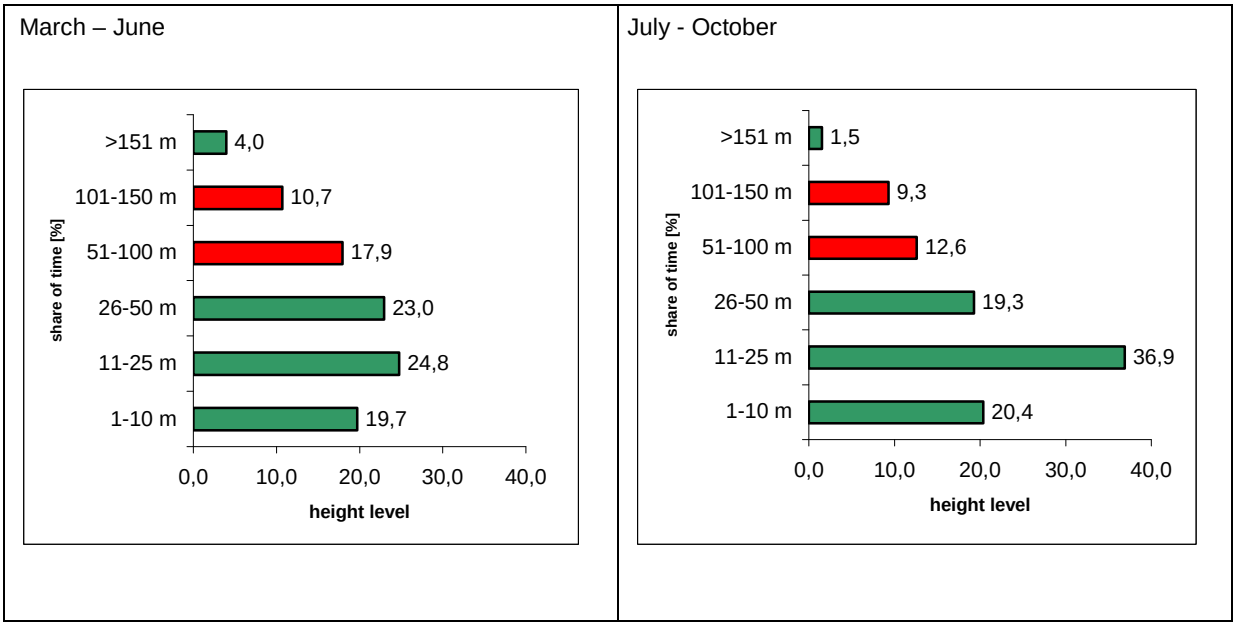

Fig. 2: Flying height of Red Kites in wind farms.

There were distinct seasonal patterns of preference of several crops and habitats. For instance, sugar beets were avoided during most time of the year. Only during harvesting in September and October a preference was registered. Fallow land was preferred only after cutting, while bare fallow and boundary structures were preferred nearly during the whole year. Rape fields with their dense vegetation cover were avoided during most time of the year. These fields were preferred only after harvesting in July and in the late September due to harrowing or ploughing.

In summary, Red Kites had an opportunistic foraging behaviour. They preferred low or open structures on which they could detect their food. This excluded rape fields and fully grown maize and sugar beet fields, while boundary structures were very important food resources in the intensively used agricultural landscape. Structures like the roads to the wind turbines and the areas directly around the tower bases also were such boundary structures, which attracted Red Kites into wind farms.

If Red Kites are searching for prey next to tower bases, they may get into risky situations. Thus, the practical question is: How has the turbine basis to be designed to become unattractive for Red Kites?

We experimentally covered the basis of three wind turbines with cling film and we compared the numbers of observations of Red Kites in the vicinity of the modified tower bases with the numbers of observations at three uncovered tower bases. At the modified turbines fewer

observations were registered than at the unmodified ones, but the total number of contacts was too low to apply statistical tools.

Another part of the Red Kite project was the radio telemetry. In 2007 five Red Kites were captured and equipped with transmitters. Two of them returned in the following year. In 2008 we tracked another Red Kite and two Black Kites.

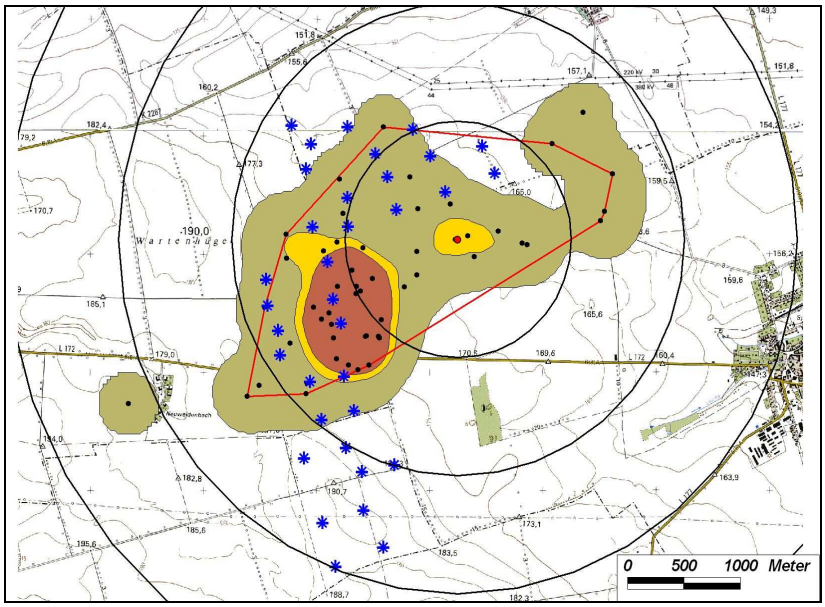

Fig. 3: Home range of the Red Kite Arthur during the breeding season 2007 (n=56 locations). Distance of breeding site (red dot) to the next turbine: 440 m; size of 95 % MCP (red line): 4.1 km²; colored areas: 95%/60%/50%-kernels. Blue stars: wind turbines.

The individual variation in home range size was remarkably. The size of the home ranges of Red Kites (MCP 95%) ranged between 1.74 km² and 74.42 km² during the breeding season, and between 2.06 km² and 213.35 km² after the breeding season. Several birds included parts of neighbouring wind farms into their home ranges (see Fig. 3). In order to measure the daily use of space and the daily travelling distance of Red Kites, we tracked all individuals over the whole day (from sun raise to sun set) once a month in 2008. An example is given in Fig. 4 by the visualized results of a day-tracking of the Red Kite Gishild.

Due to different home range sizes individual Red Kites travelled different distances from their nests. An example for a bird with a rather small home range is the Red Kite Arthur. The maximum distance of Arthur from its nest was 3228 m. 50 % of the locations of this bird were within a distance of 982 m from the nest (Fig. 5).

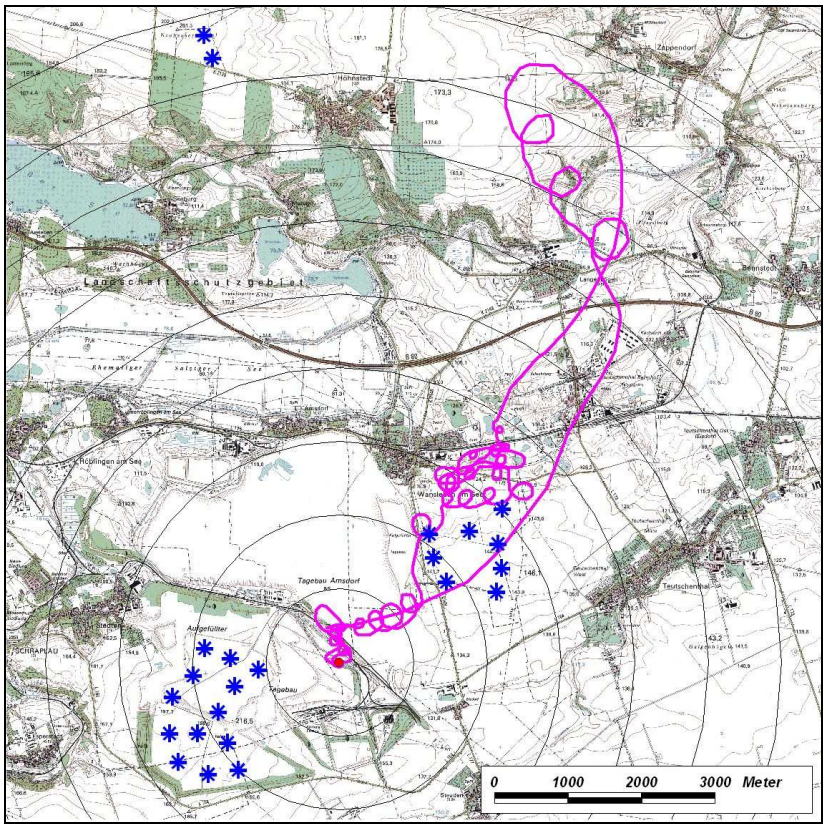

Fig. 4: Flight route of Red Kite Gishild on 2.7.2008. Length of flight route: 39.5 km; time spent flying 1 h 35 min, time spent sitting 13 h 04 min, no contact 1 h 47 min. Blue stars: wind turbines.

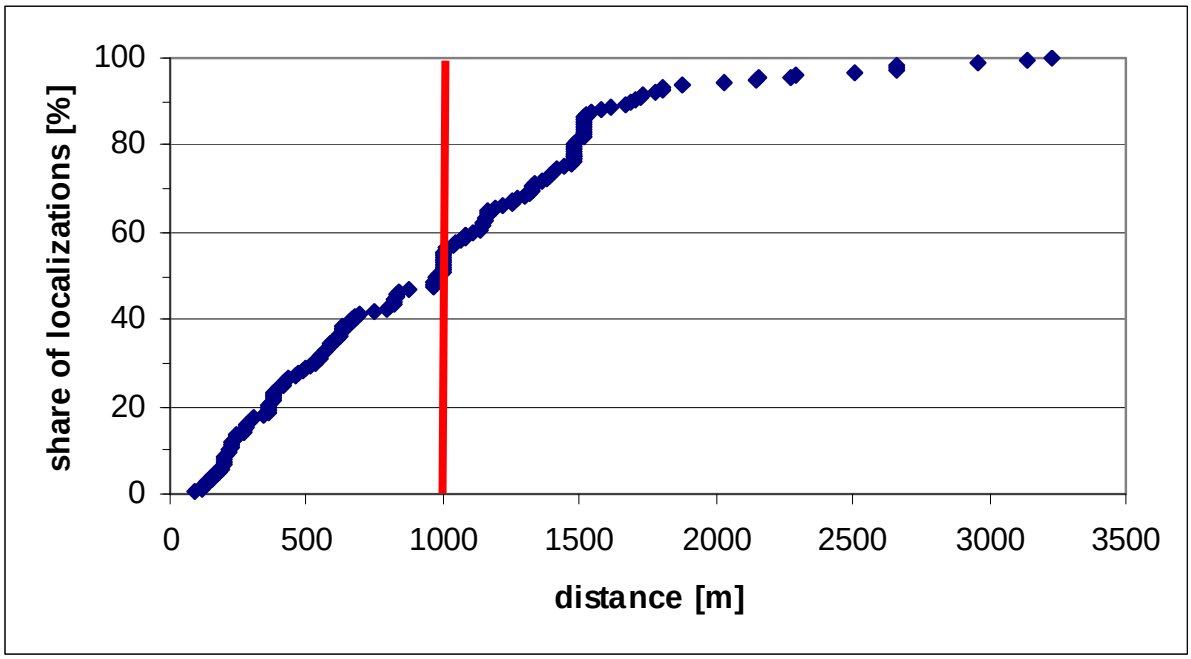

Fig. 5: Distances between radio telemetry localizations and nest site of Red Kite Arthur. The blue dots mark the cumulative percentages of observations at different distances from the nest site.

Another example is the Red Kite Barbara. The maximum distance from its nest was 13.214 m, and 50 % of the locations were within a distance of 1490 m from the nest (Fig. 6). These and all the other examples show that the risk to enter a wind park and to collide there is particularly high if a wind farm is next to the nest site. In order to minimize collision risks for Red Kites it is useful to keep the surrounding of the nest sites clear of wind turbines up to a distance of at least 1.000 m. In reality, the area of high activity is not necessarily concentric around the nest. Structures of the landscape and the position of feeding grounds may create other spatial patterns of activities. Future investigation will show how these patterns can be influenced by management.

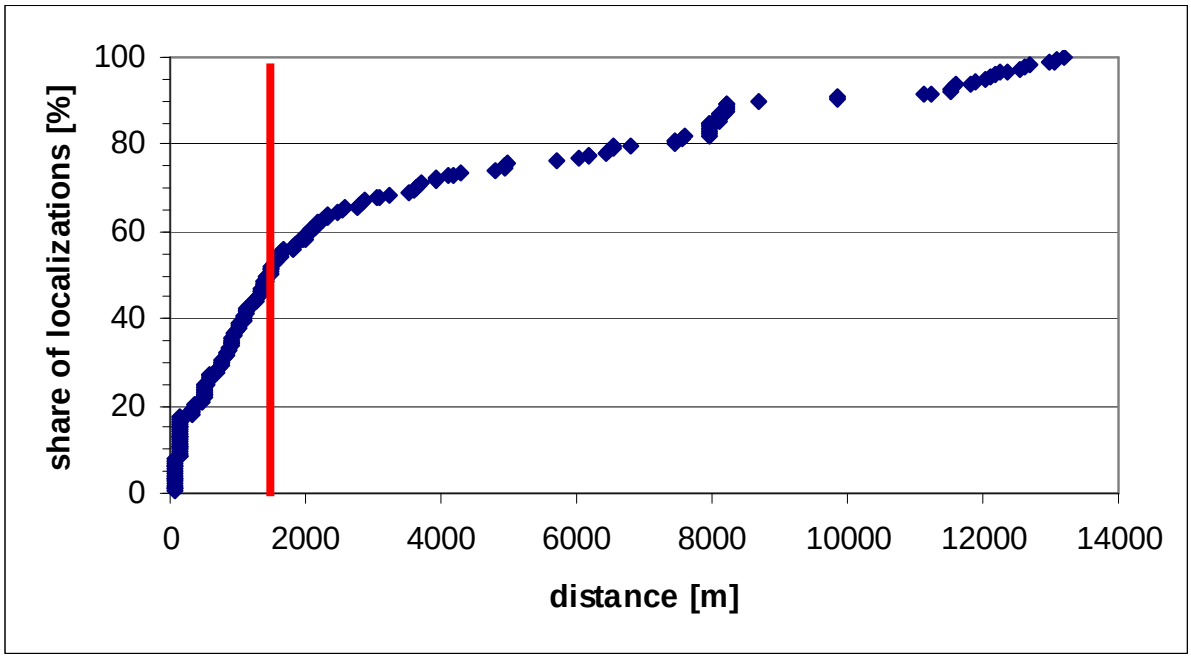

Fig. 6: Distances between radio telemetry localizations and nest site of Red Kite Barbara. The blue dots mark the cumulative percentages of observations at different distances from the nest site.

Conclusions for minimizing risk situations for Red Kites

1. No harvesting or mowing of field crops should take place in wind farms before middle of July.
2. The tower bases should be made unattractive for foraging Red Kites and should be kept as small as possible.
3. Within the wind farm fallow vegetation should not be mown.
4. Wind farms should keep a distance to nest sites of at least 1000 m.

Reference

STRAßER, C. (2006): Totfundmonitoring und Untersuchung des artspezifischen Verhaltens von Greifvögeln in einem bestehenden Wildpark in Sachsen-Anhalt. Diploma thesis. University of Trier.

Effect of wind farms on population trend and breeding success of Red Kites and other birds of prey

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Introduction

During the past decades wind farms have been constructed in many parts of Germany. Breeding and foraging sites of Red Kites, White-tailed Eagles and other endangered birds of prey have been affected. Although birds of prey have frequently been reported as victims of collisions with wind turbines, little is known about the effects of wind farms on the population dynamics of these species. The aim of this study is to compare population densities and breeding success of raptors in the past 15 years with the development of wind farms in the same areas. We use monitoring data provided by the initiative of the foundation for ecology and monitoring of Raptors and Owls in Europe in order to test whether increased numbers of wind turbines has caused a measurable effect on raptor populations.

Methods

Data on population size (number of breeding pairs) and breeding success (young fledged per pair) of several raptor species (Red Kite *Milvus milvus*, Black Kite *Milvus migrans*, White-Tailed Eagle *Haliaeetus albicilla*, Buzzard *Buteo buteo*, Honey Buzzard *Pernis apivorus*, Hobby *Falco subbuteo*, Kestrel *Falco tinnunculus*, Goshawk *Accipiter gentiles*, Sparrow Hawk *Accipiter nisus* and Marsh Harrier *Circus aeruginosus*) were provided by the MEROS-*program* (Monitoring of European Raptors and Owls; http://www.greifvogelmonitoring.de). We selected 225 monitoring areas, ranging between 30 km² and 2000 km² in size, in all parts of Germany, for which data were available between 1991 and 2006. Data sets for single species were often smaller, because not all species were recorded at every site in each year. Data on breeding success were available only until 2002. For each monitoring site the positions, commissioning time and capacity of relevant wind turbines was compiled using the wind energy database (*Windkraft Betreiber-Datenbasis*).

Repeated measurements ANOVAs (ANalysis Of VAriance**)** were used to analyze the effects of wind power plants on population development of raptors in monitoring areas. We applied linear mixed-effects models fitted by maximum likelihood, with (1) numbers of breeding pairs per standard area unit (100 km²), or (2) breeding success (number of fledglings per pair) as dependent variables and with numbers of wind turbines and/or total capacity of wind turbines per area unit as predictor variables.

Results

Number and installed capacity of wind turbines in monitoring areas increased significantly between 1991 and 2006. In spite of this, population, density and breeding success of most of the analyzed species (Red and Black Kite, Buzzard, Goshawk, Sparrow Hawk) remained stable during the study period (Fig. 1). No significant dependence of relationship between population sizes of raptors and construction of wind farms in monitoring areas could be found for the studied species. An overall population increase was observed for White-tailed Eagle, while for some other species (Kestrel, Honey Buzzard and Hobby) fluctuations in population density of more than 5 % per year were observed. None of these trends could be related to the development of wind energy in the same areas (Tab. 1).

Table 1: Results of repeated measures ANOVAs comparing the changes in population density of raptor species (Red Kite, White-tailed Eagle, Buzzard) in relation to the development of wind power plants in the same areas.

Breeding pairs			Red Kite		White-tailed Eagle		Buzzard	
			N=1050	N of areas=147	N=326	N of areas=37	N=843	N of areas=130
Factor (breeding pairs)	Model	Test	L.Ratio	p-value	L.Ratio	p-value	L.Ratio	p-value
Random	1							
Time	2	1 vs 2	3,04	0,08	**8,50**	**<0.01**	0,02	0,90
Number of wpps/100 km²	3	2 vs 3	0,00	0,97	0,34	0,56	0,59	0,44
Time x number	4	3 vs 4	0,12	0,73	0,83	0,36	0,26	0,61
Capacity in kW/100 km²	5	2 vs 5	0,02	0,88	0,42	0,52	0,03	0,86
Time x capacity	6	5 vs 6	0,03	0,85	0,67	0,41	0,11	0,74
Development of wind farms								
Number of wpps/100 km²								
Random	1							
Time	2	1 vs 2	**63,89**	**<0.0001**	**36,55**	**<0,0001**	**40,62**	**<0.0001**
Capacity in kW/100 km²								
Random	1							
Time	2	1 vs 2	**53,18**	**<0.0001**	**27,19**	**<0,0001**	**35,36**	**<0.0001**

The highest densities of breeding Red Kites were found only in areas with no wind farms. However, this effect was not statistically significant. Some of these relatively small areas had previously been designated as nature reserves, and so the construction of wind farms was not allowed on those sites.

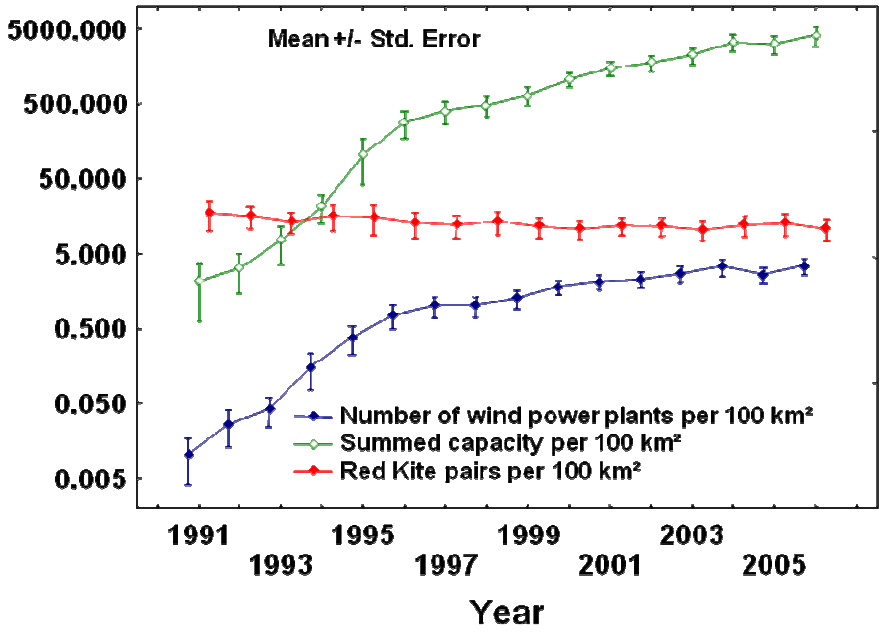

Fig. 1: Population density of Red Kite and the development of wind power plants in monitoring sites.

Discussion

The results of this study show that so far there have been no significant effects of wind farms on population sizes of raptor species in Germany. However, this result should be interpreted critically. In 2006, the average density of wind farms in the landscape was still comparatively low. Only 22 of the monitored areas (less than 10 % by number) had more than 10 turbines per 100 km². A high density of wind facilities is a very recent development. The development of industrial wind power continues, and a steady increase in number and installed capacity of wind farms can be expected in the near future. Significant losses due to collisions cannot be ruled out when wind farms are constructed in areas with very dense Red Kite populations. In these circumstances, the present analyses could be taken as a baseline for sensitivity monitoring. This monitoring would be able to indicate where and when a “critical” density of wind turbines is reached and raptor populations start to decline due to wind farms. Data on breeding success of the monitored species was available only until 2002, and so the most recent phase of wind farm development has not been covered by the analysis. Thus, in order to improve the validity of these results, the database should be completed and data collection should continue.

Summary of the discussion after the talk

H. SCHLÜTER argued that the talk contains “statement outside the legal framework” because Red Kites are not threatened. The authors disagreed with this statement.

R. MAY considers that numbers of breeding raptors per monitoring plot (as used in the presentation) does not allow any statement about the distribution of birds within the plot. It could be the case that wind turbines and raptors are locally separated at a finer spatial scale.

L. RASRAN agrees with this point of view. The present data, however, do not allow an analysis of the spatial distribution of raptors and wind turbines within study plots.

M. REICHENBACH considers the statements of the presentation to be politically sensitive. If there are no indications of an effect of wind farms on population development, he asks where is the problem?

L. RASRAN replies that the study plots do not represent regions with the highest density of wind turbines.

J. WEBER thinks that the low number of victims means that the effect of wind farms on the population development of raptors can be neglected.

B. DE WOLF asks whether it is possible to conduct more exact analyses including local data on spatial distribution of wind turbines and raptors.

H. HÖTKER replies that such an approach is possible, but requires a much higher research effort.

Analysis of collision victims in Germany

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Introduction

Injury and death of birds due to collisions with wind turbine masts and rotor blades are direct negative consequences of wind farm development. The share of raptors and large endangered bird species among the collision victims is comparatively high. Little is known about the circumstances that led to the collisions. At the *Staatliche Vogelschutzwarte Brandenburg,* information on collision victims in Germany has been collected since 1989. In this study, we analyse information on raptors and other large birds in order to find out which factors contribute to the risk of collisions at wind power plants.

Methods

Out of about 730 collision victims recorded until the end of 2008, 323 were raptors or other endangered large birds (including: 101 Red Kites *Milvus milvus*; 36 White-tailed Eagles *Haliaeetus albicilla*; 14 White Storks *Ciconia ciconia;* and eight Eagle Owls *Bubo bubo*).

In order to analyse the effects on the collision risk of technical specifications of wind turbines and habitat characteristics around wind turbines, we compared 151 turbines where fatalities of target bird species had been reported with 186 randomly selected turbines without reported fatalities. We treated randomly selected turbines as sites with average collision risk, and turbines with one or more documented collisions as sites with increased risk.

Reports detailing regular search activities at specific wind farms, and fatalities found by these controls, were treated as a separate dataset, in order to estimate bird fatality rates per turbine or per installed unit of power.

The victim register contains data on the date and place of collision, and, in some cases also on the age of the victim, and injuries caused by the collision. In addition, we collected data on the characteristics of wind farms (position; number of turbines; rotor diameters; hub heights;

installed capacities) and on the habitats surrounding the wind farm (distances to the nearest wood, water body, road and settlement, and land use within 5 km [CORINE-Database]).

We tested the relationship between of victim numbers and characteristics of wind farms by linear regression. Comparisons between wind turbines with reported collisions and randomly selected wind turbines were performed by one-way ANOVAs.

Results

Red Kites and White-tailed Eagles were the most frequent collision victims, along with the more common Buzzard *Buteo buteo* and Kestrel *Falco tinnunculus*. A Lesser Spotted Eagle *Aquila pomarina*, a rare and endangered species, has been recently registered as collision victim as well. In contrast, Goshawk *Accipiter gentiles*, Sparrow Hawk *Accipiter nisus* and Marsh Harrier *Circus aeruginosus*, although rather common in Germany, were recorded as turbine victims only rarely.

Most collisions took place in March-April and August-September, at the beginning of the breeding period and just after the fledglings leave the nest. The proportion of immature and sub adult individuals among collision victims was between 10% at species with short time of mature (Red Kite) and 30 % at species with long time of mature (White-tailed Eagle)

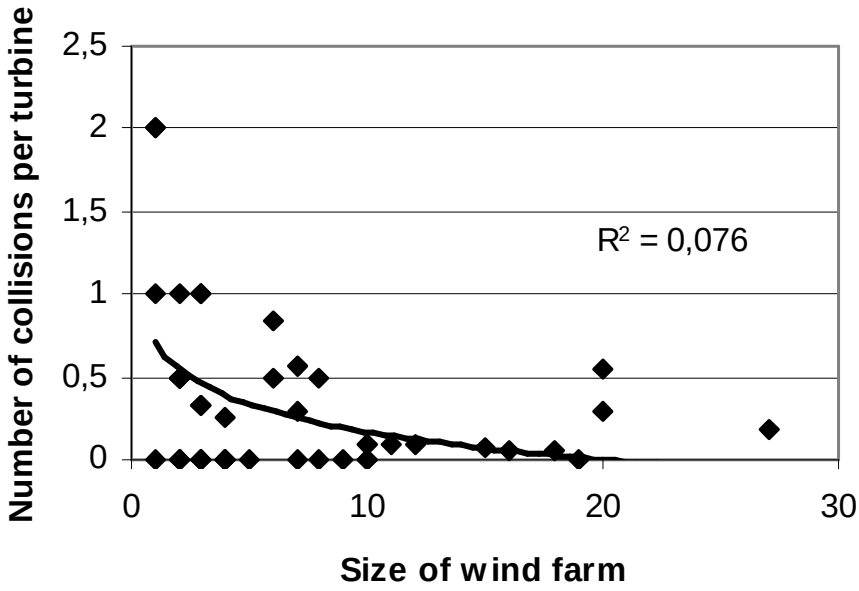

Fig. 1: Relationship between the size of wind farms and the number of registered raptor collisions per turbine. Only regularly monitored wind farms (n=65) were considered.

Large wind farms caused more collision victims than small farms. The number of collisions per single turbine, however, was lower in large farms than in smaller farms (Fig. 1). Size of wind turbines had a significant effect on a collision risk. Nominal power, rotor diameter and tower height were significantly higher in wind turbines with raptor collisions than in the turbines of the random group. However, for regularly monitored wind farms, fatality rate per installed unit of power was negatively correlated with turbine size. Thus, the overall fatality risk was growing more slowly than total installed capacity (Fig 2).

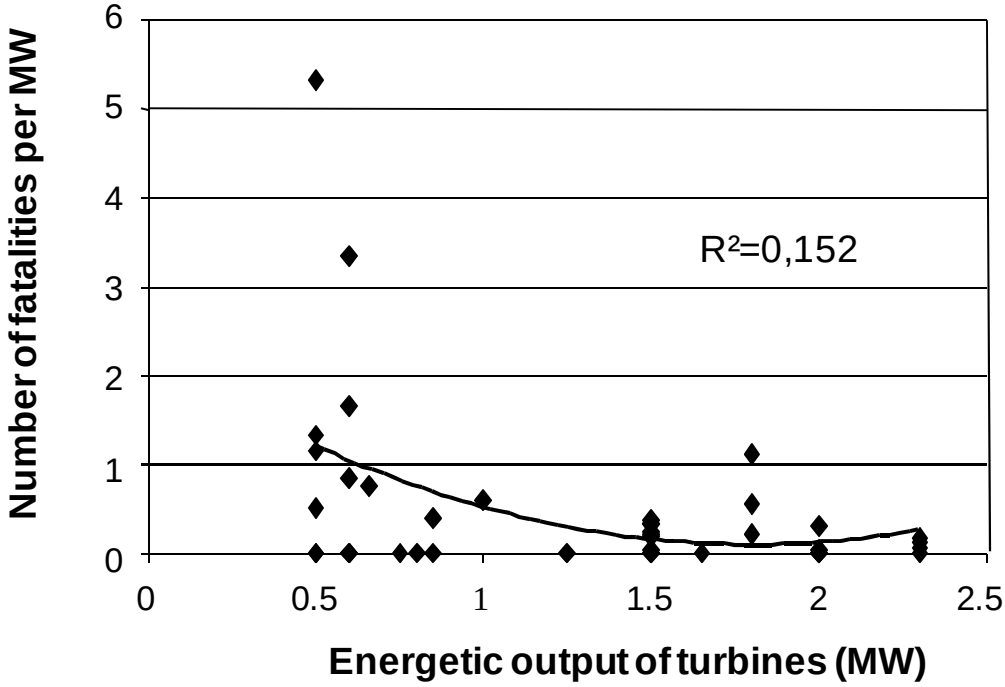

Fig. 2: Relationship between wind turbine power (MW) and number of registered fatalities per MW. Only data of regularly monitored wind farms (n=42) are used.

In terms of land use in the area surrounding wind turbines with and without reports of collision, the proportion of arable fields appeared to be important. Turbines surrounded predominantly by arable fields were recognised as collision locations more frequently than these with lower proportions of this land use type (one-way ANOVA: $F=40.24$; $p<0.0001$; Fig 3). By contrast, higher proportions of grassland had the opposite effect (one-way ANOVA: $F=35.35$; $p<0.0001$). Percentage of forested area in the landscape had no significant effect ($F=0.31$, ns).

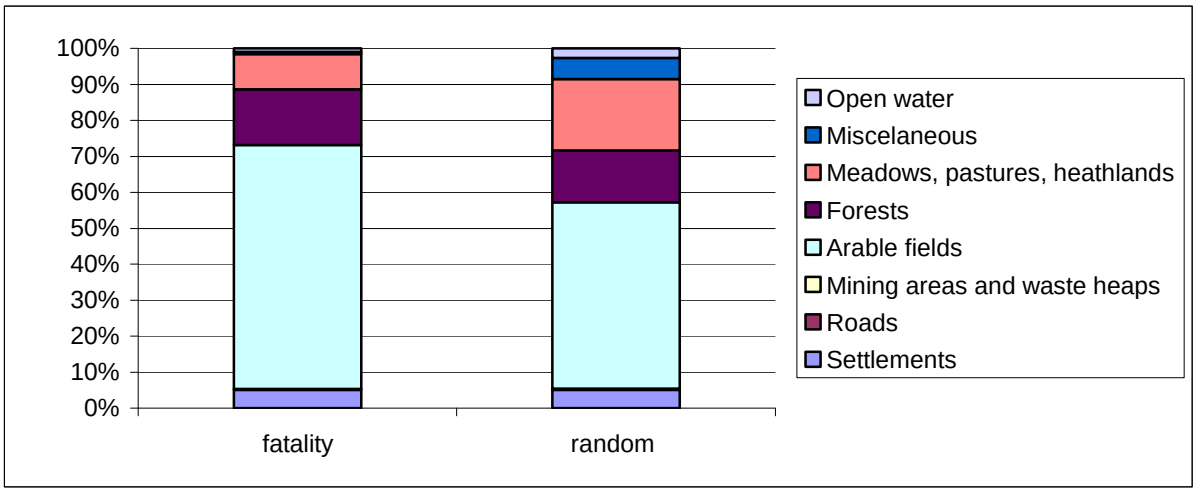

Fig. 3: Mean percentage of different land use forms in the surrounding (5 km radius) of wind turbines with (fatality, n=151) and without (random, n=186) reported raptor collisions.

Discussion

Red Kites and White-tailed Eagles are both birds of open landscapes and occur on victim lists more frequently than would be expected given their population status in Germany. White-tailed Eagle is a large and conspicuous species that is the focus of nature conservation efforts, so it can reasonably be assumed that the majority of victims were found and reported to the database. For smaller species such as Kestrel, or even Red Kite, the number and proportion of unreported cases are probably quite high.

Seasonal peaks in reported collision numbers can probably be partly explained by increased activities of birds during territory acquisition in spring when young fledge in late summer and autumn. A lower likelihood of finding carcasses in tall crops during May, June and early July, as well as individual preferences for the timing of searches will probably also have influenced reporting rates (MAMMEN et al. 2009).

Wind farms completely surrounded by arable fields clearly posed a higher collision risk to diurnal raptors than wind farms surrounded by other habitats. This effect can be probably explained by the fact that tower bases of wind farms in arable areas form the only places where many raptors can access their principal prey - small rodents. In this way raptors may be attracted to wind turbines. In other habitats rodents are more widely distributed so that mast bases are relatively less attractive. Alternatively, arable might be more risky because there is little prey - and so raptors fly over it at risky heights in order to reach “islands” of good-quality foraging habitat away from wind farms.

Our study shows that the collision rate per installed unit of power decreases with the size of the wind turbines. The result confirms the outcome of earlier studies and model calculations (HÖTKER 2006; SMALLWOOD & KARAS 2009). Repowering (replacement of old wind turbines by bigger and more efficient turbines) thus has less of a negative effect on birds than would be expected if the ratio of collisions and power is the same in small and big wind turbines.

References

HÖTKER, H. (2006): Auswirkungen des "Repowerings" von Windkraftanlagen auf Vögel und Fledermäuse. Bericht für das Landesamt für Natur und Umwelt Schleswig-Holstein. Michael-Otto-Institut im NABU, Bergenhusen.

MAMMEN, U., MAMMEN, K., KRATZSCH, L., RESETARITZ, A. & SIANO, R. (2009): Interactions of Red Kites and wind farms: results of radio telemetry and field observations. In: Hötker, H. ed.: Birds of Prey and Wind Farms. Proceedings of an international workshop, Berlin, Oct. 21-22, 2008. http://www.bergenhusen.nabu.de/forschung/greifvoegel/

SMALLWOOD, S.K. & KARAS, B. (2009): Avian and Bat Fatality Rates at Old-Generation and Repowered Wind Turbines in California. Journal of Wildlife Management 73: 1062-1071.

Summary of the discussion after the talk

R. MAY considered that the presented data cannot be compared with results of other international studies.

G. NEHLS stated that there are only a few studies on collision victims. Systematic monitoring is necessary. The main difficulty for such studies is tall vegetation height in summer, which makes it difficult to find collision victims.

Montagu‘s Harriers and wind farms: Radio telemetry and observational studies

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The abstract gives a status report of a two years study on radio-tagged Montagu’s Harriers inhabiting a wind farm area in Northern Germany.

Introduction

The Montagu’s Harrier (*Circus pyrgargus*) is rather patchily distributed in Central Europe. Since the 19th century it has suffered dramatic declines, mainly due to loss of natural breeding sites (raised bogs, fens and reed habitats). The present breeding population in Germany ranges between 410 and 470 pairs. Schleswig-Holstein, one of the most important breeding regions, presently holds 50 to 60 breeding pairs.

Due to the loss of natural breeding habitat, a large-scale settlement has taken place in agricultural areas since the 1970s. At the same time, wind farms have been developed in the same regions. At present, most Montagu’s Harrier’s territories in Schleswig-Holstein are concentrated in the areas with the highest density of wind turbines. Given the low population size of Montagu’s Harrier, it is important to know whether they are affected or threatened by wind farms.

Study areas

The investigations are focused on two areas on the North Sea coast of Schleswig-Holstein. The landscapes are characterised by salt marshes next to the sea and reclaimed polders inland, separated by dykes. The salt marshes hold high densities of breeding waders and passerines. These areas are important foraging habitats for Montagu’s Harriers and this is one factor that can explain the concentration of breeding pairs in this coastal region. Harrier nest sites are located behind the dykes in the polders. Landuse on the polders is mainly agriculture, dominated by cereals. Nests are found in barley, wheat and occasionally oil seed rape.

Methods

Birds were caught on wooden posts installed in the territories. The trap consisted of a loop, which is drawn together around the leg, triggered when the bird is landing. We caught 6 adults in 2007 (3 males, 3 females) and 5 in 2008 (4 males, 1 female).

We used VHF radio transmitters with a weight of 6,8 to 8,9 g, equivalent to 2,5 - 3 % of the birds' body mass. Dependent on the moult state the transmitters were either glued on the back, or tied to the two central tail feathers (Fig. 1).

Fig. 1: Male Montagu's Harrier with transmitter tied to the central tail feathers.

In order to describe the behaviour of the harriers towards windparks precisely, we chose a mobile tracking system with a portable radio tag receiver and a three-element antenna. The observations were done mostly by bicycle. We chose recording intervals of 1 min and tried to keep visual contact to the tagged birds. We recorded behaviour, flight height and habitat type at 1-minute intervals. The location intervals lasted between 4 and 11 h per day, dependent on the weather conditions. Every individual tagged bird was recorded 4 to 5 days a week. A total of 36.000 observation-minutes was achieved.

Telemetry fixes were entered as points into a GIS. Home ranges were derived using Kernel estimators, which calculate an utilisation distribution from the telemetry points. Two probability levels were specified: 95 %, and 50 %, the latter representing the centre of activity (core area). For the calculation of utilisation of wind farms areas, we defined the “wind farm impact area” as a 200 m radius around each wind turbine.

First results

Note that up to now only a small part of the whole dataset could be integrated to the analysis. The presented results have not been statistically tested and are to be interpreted carefully.

Nest sites and wind farms

The distance between 24 nests and the nearest turbine ranged between 76 and 890 m. The small sample size precluded statistical analysis, but the distribution of the distances showed a low tendency of displacement. If displacement did occur, it may have done so in the immediate vicinity (<100m) of the turbines (Fig. 2). We suggest that nest site selection was mainly determined by the vegetation structure of cereals. This was obvious in 2007, when isolated barley fields close to wind turbines were strongly preferred as nesting areas. Presumably the preference for barley masked any existing displacement effects of the wind turbines.

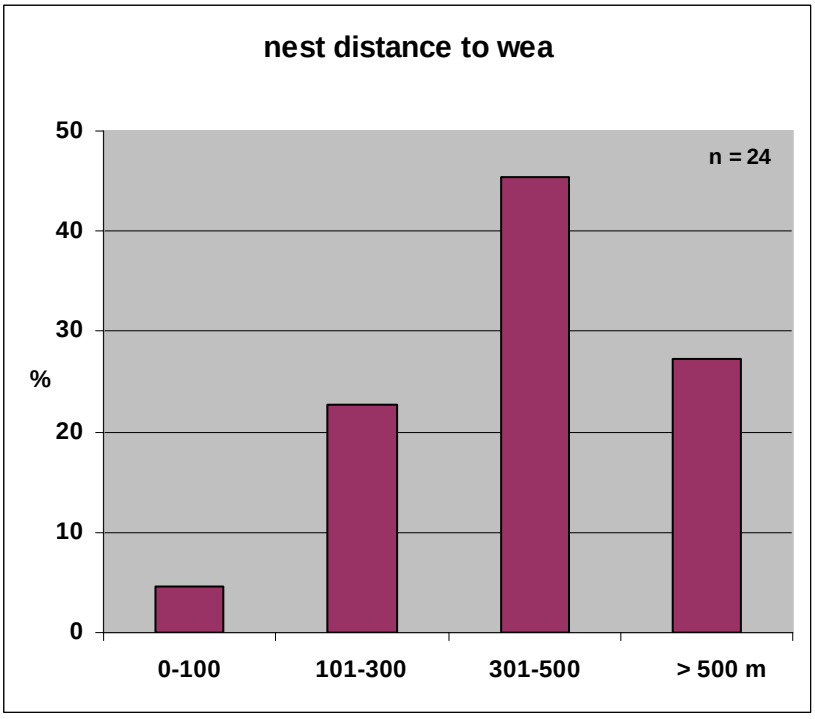

Fig. 2: Distances of Montagu’s Harrier’s nests to wind turbines (wea).

Home ranges

In Figs. 3 and 4 the locations, the resulting Kernel-home-range and the core areas of individual birds are shown. Dependent on the breeding status we found home ranges from 40 ha (female, almost exclusively provisioned by male) up to 1.200 ha (polygynous male with three females). Important foraging areas were located in the salt marshes and in grassland. The centres of activity (core areas) were located around the nests (due to food delivery and feeding nestlings).

Wind farms regularly formed a part of the home ranges (see locations inside the buffer zones of the turbines). The overlap of wind farm areas with home range of five adults ranged from 10 to 12 %. In contrast to this, two males breeding in the vicinity of two high quality foraging areas (salt marshes and wetlands) obviously showed no need to visit wind farm areas (Fig. 3).

Behaviour within wind farms

Montagu's Harriers entered wind farms mostly when travelling between nests and foraging grounds. Harriers also actively foraged within wind farms, regularly passing wind turbines at distances of less than 10 m. During hunting harriers flew at low heights, mostly less than 5 m, but 5 % of the analysed flights in wind farms occurred at the dangerous rotor swept height (30 – 100 m). So far, we have found no differences in the flight height distribution inside and outside wind farms (Fig. 5). This indicates that Montagu's Harriers do not moderate their flight behaviour close to wind turbines.

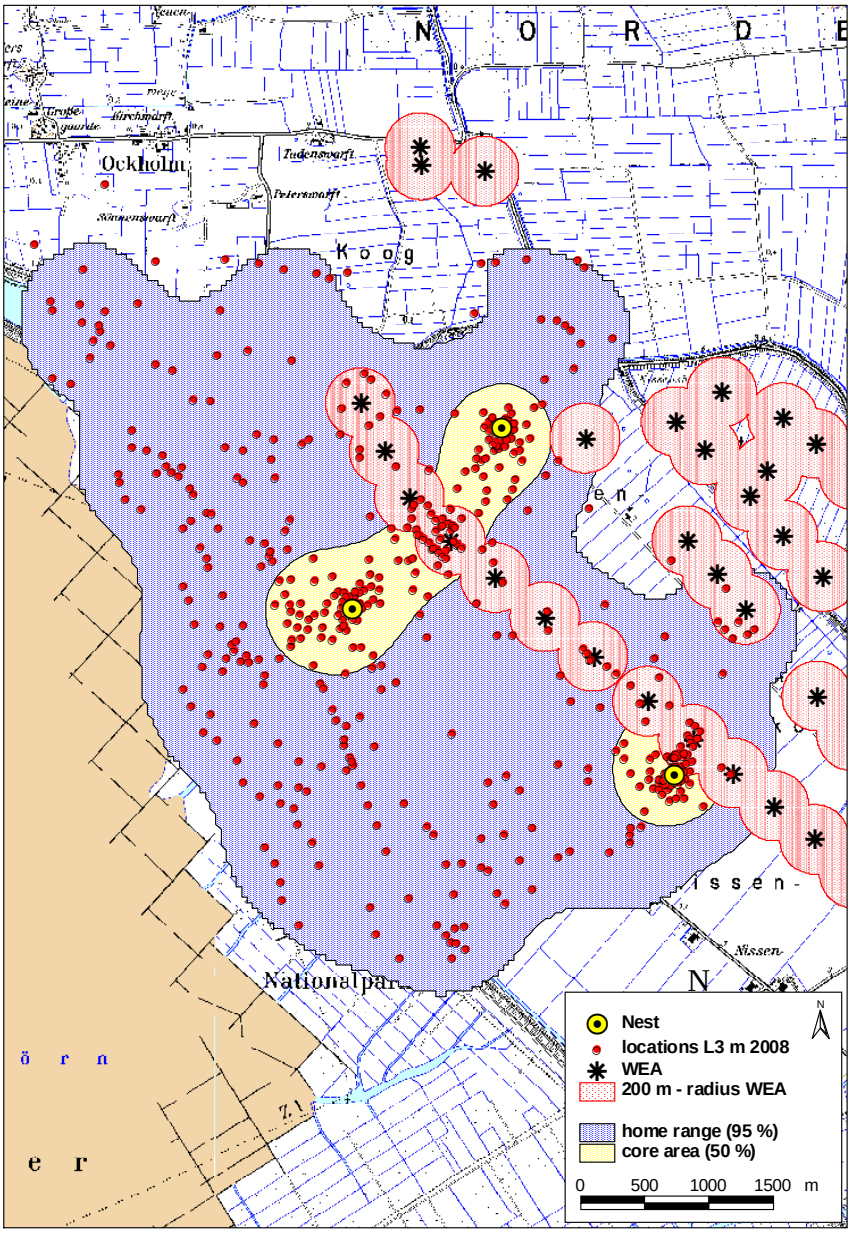

Fig. 3: Locations, resulting home-range and core area (Kernel) of a polygynous male providing three females. The core areas of activity are located in the vicinity of wind turbines (wea).

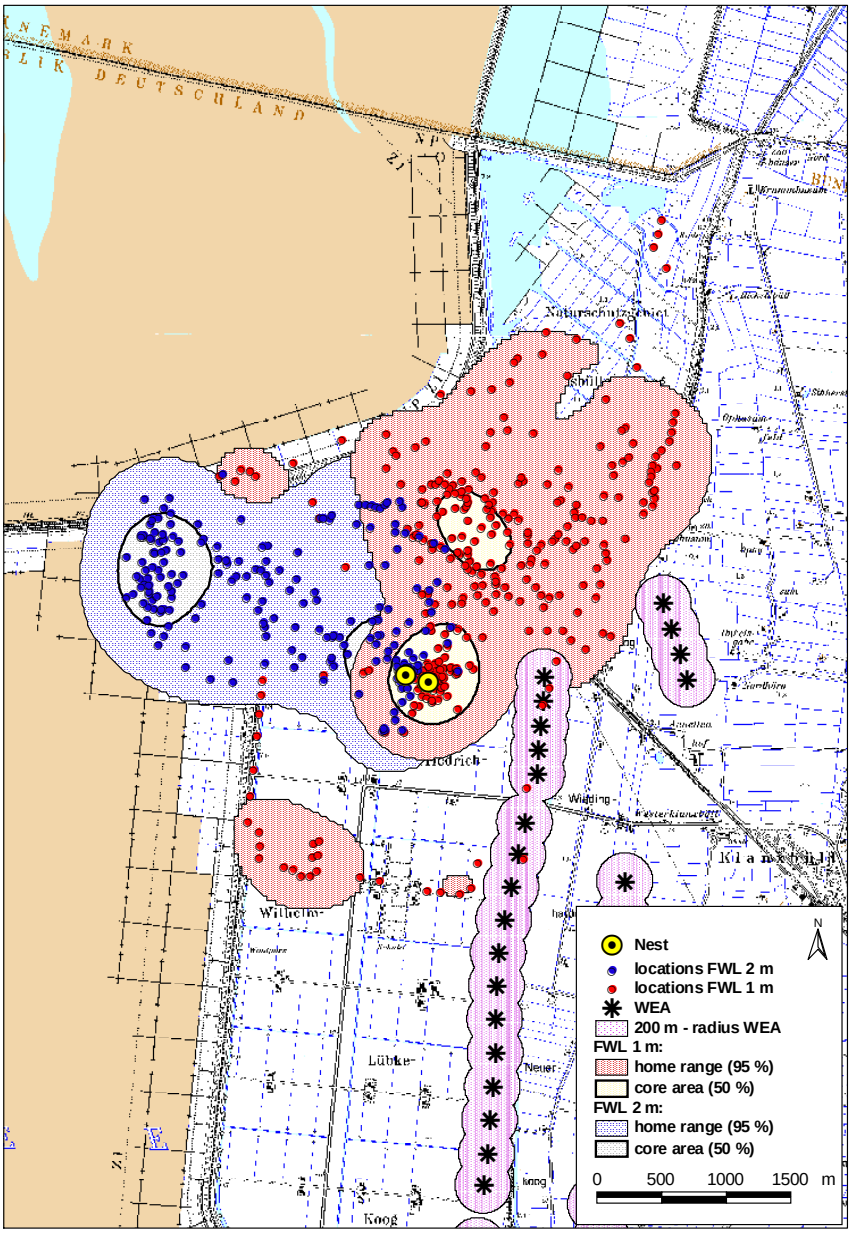

Fig. 4: Locations, resulting home-range and core area (Kernel) of two males. The core areas of activity are located at the nest sites and concentrated in the foraging habitats (salt marshes and wetlands). The high quality of the foraging areas may have prevented the males from using the wind farm area.

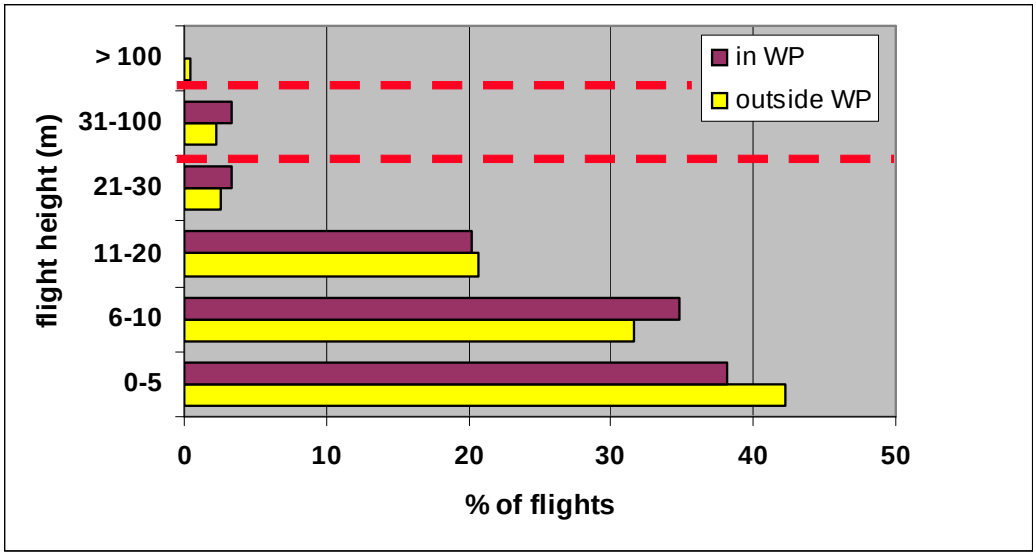

Fig. 5: Flight height distribution of three males inside and outside wind farm areas (n=179 observations). The critical rotor swept area ranges between 30 and 100 m.

Collision risk

Montagu's Harriers generally flew beneath the critical rotor swept area. Dangerous situations arise during courtship behaviour, food passing, and cruising, when the birds reach heights between 20 and 50 m. Roughly five out of 100 flights occur at the critical rotor height. We observed several dangerous situations of harriers in the vicinity of the rotors. Post mortem examination of a polygynous male, found dead 300 m from a turbine, could not exclude a death by collision with a rotor blade. The whole dataset is to be analysed and will also be incorporated in collision risk models ("CRM"), in order to estimate collision risk.

Outlook

Further analysis of the data is planned as follows:

- preparation and integration of the total data set in the analysis parameterisation of collision risk models ("Band-model"), preparation of the data for incorporation in models)
- assessment of avoidance rates,
- analysis of "dangerous situations"
- deriving mitigation methods to minimise collision risks (habitat management etc.)

Summary of the discussion after the talk

R. MAY asked about the number of researchers involved.

Answer: One person followed the focal bird by bicycle. The second person surveyed the wind farm and recorded closely passing Montagu's harriers and their behaviour and flying height.

H. SCHLÜTER asked why Montagu's Harriers fly so far away from nest and do not forage close to wind turbines?

Answer: Obviously the feeding grounds at greater distances were more attractive.

G. NEHLS noticed that the preliminary results of the study indicated a low collision risk. Nevertheless, a collision risk exists. The question whether Montagu's Harriers avoid wind turbines at close range has not yet been answered.

D. SKAMBRACKS asked how can collision risk be calculated.

Answer: Different mathematical models are available. The fact that no collision victims have been found so far does not means that no fatalities took place. Montagu's Harriers occur only in late spring and summer in the region when collision victims can easily be overlooked because vegetation is high.

R. JOEST asked whether there is a difference between operating and non-operating wind turbines.

Answer: There is not enough data to answer this question.

Are breeding Montagu's Harriers displaced by wind farms?

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Introduction

The marshes in Nordfriesland and the Hellwegbörde are two of the most important breeding areas for Montagu's Harriers in Germany. Both regions have been affected by increasing development of wind energy since 1990. This study analyses changes in breeding populations of Montagu's Harriers in relation to wind turbine development in both areas. We also investigate whether wind turbines affect nest site selection of Montagu's Harriers in the Hellwegbörde.

Study areas and material

The marshes in Nordfriesland (960 km² of dyked polders along the North Sea coast of Schleswig-Holstein are flat lowlands with few settlements and forests and maximum elevation of less than 10 m above sea level. The Hellwegbörde Special Protection Area (SPA) in Nordrhein-Westfalen (1013 km²) consists of lowlands and hilly uplands (70-410 m above sea level) with comparatively more settlements and forests. In both areas cereal farming is the predominant land-use. Montagu's Harriers breed mainly in winter-sown cereals.

In order to investigate relations the effects of wind turbines on nest site selection in Nordfriesland we compared numbers and installed capacity of wind turbines within 1 km radii around randomly set control points and around nest sites. We used linear mixed models to describe the temporal development of wind farms in the surrounding of nest and random points and compared them with ANOVAs.

In order to investigate a long-term effect of wind turbines and nest site selection of Montagu's Harrier in Hellwegbörde, we collated the locations of nest sites of Montagu's Harriers and of wind turbines up to 2007. Study area was covered with 2x2 km raster grids. In each raster cell for each year, we recorded the number and installed capacity of wind turbines, as well as

the number of breeding pairs of Montagu's Harrier. Raster cells with at least one nest or one wind turbine in any year were selected for further analyses. A linear mixed effects model was developed to describe the distribution of nest sites in the study areas. In order to investigate the effect of wind farms on the distribution of nests, we used an ANOVA to test a time-dependent model against a model including the nominal installed capacity of wind turbines. The factor "capacity" was chosen because it is highly correlated to the number, tower height and rotor diameter of wind turbines and thus gives a good impression of the intensity of use of wind energy.

In order to study the relative effects of wind turbines and other structures and landscape elements on nest site selection in the Hellwegbörde, we generated random points within potentially suitable areas for Montagu's Harrier. We recorded the following variables for nest sites and for random points: elevation above sea level; slope; plane vertical object (settlements, forests); nearest pylon; nearest wind turbine (single or within a wind farm), distance to the nearest vertical point structure object (pylons and wind turbines combined). . We tested for differences between the surroundings of nest sites and of random points for each parameter using a non-parametric rank test (Wilcoxon's rank test). As these effects of landscape features on nest site selection may not be independent, a multivariate binary logistic regression was used to identify the parameters most likely to influence nest site selection.

Results

Nordfriesland

In Nordfriesland study area, the number of wind turbines increased rapidly from 44 in 1990 to 386 in 1995. Since then, numbers have continued to increase, but more slowly. Installed capacity has increased since 2002 due to re-powering (replacement of old small turbines with larger modern ones). Average nominal power of wind turbines increased from 300 kW in 1995 to more than 1000 kW in 2007.The breeding population of Montagu's Harrier increased slightly from 15 pairs in 1995 with a maximum of 39 pairs in 2003. Linear mixed models and the ANOVA revealed no significant differences in installed wind power capacity between the nest sites of Montagu's Harrier and randomly chosen points at the marshes of Nordfriesland (Tab.1).

Table 1: Analysis of variance (ANOVA) comparing wind energy development in 1 km radii around Montagu's Harrier nests and random points in Nordfriesland. Wind farm capacity increased in time, while the time effect on number of facilities was not significant. Factor nest/random point is not significant

Factor			**Number of wind turbines**		**Sum of power capacity**	
	numDF	denDF	F	p	F	p
(intercept)	1	650	**30,99**	**<0,0001**	**19,58**	**<0,0001**
Time	1	650	1,36	ns	**14,32**	**<0,001**
Site (Nesting vs. Random point)	1	86	2,26	ns	1,37	ns
Time x Site	1	650	0,2	ns	**4,74**	**<0,05**

Hellwegbörde

In the Hellwegbörde, the number of wind turbines increased steadily from 14 in 1993 to 271 in 2007. During the same period, the number of Montagu's Harrier nests fluctuated but showed a downward trend (maximum 56 nests in 1994, minimum 17 nests in 2006). However, ANOVA showed no significant effect of either the number of wind turbines or power capacity on the number of harrier nests in 2km x 2km raster cells.

A comparison of landscape features at nesting sites and random points showed that Montagu's Harrier nests were situated at lower elevations, on gentler slopes and further away from vertical structures (settlements, forests), wind turbines and wind farms than random points. In the multivariate analyses, elevation, slope, distance to nearest vertical plane structure, distance to nearest vertical point structure (wind turbine or high-voltage pylon) all significantly affected nest site selection of Montagu`s Harrier, but distance to nearest wind turbine or wind farm did not.

In the Hellwegbörde, most wind farms have been built on higher and steeper ground, and closer to vertical structures than Montagu's Harrier nest sites (Tab. 2). Therefore, wind farms tend largely to be separated from the most heavily frequented nesting areas of Montagu`s Harriers.

Table 2: Comparison of landscape features between nest sites of Montagu's Harrier and wind farms in Hellwegbörde (Wilcoxon's rank test).

	Nest	Windfarm	Wilcoxon-Test
	Median (25%-75% Quartil)	Median (25%-75% Quartil)	
Elevation	114m (103-161m)	215m (162-276m)	<0,0001
Slope	0,8°(0,5-1,4°)	2;1°(1,1-2,9°)	<0,0001
Distance Vertical Structure	384m (271-503m)	243m (186-299m)	<0,0001

Discussion

We found no statistically significant effect of wind turbines on the number of Montagu's Harrier nests in either study area. There was no statistical evidence for an effect of wind farms on nest site selection in the Hellwegbörde. However, the combined effect of wind turbines and high-voltage pylons was significant. Both studies are based on correlative analyses of existing data and lacked experimental design. It is not possible to extrapolate from the present situation to conclude that further development of wind turbines in breeding areas of Montagu's Harrier will be without adverse effects. The data structure only allowed analyses of the effects of wind turbines on nest site selection at a low spatial resolution. Therefore negative effects of wind turbines cannot be excluded, particularly if wind farm development continues. The complete absence of nests of Montagu's Harriers within windfarms in the Hellwegbörde may indicate displacement by turbines. The number of Montagu's Harrier nests within 1 km of seven wind farms (> 3 turbines - established mostly in the middle of the study period) was considerably higher before wind farms establishment compared with afterwards. This difference remained even after taking into account the different times of wind farm establishment. The average minimum distance between nests and the nearest wind turbine was about 500 m (Median of 5 years).

Montagu's Harriers prefer nest sites in low-lying, flat landscapes, away from vertical landscape structures. Therefore, wind turbine development may potentially conflict with the conservation of these areas for breeding harriers, if the presence of turbines reduces the extent of available suitable habitat below a minimum critical area. This is particularly the case

for fragmented landscapes such as the Hellwegbörde, where fragmentation of Montagu's harrier habitat is exacerbated by new buildings for housing, industry and farming, as well as by the expansion of transport infrastructure. So far, most wind turbines are concentrated in the upper part of the area while most nests are situated in the lower part. Minor influence of wind farms on Montagu's Harrier can also be explained by this spatial separation. This was in part due to having taken Montagu`s Harrier conservation into consideration, in accordance with the precautionary principle, when planning wind farm locations.

If Montagu`s Harriers are not displaced by wind turbines, they might suffer from an increased risk of collision with rotating turbine blades.

White-tailed Sea Eagles and wind power plants in Germany – preliminary results

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Collisions of White-tailed Sea Eagles with wind turbines

Wind power provides up to 7.2% of power consumption in Germany (MOLLY 2008). The development of wind power plants has resulted in an increase in the number of birds that collided with wind turbines. The first two White-tailed Sea Eagles (*Haliaeetus albicilla*) became victims of wind power plants in 2002 (KRONE & SCHARNWEBER 2003). Since then, at least 36 White-tailed Sea Eagles (WTSEs) have been killed by collisions with the blades of wind turbines. More than 50% of the eagles were adult (n = 19) and the remaining birds juvenile to subadult (n = 17). The north-eastern federal states (Schleswig-Holstein and Mecklenburg-Vorpommern) with high numbers of White-tailed Sea Eagle breeding pairs and high numbers of wind parks especially affected. Adult WTSEs were mainly found during the winter months and in the spring, when courtship and territory demarcation were performed and flight activity was high. Young WTSEs have been found dead mainly in autumn and towards the end of winter, very likely during dispersal. To investigate whether juvenile WTSEs are affected by wind power plants (WPPs) during dispersal and whether WPPs have an influence on habitat selection and use of space by territorial eagles, we equipped WTSEs with satellite transmitters and performed visual observations.

Data generated by transmitters

One adult WTSE was caught with a bow net in January 2008. It was equipped with a data logger. Despite extensive search for VHF signals, the bird could not be located. Three nestling WTSEs from two nests were equipped with GPS-GSM transmitters at an age of six to eight weeks at the same time as being ringed in June 2008. One nest with two nestlings (eagle #5841, eagle #5901) was located 5 km inland from the Baltic Sea, between the cities of Wismar and Rostock. The other nest (with a single eagle chick -eagle #5902) was located within the Mecklenburg Lake District east of Schwerin, capital of the federal state

Mecklenburg-Vorpommern. The satellite transmitter of eagle #5841 was programmed to receive three positions per day. The device generated 527 positions in 178 days. Using all positions the calculated dispersal area was 13.885 km² (100% minimum convex polygon - MCP). Within this area 53 wind farms and thirteen single wind turbines were found. The transmitter of eagle #5901, which received four positions per day, generated 696 positions in 174 days resulting in an area of 9.144 km² (100% MCP) including an extensive excursion to the coast of the North Sea west of Bremerhaven. Without this excursion, the reduced MCP covers 2.894 km² including 11 wind parks and seven single turbines. Neither eagle was recorded near wind turbines or flying through wind farms. Even wind power plants close to the natal nests were not crossed or approached. The satellite transmitter of eagle #5902 receiving four positions per day sent 647 locations over 173 days giving a dispersal area of 43.082 km² (100% MCP), also including one large single excursion to the Netherlands, west of Arnhem. Removing this long excursion from the MCP resulted in a dispersal area of 2.020 km² including 11 wind farms. The closest distance of a single satellite fix to a wind turbine was 150 m. Assuming that direct connections between two single positions representing more or less direct flight routes, 15 flights went directly through or very close to the wind park closest to the natal nest. One subadult WTSE (#2356) was captured in the Mecklenburg Lake District by using the noosed fish method and fitted with a GPS-GSM device in August 2008. This still active satellite transmitter was programmed for only one position per day to save battery power. It has sent 99 positions since capture. The position data from 99 days were used to calculate a dispersal area of 2.298 km² (100% MCP). Nine wind parks and three single wind turbines were located within the dispersal area. The closest distance of a single position of this eagle to a wind turbine was 150 m. The core area of activity (5% Kernel) lies only 10 km southwest from the place where the eagle was captured.

Visual observations

Visual observations of the juvenile eagle #5902 confirmed that the eagle flew through the wind park as suggested by the automatically received GPS positions. However, 97% of the time of observation (~ 110 hours), the eagle did not move or was out of sight (Fig. 1). During the 185 min. when the eagle was flying or circling in the area of the wind park, (only 3% of total observation time, Fig. 1), the bird often flew above the blades of the generators (39% of observed flight time, Fig 2). In two out of three cases when the eagle flew within the area swept by rotor blades there was no wind and no movement of the propellers. During time spent observing the young eagle, the parent birds were also observed passing through the wind park. An adult White-tailed Sea Eagle visited the wind park on two consecutive days in

August, when up to three pairs of Red Kites (*Milvus milvus*) were also present, searching for food after a farmer had spread dung on the field.

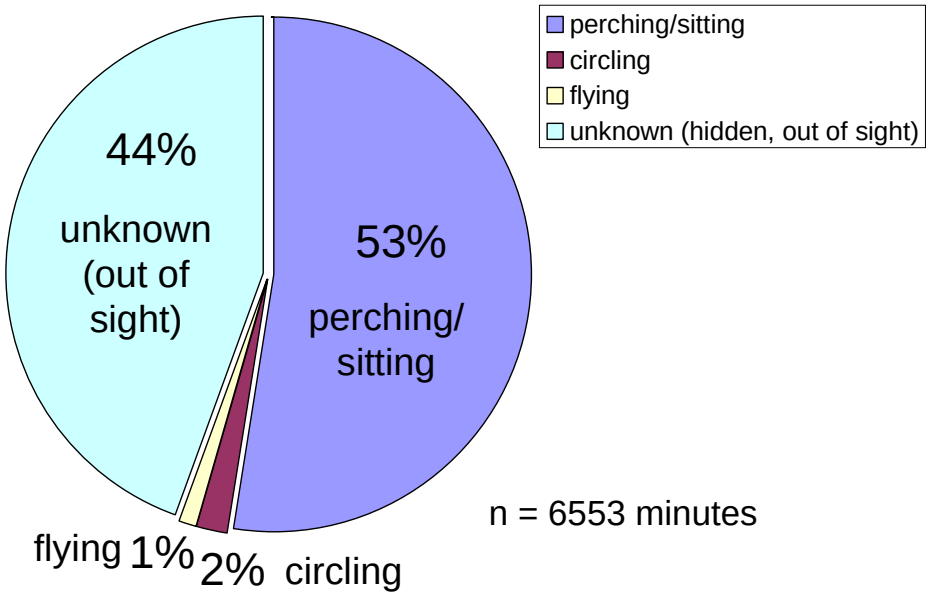

Fig. 1: Time budget of the juvenile White-tailed Sea Eagle #5902 in the post-fledging period from July to September 2008 (overall observed time = 6553 min.).

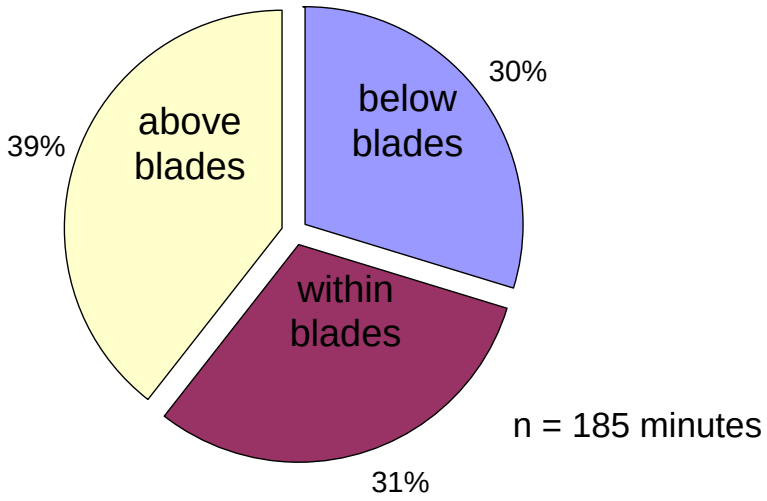

Fig. 2: Flight heights of the juvenile White-tailed Sea Eagle #5902 in the post fledging period from July to September 2008. Graph shows the flight heights during the time when the observed eagle was flying or circling near turbines in the wind park (185 min. = 3% of the overall observed time in Fig. 1).

Discussion

Both our visual observation and telemetry results show that both young and adult WTSEs fly into and through wind parks, exposing themselves to the risk of collision. Obviously, WTSEs are not afraid of wind turbines. Permanent or temporary structures or food availability may be one reason why eagles approach and hunt or feed on carcasses near to or within wind farms. As shown in our study, a sub adult eagle visited a field water hole only 150 meters from a wind park consisting of eight turbines. An adult, together with a juvenile eagle, was seen crossing a neighbouring wind park. In addition, an adult eagle was observed circling above the wind park while a farmer was spreading dung on the field. , Wind power plants are mainly situated in places with the highest number of windy days, which may depend on region, relief, wind speed, thermals and updrafts. Those places maybe open countryside, hills, mountains, ridges, and fjords [use “sea inlets” unless referring to Norway or Greenland] which are also frequently used by large birds for hunting, aerial display or other daily requirements, taking advantage of updrafts and thermals. In contrast to other studies on the problem of birds colliding with wind turbines (FOLLESTAD et al. 2007, HUNT 2002, SMALLWOOD & THELANDER 2004) in Germany collision can potentially occur throughout the landscape, without any particular concentration at specific locations. In order to reduce the risk of collisions in wind farms, permanent or temporary structures that provide perches or potential prey should be reduced, or should be considered for omission at the planning stage. Regardless of potential perches, prey abundance in the wind park area is possibly one of the most important factors that attracts raptors into wind farms. Wind parks should be built outside the average home range size of the WTSE. However, only very few data exist on the home range size of WTSE. Most estimates varied between 12 to 120 km² (LOOFT & NEUMANN 1981, OEHME 1975, STRUWE-JUHL 2000). The first telemetry study on a territorial WTSE in Germany revealed a 4,5 km² home range size calculated as 95% kernel, and 8,2 km² calculated as minimum convex polygon (KRONE et al. 2009). The rather small home range size may be explained in this case by good quality habitat including part of a large freshwater lake. Other home ranges may be much larger and excursions might also lead into wind farm areas. To reduce the risk of collision the Länder-Arbeitsgemeinschaft der Vogelschutzwarten (Working Group of German State Bird Conservancies) suggests a minimum separation distance of 3 km between wind power plants and the nearest WTSE breeding place. Additionally, within a radius of 6 km to the breeding place, eagle flight lines and hunting grounds should be considered when planning a wind park (*Länder-Arbeitsgemeinschaft der Vogelschutzwarten* 2007). Those measures may mitigate the risk for breeding pairs, but not for young eagles during their dispersal, or older birds searching for a territory. Regardless of age and spatial behaviour, hunting eagles might be attracted into the area of a wind park due

to potential prey. Thus, the structure within a wind park should not form a feeding ground for geese or other waterfowl, nor for small mammals. Even occasional fertilizing of the field by the farmer with dung, which might have contained dead mice or rats, attracted raptors into a wind farm and increased their risk of collision.

References

FOLLESTAD, A., Ø. FLAGSTAD, T. NYGÅRD, O. REITAN & J. SCHULZE (2007): Wind power and birds at Smøla 2003 – 2006. – NINA Report 248.

HUNT, W. G. (2002): Golden eagles in perilous landscape: predicting the effects of mitigation for wind turbine blade-strike mortality. Californian Energy Commission, available at http://www.energy.ca.gov/reports/2002-11-04_500-02-043F.PDF

KRONE, O. & C. SCHARNWEBER (2003): Two white-tailed sea eagles (Haliaeetus albicilla) collide with wind generators in northern Germany. J. of Raptor Res. 37: 174-176.

KRONE, O., BERGER A., & R. SCHULTE (2009): Recording movement and activity pattern of a White-tailed Sea Eagle (Haliaeetus albicilla) by a GPS datalogger. J. Ornithol. 150: 273–280.

Länder-Arbeitsgemeinschaft der Vogelschutzwarten (2007): Abstandsregelungen für Windenergieanlagen zu bedeutsamen Vogellebensräumen sowie Brutplätzen ausgewählter Vogelarten. Berichte zum Vogelschutz 44: 151-153.

LOOFT, V. & T. NEUMANN (1981): Seeadler – Haliaeetus albicilla. In: LOOFT V, BUSCHE G (eds) Vogelwelt Schleswig-Holsteins Bd 2, Wachholtz, Neumünster, Germany

MOLLY, J. P. (2008): Ermittlung der deutschen Wertschöpfung im weltweiten Windenergiemarkt für 2007. Erhebung des Deutschen Windenergie Institutes (DEWI) im Auftrag des Bundesverbandes WindEnergie und des VDMA (http://www.dewi.de/dewi/fileadmin/pdf/publications/Statistics%20Pressemitteilungen/30.06.08/Statistik_1HJ_2008.pdf)

OEHME, G. (1975): Zur Ernährungsbiologie des Seeadlers (Haliaeetus albicilla), unter besonderer Berücksichtigung der Populationen in den drei Nordbezirken der Deutschen Demokratischen Republik. Ph. D. Thesis, Universität Greifswald, Germany.

SMALLWOOD, K.S. & C.G. THELANDER (2004): Methods to reduce bird mortality in the Altamont Pass Wind Resource Area. Californian Energy Commission, available at http://www.energy.ca.gov/reports/500-04-052/2004-08-

STRUWE-JUHL, B. (2000): Funkgestützte Synchronbeobachtung - eine geeignete Methode zur Bestimmung der Aktionsräume von Großvogelarten (Ciconiidae, Haliaeetus) in der Brutzeit. Populationsökologie Greifvogel- und Eulenarten 4: 101-110.

Summary of the general discussion on Tuesday, 21st October

R. MAY asked about the general purpose of the project.

Answer: The project aims to achieve better understanding of the reasons for collisions of raptors at wind farms. With better knowledge about the reasons for collisions, management measures to avoid or reduce collision risk for Red Kites and other raptors at wind farms can be developed. Some proposals for this purpose already exist, e.g. the management of habitat at tower bases.

R. MAY explained that there are plans in Norway to shut down wind turbines in the spring, in order to protect White-tailed Eagles. This measure would be very expensive.

T. NYGARD asked whether removal of corpses by predators and scavengers had been accounted for adequately when analysing the results of searches for collision victims.

G. NEHLS replied that more detailed studies at monitoring sites are necessary on this topic.

Several representatives of wind energy planning agencies stressed that concrete proposals for the reduction of raptor collisions at wind farms are necessary. They asked whether the project can fulfil this demand.

It is expected that such proposals can be developed based on the results of the project. A very careful analysis of data is necessary, as public authorities and politicians will use the results for their decisions. Further studies are necessary and will be carried out when the project is extended until 2010.

Radar studies on White-tailed Sea Eagle at an onshore wind farm on the island of Smøla

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Wind energy provides renewable non-polluting energy. Norway has a large potential to utilize the wind along its long coast line by establishing offshore, near-shore or onshore wind farms. However, wind farms may also have unfavourable effects on the environment, in particular on birds. Since autumn 2005, twenty White-tailed Sea Eagles (*Haliaeetus albicilla*) have been found killed by collisions at a single wind farm on the island of Smøla, Central Norway. The Smøla wind farm is with its 68 turbines Norway's largest, and was built in two stages between 2001 and 2005. Smøla has one of the world's densest populations of White-tailed Sea Eagle.

In 2003 the Norwegian Institute for Nature Research (NINA) started an extensive research project at the wind farm on Smøla to study the impact of wind turbines on avian wildlife; with a special focus on the White-tailed Sea Eagle. The objective of the project is to obtain an improved information base and tools for the energy industry and environmental and energy authorities to use in determining siting and conflict-reduction of new wind turbine projects. The project further aims to identify the biological, species-specific, ecological and external factors which make birds vulnerable to wind turbines, and assess the population consequences of wind turbine induced bird mortality.

To assess the spatial responses and consequent collision risk of White-tailed Sea Eagles to wind turbines we employ avian radar technology, in addition to GPS satellite telemetry. The first part aims to investigate the spatial responses of White-tailed Sea Eagles to wind turbines at different spatial scales (i.e. loss of habitat due to displacement effects, and movement patterns and avoidance effects). The second part aims at constructing statistical collision models for estimating the risk of collisions between White-tailed Sea Eagle and wind turbines, given their resource utilisation and flight behaviour.

In spring 2008 the Merlin Avian Radar System (DeTect, Inc.) was set up at the Smøla wind farm, and has recorded bird activity continuously since. The radar system gathers data using horizontal S-band radar and vertical X-band radar. Within the trailer the radar images are automatically analysed and detections are stored in Access databases, which are downloaded automatically once a day to NINA headquarters in Trondheim through a wireless broadband connection. The radar system detects and tracks birds ('targets') of various sizes on the horizontal plane within a circular area with a radius of 3.7 km (2 nautical miles). In addition flight altitudes up to 5,000 m are recorded within a strip with a width of approx. 300 m and a range of 2.8 km (1.5 nautical miles). Because the system is built on top of a trailer, it can be placed practically everywhere on level ground. It may be powered either by generator or commercial power; at Smøla it is connected to one of the turbines. The radar was placed in the best suitable place in the centre of the wind farm to enable the capture of all bird activity within and directly surrounding the wind farm.

The first preliminary results from the radar data clearly show the spring migration activity, which is at its heaviest in April. Migration activity was highest during the night; whereas daytime activity shows a pattern more characteristic to resident bird activity (see examples below). The migration was directional towards north to northeast and mainly happened at higher altitudes (i.e. high over the wind farm); although some avoidance of the wind farm has been recorded.

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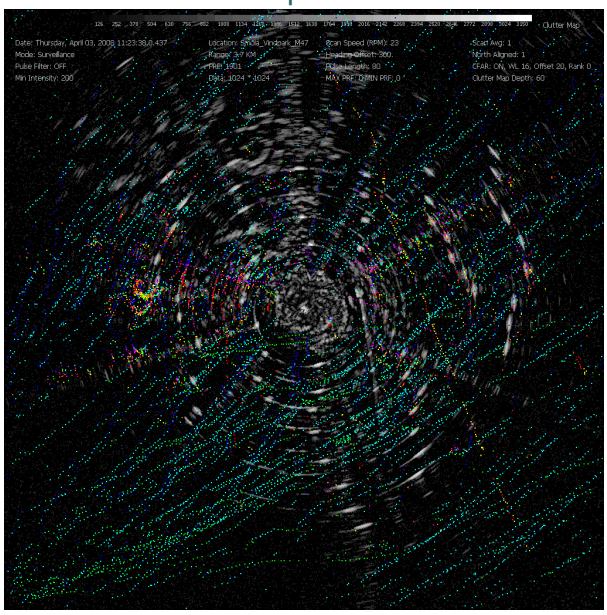

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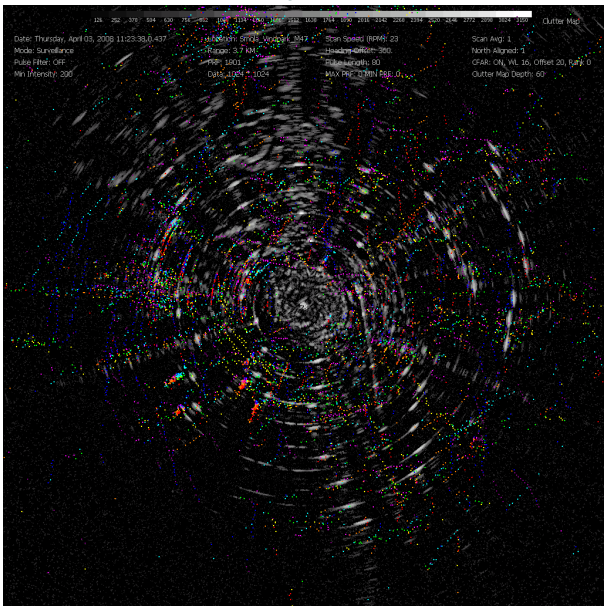
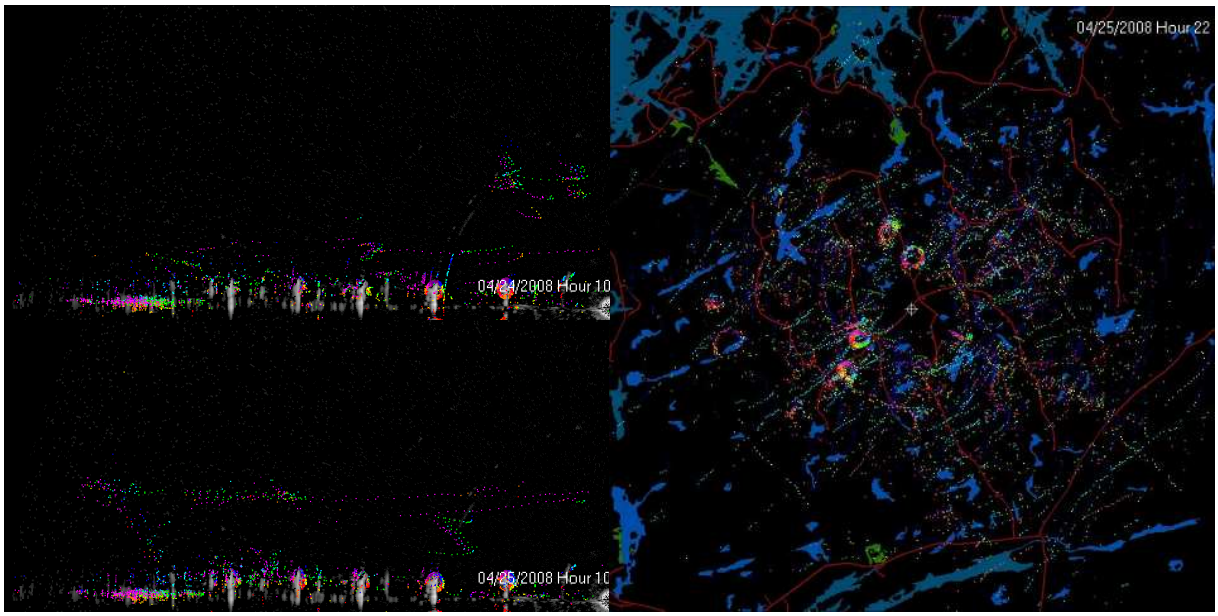


A central component within the radar studies is the verification whether Sea Eagles that have been found killed by a wind turbine have actually been tracked by the radar. A first check on the six dead eagles found in spring and summer 2008, revealed that in most cases one or two tracks were recorded to have ended within a 50 m radius of the wind turbine. These tracks were recorded during late evening or early morning.

The fine-scale recording of avian movements of the radar (i.e. one tracking point every third second) enables us in our further work to analyse movement patterns carefully, and investigate bird behaviour more closely. Specific Sea Eagle behaviour, such as thermal circling (see examples below – left-hand panel), can easily be distinguished. Also other behavioural phenomena have been recorded this spring; so-called bird circles (below – right-hand panel). As yet we do not know which species is responsible for these circles, which were performed at one specific altitude below or at rotor swept height, they were created especially at night (21:00-03:00) towards the end of April.



Within the next stages of the project, the methodological aspects of using radar technology will be assessed. This includes ground-truthing radar data, executing detection and calibration tests using model airplanes and aluminous spheres, and developing the information-technological infrastructure for data flow and storage (many terabytes of data). When these methodological challenges have been met, filtering of and analysing the data can commence.

Investigation of the spatial requirements (i.e. habitat selection, flying patterns) of White-tailed Sea Eagle enhances our understanding of their spatial response to wind turbines at different scales. Flying behaviour will be assessed using direct observations, GPS satellite telemetry data and radar flight tracks. The spatial responses of White-tailed Sea Eagles to wind turbines at different spatial scales will simultaneously form important bird-related information for the development of the collision risk models. The purpose of constructing collision risk models is to identify which factors contribute to an increased risk of collision between birds and wind turbines.

Summary of the discussion see next contribution (P. Lund-Hoel)

Do wind power developments affect the behavior of White-tailed Sea Eagles on Smøla?

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Introduction

Concerns about climate change have resulted in promotion of renewable energy sources, and in Norway there has been increased focus on the potential of wind energy production. A concern raised against widespread wind power plant development is, however, that it may negatively impact bird populations as a result of collisions with turbines, habitat loss and disturbance. One important aspect to consider when assessing the possible impact of wind power development on bird populations is changes in behavior as a response to the wind power plant and the turbines.

In this study I investigated the effects of a wind power plant development on the behavior of White-tailed Sea Eagles (*Haliaeetus albicilla*) (WTSE) on Smøla on the coast of mid-Norway (63°24´N, 8°00´E), which is a stronghold of this sp ecies. In this area 21 individuals have been found killed by collisions with wind turbines since the second phase of the wind power plant became operational in August 2005 and until January 2009 (BEVANGER, CLAUSEN et al. 2008).

Methods and materials

In order to see if there were any behavioral differences related to the distance from turbines, data on flight activity and flight height were collected at 12 vantage points, 6 inside the wind power plant area and 6 control areas. In the analysis they are named wind power plant area (WPA) and control area (CA). The flight activities were categorized into three groups; moving flight, social behavior (containing chasing/fighting and spiraling/playing), and soaring. The flight heights are categorized into three groups; below rotor zone (0-29 m), in rotor zone (29-111 m) and above rotor zone (>111 m).

Firstly, I wanted to investigate which explanatory variables could account for variation in the general activity. General activity was calculated using percentage of total duration of observed activity in each two-hour observation period. Secondly, I investigated which variables could account for variation in flight activity, and thirdly which variables could explain differences in flight height.

Any variation in the two response variables (flight activity and flight height) could possibly be explained by several different explanatory variables. In order to investigate which variables influenced the response variables, the following data were collected: (a) distance to nearest turbine (0-500m and >500m), (b) distance to nearest active nest (0-500m and >500m), (c) number of individuals observed together (1, 2, or >=3), (d) date (week number), (e) time of day, (f) weather (precipitation, temperature and wind speed), and (g) age (sub adults, adults, unknown). Binoculars with range-finders were used to determine distance.

Data collected from 144 observation hours, during mid- March to the end of May 2008 were analyzed using ANOVA, Chi-square tests and multinomial logistic regression analysis.

Results

The explanatory variables that showed a statistically significant effect on the general activity were week number and distance to nearest active nest. The results showed a statistically significant difference in activity between the weeks, with a peak in activity during April (Figure 1; week 15 and 17). This is also the period were highest number of killed Sea Eagles have been recorded (BEVANGER, CLAUSEN et al. 2008).

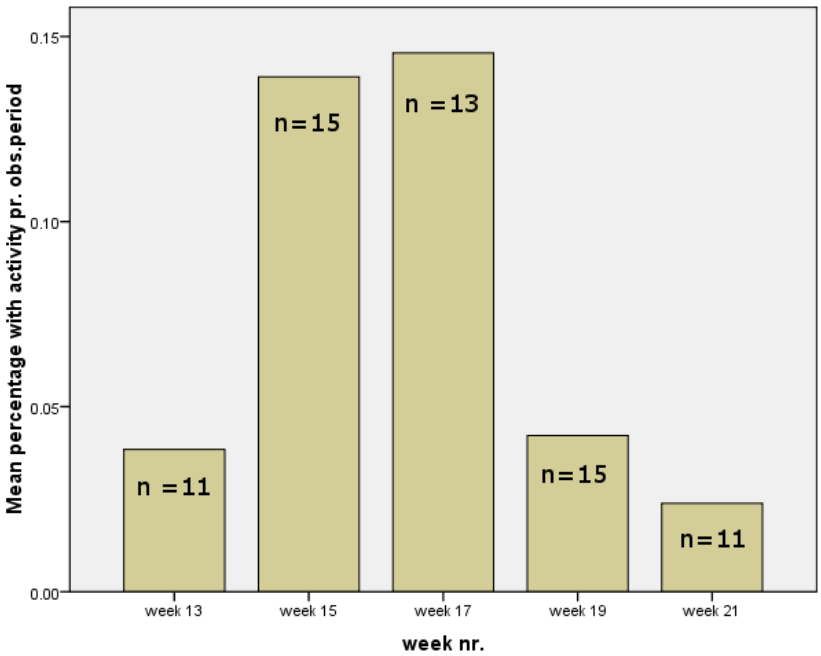

Fig. 1: Share of observed flight activity of WTSE of total observation time per observation week.

The distance to the nearest active nest did also have a statistically significant effect on the general activity, with much more activity more than 500 m from the nearest active nest; 14 % of the general activity was observed between 0-500m and 86% of the general activity at distances more than 500m.

Neither distance to nearest turbine, nor the locations seem to have any effect on the general activity. Although neither of the three weather variables did have any statistically significant effect on the general activity, there seems to be a decrease in activity with increasing wind strength and increase in activity with higher temperatures. This could be due rising air currents and thermals that can provide lift that enables a bird to maintain height or gain a greater altitude at less cost.

Furthermore, there was a statistically significant difference in age distribution between the two locations, with a higher percentage of adults in CA and a higher percentage of sub adults in WPPA. Of the 21 killed sea eagles found on Smøla, there are 14 adults and 7 sub-adults.

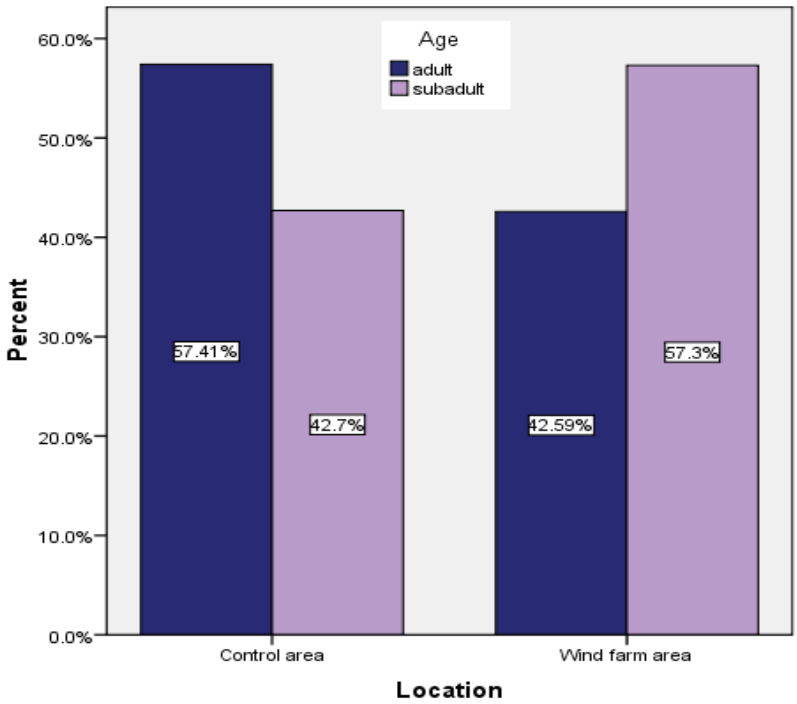

Fig. 2: Age distribution (%) of WTSE in the control area and the wind power plant area ($N_{CAadult}$=182, $N_{CASubadult}$=79, $N_{WPPAadult}$=135, $N_{WPPAsubadult}$=106).

Regarding flight activity, Table 1 shows which variables had significant effect on the differences between the flight activities. There were, as expected, more individuals observed flying together during social behavior than the other two activity categories. There was also a significant difference between social behavior and the other two activities related to age, with more adults than sub adults in social behavior than in moving flight and soaring. Comparing this result with the age distribution found among the collision victims, this could indicate that social behavior could expose the individuals to a higher risk than the other activities. The analysis did not, however, show any statistically significant differences between the flight

activities related to distance to nearest turbine. Therefore, the reasons for more adults than sub adults killed in the wind power plant area remain open.

Moving flight and social behavior occurred more frequently in the flight height below the rotor zone than soaring, which was not surprising as soaring as a rule is performed quite high above the ground.

Table 1: Results from the multinomial regression analysis.

Flight behavior	Explanatory variable	B	SD	df	Sign.
Moving flight vs. Social behavior	Number of individuals observed together	4.201	0.503	1	<0.001
	Age	1.084	0.535	1	0.042
Moving flight vs. Soaring	Number of individuals observed together	- 1.900	0.762	1	0.013
	Flight height: below rotor zone	-3.721	1.022	1	<0.000
Social behavior vs. Soaring	Number of individuals observed together	-6.101	0.852	1	<0.000
	Flight height: below rotor zone	-2.663	1.182	1	0.024
	Age	-1.221	0.569	1	0.032

When considering flight height as the response variable, there was a statistically significant difference between the WPA and CA in use of the different flight heights, with more activity below rotor zone in CA than in WPA (Figure 3). This could possibly be due to statistically significantly differences in mean temperature between the locations when conducting the observations, with warmer mean temperature, during observations in the WPA than in CA.

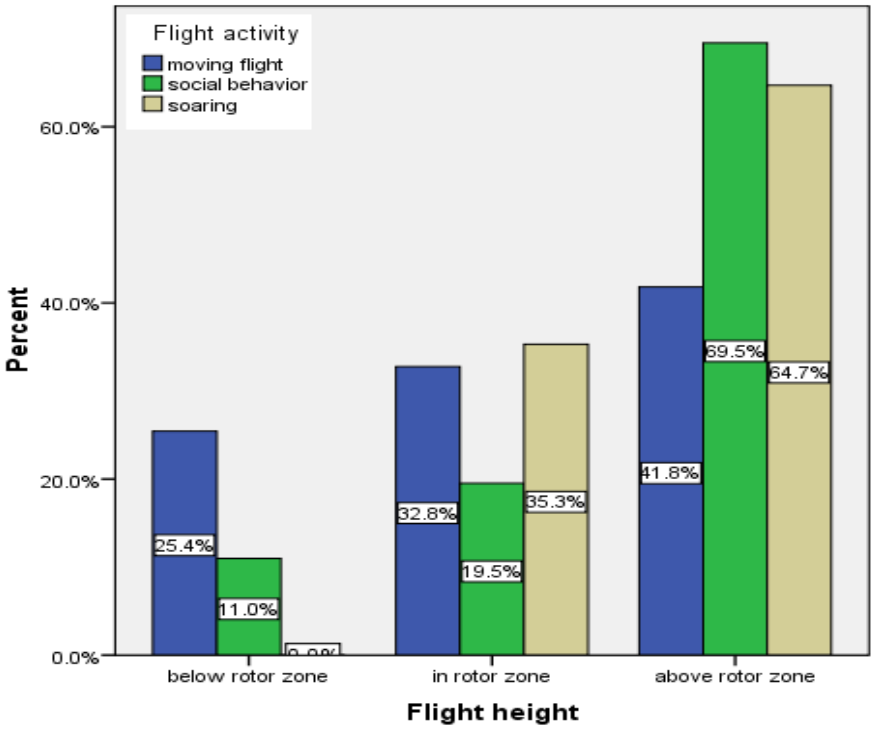

Fig. 3: The distribution (%) of the different flight activities of WTSE in the different flight height categories.

Table 2 show which variables that had significant effect on the differences between the flight heights. There was a statistically significant difference between the flight height in the rotor zone and above the rotor zone related to number of individuals observed together, with more individuals observed together above the rotor zone than in the rotor zone. This is consistent with the results from multinomial logistic regression with flight activities as response variable, showing that there are more individuals involved in social activities than in the other activities, and that social activities mostly occur above the rotor zone.

Table 2: Statistically significantly results from the multinomial regression analysis, with the flight height categories as response variable.

Flight height	Explanatory variable	B	SD	df	Sign.
Below rotor zone vs. in rotor zone	Temperature (ºC)	0.195	0.070	1	0.006
	Between moving flight and the other activities	-3.300	1.030	1	0.001
	Between social behavior and the other activities	-2.706	1.216	1	0.026
Below rotor zone vs. above rotor zone	Temperature (ºC)	0.218	0.068	1	0.001
	Between moving flight and the other activities	-3.560	1.025	1	0.001
	Between social behavior and the other activities	-2.672	1.182	1	0.024
In rotor zone vs. above rotor zone	Number of individuals observed together	0.605	0.320	1	0.059
	Precipitation	0.912	0.478	1	0.056

Discussion

These results indicate that the White-tailed Sea Eagles on Smøla do not have any behavioral responses to the wind power plant construction, as none of the response variables differed significantly within the wind power plant area versus the control areas. It may, however, contribute to explain why the WTSE is vulnerable to collisions with the turbines and the high number of killed individuals recorded within the power plant area. The WTSE has a peak activity during the breeding period, which can be fatal to both adult individuals and thus also the nestlings. This should be carefully considered when looking at the possible long-term effects of the wind power plant on the White-Tailed Sea Eagle population on Smøla, and for further developments of wind power plants along the Norwegian coast. When considering mitigation measures and management actions it should be noted that the activity also changes with weather conditions, and that the collision risk probably will increase during periods with high temperatures and low wind speed– especially combined with increased activity during the breeding season.

Acknowledgements

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Reference

BEVANGER, K., S. CLAUSEN, et al. (2008). “Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway” Progress Report 2008. Trondheim, NINA. Report 409.

Summary of the discussion after all talks of the White-tailed Sea Eagle project on Smøla

D. SKAMBRACKS asks why the breeding success of White-tailed Sea Eagles originally had been higher within wind farm than in the surroundings?

Answer: Probably the lower human settlement density had been the cause for high breeding success in this area.

Some additional remarks by the authors: Wind turbines had no signal lights. One turbine was monitored with the help of infra-red camera. In comparison to humans dogs appeared to be very effective in search for collision victims.

It is asked what the consequences of the results were for other wind farms in Norway.

Answer: The realisation of new wind farm projects is stopped until the final results of the studies at Smøla are available.

The opportunities to avoid collisions were discussed. The question was raised whether radar and cameras could be used to stop the rotor when a bird approaches.

B. DE WOLF states, that although wind turbines can be stopped within a short time, this would not be quick enough to react to a flying bird. Stopping time is also dependent on current wind velocity. In general, the turbines could be temporarily cut off at special conditions (migration weather).

Studies on threatened species of birds of prey and wind farms in eastern North America

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Introduction

With the world wide development of the wind industry, there are a growing number of wind facilities that have been built in sensitive areas where birds of prey may collide with wind turbines, increasing mortality rates in populations of species that are often at risk. Wind energy is rapidly growing in North America. In Canada, the total production has grown from only 137 MW in 2000 to 1876 MW in 2008 (Canadian Wind Energy Association 2008). This rapid wind energy development is occurring in almost all Canadian provinces. In the province of Quebec, where there are presently 450 turbines in operation, there are plans to attain a total of about 1900 turbines by the year 2015 (Ministère des Ressources naturelles et de la Faune 2008). Two-thirds of these are planned in the Gaspe Peninsula, in the eastern part of the province. There are three species of raptors designated as vulnerable in the province, the Golden Eagle (*Aquila chrysaetos*), the Bald Eagle (*Haliaeetus leucocephalus*) and a subspecies of the Peregrine Falcon (*Falco peregrinus anatum*). All three of these species breed on the Gaspe Peninsula. A research project has been initiated in Quebec in order to reduce collision risk during the breeding season for these species.

Many raptor species nesting in eastern Canada also migrate through the Appalachians in their movements to and from their wintering grounds in the eastern United States where they are also facing wind energy development. A collaborative work has been initiated to track Golden Eagles during these migratory movements. This paper has thus two sections, each presenting the studies carried out on the breeding grounds and during migration, in a coordinated effort to protect raptors during their whole life cycle.

Breeding grounds in Quebec, Canada

Nests of the three vulnerable raptor species located within 20 km of planned wind facilities are targeted for the capture of birds that are equipped with Argos/GPS satellite transmitters. The objective is to delineate the home ranges of these birds and to determine if there will be

an overlap with the projected limits of the wind facility. In 2007-2008, 17 birds have been marked: 5 adult and 2 juvenile Golden Eagles, 6 adult and 2 juvenile Bald Eagles, and 2 adult Peregrine Falcons.

The general idea is to provide protection within the home range of the birds, the dimensions and configuration of which may vary considerably from site to site according to habitat availability and other environmental conditions, instead of having a fixed buffer area around the nest which may not provide adequate protection. Should overlap occur between the home range of one of the marked birds and the wind facility, detailed data obtained from the transmitters (altitude, seasonal use, etc) will help determine collision risk and identify possible mitigation measures to reduce this.

For Bald Eagles, preliminary results indicate relatively small home ranges (30-50 km^2). Moreover, Bald Eagles usually nest alongside big lakes where they mostly hunt and eat fish during the breeding season. Thus, their home ranges are mostly concentrated along the shores of these lakes. There are cases where Bald Eagle home ranges are split in more than one core activity area. But altitudinal data clearly indicate that the birds fly considerably higher than turbine height during their movements between these areas. And finally, in many areas, planned buffers already exist around large lakes for landscape protection. Because of all these factors, wind facilities may not represent a major threat for Bald Eagles.

Golden Eagle home ranges are not concentrated around lakes and cover areas (580-750 km^2) that are more than ten times that of Bald Eagle home ranges. With such large home ranges, there is a much greater probability of overlap with future wind facilities. The Golden Eagle nest that was the closest to a planned wind facility was not occupied in 2008, so the birds could not be captured and equipped with a transmitter. Construction of this wind facility is planned for 2009, so it will not be possible to delineate pre-construction home ranges. Efforts will be made in early spring of 2009 to mark one of the adults. Tracking the movements of this bird will help compare the behavior before and after construction and, if the bird does use the wind facility area, possibly lead to mitigation measures to reduce collision risk.

Preliminary results also indicate relatively large home ranges (245 km^2) for Peregrine Falcons. For one of the two marked falcons, we have obtained the first case of confirmed overlap between the home range and a projected wind facility. Since this overlap covers most of the wind facility, considerable discussions are expected during the next few months to identify possible mitigation measures.

In the near future, research effort will target the cases of overlap between home ranges of vulnerable species and future wind facilities. Mitigation measures adapted to each case may be identified from the data obtained. The altitude of flight of birds within overlap zones will be examined to determine collision risk. There will be fewer concerns in situations where data indicate that birds fly over turbine height. But adaptive approaches will have to be developed when flight altitude will be mostly within turbine height. In these cases, data will also be examined to determine if part or the whole of the overlap zone may be used only seasonally, indicating that the birds may be attracted to these areas by food sources that become available at particular times of the year. In such situations, partial shut down of wind turbines within the overlap zone could be proposed during the period of collision risk. Ultimately, if there is absolutely no way of identifying adequate mitigation measures, the process could lead to the complete exclusion of wind turbines within the overlap zone.

Habitat modeling to predict home range limits

Since it would be presumptuous and costly to continue marking all individual birds whose nests will be located close to wind facilities in the future, there is another objective to our project. GIS habitat analyses will be carried out within the home ranges of the birds that will be tracked, in order to develop habitat models (McGrady et al. 2002, McLeod et al. 2002) for each of the three vulnerable species that we monitor. Based on habitats available around the nests of birds that will be located near future wind farms, these habitat models will be used to determine the potential home range limits of these birds. The same approach of determination of overlap zone and subsequent development of mitigation measures could then be adopted.

Migration of Golden Eagles in the eastern United States

In addition to delineating home ranges in the Gaspe Peninsula, we are also focusing on identifying potential conflicts that may arise during Golden Eagle migration. Here we explore indicators that may be used to identify and quantify potential conflicts and the effects of those potential conflicts at a population level.

Raptors use two strategies in order to minimize energetic costs of migration. They often use thermal lift which is generated when the sun warms the ground and the ground warms the air. This warm air rises and creates lift which birds utilize to gain altitude. Often times, especially during the warmer months, birds circle, rise and then glide off to catch another thermal.

However, thermal activity decreases during the colder months of the year and birds migrating through Pennsylvania at that time, including Golden Eagles, rely much more on topographic

lift or updrafts. Updrafts are created when wind blows and hits a ridge or other high relief topographic feature. These updrafts are very important for birds utilizing the Appalachians. And this is where the potential for conflict occurs, because birds and wind facilities both utilize the same resource.

During fall migration, Golden Eagles are spatially and temporally segregated by age class. Adults are more abundant along the western ridges of the mid-Appalachian region, juveniles along eastern ridges. Spring migration is less segregated; Golden Eagles concentrate along the central and western ridges. Because these ridges are also being targeted for wind power facilities, there is a potential for negative wind-wildlife interactions. Among the raptor species migrating along these ridges, eagles may be the most at risk. FARMER (2006) conducted a pilot study at Hawk Mountain, located in the ridge area, and found that 88% of eagles, both Bald and Golden Eagles, passed within the strike zone altitude of turbine blades.

Sinuosity index

To determine if there is a difference in migratory behavior among age classes, we calculated a sinuosity index of full length migratory tracks. The sinuosity index is a measure of how directly birds travel from wintering grounds to breeding grounds. The higher the sinuosity index, the less direct the flight path and greater the distance a bird is actually flying to get from point A to point B. Not unexpectedly, we found that young birds have a significantly higher sinuosity index than adults, indicating that their potential for negative interactions with turbines may be greater. Eventually, this index will be one of the many variables incorporated into a population level model of the potential impacts of wind power.

Roost site habitability model

Negative effects of wind power development in the mid-Appalachians include not only collision, but also indirect effects such as habitat loss. To examine the potential loss of migratory stopover habitat, we generated a roost site habitat suitability model, following HIRZEL et al. 2002, and compared turbine sites with optimal, suitable, marginal and unsuitable roost habitat. Thus, a map was created indicating turbine sites more and less likely to impact roosting habitat, based on the habitat predicted by the model.

We then compared 36 turbine sites within the study area to predicted habitat within 100 m and 500 m. Eighty-six percent of proposed or existing turbine facilities are within 100 m of suitable habitat and 59% are within 100 m of optimal roosting habitat.

Direct habitat loss was measured within these same two buffers. Within a 500 m buffer of a turbine facility, the mean area of suitable habitat is 254 ± 55 ha. The mean area of suitable

habitat within 100 m of a turbine facility is 22.9 ± 5.4 ha. These results suggest that most wind power facilities have the potential to negatively impact migratory roost sites. With a limited number of wind power facilities, this may not be an issue, but cumulative effects of a large number of wind facilities in a concentrated migratory corridor could have a significant impact on the population and this must be considered and investigated further.

Temporal migratory patterns of Golden Eagles in eastern North America

Most wind facility projects in North America require some kind of environmental assessment prior to construction and some require post-construction monitoring. In order for pre- and post-construction monitoring to be useful, knowledge of temporal migratory patterns is imperative. Although rare, site environmental assessments need to be adjusted accordingly to incorporate these patterns. Furthermore, many turbine facilities already exist or are currently under construction. If, through post-construction monitoring, a facility is deemed to be a hazard to migratory birds, then knowledge of daily and seasonal movements can be used for mitigation by guiding daily and seasonal shutdown.

Using GPS satellite telemetry, we determined the timing of daily and seasonal migratory movements. Birds depart wintering grounds on March 15 ± 18 days and arrive at breeding grounds on April 9 ± 23 days. Fall departure and arrivals are more tightly concentrated, with birds departing breeding grounds October 21 ± 15 days and arriving at wintering grounds on November 22 ±12 days. Peak daily migratory activity occurs between 9:00 am and 3:00 pm.

Conclusions

A few cases of overlap have been obtained in Quebec between home ranges of threatened species of birds of prey and wind facilities planned in the vicinity of their nests. In the near future, data from these overlap zones will be examined closely to help identify mitigation measures. Eventually, a habitat model will be developed as a mechanism to predict home range limits around nests where birds cannot be tracked with telemetry units.

We need to learn more about the habits and habitats used by Golden Eagles in Eastern North America to improve and quantify our understanding of their behavior throughout the annual cycle. Preliminary results suggest that, in the East, remote forest is an important component of Golden Eagle habitat. And forested habitat in certain portions of the eastern range is being developed for wind power. This could have a negative impact on the population, but the potential impacts need to be quantified.

Our first steps at quantifying habitat loss indicate that nearly all proposed or existing wind facilities in Pennsylvania may impact potential migratory roost habitat of Golden Eagles.

However, the current model needs to be improved. BRANDES & OMBALSKI (2004) identified coarse-scale migratory routes through Pennsylvania by tracking Southeast winds through the south-central part of the state. Using this theoretical model to further refine the study area may improve prediction of roost sites.

We can use daily and seasonal peak movement timing data, for example, to guide sampling design for pre- and post-construction surveys. Furthermore, these data can be used to guide seasonal/daily shutdown of hazardous facilities.

One of the most important efforts necessary to assessing, minimizing and mitigating risk during migration, is to relate flight characteristics to topography and weather. Migration routes through Pennsylvania are relatively direct and seem to bottleneck on in the southwestern part of the state. However, it is not enough just to map one state; we have to look at migration routes through other states in the eastern United States and Canada. Satellite data are useful for modeling habitat and home ranges, and coarse migratory corridors, but are too coarse for our scale of interest, i.e., 30 m resolution. Those data cannot, at a fine scale, show how weather and topography effect fine scale flight altitude and position relative to topographic features where wind turbines are being constructed. We intend to work with high frequency data to show more precisely where problems might exist, and also help us understand behavior in relation to weather and topography, e.g., ridge life, thermaling, and how birds respond to existing wind turbines. Our eventual goal is to create a 3-D model to identify strike probability and push industry to respond with micro-siting changes.

Further research will also focus on conflicts on the winter grounds, where arguably some of the greatest conflict may occur. Thus, combining telemetry studies initiated on both sides of the Canada-US border provides an ideal coordinated effort to protect raptors during their whole life cycle.

References

BRANDES, D. & OMBALSKI, D. W. (2004): Modeling Raptor Migration Pathways Using A Fluid-Flow Analogy. Raptor Res. 38(3):195–207.

Canadian Wind Energy Association. (2008): Canadian wind farms. http://canwea.ca/farms/index_e.php

FARMER, C. (2006): Counts and flight altitudes of migratory raptors at Hawk Mountain Sanctuary, Pennsylvania. Wildlife & Wind Energy Conference. Kutztown, PA.

HIRZEL, A. H., J. HAUSSER, D. CHESSEL, & N. PERRIN (2002): Ecological-niche factor analysis: How to compute habitat-suitability maps without absence data? Ecology 83:2027-2036.

MCGRADY, M.J., J.R. GRANT, I.P. BAINBRIDGE & D.R.A. MCLEOD (2002): A model of Golden Eagle (*Aquila chrysaetos*) ranging behavior. J. Raptor Res. 36 (1 Supplement): 62-69.

MCLEOD, D.R.A., D.P. WHITFIELD, A.H. FIELDING, P.F. HAWORTH & M.J. MCGRADY (2002): Predicting home range use by Golden Eagles *Aquila chrysaetos* in western Scotland. Avian Science 2:183-198.

Ministère des Ressources naturelles et de la Faune (2008): Projets éoliens au Québec. http://www.mrnf.gouv.qc.ca/energie/eolien/eolien-potentiel-projets.jsp.

Summary of the discussion after the talk

C. MAISONNEUVE replies to a remark concerning buffer circles that are kept free of wind turbines around nest sites. No circular buffer zones around the nest location have been used in the study presented in the talk. Instead a habitat model was developed based on the home ranges of the individuals studied. Buffer zones resulted out of this model.

Mitigation in U.S. wind farms

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Introduction

Wind power generation has been proliferating across the U.S.A., so there has been considerable discussion about mitigation of wind turbine impacts on birds and bats. This discussion has been complex and contentious for a number of reasons. First, the need for mitigation has been effectively challenged by the wind industry since the National Wind Coordinating Committee's (NWCC) report claimed that buildings, autos, house cats and other anthropogenic factors cause more bird fatalities than wind turbines (ERICKSON et al. 2001). Second, wind power development outpaced the implementation of scientifically sound fatality monitoring, so scientists have lacked defensible impact estimates or predictions. Third, needed investments are expensive and have yet to be implemented sufficiently, such as pre-construction surveys for estimating both background mortality and utilization of project sites. Conclusions based on speculation and anecdotes preceded those based on scientific evidence, and mitigation plans for wind power projects too often give more weight to the unsubstantiated conclusions.

No mitigation measures were provided with the earliest wind turbine installations in the U.S. because nobody knew the nature of the impending impacts. Only after the first installations did somebody notice dead birds under wind turbines, and only afterwards did discussion of mitigation measures begin. Adverse impacts now known to be caused by wind turbines include direct, indirect, and cumulative impacts. Direct impacts include fatalities caused by collisions of volant animals with wind turbines, guy wires, anemometer towers, electric distribution lines, and transmission lines, as well as electrocutions on electric distribution poles and entrapment within wind turbine motors. Other direct impacts include habitat loss due to grading for tower pads and access roads. Indirect impacts include displacement of certain species that cannot tolerate the presence of wind turbines, or alterations of migratory flight paths and foraging patterns. Both direct and indirect impacts combine with other anthropogenic impacts, such as those described by ERICKSON et al.'s (2001) report, to qualify as cumulative impacts. Whereas all of these impacts I just listed are known to occur,

quantitative impact estimates remain relatively rare and associated with large error terms, and their rarity and associated uncertainty have been effectively used by wind project advocates to minimize mitigation requirements.

Contributing to scientific uncertainty around impact estimates, too many people in the U.S. have mistakenly regarded fatality monitoring performed by wind company consultants as scientific monitoring. In fact, the majority of monitoring reports at U.S. wind farms have not involved scientific hypothesis testing, and most did not lead to publications in peer-reviewed scientific journals. Survey methodology at U.S. wind farms has varied greatly, including field techniques, monitoring duration, and estimators of fatality rates and utilization rates that have yet to be generally accepted by the scientific community. As a result, many impact estimates are not comparable, though they are often compared anyway. Also, predictions of impacts have been consistently lower than realized impacts, sometimes astonishingly lower. However, most wind power projects went forward without impact predictions, and most of the predictions that were made have yet to be compared to post-construction estimates of impacts. In short, the wind industry's consultant reports have not been subjected to anywhere near the same level of scientific scrutiny that publicly funded research reports have been subjected, yet these reports have often been attributed equal weight.

Publicly funded research of wind farm impacts has been directed toward accurately quantifying impacts and understanding collision mechanisms, and much of this work was done in the Altamont Pass Wind Resource Area (APWRA) dating from 1989 to 2007. This is one reason why the APWRA is the logical first place to look for reviewing mitigation efforts in U.S. wind farms. Another reason is the notoriety the APWRA has earned as a source of high raptor mortality, and another is the APWRA's composition of old-generation wind turbines which ought to be considered easier to move or manipulate to test the effectiveness of mitigation measures.

Types of Mitigation

The California Environmental Quality Act Guidelines § 15370 categorized mitigation measures as generally discussed across the U.S.:

1. Avoid the impact altogether by not taking a certain action;
2. Minimize impacts by limiting the degree or magnitude of the action;
3. Rectify the impact by repairing, rehabilitating or restoring the impacted environment;

4. Reduce or eliminate the impact over time by preservation and maintenance operations during the life of the project; and,

5. Compensate for the impact by replacing or providing substitute resources or environments.

Wind farm impacts could be *avoided* by not building the wind farm, not building it where impacts to particular species are of concern, or using alternative designs that do not kill birds or bats. I am not aware of any wind power mitigation in the U.S. that involved avoidance.

To *minimize* impacts, potential wind farm and wind turbine sites could be screened for environmental impacts, and the least harmful sites selected (SMALLWOOD et al. in press). Wind turbines could be placed where birds or bats fly less often or where they are least vulnerable to collision (SMALLWOOD & NEHER in press). The blades could be placed at heights above ground where species of concern fly less often. Turbine operations could be scheduled to avoid seasons, weather events or times of day more hazardous to birds or bats, especially when power generation would be low anyway. Perhaps turbines could be designed to lock blades in place while not operating, or during peak bird or bat activity. Wind turbine operations could be synchronized throughout the row to prevent birds from attempting crossing of the row during operations. Turbines could be concentrated as much as possible, leaving open areas for traveling and foraging flights. Almost all of these measures would require extensive pre-construction utilization and behavior surveys, and most would need to be implemented before the wind turbines are operational.

The only wind turbine impacts that could be *rectified* would be the extremely rare case of injured birds being found, rehabilitated, and successfully returned to the wild. In my experience, almost all injured birds taken to rehabilitation centers are euthanized and a few are donated to zoos or public outreach programs.

After the wind farm is developed, there are few options for effectively *reducing* the impacts, even though these types of mitigation measures have been debated a great deal for two decades in the APWRA. Highly dangerous wind turbines can be identified through fatality monitoring and relocated or shut down during time periods recognized to be most dangerous (Alameda County SRC 2008). Other recommended measures in the APWRA were to install flight diverters or hazing devices, remove broken and non-operating wind turbines, remove derelict towers, and paint blades using the HODOS (2003) scheme, effectively achieving one blade black and two white. All of these measures were recommended by the Alameda County Scientific Review Committee (SRC), of which I am a member. However, the

effectiveness of none of them was tested over the last three years of Alameda County's Avian Protection Program because none were implemented adequately. Fatality rates in the APWRA did not change from earlier rates (Alameda County Avian Monitoring Team 2008, SMALLWOOD 2008a).

One APWRA company painted one blade black on 42 wind turbines, but measuring effectiveness was impossible because the company refused to cooperate with the SRC in implementing an experimental design. The treatment was applied to all the turbines in the lower of two closely aligned rows of turbines which differed in tower height, referred to as wind walls, so it was impossible to determine whether bird carcasses were deposited by treated or untreated turbines. I am also dubious that the HODOS painting scheme would be effective on large, modern wind turbines, because a bird close enough to the rotor plane for the hazard to be critical would also be unable to see enough of the rotor plane within its field of view for the HODOS scheme to have any effect on the bird.

Most of the APWRA companies agreed to shut down their wind turbines over the winter months, but not in the manner recommended by the SRC. The shutdowns were too brief relative to the fatality search interval, and without synchronization of fatality searches and turbine shutdown and reactivation dates. Also, the first two years involved a crossover design that the SRC felt might have killed more of the birds that were prone to habituation of non-operating turbines, so when the shut-down turbines were reactivated during the peak of the winter-time raptor congregation in the APWRA, many more birds were killed.

Reduction measures were also tried in the APWRA before the SRC was established. For example, the blade tips of some turbines were painted green or red, and some blades were striped with black. These treatments did not affect fatality rates (SMALLWOOD & THELANDER 2004, 2005). Also, the companies funded a rodent eradication program between 1997 and 2002, and they recruited land owners to cooperate with the program. The objective was to eliminate the main raptor prey species from the APWRA so that raptors would no longer visit. However, I discovered the program in 2002, learned where the poison had been broadcast, and tested whether the treatments affected raptor utilization and fatality rates. In most cases, I found no effects, and in some I found higher fatality rates where rodents had been poisoned. The program was halted by state and federal regulatory agencies after they learned about it, because it jeopardized the continued existence of burrowing owls and multiple threatened and endangered species that occur in the APWRA.

Outside the APWRA, the turbines in one wind farm were experimentally treated with a UV reflective paint, but no effect was found (YOUNG et al. 2003). Rodent control was promised as

a mitigation measure for the High Winds Power Project in Solano County, California (ESA 2002), again based on the unproven notion that elimination of prey base will keep raptors from visiting the areas around wind turbines.

Compensating for impacts has been the most popular mitigation measure implemented among US wind farms. The ideal compensation for impacts achieves no net loss or a net gain of the resource that was adversely affected by the project. However, compensation ratios have been arbitrary and their effectiveness unknown because no nexus has been established between wind power project impacts and mitigation benefits.

Compensation ratios offered by wind farm developers have included a 1:1 habitat area for rotor swept area among the wind turbines (Ecology and Environment, Inc. 2005, 2006), $500-$1000 for each MW of rated capacity for use in conserving property bearing raptor habitat (ERICKSON et al. 2003), and $55 / acre for twice the acreage permanently disturbed by wind turbines (LAMPHIER-GREGORY et al. 2005). Also, The Cape Wind DEIS promised $780,000 toward Roseate Tern habitat restoration on the 1.5-acre Bird Island (Minerals Management Service 2008).

Trends in Mitigation Planning Among U.S. Wind Farms

Environmental planning documents for U.S. wind farms usually portray the following wind turbine design elements as mitigation measures: Tubular versus lattice towers, slower moving blades, wider turbine spacing, and aircraft hazard lighting reduced to minimum FAA standards. However, none of these design elements were included specifically to minimize bird and bat impacts, and none have been demonstrated to do so. Research evidence in the APWRA indicates birds do not perch on lattice towers while the turbines are operating, and fatality rates were the same between turbines with lattice versus tubular towers. As for slower moving blades, the truth is that the tip speed is essentially equal across turbine sizes, whereas it is the RPM that lessens with increasing turbine size. The evidence from the APWRA was that birds were more likely to fly through the rotor zones of turbines with lower RPM, so it remains unclear whether modern turbines with lower RPM are actually safer. Likewise, birds in the APWRA were more likely to fly through rotor zones of turbines at the edges of gaps, so wider turbine spacing might not reduce fatality rates. Finally, the presence of FAA hazard lighting has repeatedly been found to not affect fatality rates of birds or bats (ERICKSON et al. 2004, KERNS & KERLINGER 2004, JAIN et al. 2007). These often seen design elements are misleading and serve to perpetuate myths about the mechanisms affecting bird and bat collisions.

Another approach to mitigation in U.S. wind farms has been to postpone formulation of specific measures by promising the appointment of a Technical Advisory Committee (TAC), which will later implement adaptive management. For example, in three sentences the Cape Wind DEIS promised to minimize impacts by claiming that post-construction monitoring data will be collected and applied to adaptive management by a TAC. The DEIS did not explain how post-construction data would be collected at sea, or how the TAC would identify mitigation measures that have not been identified anywhere else. No candidate measures were listed, nor did the DEIS explain what was meant by *adaptive management* or whether it had any resemblance to the approach as conceived by HOLLING (1978) and WALTERS (1986). Similarly, Audubon Society agreed with Alameda County and the APWRA wind companies that adaptive management developed by the SRC would be used to reduce avian fatality rates in the APWRA beginning in 2009. However, adaptive management cannot work in the absence of candidate impact reduction measures, which are very few in wind farms and so far non-existent due to the unwillingness of wind companies to implement effective reduction measures.

Mitigation plans also promise substantial measures that are contingent on population-level impacts. For example, the Hatchet Ridge Wind Project Environmental Impact Report (Jones & Stokes Associates 2007) promised that wind turbines would be subject to permanent shutdown, relocation, or time-of-day or seasonal restrictions on operations, but only if fatality rates exceed population-level effects. However, no population-level monitoring will be performed, so no data will be available to determine whether such as impact will be realized. Furthermore, the consultants who prepared the EIR were probably aware of the debate that has raged amongst wind companies and biologists over what qualifies as biologically significant impacts, so even if data were available to support a conclusion of population-level effects, the wind companies would likely successfully argue over the standard of biological significance and the uncertainties surrounding the significance finding. I predict the reduction measures listed in the EIR will never be implemented. No other measures were proposed for avoiding, minimizing, rectifying, reducing, or compensating the impacts of this wind farm.

Conclusions

Mitigation measures would be more effective if based on scientifically founded conclusions of factors affecting bird and bat collisions with wind turbines. It is essential to perform scientifically rigorous pre- and post-construction monitoring of bird and bat fatalities and flight behaviors in wind farms, as well as ecological investigations. These types of investigations have not been performed at most wind farms in the U.S., so the scientific basis for mitigation measures remains weak.

Following wind turbine installations little has been done to reduce impacts to birds and bats, and little can be done. Avoidance and minimization measures will be the most effective mitigation at wind farms, but these have yet to be implemented at U.S. wind farms. Adaptive management is often promised in environmental review documents, but largely unviable in wind farms. Offsite compensation may be the only substantial means of mitigating impacts following wind farm development. A scientifically defensible nexus between project impacts and mitigation benefits still needs to be established for compensation ratios directed toward wind farms.

The shortfalls in mitigating avian and bat impacts caused by U.S. wind turbines indicate the need for clearly written mitigation measures along with thresholds of success, the establishment of a soundly structured TAC, a substantial performance bond, and permitting by an agency that has no vested interest in the project. There is also the need for a mitigation monitoring fund and a dedicated monitor. Finally, and most importantly, the enforcement of laws and permits is essential because the APWRA companies have amply demonstrated an unwillingness to comply with their operating permits (SMALLWOOD 2008b).

References

Alameda County Avian Monitoring Team (Jones & Stokes, Inc., BioResource Consultants, Inc., University of Santa Cruz Predatory Bird Research Group) (2008): Bird fatality study at Altamont Pass Wind Resource Area: October 2005 to September 2007. Alameda County Scientific Review Committee Document M21, Alameda County Community Development Agency Planning Department, Hayward, California. http://www.altamontsrc.org/alt_-doc/m21_2008_altamont_bird_fatality_report.pdf

Alameda County SRC (SMALLWOOD, K. S., S. ORLOFF, J. ESTEP, J. BURGER, & J. YEE) (2008): Guidelines for siting wind turbines recommended for relocation to minimize potential collision-related mortality of four focal raptor species in the Altamont Pass Wind Resource Area. Alameda County SRC document P-70. P70 SRC Hazardous Turbine Relocation Guidelines

Ecology and Environment, Inc. (2005): Draft Environmental Impact Report, Shiloh I Wind Plant Project. Solano County Department of Resource Management, Fairfield, California.

Ecology and Environment, Inc. (2006): Draft Environmental Impact Report, Shiloh II wind Plant Project. Solano County Department of Resource Management, Fairfield, California.

ESA (Environmental Science Associates) (2002): Solano County High Winds Power Project. Draft EIR. Prepared for Solano County Department of Environmental Management. Appendices C and D. Fairfield, California.

ERICKSON, W. P., G. D. JOHNSON, M. D. STRICKLAND, D. P. YOUNG, JR., K. J. SERNKA, & R. E. GOOD (2001): Avian collisions with wind turbines: A summary of existing studies and comparisons to other sources of avian collision mortality in the United States. National Wind Coordinating Committee, c/o RESOLVE, Washington, D.C. 62 pp.

ERICKSON, W. P., K. KRONNER, & B. GRITSKI (2003): Nine Canyon Wind Power Project avian and bat monitoring report. Unpubl. report to Nine Canyon Technical Advisory Committee, Energy Northwest, Unreported location. 32 pp.

ERICKSON, W. P., J. JEFFREY, K. KRONNER, & K. BAY (2004): Stateline wind project wildlife monitoring final report, July 2001–December 2003. Technical Report submitted to FPL Energy, the Oregon Energy Facility Siting Council and the Stateline Technical Advisory Committee. 98 pp.

HODOS, W. (2003): Minimization of motion smear: Reducing avian collisions with wind turbines. Period of Performance July 12, 1999 – August 31, 2002. NREL/SR-500-33249, National Renewable Energy Laboratory, Golden, CO. 43 pp.

HOLLING, C.S. (ed.) (1978): Adaptive environmental assessment and management. John Wiley & Sons, New York.

JAIN, A., P. KERLINGER, R. CURRY, & L. SLOBODNIK (2007): Annual report for the Maple Ridge Wind Power Project postconstruction bird and bat fatality study – 2006. Prepared for PPM Energy and Horizon Energy.

Jones & Stokes Associates (2007): Draft Environmental Impact Report for the Hatchet Ridge Wind Project. Shasta County Department of Resource Management. Redding, California.

KERNS, J. & P. KERLINGER (2004): A study of bird and bat collision fatalities at the Mountaineer Wind Energy Center, Tucker County, West Virginia: Annual Report for 2003. Prepared for FPL Energy and Mountaineer Wind Energy Center Technical Review Committee.

Lamphier-Gregory, West Inc., Shawn Smallwood, Jones & Stokes Associates, Illingworth & Rodkin Inc. and Environmental Vision (2005): Environmental Impact Report for the Buena Vista Wind Energy Project, LP# 022005. County of Contra Costa Community Development Department, Martinez, California.

Minerals Management Service (2008): Cape Wind Energy Project Draft Environmental Impact Study. Minerals Management Service, U.S. Department of the Interior. OCS Publication No. 2007-024, Herndon, Virginia.

SMALLWOOD, K. S. (2008a): Comparison of mortality estimates in the Altamont Pass Wind Resource Area. Alameda County SRC document P-76. http://www.altamontsrc.org/alt_-doc/p76_mortality_estimates_apwra_2005_07.pdf

SMALLWOOD, K. S. (2008b): Wind power company compliance with mitigation plans in the Altamont Pass Wind Resource Area. Environmental & Energy Law Policy Journal 2(2):229-285.

SMALLWOOD, K. S., & L. NEHER. In press. Map-Based Repowering of the Altamont Pass Wind Resource Area Based on Burrowing Owl Burrows, Raptor Flights, and Collisions with Wind Turbines. Final Report to the California Energy Commission, Public Interest Energy Research – Environmental Area, Contract No. Pending. Sacramento, California.

SMALLWOOD, K. S. & C. THELANDER (2005): Bird mortality in the Altamont Pass Wind Resource Area, March 1998 – September 2001 Final Report. National Renewable Energy Laboratory, NREL/SR-500-36973. Golden, Colorado. 410 pp.

SMALLWOOD, K. S. & C. THELANDER (2004): Developing methods to reduce bird mortality in the Altamont Pass Wind Resource Area. Final Report to the California Energy Commission, Public Interest Energy Research – Environmental Area, Contract No. 500-01-019. Sacramento, California. 531 pp.

SMALLWOOD, K. S., K. HUNTING, L. NEHER, L. SPIEGEL & M. YEE. In press. Indicating Threats to Birds Posed by New Wind Power Projects in California. Final Report to the California Energy Commission, Public Interest Energy Research – Environmental Area, Contract No. Pending. Sacramento, California.

WALTERS, C.J. (1986): Adaptive management of renewable resources. McGraw-Hill, New York.

YOUNG, D. P., JR., W. P. ERICKSON, M. D. STRICKLAND, R. E. GOOD, & K. J. SERNKA (2003): Comparison of avian responses to UV-light-reflective paint on wind turbines. Subcontract report July 1999 – December 2000. NREL/SR-500-32840, National Renewable Energy Laboratory, Golden, CO. 67 pp.

Summary of the discussion after the talk

G. NEHLS asks whether there are any effects of wind parks on population dynamics of raptors?

S. SMALLWOOD answers that at present, no significant effects are detectable.

Summary of the general discussion on Wednesday, 22nd October

R. LANGSTON stated that the selection of appropriate sites is the most important way to resolve conflicts between birds and wind energy. As the distribution and density of bird species is well known, these data should be used to select the appropriate areas for wind energy.

H. HÖTKER replied that this may be the case for Great Britain, where comprehensive datasets for birds are available, but not for Germany.

It was asked whether there is proof that painting one of the rotor blades black helps to reduce the number of bird collisions.

S. SMALLWOOD answered that such tests were only performed in the laboratory, and no field experiments have taken place so far. He himself is pessimistic about the effectiveness of such a measure.

A suggestion for compensation measures was made. Improved management for protecting raptors away from wind farms could compensate for bird losses at wind farms, with the result that negative effects of wind farms have a smaller net effect on the population as a whole.

Financial support for monitoring at wind farms was considered to be important, as data about the exact mortality rates are required.

A follow up project to provide a list of management measures for the reduction of wind farm impacts on birds of prey was proposed.