Working Group of German State Bird Conservancies (Länderarbeitsgemeinschaft der Vogelschutzwarten LAG VSW)

Recommendations for distances of wind turbines to important areas for birds as well as breeding sites of selected bird species (as at April 2015)

Länderarbeitsgemeinschaft der Vogelschutzwarten (LAG VSW) (2014): Recommendations for distances of wind turbines to important areas for birds as well as breeding sites of selected bird species. Ber. Vogelschutz 51: 15–42.

This paper further develops the 2007 recommendations of the Working Group of German State Bird Conservancies for the conflict between wind energy use and bird protection. This renewed version has arisen from new scientific knowledge and new developments, such as the increasing use of wind energy in forests. For inland and coastal areas, requirements for distances of wind turbines to important areas for birds (including protected areas and sites with large bird congregations) and breeding sites of birds sensitive to wind turbines are recommended. The latter include species of grouse, herons and egrets, storks, raptors, falcons, Common Crane, Corncrake, Great Bustard, waders, gulls, terns, owls, European Nightjar and Hoopoe. For the first time, minimum distances are recommended for Honey Buzzard, Golden Eagle, Woodcock, European Nightjar and Hoopoe. For a majority of species with large home ranges, ranges of verification around wind farms are recommended beyond the minimum distances, where an increased likelihood of occurrence should be checked for and taken into account. In addition, potential cumulative impacts of wind turbines, in connection with other impact factors, are pointed out, as well as the need to keep areas of high densities of large bird species free of wind turbines due to potential impacts at the population level.

Key words: wind energy, bird protection, land-use planning, Working Group of German State Bird Conservancies

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1 Introduction

In 2007, the Working Group of German State Bird Conservancies (LAG VSW) published the position paper "recommendations for distances of wind turbines to important areas for birds as well as breeding sites of selected bird species" (Ber. Vogelschutz 44 (2007): 151-153; also known as 'Helgoland position paper'). Additional wind farms have been set up since then, providing a total capacity of 17,000 MW. By the end of 2014, a total of 24,867 wind turbines had been set up. A renewed version of the 2007 distance recommendations became necessary due to new developments:

- Climate protection and energy policy do not necessarily contradict biodiversity protection. Nevertheless, conflicts regularly occur when wind turbines are being planned. In order to minimize these conflicts, LAG VSW has reviewed the current knowledge and describes how the planning and setting up of wind turbines can be optimized on the bird interest.
- Jurisdiction has increasingly contoured nature conservation legislation. This mainly applies to special species conservation (§ 44 of the Federal Nature Conservation Act) and to site protection in Europe (§ 34 of the Federal Nature Conservation Act).
- Furthermore, there is new scientific knowledge concerning the conflicts between wind energy use and bird protection, for example regarding cumulative impacts (see chapter 4).
- Also, there is an increasing use of wind energy in forests, which until recently only played a minor role. This means that there is now a stronger focus on bird species occurring in forests.

German State Bird Conservancies have extensive knowledge about wind energy and bird conservation. The State Bird Conservancy Brandenburg has been collecting all available data on birds that have collided with wind turbines. This database is continuously updated and available on the internet (http://www.lugv.brandenburg.de/cms/detail.php/bb1.c.312579.de). It was in spring 2002 that the LAG VSW decided to collect data systematically; nevertheless the database also contains some older data.

This database is an ideal tool to assess relative collision risks for different bird species (ILLNER 2012), even though it does not exclusively contain data from systematic surveys, but also incidental finds. It is important to note that incidental finds are only the tip of the iceberg and that far more birds are being killed after having collided with a wind turbine. This is because the chance to actually find collided birds is very low and because the carcasses only remain for a very short time under the towers. We know from former surveys that collided birds are quickly removed by predators, scavengers and also by humans. The number of losses is therefore remarkably higher than the number of birds actually found. A systematic search for carcasses accompanied by further investigations enable us to extrapolate and to assess effects on population scale, as did BELLEBAUM et al. (2013) for the red kite.

Not only does the State Bird Conservancy Brandenburg collect data concerning collisions, it also compiles scientific studies about the risk potential of sensitive bird species (http://www.lugv.brandenburg.de/cms/media.php/lbm1.a.3310.de/vsw_dokwind_voegel.pdf). This document contains a variety of species-specific information and data sources and is therefore an important cornerstone of this paper.

2 Application of distance recommendations

The distance recommendations given in this paper bear in mind the minimum standards for the conservation of biodiversity. Taking into account environmental protection issues creates legal certainty and helps to speed up procedures.

The distances and ranges of verification mentioned below (see tables 1 and 2) exclusively refer to the development, operation and repowering of onshore[1] wind farms in Germany. These recommendations should be used in spatial planning and in case-by-case reviews. It should be taken into account that landscape features, land use and number of affected species can vary from state to state. Therefore it might be necessary to adjust the recommendations to the specific situation of each state.

When it comes to repowering, i.e. replacing older wind turbines with new ones, it should be recognised that it is not possible to transfer permissions for the operation of existing wind farms to new wind turbines at the same site. For repowering it is necessary to carry out an assessment for the construction and operation of new wind turbines. For these assessments our distance recommendations can also be taken into account. Further aspects like landscape capacity, planned size and change in the number of wind turbines should also be taken into consideration.

From a bird conservation standpoint, repowering offers the possibility to reduce the number of wind turbines or to dismantle wind turbines in sensitive areas. Also, wind turbines become taller, which means that the rotor zone is further away from the ground. The distance between the individual wind turbines also increases. This reduces the risk of collision. However, this only applies to bird species that predominantly fly/hunt at lower heights, not to thermal soaring birds (see chapter 5). We are critical of the use of longer rotor blades because they produce much greater vortices and turbulences in their wake as they rotate. The longer wind turbine blades become the larger the areas for tower cranes and for assembly need to be. This causes increased consumption of land and also has effects on thermal conditions in the vicinity of the turbines. In forests, larger areas need to be cleared, possibly causing secondary effects.

3 Distance recommendations

Tables 1 and 2 give an overview of recommended minimum distances and ranges of verification of wind turbines to important bird areas as well as breeding sites of bird species sensitive to wind turbines. These recommendations take into account risk of collision, avoidance and barrier effects caused by wind turbines. Applying these distance recommendations in approval procedures helps to avoid conflicts with protected species. The distances given in tables 1 and 2 can also be used in spatial planning in order to identify areas of high densities of bird species sensitive to wind turbines. They help to point to higher potential for conflicts within these distances and to focus preferably on the development of wind farms beyond the minimum distances.

Table 1 shows minimum distances of wind turbines to important bird habitats. They are often situated in areas that are protected under European or national law. Not only are these areas important breeding sites, but they are also used by large congregations of resting migratory birds or for molting. The effects on these large bird congregations become stronger with increasing height of the wind turbines. Recommended minimum distance is therefore the total turbine height multiplied by ten. A minimum distance of 1,200 m has to be kept with wind farms that require immission control approval and that are comparatively low. Wind turbines higher than 200 m require distances of more than 2,000 m. In some cases even larger distances are recommended, e.g. at stopover sites for migratory birds (Köhler et al. 2014) or in areas along a major migration route (Isselbächer& Isselbächer 2001).

Table 2 shows recommended minimum distances to breeding sites of bird species sensitive to wind turbines. These recommendations are based on species-specific telemetry studies, collision data, functional-spatial analyses, long-term observations and expert assessments (see chapter 5). They represent the area around the nest site where most activity is taking place during breeding time (more than 50 % of flight activities). The recommendations for minimum distances are based on the accuracy of the data available and on the varying areas of activity. Distances are gradually set in steps of 500 meters. If a wind energy facility is being planned in an area where species with large home ranges occur, it should be examined also beyond the minimum distances if the facility is situated along frequently used flyways or in feeding or roosting grounds. Furthermore, activity patterns of territorial breeding birds should be examined when they are not breeding and when they are not restricted to their nest sites (e.g. white-tailed eagle *Haliaeetus albicilla*). Analyses of space use patterns (see Langgemach & Meyburg 2011) are appropriate methods for this. Tables 1 and 2 show ranges of verification for these analyses. These ranges of verification take into account spaces, in which there could be a higher probability for an individual bird to occur. These spaces can be derived from flight corridors, preferred hunting grounds of breeding adults and juveniles, roosting sites or certain landforms that cause favorable thermal conditions.

The size of these ranges of verification depends on the home range, i.e. the total use of space by an animal. Telemetry data, long-term observations and expert estimates were used to assess the home range of a species (see chapter 5). It does not make sense to establish ranges of verification for certain species due to their behaviour, for example for common crane (*Grus grus*), little bittern (*Ixobrychus minutus*) and honey buzzard (*Pernis apivorus*). For other species like lesser spotted eagle (*Aquila pomarina*) (Meyburg et al. 2007), the recommended distance is in most cases sufficient and takes into account changing use of habitats in a large activity area.

[1] small-scale wind turbines are outside the scope of these recommendations

Table 1:
Overview of recommended distances of wind turbines to important areas for birds: minimum distances and, in brackets, ranges of verification around wind farms.

Bird Habitats	Recommended minimum distance of wind turbine (range of verification in brackets)
Special Protection Areas (SPA) under the EU Birds Directive, with species sensitive to wind turbines in protective purpose	10 times the turbine height, at least 1,200 m
All types of protection areas under national law with species sensitive to wind turbines in protective purpose or in conservation objectives	10 times the turbine height, at least 1,200 m
Wetlands of international importance listed under the Ramsar Convention with water birds as essential subjects of protection	10 times the turbine height, at least 1,200 m
Habitats of visiting birds of international, national and regional importance (resting and feeding sites; e.g. of cranes, swans, geese, lapwings, European golden plover and Eurasian dotterel, as well as other waders and waterfowl)	10 times the turbine height, at least 1,200 m
Regularly frequented roosting sites: cranes, swans, geese (except invasive bird species), all starting with the 1 % criterion according to Wahl & Heinicke (2013); furthermore raptors/falcons and short-eared owl	crane: 3,000 m (6,000 m) swans, geese (except invasive species): 1,000 m (3,000 m) raptors/falcons* & short-eared owl: 1,000 m (3,000 m)
Main flight paths between roosts and feeding areas of cranes, swans, geese (except invasive species) and raptors	Keep free
Important national flyways with high concentrations of migratory birds	Keep free
Waters and interconnected water bodies >10 ha that are at least of regional importance for breeding or resting water birds.	10 times the turbine height, at least 1,200 m
* harriers, kites, white-tailed eagle and merlin	

Table 2:
Overview of recommended minimum distances of wind turbines to breeding sites of bird species sensitive to wind turbines. In brackets recommended ranges of verification around wind farms for frequently used feeding sites, roosts or other significant habitats.

species, group of species	Minimum distance of wind turbine (range of verification in brackets)
Grouse: Capercaillie (*Tetrao urogallus*), Black Grouse (*Tetrao tetrix*), Hazel Grouse (*Tetrastes bonasia*), Rock Ptarmigan (*Lagopus muta*)	1,000 m around areas of occurrence; keeping corridors between adjacent areas of occurrence
Eurasian Bittern (*Botaurus stellaris*)	1,000 m (3,000 m)
Little Bittern (*Ixobrychus minutus*)	1,000 m
Black Stork (*Ciconia nigra*)	3,000 m (10,000 m)
White Stork (*Ciconia ciconia*)	1,000 m (2,000 m)
Osprey (*Pandion haliaetus*)	1,000 m (4,000 m)
Honey Buzzard (*Pernis apivorus*)	1,000 m
Golden Eagle (*Aquila chrysaetos*)	3,000 m (6,000 m)
Lesser Spotted Eagle (*Aquila pomarina*)	6,000 m
Hen Harrier (*Circus cyaneus*)	1,000 m (3,000 m)
Montagu's Harrier (*Circus pygargus*)	1,000 m (3,000 m); areas with high densities should be taken into account regardless the position of the current breeding sites.
Western Marsh Harrier (*Circus aeruginosus*)	1,000 m
Red Kite (*Milvus milvus*)	1,500 m (4,000 m)
Black Kite (*Milvus migrans*)	1,000 m (3,000 m)
White-tailed Eagle (*Haliaeetus albicilla*)	3,000 m (6,000 m)
Eurasian Hobby (*Falco subbuteo*)	500 m (3,000 m)
Peregrine Falcon (*Falco peregrinus*)	1,000 m, breeding pairs of tree-nesting population 3,000 m
Common Crane (*Grus grus*)	500 m
Corncrake (*Crex crex*)	500 m around regular breeding occurrence. Areas with high densities should be taken into account regardless the position of the current breeding sites.
Great Bustard (*Otis tarda*)	3,000 m around breeding sites; winter roosts; keep free all corridors between the areas of occurrence
European Golden Plover (*Pluvialis apricaria*)	1,000 m (6,000 m)
Eurasian Woodcock (*Scolopax rusticola*)	500 m around mating areas; areas with high densities should be taken into account regardless the position of the current breeding sites.
Eurasian Eagle-Owl (*Bubo bubo*)	1,000 m (3,000 m)
Short-eared Owl (*Asio flammeus*)	1,000 m (3,000 m)
European Nightjar (*Caprimulgus europaeus*)	500 m around regular breeding occurrence
Eurasian Hopooe (*Upupa epops*)	1,000 m (1,500 m) around regular breeding occurrence
Threatened species, sensitive to disturbance: Common Snipe (*Gallinago gallinago*), Black-tailed Godwit (*Limosa limosa*), Common Redshank (*Tringa totanus*), Eurasian Curlew (*Numenius arquata*) and Northern Lapwing (*Vanellus vanellus*)	500 m (1,000 m), also applies for regular breeding occurrences of northern lapwing in agricultural landscapes, insofar as they are at least of regional importance

Colony breeders:	
Herons	1,000 m (3,000 m)
Gulls	1,000 m (3,000 m)
Terns	1,000 m (at least 3,000 m)

4 Aspects of population biology – cumulative impacts

In immission control approval procedures exclusively individuals and breeding pairs occurring in the immediate vicinity of wind turbines can be taken into account. The combined effect of a set of wind turbines taken together or the combined effect of wind turbines and other anthropogenic causes of death (e.g. electricity poles, power lines, roads, railway lines or illegal killing) are not being taken into account at this level. According to population biology, secondary effects also play a role. This may be breeding loss or reduced breeding success after an adult has died, often being the case with breeding raptors. Such cumulative impacts range from a gradual degradation of a habitat - caused by a set of wind farms - to the summation of collisions. These cumulative impacts may be far-reaching, affecting a species at population level (MASDEN et al. 2009). This means that the conservation status of a population may deteriorate in the long term, although all requirements stated in nature protection law have been fulfilled in every single approval procedure. These cumulative impacts can exclusively be taken into account on a spatial planning level. Especially large bird species depend on areas that are free of wind turbines. Only then can source populations be preserved. In this chapter we would like to draw attention to this issue. These impacts are of particular relevance to long-lived territorial species with low reproductive rates and late maturity. Even small increases in death rate can already lead to rapid national population declines of these species.

Examples from Germany and Europe

BELLEBAUM et al. (2013) estimated for the German federal state of Brandenburg that at least 308 red kites (*Milvus milvus*) are killed annually by wind turbines, representing 3.1% of the estimated post-breeding population. This number may rise to 4-5 % of the post-breeding population when turbine numbers will increase within a few years. Wind turbines as well as red kite territories are evenly distributed across Brandenburg. The authors conclude that the expansion of wind energy production will have negative effects on the breeding population of the red kite in the near future, i.e. on its conservation status. The conditions in Brandenburg, i.e. high density of red kites, evenly distributed breeding territories and number of existing wind turbines, cannot be directly applied to other Federal states.

The Landesamt für Umwelt, Naturschutz und Geologie Mecklenburg- Vorpommern (HERRMANN, unpubl.; TREU & KRONE in prep.) has analysed the mortality of white-tailed eagles. The results show that it is very important to keep areas of high densities free of wind turbines. According to the analysis the mortality risk (number of collided white-tailed eagles per wind turbine) caused by a wind turbine is seven times higher in high-density areas than in areas of low densities. That does not surprise. However, the cause for this is not just the larger number of territorial birds in areas of high density – resulting in a larger breeding population – but also the fact that non-breeding birds also congregate in these areas. Until today, areas of high densities of white-tailed eagles – regions with larger lakes and the Bodden (coastal inlets) of Mecklenburg-Western Pomerania - have been kept free of wind turbines. Development of wind turbines in these areas would cause considerable increase in mortality of the white-tailed eagle.

The situation is similar with the lesser spotted eagle. In the Brandenburg part of its range alone there are currently 662 wind turbines. These wind turbines are located along the main migratory flyway of individuals breeding in Mecklenburg-Western Pomerania. There is hardly any monitoring of avian collisions with wind turbines in the area of distribution of the lesser spotted eagle in Germany. Nevertheless 5 collisions, 4 of them lethal, have been recorded. The actual number of lesser spotted eagles killed by wind turbines is probably much higher. Modelling the population dynamics of the lesser spotted eagle in Brandenburg has shown that every single bird is important to maintain smaller populations (BÖHNER & LANGGEMACH 2004). Reduced breeding success is going hand in hand with an increasing number of wind turbines within a radius of 3 km around nest sites (SCHELLER 2007). One reason for this is the mortality of adult birds. Breeding losses and reduced breeding success – in case new breeding pairs form in subsequent years – are the consequence (see Pfeiffer 2009 for red kite). A radius of at least 6 km around the nest sites is considered imperative (LANGGEMACH & MEYBURG 2011).

CARRETE et al. (2012) have carried out studies in southern Spain, showing that mortality at wind farms is positively related to large-scale distribution and aggregation in griffon vultures (*Gyps fulvus*). Although more birds died during the non-breeding season the mortality of breeding birds is more relevant for the conservation status of the population. In their study area 342 griffon vultures were found dead, all of them were killed by 214 out of 799 turbines (approx. 27%) and more than 50% of those deaths occurred in only two wind farms.

CARRETE et al. (2009) evaluated potential consequences of wind farms on the population dynamics of the Egyptian vulture (*Neophron percnopterus*) in Spain. They came to the conclusion that Egyptian vultures have a higher mortality rate if their breeding territories (about one third) are located in wind farm risk zones. Increments in mortality rates increase extinction probability of this species. Already very slight increments in annual mortality rates (in their model 1.5 % for territorial breeding birds and 0.8 % for non-breeding birds) can have significant impact on the population of this long-lived, slowly maturing species. Territorial as well as non-territorial birds can collide with wind turbines. The maximum distance at which a wind farm killed a territorial Egyptian vulture was 15 km from its nest.

SCHAUB (2012) studied how the spatial configuration of wind turbines in the landscape affects red kite populations. He found that population growth rates declined progressively with an increasing number of wind turbines. These negative effects can be weakened if wind turbines are placed in unproblematic areas and if they are aggregated in power plants and not evenly spread across the area of distribution of the red kite.

The conclusions of these studies and analyses are:

Areas of high densities of relevant large bird species should be kept free of wind turbines. The population occurring in these areas should be able to maintain its function as source population. This source population produces an excess of individuals that can compensate losses in other regions with lower densities and lower habitat quality.

Keeping high-density areas free of wind turbines solves another problem: Feeding grounds differ in size and location in the course of a year, and from one year to the next, depending on the land use. This cannot be taken into account in analyses of space use patterns, as these are mostly restricted to a single breeding period (see LANGGEMACH & MEYBURG 2011). Furthermore, there are changes in feeding habitats due to the construction of roads and areas for assembly. They could attract raptors and could cause a higher risk of collision. This problem could also be avoided if these areas were kept free of wind turbines.

Outside of the areas of high densities wind turbines should not be spread evenly across the regions but aggregated in wind farms (see SCHAUB 2012).

In case of declining populations further analyses should be carried out at the sites where collided birds were found. This will help to identify crucial areas (as has happened in Spain with the griffon vulture, see CARRETE et al. 2012) and to carry out mitigation measures. Mitigation measures could be powering down wind turbines at certain times, reducing attractiveness of habitats, or removing particularly risky turbines.

5 Remarks on individual species and species groups

This chapter contains specific information about bird species which are described as being especially sensitive towards wind turbines due to their biology and autecology. On a case-by-case basis, further species (which are not dealt with in this document) may be added. Whether or not a species is in special danger of colliding with wind turbines does not exclusively depend on the collision risk but also on various other effects. Birds can not only collide with rotors or occasionally towers of wind turbines, they can also be disturbed by turbulences in the wake of the blades, by the noise of the turbines or maintenance work. In contrast to bats, which have been found to be killed by barotrauma (damage of the organism through sudden extreme changes in air pressure in front of or behind wind turbine rotor blades), it is not yet clear whether barotrauma counts as a cause of death amongst birds.
Furthermore, land development can alter habitats by, for instance, creating new path networks in formerly undivided landscapes. This can lead to a long-term damage of habitats, abandonment of breeding grounds or permanently reduced breeding success, for example if predators find improved habitat conditions. Many species show clear avoidance behaviour towards wind turbines which is why wind farms can act as barriers between important habitats. The following remarks are based on scientific literature and on expert opinions. With regards to the home ranges of individual species, the compilation by LAMBRECHT & TRAUTNER (2007: 126 et. seq.) provided relevant information. ILLNER (2012) studied collision risks of specific bird species and DIERSCHKE & BERNOTAT (2012) analysed the effects of mortality on bird populations, independent of specific causes of loss.

The above mentioned document by LAG VSW offers a detailed overview of wind farms' threat potential for bird species listed here (http://www.lugv.brandenburg.de/cmsmedia.php/lbm1.a.3310.de/vsw_dokwind_voegel.pdf).

The numbers of collision victims are taken from LAG VSW's collision victim database (as at March 28 2015) which has been systematically updated since 2002 but also includes older data. Upon request from court or authorizing agencies, LAG VSW appoints experts for the individual bird species.

Grouse: Capercaille (Tetrao urogallus), Black Grouse (Tetrao tetrix), Hazel Grouse (Tetrastes bonasia) and Rock Ptarmigan (Lagopus muta)

Until today, no collision victims amongst capercaille, black grouse, hazel grouse and rock ptarmigan have been registered in Germany. In Austria, six individuals of black grouse were identified as collision victims in close proximity to their lek. The towers of wind turbines are responsible for most of the collision risks amongst grouse (including red grouse in Norway).

In several areas, black grouse abandoned leks with up to 1,000 meters distance to wind turbines. Also, stable or growing populations dropped in numbers shortly after the construction of wind turbines. The sensitivity of capercaille towards man-made infrastructure developments is widely known and studied. As an example, wind turbines in a Spanish capercaille habitat decreased the bird's activity to such an extent that the birds disappeared altogether. Similar effects of wind turbines on hazel grouse are expected. This can be explained by either loss of individuals or habitat avoidance as a reaction to the increasing disturbance caused by wind farm development and operation.

It is therefore recommended to keep a minimum distance of 1,000 meters around grouse habitats. Furthermore, corridors between adjacent habitats should be kept free in order to protect existing metapopulational structures.

Sources: BEVANGER et al. (2010), BOLLMANN et al. (2013), BRAUNISCH & SUCHANT (2013), BRAUNISCH et al. (2015), DÜRR (2011), GLUTZ VON BLOTZHEIM & BAUER (1994A), GONZÁLEZ & ENA (2011), GRÜNSCHACHNER-BERGER & KAINER (2011), KLAUS (1996), KORN & THORN (2010), KRAUT & MÖCKEL (2000), LEHMANN (2005), LINDNER & THIELEMANN (2013), MLUR (2000, 2002), MÖCKEL et al. (1999, 2005), NIEWOLD (1996), SUCHANT (2008), TRAXLER et al. (2005), UNGER & KLAUS (2013), ZEILER & GRÜNSCHACHNER-BERGER (2009)

Eurasian Bittern (Botaurus stellaris) and Little Bittern (Ixobrychus minutus)

So far, three collided Eurasian bitterns have been registered, two of which were found in Germany. Collisions of Eurasian bitterns with overhead lines are well known from Spain, Italy and Great Britain. Collision risks increase due to its nocturnal lifestyle, its tendency to fly to adjacent territories and its foraging flights far off its regular breeding waters.

Furthermore, Eurasian bitterns and little bitterns react sensitively to acoustic interferences and are strongly affected. Therefore, and because these two species are very rare in Germany, the recommended minimum distance is 1,000 meters to wind turbines. The nocturnal flight activity of bitterns requires an additional range of verification of 3,000 meters in which the presence of attractive foraging habitats including direct flight paths to such habitats should be examined.

Sources: CRAMP (1977), GARNIEL et al. (2007), GLUTZ VON BLOTZHEIM & BAUER (1987), MAHLER (2002), ULBRICHT (2011), WHITE et al. (2006)

Black Stork (Ciconia nigra)

Until today, five collision victims have been recorded amongst black storks (one in Germany), and studies in Spain and Germany revealed a high percentage of critical flight situations near wind turbines. This secretive and sensitive species can easily be disturbed by wind turbines during breeding season, showing a decrease in breeding success and abandonment of nest sites. In Brandenburg, Germany, six evaluable breeding sites within a radius of 3 km around wind turbines showed low breeding success over years and/or were only irregularly used.

There are no usable telemetry studies available for the black stork yet. However, consistent observations in Germany's counties prove that black storks fly long distances – up to 20 km or more - during breeding season in order to reach fruitful feeding habitats. When doing so, they ascent, using favourable thermal conditions, and then glide along, losing height. Therefore, it is possible and necessary to define preferred flight routes in ranges of verification that should be kept free of wind turbines.

ROHDE (2009) published the first and only functional-spatial analysis, evaluating 21 black stork breeding sites over a period of 14 years. His study indicates that black storks regularly fly 7 km or more from their breeding forests to reach feeding places. Based on these results and long-term monitoring by experts, a minimum distance of 3,000 meters to nest sites as well as a range of verification of 10,000 meters is recommended for black storks. The restriction area of 7 km as recommended by ROHDE (2009) is measured from the edge of the breeding forest and, thus, roughly correlates with the above suggested range of verification which is measured from the nest site location.

Sources: BRAUNEIS (1999), BRIELMANN et al. (2005), JANSSEN et al. (2004), LEKUONA & URSÚA (2007), ROHDE (2009), SPRÖTGE & HANDKE (2006)

White Stork (Ciconia ciconia)

To date, 44 collision victims have been recorded in Germany, 41 in Spain and one in Austria. 80 % of all foraging flights during breeding season take place within a radius of 2,000 m around the nest site; however, the range of activity is larger in agricultural land than in grassland. Due to habituation effects in attractive foraging habitats and less pronounced avoidance behaviour towards wind turbines, the risk for a white stork to collide with a wind turbine is comparatively high. A considerable amount of foraging flights (22%) takes place at heights of 50 to 150m (TRAXLER et al. 2013). The main feeding areas can be protected by keeping a minimum distance of 1,000 meters between nest sites and wind turbines. A range of verification of 2,000 m around the nest is recommended to take into account additional important feeding areas (especially meadows and pastures).

Sources: CREUTZ (1985), DÖRFEL (2008), DZIEWIATY (2005), EWERT (2002), LUDWIG (2001), MÖCKEL & WIESNER (2007), OŻGO & BOGUCKI (1999), STRUWE-JUHL (1999), TRAXLER et al. (2013)

Osprey (Pandion haliaetus)

To date, 16 collision victims have been registered in Germany, seven in Spain and one in Scotland. In the federal state of Brandenburg, Germany, the average flight distance from the nest site to the nearest lake was found to be 2.3 ± 0.7 km, with foraging flights leading up to 16 km away from the aerie. The area of activity of males is reported to be more than 100 km². This bird species does not show obvious avoidance behaviour towards wind turbines. Researchers recommend a minimum distance of 1,000 meters to wind farms. Within the recommended range of verification of 4,000 meters around nest sites, preferred foraging waters as well as frequently used flight routes to such waters and to other feeding waters located outside the range of verification should be taken into consideration. The GPS telemetry of a male osprey showed that 37% of its tracking records were located in a foraging habitat 14 km away from the nest site (B.-U. MEYBURG, unpublished). This underlines the importance of keeping such flight corridors free of wind turbines.

Sources: HAGAN & WALTERS (1990), MEYBURG & MEYBURG (2013), MLUV (2005), SCHMIDT (1999)

Honey Buzzard (Pernis apivorus)

Six collision victims have been found in Germany (all of them adult birds) and eight in Spain. This number seems to be small, but it is relevant when compared to the total population size. It must be assumed that the number of honey buzzards colliding with wind turbines is actually much higher, because the chance to find collided birds is very low. Furthermore, honey buzzards get often mistaken for the common buzzard. Due to the increasing use of wind energy in forests it must be assumed that impacts on this species are growing.

Several studies found evidence for honey buzzards avoiding as well as passing through wind farms (with and without reaction), showing partially differing behaviour between breeding and migratory birds. One bird in Brandenburg was found to abandon its territory after a wind farm had been built. Also, honey buzzards might get attracted to wind turbines: The larvae of bumblebees and wasps, which often occur at the fallow land around the towers, belong to its main food source. This may attract honey buzzards to those dangerous areas and increase the risk of collision. Furthermore, a higher risk of collision can be expected in the vicinity of their nests: displaying and territorial fights, soaring, foraging flights, prey transfer – they all take place at critical heights.

A minimum distance of 1,000 meters offers protection for these main activities near nest sites.

Sources: BIJLSMA (1991, 1993), Diermen et al. (2009, 2013), GAMAUF (1995), ILLNER (2012), MEYBURG et al. (2011), MEYBURG & MEYBURG (2013), MÖCKEL & WIESNER (2007), TRAXLER et al. (2004), VAN MANEN et al. (2011), ZIESEMER (1997, 1999)

Golden Eagle (Aquila chrysaetos)

There are 16 reported collision victims in Europe (seven in Sweden, eight in Spain, one in Norway), whereas four-digit numbers have been recorded in the US.

The countless collision victims recorded in California (Altamont Pass Wind Resource Area, U.S.) prove that wind turbines in suitable habitats can cause a high mortality rate amongst golden eagles. In Scotland, predominantly the expulsion and disturbance of golden eagles near wind farms is considered problematic.

In Germany, the federal state of Bavaria has sole responsibility for the German population of the golden eagle. The golden eagle has also started to colonize regions outside the Alps, with first individuals being reported from Denmark. Further occurrences in northern Germany, in the alpine uplands and in the Black Forest seem possible. Therefore, the golden eagle could become relevant for future wind farm planning outside Bavaria. In that case, a minimum distance of 3,000 meters around breeding sites and a range of verification of 6,000 meters in order to identify preferred foraging habitats around wind turbine locations should be adhered to.

Sources: AHLÉN (2010), ATIENZA et al. (2011), BEZZEL & FÜNFSTÜCK (1994), FIELDING & HAWORTH (2010), HALLER (1996), HUNT et al. (1998), ICF INTERNATIONAL (2014), KATZNER et al. (2013), PAGEL et al. (2013), SMALLWOOD & THELANDER (2004, 2008)

Lesser Spotted Eagle (Aquila pomarina)

The lesser spotted eagle is said to be a flagship species for unfragmented habitats with a low density of anthropogenic infrastructure. Seven collisions of this rare species have been reported, five of which happened in Germany where one bird survived. Two birds were ringed, which probably explains why they were reported at all. This confirms the suspicion that the actual number of lesser spotted eagles colliding with wind turbines is much higher but that they are not being reported. Since the species is very rare and since there is hardly any search for collision victims, the relatively high number of reported birds suggests a high collision risk. The birds regularly hunt from a height of several hundred meters. This increases the risk of collision, even with new wind turbines. Modelling the population dynamics of the lesser spotted eagle in Brandenburg has shown that every single bird is important to maintain smaller populations. In Mecklenburg-Pomerania, reproduction decreased with an increasing number of wind turbines within a radius of 3 km around nest sites, and even further. Similar results were obtained for Brandenburg.

A greater collision risk resulting from habituation of individual birds to wind farms as well as the loss of feeding areas due to avoidance of wind farms are must be seen critical because of the small total population. A minimum distance of 6,000 meters is recommended, based on the lesser spotted eagle's complex habitat needs and the existing telemetry studies regarding the birds' habitat use.

Sources: BÖHNER & LANGGEMACH (2004), DIERSCHKE & BERNOTAT (2012), LANGGEMACH et al. (2001, 2009, 2010), LANGGEMACH & MEYBURG (2011), MEYBURG & MEYBURG (2009A, 2013), MEYBURG et al. (2006, 2007), MLUV (2005), SCHELLER (2007, 2008), SCHELLER et al. (2001)

Montagu's Harrier (Circus pygargus)

In Germany, two breeding birds have been registered as collision victims (in addition „almost collisions" in Lower Saxony and North Rhine-Westphalia); 38 further collisions were reported from Spain, Portugal, France and Austria, suggesting an increased risk of collision. There is an increased risk when birds fly at greater heights, which is mainly the case when flying near their aeries (displaying, soaring, territorial fights, prey transfer and passing food). However, collisions also happen during flights to feeding habitats, which are sometimes located several kilometers away. Attractive structures and rich food supply around wind farms can attract Montagu's harriers. Effects on habitat use vary from region to region: In Schleswig-Holstein, many breeding sites are located in regions with a very high density of wind turbines. In North Rhine-Westphalia however, avoidance behaviour and decreasing populations were noted after wind turbines had been set up. Results from Brandenburg and Spain differ (one study each with stable and significantly decreasing breeding population).

Due to the increased collision risk near breeding sites and regional avoidance of wind farms, it is recommended to keep a minimum distance of 1,000 meters and a range of verification of 3,000 meters. Because Montagu's harrier is very mobile when choosing a breeding site, it is especially important to keep areas with high concentrations of breeding sites and regularly used individual breeding sites completely free of wind turbines. It should be taken into account that the location of the nest sites depends on the surrounding crops and that it may vary due to crop rotation. Montagu's harriers gather at sleeping places during summer, often at the same locations for several years. These sleeping places should also be taken into consideration when planning wind farms (see table 1).

Sources: ARROYO et al. (2013), BAUM & BAUM (2011), BEHM & KRÜGER (2013), BERNARDINO et al. (2012), BOUZIN (2013), GRAJETZKY et al. (2008, 2010), GUIXÉ & ARROYO (2011), HERNANDEZ et al. (2012), ILLNER & JOEST (2013), JOEST & RASRAN (2010), JOEST et al. (2008, 2010), KLAASSEN et al. (2014), PILAR (2013), RYSLAVY (2000, 2005), SCHARON (2008), SCHELLER (2010), SCHELLER & SCHWARZ (2008, 2011), TRAXLER et al. (2013), TRIERWEILER et al. (2014), VAN LAAR (2014), VAZQUEZ (2012), WERKGROEP, KIEKENDIEF (2013): http://www.werkgroepgrauwekiekendief.nl/?id=171&action=datalogger

Western Marsh Harrier (Circus aeruginosus)

In Germany, 17 collision victims have been recorded so far, 15 more have been reported from other countries. The risk for marsh harriers to collide with wind turbines was rated high, after comparing the figures from Germany to the breeding population and probable actual collision rates. Marsh harriers avoid potential breeding sites if wind farms are built nearby (<200m), however, research has shown that the birds do not generally avoid wind turbines during breeding season. As with the Montagu's harrier, the marsh harrier frequently flies at great heights near nest sites (up to several hundred meters) entering dangerous space around wind turbine rotors. Flights to feeding habitats, which can be located several km away, also take place at these critical heights.

Due to the risk of collision and the lack of avoidance behaviour, a minimum distance of 1,000 meters is recommended for marsh harriers. Marsh harriers also tend to gather at sleeping places during summer, often at the same locations for several years. These locations should also be considered in wind farm planning activities (see table 1).

Sources: BAUM & BAUM (2011), BERGEN (2001), DÜRR & RASRAN (2013), GLUTZ VON BLOTZHEIM & BAUER (1989), HANDKE (2000), HANDKE et al. (2004a), LANGE (1999), MÖCKEL & WIESNER (2007), OLIVER (2013), RYSLAVY (2000), SCHELLER & VÖKLER (2007), SCHELLER et al. (2012), STRASSER (2006), TRAXLER et al. (2013)

Hen Harrier (Circus cyaneus)

To date five collision victims have been reported from Europe and more from North America. The behavior of the hen harrier towards wind turbines complies with the behaviour of other harrier species.

In general, it is recommended to keep a minimum distance of 1,000 meters and a range of verification of 3,000 meters around the breeding areas, in order to protect the few breeding sites, which however are mostly located within protected areas. As far as breeding sites outside protected areas are concerned, we recommend greater distances, as the hen harrier is a rare and endangered species. Because the population in Germany is very small, the loss of an individual bird affects the whole population. When planning wind turbines, sleeping sites used regularly by hen harriers during the winter months should also be taken into account (see table 1).

Sources: ARROYO et al. (2014), ATIENZA et al. (2008), DÜRR & RASRAN (2013), GARCIA & ARROYO (2005), HANDKE et al. (2004a), HENSCHEL (1990), ICF INTERNATIONAL (2014), ILLNER (2012), MÖCKEL & WIESNER (2007), MÖLLER (1995), O'DONOGHUE et al. (2011), PEARCE-HIGGINS et al. (2009), SMALLWOOD & THELANDER (2008), STANEK (2013), TRAXLER et al. (2013), WHITFIELD & MADDERS (2006)

Red Kite (Milvus milvus)

The range of distribution of the red kite is small and almost exclusively restricted to Europe. Germany bears more responsibility for the red kite than for any other bird species, because more than 50 % of the world's population is found here. However, less than 20 % of the red kite in Germany is breeding within Special Protection Areas.

Breeding habitat of the red kite is a mosaic of woodland and open country; it prefers edges of forests mixed with meadows and pastures. The red kite needs open country for hunting. Compared to many other birds of prey it hunts during flight (not when soaring) and it does not show avoidance behaviour towards wind farms. There is a very high risk of collision because courtship during springtime, soaring and hunting take place at heights where wind turbine rotors occur (including repowered wind turbines). Therefore, the red kite is one of the species that collides most frequently with wind turbines –with regard to the total number of birds and to the breeding population. Already 265 losses due to collision have been reported from Germany alone. In the German federal state of Brandenburg wind energy usage quickly became the most important threat to the post-breeding population.

Applying a model based on systematic search for collision victims, it was estimated that in Brandenburg (which to date has 3.044 wind turbines) at least 308 red kites are killed annually due to collisions. The losses caused by wind turbines alone my already impose a threat to the whole Brandenburg population. Most losses are found amongst adult birds during breeding period, leading to a loss of broods. As young breeding birds have a lower breeding success than older birds, new pairings often have reduced breeding success after the death of experienced adults. Thus, the loss of one partner can decrease the breeding success of a whole territory over several years.

Recently, a scientific study about the spatial and temporal behaviour of red kites was carried out in Thuringia, using satellite telemetry. It was found that only 40% of the flight activities took place within 1,000 meters around the breeding site, looking at more than 30 adult birds with almost 10,000 GPS tracking locations (PFEIFFER & MEYBURG 2015). Based on the assumptions as found in chapter 4, an extension of the minimum distance compared to the existing recommendations (LAG VSW 2007) is needed. Due to Germany's high responsibility for this species, a minimum distance of 1,500m, where about 60 % of all flight activities take place, is recommended. Regarding the range of verification, the radius can be reduced to 4,000m, which covers most of the flight activities (on average more than 90%).

Regularly used sleeping sites should also be considered when wind turbines are being planned (see table 1).

Sources: AEBISCHER (2009), BELLEBAUM et al. (2013), BERGEN (2001), BUSCHE (2010), DÖRFEL (2008), DÜRR (2009), DÜRR & LANGGEMACH (2006), DÜRR & RASRAN (2013), GELPKE & HORMANN (2010), GEORGE & HELLMANN (2000), JOEST et al. (2012), LANGGEMACH & RYSLAVY (2010), LANGGEMACH et al. (2010), MAMMEN (2009), MAMMEN & MAMMEN (2008), MAMMEN et al. (2008, 2009, 2010), NACHTIGALL & HEROLD (2013), NACHTIGALL et al. (2010), PFEIFFER (2009), PFEIFFER & MEYBURG (2015), PORSTENDÖRFER (1994), RASRAN et al. (2010a, b), RIEPL (2008), SCHAUB (2012), STRASSER (2006), WAG (2013), WALZ (2001, 2005, 2008)

Black Kite (Milvus migrans)

Black kites show largely the same behaviour towards wind turbines as red kites. There is almost no avoidance behaviour towards wind turbines. Until today, 28 collision victims have been reported from Germany and 84 from the rest of Europe. Due to the slightly reduced risk of collision and the preference of hunting in the vicinity of waters, a minimum distance of 1,000 meters and a range of verification of 3,000 meters are recommended. Important foraging areas (including waters for the black kite) and flight corridors to such areas should be especially taken into consideration when setting up ranges of verification.

Regularly used sleeping sites should also be considered when wind turbines are being planned (see table 1).

Sources: BERGEN (2001), CRAMP (1977), EICHHORN et al. (2012), HAGGE & STUBBE (2006), JOEST et al. (2012), MEYBURG & MEYBURG (2009B), ORTLIEB (1998), RIEPL (2008), URA et al. (2015), WALZ (2001, 2005, 2008)

White-tailed Eagle (Haliaeetus albicilla)

In Germany, 108 collisions of white-tailed eagles have been reported to date, further 71 from other European countries. Although there is also a collision risk beyond the recommended distance of 3,000 meters around aeries of the white-tailed eagle in Germany, these distances have considerably contributed to the protection of this breeding bird and its breeding sites. In Norway, the breeding population near a wind farm decreased from 13 to five pairs, and the breeding success dropped within a distance of 3,000 meters to wind turbines as adult mortality, disturbance and habitat loss increased. Avoidance behaviour towards wind farms was not observed.

Hence, LAG VSW recommends a minimum distance of 3,000 meters and a range of verification of 6,000 meters. Foraging waters that are located further away and flight corridors to such waters that have a minimum width of 1,000 meters should be taken into account in the range of verification.

Furthermore, regularly used sleeping sites should be considered when planning wind turbines (see table 1).

Sources: AHLÉN (2010), BEVANGER et al. (2010), DAHL et al. (2012), HOEL (2008), KRONE & SCHARNWEBER (2003), KRONE et al. (2002, 2008, 2009, 2010), MAY & BEVANGER (2011), MEYBURG et al. (1994), MLUV (2005), MÖCKEL & WIESNER (2007), NYGARD et al. (2010), STRUWE-JUHL (1996), TRAXLER et al. (2013)

Eurasian Hobby (Falco subbuteo)

So far, ten collision victims have been registered in Germany including seven breeding birds; 12 collisions have been recorded in other countries. This secretive species is hard to observe because it only occurs in Germany during summer, when trees are leafed out. As it prefers to fly at rotor heights when displaying, soaring, during territorial fights and foraging flights, a higher number of losses is suspected. In some cases, the construction of wind farms led to the abandonment of breeding sites. Some of these breeding sites were used again in the following years, however at two of three sites collision victims were found.

A minimum distance of 500 meters should be kept around regularly used breeding sites. Flight corridors to preferred feeding habitats (waters, residential areas) should be kept free of wind turbines within a radius of 3,000 meters around breeding sites. It is especially important to avoid that breeding sites are completely surrounded by wind turbines. Further research is needed, for instance about the collision risk of fledglings.

Sources: CHAPMAN (1999), FIUCZYNSKI (2010), FIUCZYNSKI & SÖMMER (2011), FIUCZYNSKI et al. (2009, 2012), KLAMMER (2011), MÖCKEL & WIESNER (2007)

Peregrine Falcon (Falco peregrinus)

Ten collision victims were registered in Germany, three of those during breeding time. Another ten collided birds were reported from other European countries. The species mostly hunts high up in the air, quickly flying at critical heights. Also, peregrine falcons are not very maneuverable. When searching for food, they regularly fly up to 3 km away from their aerie. A minimum distance of 1,000 meters is recommended between nest and wind turbine.

The tree-nesting population in the north of Germany is unique on this planet. It is largely isolated from other populations of the peregrine falcon. In 2010, an internationally recognized repopulation program for this formerly large population, which became extinct during DDT-times, could be successfully completed after 20 years. The small initial population of tree-nesting peregrine falcons (now about 40 breeding pairs) was once widely distributed, its range stretched to the Ural Mountains. In order to stabilize this population – also in terms of the Convention on Biological Diversity - a minimum distance of 3,000 meters is suggested. First telemetry results show that this would help to protect the central part of the regularly used hunting territory.

Sources: ALTENKAMP et al. (2001), ATIENZA et al. (2011), KLEINSTÄUBER et al. (2009), LANGGEMACH & SÖMMER (1996), LANGGEMACH et al. (1997), LAPOINTE et al. (2011), LEKUONA & URSÚA (2007)

Common Crane (Grus grus)

The risk of collision can be rated as low for this species, as 14 collision victims were recorded in Germany and four more in Sweden, Poland and Bulgaria. In a few cases, nests were found in less than 200 m distance to wind turbines. The breeding density and reproduction in or near wind farms tended to be lower than in reference areas free of wind turbines. This suggests that the construction and operation of wind farms might disturb the species, leading to a loss of broods or increased predation of clutches. In foraging habitats, avoidance behaviour increases with group size. Groups consisting of more than 100 individuals rarely or only in case of extreme weather conditions (e.g. when over-wintering) approach wind turbines closer than 1,000 meters.

Hence, a minimum distance of 500 meters is seen as sufficient for breeding sites. For important, regularly used sleeping sites we recommend a minimum distance of 3,000 meters. The recommended range of verification is 6,000 meters (see table 1).

Sources: GRÜNKORN (2015), MÖCKEL & WIESNER (2007), NOWALD (2003), PRANGE (1989), SCHELLER & VÖKLER (2007), SCHELLER et al. (2012)

Corncrake (Crex crex)

To date, the collision of one corncrake has been registered. Avoidance behaviour towards wind turbines up to a distance of 500 meters and the abandonment of calling sites and possibly even whole territories have been recorded. This species strongly depends on acoustic communication, which is why it is very likely to be affected by wind turbines. As entire wind farms are louder than individual wind turbines, they may have an even greater impact.

Corncrakes are sequentially polygamous, i.e. both males and females change partners between breeding attempts. Furthermore, they form species-specific calling groups, their habitat preferences differ in the course of the breeding period and they have high population dynamics. This means that the whole home range of the corncrake must be taken into account to guarantee breeding success.

Regularly occupied breeding habitats of the corncrake should be kept coherent and free of wind turbines, a protection zone of 500 meters around nests is recommended.

Sources: FLADE (1991), GARNIEL et al. (2007), Joest (2009, 2011), MAMMEN et al. (2005), MÜLLER & ILLNER (2001), SCHÄFFER (1999), ZEHTENDJIEV (2015)

Great Bustard (Otis tarda)

Breeding and wintering grounds of the great bustard have been protected quite well by the current recommendations for minimum distances of wind turbines in Germany. However, flight corridors between those areas have already been negatively affected by wind farms. Additional wind farms are being planned along the flight paths. This poses a threat to the cohesion of the three remaining populations and, thus, to the survival of this species which is threatened with extinction in Germany. Three collided birds have been reported from Spain (as well as one little bustard). Great bustards go on long-distance flights at great heights and adult birds are often killed when colliding with overhead lines. Therefore, wind turbines placed in their territories and along flight paths impose a collision risk. Furthermore, strong barrier effects occurred in Brandenburg as the number of wind turbines increased. Studies in Austria and Germany clearly show avoidance behaviour of great bustards towards wind turbines (closest approach about 600 meters, mostly much farther away).

Breeding habitats should be kept free of wind turbines. The recommended minimum distance is 3,000 meters. The areas used in the non-breeding season and regularly used flight corridors should also be kept free of wind turbines. The "memorandum of understanding" for great bustards in Central Europe, published in the context of the Bonn Convention on the Conservation of Migratory Species, recommends including abandoned areas with repopulation potential into protection efforts, meaning that they should not be further fragmented or developed. Existing wind farms in sensitive areas (including the corridors described above) should not get repowering-permission.

Sources: ALONSO (2013), ALONSO et al. (1995, 1998, 2000, 2003a, b), ATIENZA et al. (2011), BLOCK (1996), CAÑIZARES (2006), DIERSCHKE & BERNOTAT (2012), DORNBUSCH (1981, 1987), EISENBERG (1996), GARRIDO & DE LAS HERAS (2013), LANGGEMACH & WATZKE (2013), LITZBARSKI & LITZBARSKI (1996), LITZBARSKI et al. (2011), MAGAÑA et al. (2011), MARTIN (2011), MARTIN & SHAW (2010), MARTINEZ-ACACIO et al. (2003), MORALES et al. (2000), PALACÍN et al. (2012), PITRA et al. (2010), RAAB et al. (2012), SCHWANDNER & LANGGEMACH (2011), TRAXLER et al. (2013), WURM & KOLLAR (2002)

European Golden Plover (Pluvialis apricaria)

Resting and foraging birds kept avoidance distances of up to 600 m to wind turbines 100 meters in height. Some studies showed that this distance decreased over the years due to habituation effects, potentially leading to a gradually increasing collision risk. Not much is known about the birds' behaviour towards wind turbines at breeding sites.

Despite their obvious and pronounced avoidance behaviour, golden plovers regularly collide with wind turbines. To date, 25 dead birds have been reported from Germany and twelve from other European countries. One of the few systematic studies conducted in resting areas of golden plover found that eight of 43 collision victims were golden plovers, indicating a high mortality rate due to wind turbines.

Central Europe's last remaining breeding population is located in the German federal state of Lower Saxony. There, golden plovers breed in bogs, preferably in scarcely vegetated areas and in areas bare of any vegetation. Since 1991, this species has only populated milled peat areas where peat digging is under progress. Pastures and meadows located in the vicinity of the bogs are important feeding habitats for this species, especially when laying eggs and incubating. These areas are located at distances of up to 6 km distance from the nests. For this reason the existing distance recommendations from 2007 of wind turbines will be maintained: a minimum distance of 1,000 meters and range of verification of 6,000 meters. Single losses of Central European golden plovers always affect the total population, which consists of less than 10 breeding pairs. The most important resting and foraging habitats of this species must be kept free of wind turbines (see table 1).

Sources: BEVANGER et al. (2010), DEGEN (2008), GRÜNKORN et al. (2005, 2009), HANDKE et al. (2004a, b), HÖTKER (2006), HÖTKER et al. (2005), OLTMANNS & DEGEN (2009), PEARCE-HIGGINS et al. (2009), REICHENBACH et al. (2004), REICHENBACH & STEINBORN (2011)

Eurasian Woodcock (Scolopax rusticola)

To date five collision victims have been reported from Germany, six in addition from five other European countries. As there is an increasing use of wind energy in forests, there is now a stronger focus on this species. In the northern Black Forest a study was conducted before and after the construction and commissioning of a wind farm. The population declined from 10 males/100ha to 1.2 males/100ha (display flying birds). The reason for this decline is seen in the barrier effect of the turbines (also idle!). Effects on the acoustic communication of the woodcocks during display flights and mating must also be assumed. It is very difficult to detect the nests of Eurasian woodcocks, which is why displaying birds are counted in order to assess a population. For this reason it is recommended to keep distances of at least 500 meters around the display territories (based on the flight paths of the birds). The display flights take place over a wide area and territories of several males may overlap. Eurasian woodcocks have a promiscuous mating system, which means that several females may breed in the territory of one male. As a consequence of this behaviour and of the difficulty to locate the breeding sites, the whole home range must be taken into account to guarantee a successful reproduction. Areas with a high population density should be given particular consideration. Further research on the impact of wind turbines on the Eurasian woodcock is desirable.

Sources: DORKA et al. (2014), GARNIEL et al. (2007), GLUTZ VON BLOTZHEIM & BAUER (1994), HARTMANN (2007), SCHMAL (2015), SKIBBE (2014), STRAUB et al. (2015)

Eurasian Eagle-Owl (Bubo bubo)

Until today 16 collision victims have been registered in Germany, in addition 18 in Spain and one each in France and Bulgaria. Eagle owls are especially prone to collision when they fly at greater heights, for example when undertaking longer-distance flights from their breeding sites in mountainous areas as well as in lowlands. Collisions have also been observed with rotors located quite high above the ground. Acoustic impairments must also be taken into consideration, which is also the case with other nocturnal species.

Wind turbines should not be constructed as lattice towers, not even in the wider surroundings of eagle-owl territories. Lattice towers may serve as perches for the eagle-owl (and for other diurnal and nocturnal birds of prey). At least two dead eagle-owls have been found beneath those towers. In the U.S. similar cases have been described for the great horned owl (*Bubo virginianus*). The LAG VSW recommends a minimum distance of 1,000 meters to the wind turbines and a range of verification of 3,000 meters, where especially the occurrence of regular, attractive food sources has to be examined.

Sources: AEBISCHER et al. (2010), BAUMGART & HENNERSDORF (2011), DALBECK (2003), DALBECK et al. (1998), GARNIEL et al. (2007), LEDITZNIG (1999), NYFFELER (2004), SITKEWITZ (2005, 2007, 2009)

Short-eared Owl (Asio flammeus)

To date, two collision victims have been registered in Brandenburg and another one in Spain. The ground breeding species occurs in swamps and mires and along the coasts also in dunes. It primarily feeds on voles, hunting at differing heights in search flight or stationary flight. Display flights may occur at rotor height.

The short-eared owl is a rare breeding bird in Germany, with irregular breeding occurrences. This makes it harder to take into account this species in planning activities. A minimum distance of 1,000 meters (range of verification 3,000 meters) is recommended when breeding occurs regularly. Not just single breeding sites should then be taken into account but the entire area that was used regularly for breeding in the past years. Because of the small population size the death of one single bird may affect the entire breeding population. Especially during the winter the short-eared owl tends to sleeping in communities, often sharing its sleeping places with long-eared owls. Therefore, sleeping places of the long-eared owl should also be taken into account during the planning process (see table 1).

Sources: ATIENZA et al. (2011), GARNIEL et al. (2007), GLUTZ VON BLOTZHEIM & BAUER (1994B), JEROMIN & KOOP (2007)

Eurasian Nightjar (Caprimulgus europaeus)

To date, collisions of nightjars have only been reported from Spain. The nocturnal species shows pronounced avoidance behaviour towards wind turbines, probably also because it is dependent on acoustic communication. Noises caused by operation of the wind turbines as well as during construction, dust formation and ground vibrations during construction led to an immediate displacement of nightjars from their breeding and feeding grounds. Some feeding habitats were still visited by single birds and only with calm air.

Several studies in and around wind farms came to the conclusion that the breeding habitats became either completely deserted or that the breeding population declined by at least 50 %. It was observed that the birds kept distances of at least 250 meters to the turbines and that population declined within a radius of 500 meters. Therefore, the LAG VSW recommends a minimum distance of 500 meters from wind turbines to breeding sites.

Sources: ABBO (2001), GARNIEL et al. (2007), GLUTZ VON BLOTZHEIM & BAUER (1994), K&SUMWELTGUTACHTEN (2008), KAATZ (2014), KAATZ et al. (2007, 2010), LEKUONA (2001), MÖCKEL (2010, 2012), MÖCKEL & WIESNER (2007), OEHLSCHLAEGER (2006), WALLSCHLÄGER et al. (2002)

Eurasian Hoopoe (Upupa epops)

The hoopoe is still a very rare breeding bird in Germany. It reacts sensitively to disturbances in the air within and in the immediate surroundings of its breeding territories. Especially moving objects in the air pose a considerable threat. The effects of wind farms on breeding sites strongly depend on the topography.

In the German federal states Rhineland-Palatinate and Brandenburg hoopoes abandoned their breeding sites after wind turbines had been set up, although suitable breeding sites as well as favourable feeding areas still existed. Furthermore, it was found out that breeding was often unsuccessful within the close range (750- 1,000 meters) of wind turbines. Territory sizes vary between 50 and 300 ha and the hoopoe flies 1 km and more from its nest to its feeding habitats. Wind turbines obviously have had negative impacts on the feeding grounds. The collision risk is rated as relatively low with nine collision victims (outside Germany) recorded so far.

The LAG VSW recommends a minimum distance of 1,000 meters. The range of verification around breeding sites should be 1,500 meters.

Sources: HÖLLGÄRTNER (2000–2011, 2012), OEHLSCHLAEGER (2001, 2006)

Threatened meadow bird species, sensitive to disturbance: Common Snipe (Gallinago gallinago), Black-tailed Godwit (Limosa limosa), Common Redshank (Tringa totanus), Eurasian Curlew (Numenius arquata) and Northern Lapwing (Vanellus vanellus)

The areas of high density of threatened meadow bird species like common snipe, black-tailed godwit, common redshank, Eurasian curlew and lapwing should be kept free of wind turbines. All these species undertake extended display flights during the breeding season and thus they are generally prone to collision risk. They also migrate in partly big swarms through many regions and therefore encounter wind turbines also outside their breeding habitats. For resting as well as breeding birds, avoidance distances of more than 100 meters are observed regularly. The black-tailed godwit avoids keeps the greatest distance of all meadow waders (usually >300 meters). Furthermore, the construction of wind turbines usually goes hand in hand with the building of infrastructure, which again may have negative effects on these very sensitive meadow species (road construction, overhead power lines, recreational use, predation etc.).

For areas of high density of threatened meadow bird species a minimum distance of 500 meters is recommended. Within a range of 1,000 meters it should also be examined if important feeding and resting habitats are affected. Flight corridors between breeding and feeding habitats must also be kept free of wind turbines. In many regions in Germany the lapwing does not breed in meadows anymore, but primarily on wet arable land. Therefore, these minimum distances and areas of verification also apply to these habitats, provided that they are at least of regional importance. There is still research to be done on possible impacts of wind turbines on the breeding success of meadow waders.

Sources: EILERS (2007), GLUTZ VON BLOTZHEIM et al. (1986), HANDKE et al. (2004a, b), HÖTKER et al. (2004, 2005), KREUZIGER (2008), LANGGEMACH & BELLEBAUM (2005), PEARCE-HIGGINS et al. (2009), REICHENBACH (2004), REICHENBACH & STEINBORN (2006, 2011), SINNING (2004), SINNING et al. (2004), STEINBORN et al. (2011)

Colony breeders: Gulls, Terns and Herons

Collision victims of nearly all species occurring in Germany have been reported from several countries, this is especially the case with gulls. More than 1,900 collided gulls have been recorded so far in Europe. In Belgium, a great number of common terns (*Sterna hirundo*), especially males as food providers during the breeding season, have been killed by wind farms. In Germany, gulls rank third - after birds of prey and singing birds- in collision victim statistics. From the German federal states Bremen, Lower Saxony and Schleswig Holstein, which are located along the coast, they are reported most frequently. However, gulls may also be the family with the highest collision risk in the inland areas. So far, only few grey herons (*Ardea cinerea*) have been reported (28 cases in Europe, thereof eleven in Germany). The reason for this may be that only a few colonies exist in areas with wind turbines. Risks for colony breeders must be taken into account thoroughly because of the high number of breeding birds at one site.

The low avoidance and the high collision rates for almost all mentioned species require a minimum distance of 1,000 meters as well as a range of verification of 3,000 meters (for gulls and herons). For terns it may be necessary to take into account much larger ranges because the males fly quite far when searching for food, using relatively narrow flight paths.

Sources: EVERAERT (2003, 2008, 2014), EVERAERT & STIENEN (2007), EXO et al. (2008), NEUBAUER (1998), REICHENBACH & STEINBORN (2007), RYDELL et al. (2012), SCHOPPENHORST (2004), STEINBORN et al. (2011), STIENEN et al. (2008), TRAXLER et al. (2013)

6 Summary

This paper further develops the 2007 recommendations ("Helgoland Paper") of the Working Group of German State Bird Conservancies for the conflict between wind energy use and bird protection. This renewed version has arisen from new scientific knowledge and new developments, such as the increasing use of wind energy in forests. For inland and coastal areas, requirements for distances of wind turbines to important areas for birds (including protected areas and sites with large bird congregations) and breeding sites of birds sensitive to wind turbines are recommended. The latter include species of grouse, herons and egrets, storks, raptors, falcons, Common Crane, Corncrake, Great Bustard, waders, gulls, terns, owls, European Nightjar and Hoopoe. For the first time, minimum distances are recommended for Honey Buzzard, Golden Eagle, Woodcock, European Nightjar and Hoopoe. For a majority of species with large home ranges, ranges of verification around wind farms are recommended beyond the minimum distances, where an increased likelihood of occurrence should be checked for and taken into account. In addition, potential cumulative impacts of wind turbines, in connection with other impact factors, are pointed out, as well as the need to keep areas of high densities of large bird species free of wind turbines due to potential impacts at the population level.