The impact of repowering of wind farms on birds and bats

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Contents

1 Introduction

Wind energy generation has developed in Germany into by far the most important source of renewable energy production. Over 18,000 wind turbines with an installed capacity of over 19,000 MW are now in operation (status 30.6.2006, Bundesverband Windenergie, http://windenergie.de/de/statistiken/). The wind-rich offshore areas are seen as the best opportunity to increase the generation of wind energy. On the mainland, however, the expansion of wind energy is becoming increasingly more difficult, as most of the best sites are already taken and further extension of existing wind farms is restricted by the lack of wind in most of the inland regions, as well as planning restrictions for interests (protection of the environment, nature conservation and landscape). Therefore, „repowering“ provides a possibility to increase the production of electricity without simultaneously increasing the space required. „Repowering“ means that older, smaller and less powerful wind turbines are replaced by newer and more powerful ones. These new turbines are much higher than older ones - heights above 100m are now the norm.

The literature review of Hötker et al. (2005) (hereafter called the NABU-BfN report), which was funded by the German Agency for Nature Conservation (BfN), showed that wind turbines have only a relatively small disturbance effect on breeding birds, although many potentially sensitive species have not yet been analysed. Resting birds, in particular geese, ducks and waders responded sensitively to wind turbines and could be displaced from their resting areas. Wind turbines at certain sites, especially on bare mountain ridges and water bodies, are a collision risk for birds. In particular, birds of prey were affected, in Germany notably Red Kite and White-tailed Eagle. Bats were also killed by wind turbines, especially when these were located close to or within woodlands. The extent to which wind turbines have a harmful impact on the natural environment is mainly determined by their location. Practically the only effective means of avoiding damage was appropriate site selection.

The references used by Hötker et al. (2005) were generally studies which had been carried out on older, relatively small wind turbines. Although one could estimate a relationship between the size of wind turbines and the disturbance impact or collision risk for birds and bats, these relationships were not (with some exceptions) statistically significant. In order better to assess the impacts of the new generation of wind turbines on birds and bats, this report will analyse the more recent publications (up to summer 2006). The main emphasis was in particular the extent to which the danger for birds and bats caused by wind turbines is expected to change due to repowering. In this report, collisions of birds and bats and the displacement of birds by wind turbines have been considered as the potential impacts on these taxa. To our knowledge, no further essential studies about the displacement of bats and other mammals by wind turbines have been carried out recently (Bach & Rahmel, 2004) and therefore this aspect is not dealt with in this report.

2 Material and Methods

The methods used in this report are the same as the ones of the NABU-BfN report, so that the collected material of the NABU-BfN report could be included here. In addition, ca. 60 new publications were analysed, which had been derived from 45 individual studies. Data from each wind farm was treated as a single study, even if the data were gathered in different years and by different observers, to ensure the independence of the data and to avoid analysing the same study more than once.

The following publications were used in the NABU-BfN-report:
Ahlén, 2002; Albouy et al., 1997; Albouy et al., 2001; Anderson et al., 2000; Bach et al., 1999; Bach, 2001;Bach, 2002; Barrios & Rodriguez, 2004; Bergen, 2001a; Bergen, 2001b; Bergen, 2002a; Bergen, 2002b; Bergh et al., 2002; Boone, 2003; Böttger et al., 1990; Brauneis, 1999; Brauneis, 2000; Clemens & Lammen, 1995; De Lucas et al., 2004; Dulas Engineering Ltd, 1995; EAS, 1997; Erickson et al., 2003; Everaert, 2003; Everaert et al., 2002; Förster, 2003; Gerjets, 1999; Gharad-jedaghi & Ehrlinger, 2001; Guillemette & Larsen, 2002; Guillemette et al., 1999; Hall & Richards, 1962; Hormann, 2000; Hydro Tasmania; Isselbächer & Isselbä-cher, 2001; Janss, 2000; Johnson, 2002; Johnson et al., 2003; Johnson et al., 2000; Kaatz, 2000; Kaatz, 2002; Kerlinger, 2000; Ketzenberg et al., 2002; Koop, 1997; Koop, 1999; Korn & Scherner, 2000; Kowallik & Borbach-Jaene, 2001; Kruckenberg & Borbach-Jaene, 2001; Kruckenberg & Jaene, 1999; Leddy et al., 1999; Lekuona, 2001; Meek et al., 1993; Menzel, 2002; Menzel & Pohlmeier, 1999; Musters et al., 1996; Orloff & Flannery, 1996; Osborn et al., 1996; Peder-sen& Poulsen, 1991; Percival, 2000; Phillips, 1994; Reichenbach, 2002; Reichen-bach, 2003a; Reichenbach & Schadek, 2003; Reichenbach & Sinning, 2003; Sachslehner & Kollar, 1997; Scherner, 1999; Schmidt et al., 2003; Schreiber, 1992; Schreiber, 1993a; Schreiber, 1993b; Schreiber, 1999; Schreiber, 2002; SEO, 1995; SGS Environment, 1994; Sinning, 1999; Sinning & Gerjets, 1999; Smallwood & Thelander, 2004; Sommerhage, 1997; Steiof et al., 2002; Still et al., 1996; Strickland et al., 2001; Stübing & Bohle, 2001; Thelander & Rugge, 2000; Thelander et al., 2003; Trapp et al., 2002; van der Winden et al., 1999; Vierhaus, 2000; Walter & Brux, 1999; Winkelman, 1989; Winkelman, 1992a; Winkelman, 1992b; Young et al., 2003a; Young et al., 2003b.

And the following sources were included in this report:
Behr & Helversen, 2005; Brandt et al., 2005a; Brinkmann & Schauer-Weisshahn, 2006; Everaert & Stienen, 2006; Grünkorn et al., 2005; Handke et al., 2004a, b, c, d; Kerns et al., 2005; Koford et al., 2003; Lucas et al., 2005; Petersen et al., 2004; Reichenbach & Steinborn, 2006; Sinning, 2004a, b, c; Sinning & Bruyn, 2004; Sinning et al., 2004; Traxler et al., 2004.

As with the NABU-BfN report, the intention was to produce a report primarily rele-vant to Germany, and therefore the main emphasis was on research from Germa-ny. The number of studies included from other countries also partly reflects here the scale of the research carried out in each country (Tab.1).

Country	Number of studies
Belgium	8
Germany	107
Denmark	3
France	2
Great Britain	6
Netherlands	5
Austria	5
Spain	11
USA	31
Australia	2

Table 1*: Countries of the 180 studies evaluated in this report.*

Most of the new studies cover several bird or bat species. For each species often several parameters were analysed (e.g. minimum distance to wind turbines and change in resting populations after installation of a wind farm; for further details see below). The division of species and parameters led to a data matrix with 207 data sets. Combined with the 1,789 data sets of Hötker et al. (2005), in total 1,996 data sets were available.

Most of the new data sets are quantitative analyses and only a few are „single observations“. Many of these „single observations“ have their source in systematic surveys, in the framework of which certain bird species were observed only rarely.

In spite of the addition of new references, the data material was still not suitable for a formal meta-analysis (Fernandez-Duque & Valeggia, 1994). Therefore, as with the NABU-BfN report, all the available results were included in the analysis. No distinction was made between results derived from systematic surveys and those based on only a few casual observations. The disadvantage of using all available studies is that, in statistical terms, casual observations are given equal weight to extensive research. It cannot be ruled out that „extreme“ observations have been recorded more frequently that less spectacular events. Also, additional factors, which could have been important in individual cases, may not have been fully considered. However, the advantage of this method is that the number of studies included in the analysis is large and therefore the results are less dependent on single, well-researched, but possibly atypical, studies. The independence of the data is also guaranteed. With a large number of studies, there is a greater chance that confounding factors may cancel each other out.

Unless stated otherwise, the statistical tests in this report use the „null-hypothesis“ that wind turbines have no influence on the parameter under consideration (for example population size before and after wind farm installation). The alternative hypothesis is that wind turbines do have an influence. In order to carry out the statistical tests, it was determined how many studies had a negative or positive effect (e.g. decrease or increase of population). As mentioned above, neither the strength of effect, nor statistical significance were considered. Neutral results (e.g. constant population) were classified as positive, in order to avoid any false association of wind energy with negative impacts. At the same time, statistically significant negative effects are made in this way more convincing and safer, and are not „diluted“ by the inclusion of neutral results. If wind power has no influence on bird populations, one would expect roughly equal proportions of positive and negative effects. If the frequency of positive and negative effects differs strongly, some impact of wind energy can be assumed. In these cases, the statistical test used is the binomial test. Because not all of the available information is used in this procedure (for example the strength of the effects), it is very conservative, meaning that differences and trends are only classified as significant when they are very strong. The statistical tests were carried out using SPSS 7.5 statistical software.

Because the individual bird and bats species differ greatly in their biology and their use of habitat, whenever possible the evaluation was carried out for separate species. In cases when such differentiation was not possible, species were grouped.

It is assumed that animals which are relatively tied to their breeding areas react differently to wind turbines than those, which only pass through areas outside the breeding season, when they are less tied to a single area and lack local knowledge. Therefore a distinction was made between studies carried out during and outside the breeding season (definition varies, depending on the species concerned). Most studies did not indicate what activities the animals were carrying out at the time of observation (e.g. foraging, resting, roosting) and so this factor could not be considered in this report.

3 Analysed wind turbines

A substantial objective of this report was to estimate the impact that larger „new generation“ wind turbines have on birds and bats, as most of the data from the studies used by Hötker et al. (2005) was based on small wind turbines. For this reason, first of all the wind turbines used in this report shall be described and their different characteristics related to each other.

This report covers almost the whole spectrum of operational wind turbines used, from the beginning of wind energy production until the middle of 2006. The power capacity of the turbines ranges from less than 0.1 MW up to 2.0 MW. There was a similar spread for turbine hub height (22m to 114m), rotor diameter (14m to 80m) and accordingly total height (30m to 146m) to blade tip. As expected, the parameters capacity, hub height, rotor diameter and total height are closely correlated (Fig. 1-3). The relationship between the power capacity of the wind turbines and the remaining parameters can be described by the following equation, whereas the choice of the regression equation had been chosen in a way that the defining R^2 value was maximised (n=741):

$$\textbf{Hub height (m)} = 28.98 * \textbf{power capacity (MW)} + 30.29$$
$$R^2 = 0.67\ (p<0.001)$$

$$\textbf{Total height (m)} = 87.01 * \textbf{power capacity (MW)}^{0.382}$$
$$R^2 = 0.73\ (p<0.001)$$

$$\textbf{Rotor diameter (m)} = 54.75 * \textbf{power capacity (MW)}^{0.382}$$
$$R^2 = 0.79\ (p<0.001)$$

In these equations and in Fig. 1-3, all available data points were used. Single wind turbines were thus counted repeatedly if more data analyses were available. This procedure was chosen because, first of all, it was necessary to clarify the relationships between the individual parameters within the data material, rather than to describe the technical development of the wind energy production.

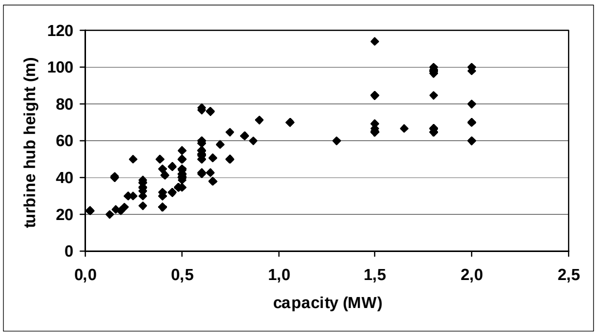

***Figure 1**: The relationship between power capacity of wind turbines and their hub height.*

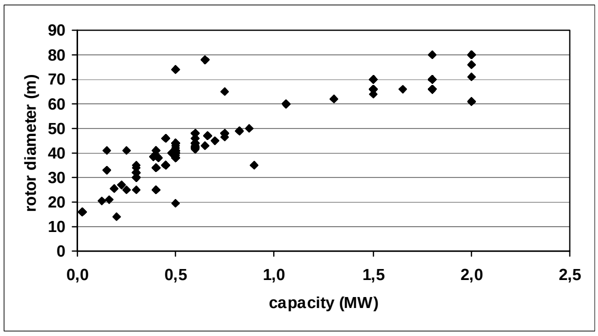

***Figure 2**: Relationship between the power capacity of wind turbines and their rotor diameter.*

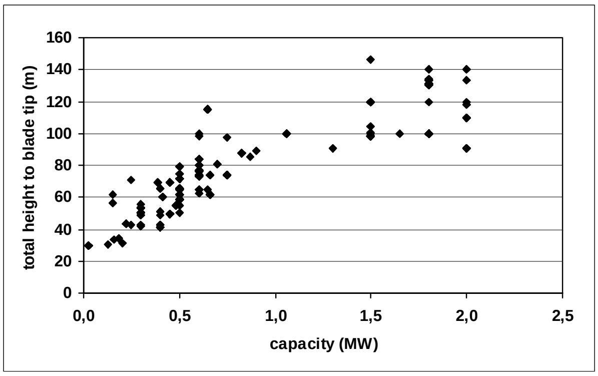

***Figure 3**: Relationship between the power capacity and the total height of wind turbines.*

Power capacity and turbine size define strong linear trends in the early stages of technical development. However, from a capacity of around 1 MW, wind turbine size remains nearly constant as capacity increases.

Within the framework of this study, it was assumed that the overall height of a wind turbine is the parameter, most likely to determine if it has a disturbance impact and therefore in this report, the total height of turbines was the main parameter analysed.

4 Impacts of wind power on birds

4.1 Non-lethal impacts of wind turbines on birds (disturbance, displacement, habitat loss)

4.1.1 Change in distribution due to wind turbines

Because more material was available for this report than for the NABU-BfN report, the question of whether wind turbines have an impact on bird populations could be tested more thoroughly***.*** Only activity taking place on the ground or in vegetation has been considered (breeding, resting, foraging). Despite the better availability of data, only a small number of studies permitted before-after-control impact comparison, and therefore studies that compare bird populations on the wind farm site with bird populations at similar sites in the surrounding area were also taken into account. As the analysed studies differ greatly from each other, it was only considered whether wind turbines had „positive" or „negative" effects. Negative effects are: (1) population decline after installation of the wind turbines; or (2) reduced numbers of birds within wind farms or the surrounding area, in comparison to control areas. Positive effects are accordingly population increase after installation of turbines, or increased bird numbers around the wind farm. The strength of the effects was not considered. If no population differences were detected, the effects were classified as positive in order to avoid falsely inflating the impact of negative effects (see above).

If wind energy has no impact, equal ratios of positive or negative effects are expected and statistical significance of these expectations was tested using a binomial test (for which the null hypothesis is that data are randomly distributed) (Tab. 2).

For 52 species or species groups enough studies (at least six) were of good enough quality to be included in statistical tests. Negative population impacts of wind farms during the breeding season could not be verified for any bird species. Only quail, redshank and lapwing displayed reduced numbers in connection with wind farms. The summarised material of all analysed studies on waders showed a statistically significant majority of negative reactions towards wind turbines. Positive or neutral effects predominate for the remaining species. Two species, which breed in reeds (marsh warbler and reed bunting) as well as stonechat even showed significantly more positive or neutral reactions towards wind turbines than negative ones.

One of the reasons for this phenomenon (i.e. „positive effects") could be that due to construction of wind farms and their supply roads, trenches and high shrub fields had developed, which had not existed before in the uniform farmland and meadows. It is unlikely that these particular species are especially attracted to wind turbines themselves.

Studies carried out outside the breeding season show a very different picture and negative impacts of wind turbines predominate. Wigeon, Lapwing, Common Snipe and Golden Plover display significantly more negative than positive effects. The same applies to wildfowl which have been summarised according to their habits as followed: Geese (White-fronted Goose, Bean Goose, Greylag Goose, Brent Goose and Barnacle Goose*),* dabbling ducks *(*apart from Wigeon: Pintail, Shove-

***Table 2**: Impacts of wind turbines on bird populations showing the number of studies with positive or negative effects as revealed from literature (for details see text). The last column gives the result of sign tests (ns: not significant). Grey shading indicates predominately negative effects.*

Breeding season		Positive effect	Negative effect	Significance
Carrion/Hooded Crow	Corvus corone	6	2	ns
All Waders		30	53	0,016
Blackbird	Turdus merula	6	4	ns
Oystercatcher	Haematopus ostralegus	6	8	ns
White Wagtail	Motacilla alba	4	4	ns
Blue Tit	Parus caeruleus	4	3	ns
Whinchat	Saxicola rubetra	2	7	ns
Chaffinch	Fringilla coelebs	2	4	ns
Common Whitethroat	Sylvia communis	8	5	ns
Skylark	Alauda arvensis	18	16	ns
Willow Warbler	Phylloscopus trochilus	4	2	ns
Yellowhammer	Emberiza citrinella	4	6	ns
Linnet	Carduelis cannabina	3	6	ns
Northern Lapwing	Vanellus vanellus	12	23	ns
Common Buzzard	Buteo buteo	3	3	ns
Grey Partridge	Perdix perdix	5	5	ns
Reed Bunting	Emberiza schoeniclus	11	2	0,022
Redshank	Tringa totanus	2	9	ns
Yellow Wagtail	Motacilla flava	8	3	ns
Sedge Warbler	Acrocephalus schoenobaenus	10	0	0,002
Stonechat	Saxicola torquata	8	1	0,039
Mallard	Anas platyrhynchos	7	6	ns
Marsh Warbler	Acrocephalus palustris	7	4	ns
Reed Warbler	Acrocephalus scirpaceus	7	1	ns
Black-tailed Godwit	Limosa limosa	5	7	ns
Quail	Coturnix coturnix	1	6	ns
Meadow Pipit	Anthus pratensis	16	8	ns
Wren	Troglodytes troglodytes	6	1	ns
Chiffchaff	Phylloscopus collybita	4	2	ns
Outside breeding season				
Carrion/Hooded Crow	Corvus corone	13	8	ns
Oystercatcher	Haematopus ostralegus	4	3	ns
Common Snipe	Gallinago gallinago	0	6	0,05
Skylark	Alauda arvensis	5	2	ns
Geese		2	12	0,013
Golden Plover	Pluvialis apricaria	8	23	0,012
Grey Heron	Ardea cinerea	5	1	ns
Curlew	Numenius arquata	13	19	ns
Dabbling Ducks (except Wigeon)		3	15	0,008
Northern Lapwing	Vanellus vanellus	13	30	0,015
Black-headed Gull	Larus ridibundus	15	5	0,041
Common Buzzard	Buteo buteo	13	12	ns
Wigeon	Anas penelope	0	9	0,004
Tufted Duck	Aythya fuligula	2	6	ns
Wood Pigeon	Columba palumbus	2	7	ns
Red Kite	Milvus milvus	3	4	ns
Swans		2	6	ns
Herring Gull	Larus argentatus	2	5	ns
Starling	Sturnus vulgaris	17	6	0,035
Mallard	Anas platyrhynchos	3	8	ns
Common Gull	Larus canus	3	6	ns
Diving Ducks		2	12	0,013
Kestrel	Falco tinnunculus	15	7	ns
Fieldfare	Turdus pilaris	1	6	ns

ler, Mallard and Gadwall) and diving ducks (Common Pochard, Tufted Duck, Greater Scaup and Goldeneye). Exceptions were Starling and Black-headed Gull for which significantly more positive (or neutral) effects were recorded.

Overall, this study statistically confirms the results of others (Horch & Keller, 2005; Langston & Pullan, 2003; Reichenbach, 2003b), namely that wind farms have less impact on breeding birds, but greater impact on non-breeding birds. However, in contrast to the hypothesis so far, this analysis also showed that breeding populations may be locally threatened by wind turbines.

4.1.2 Minimum avoidance distance of birds to wind turbines

One of the essential questions of this report was to determine the impact particularly of newer, larger wind turbines on birds. It could be that disturbance factors of such turbines are much greater than those of smaller turbines previously analysed. Minimum avoidance distance of birds to wind turbines was included in 730 data sets. Results were available for 29 species or species groups or 26 species or species groups from the breeding season and the non-breeding season respectively (with at least four results for each species or species group to demonstrate a significant correlation of the chosen parameter in the analysis). The data are summarised in Table 3. With the help of regression calculations (the models used „power functions“), it was also possible to estimate to which extent the turbine influence displacement distances. Some of the studies are the same as those used in the previous chapter („impacts of wind turbines on population“).

The data show great variation, which was demonstrated by comparing results „between“ species and „within“ species. Therefore, in some cases standard deviations are very high (Tab.3). This may be explained either by the inclusion of casual observations that naturally show higher dispersion, or by larger differences between individual wind farms.

Despite the high degree of variation, some previously known trends could be clearly confirmed. Avoidance distances during the breeding season were smaller than outside the breeding season. Only a few wader species avoided close contact with wind farms at all times of the year.

Greater avoidance distances from wind turbines were generally observed outside the breeding season. As expected, birds of open habitats, e.g. geese, ducks and waders, generally avoided turbines by several hundred metres. However, under certain circumstances some individuals from nearly all of these species or species groups were observed very close to wind turbines. These observations were exceptional and therefore do not prove that the species concerned are generally insensitive to disturbance by wind turbines. In contrast, grey heron, birds of prey, oystercatcher, gulls, starling and crows were often observed close to or even within wind farms, which contributed partly to higher collision rates (see chapter 4.2.1 and Appendix). Sensitive species roosted at least 400-500m away from wind turbines (Tab.3). Greater avoidance distances are likely to cause negative effects only in exceptional circumstances. To a large extent, the results correspond with the conclusions of single studies on this topic (Kruckenberg & Jaene, 1999; Reichenbach, 2003b; Schreiber, 1993a; Schreiber, 1999).

***Table 3**: Minimum distances of different bird species from wind turbines according to different literature studies. The equations (minimum distance = coefficient * wind turbine height-^{exponent}) demonstrate the relationship between the total height of wind turbines and the minimum distance of birds. Grey shading indicates cases where distance has increased with turbine height. SD: standard deviation. F: values of the variance-analyses in order to verify the regression coefficients.*

Breeding season									
	Species	**n**	**Median**	**Mean**	**SD**	**Coefficient**	**Exponent**	**p**	**F**
Blackbird	Turdus merula	5	100	82	76	108812	-0,2290	ns	
Oystercatcher	Haematopus ostralegus	9	50	81	106	638,605	-0,7214	ns	
White Wagtail	Motacilla alba	5	50	72	51	5324,82	-1,0720	ns	
Bluethroat	Luscinia svecica	8	25	63	92	0,0004	2,5573	ns	
Curlew	Numenius arquata	4	125	163	144	83000000	-3,3837	ns	
Whinchat	Saxicola rubetra	5	125	155	60	125,073	0,0378	ns	
Common Whitethroat	Sylvia communis	12	70	75	57	852,679	-0,6752	ns	
Skylark	Alauda arvensis	26	105	120	116	3814,46	-0,9397	ns	
Finches		12	125	104	64	1659,37	-0,7498	ns	
Willow Warbler	Phylloscopus trochilus	5	50	42	40	59,5263	-0,0269	ns	
Garden Warbler	Sylvia borin	4	55	72	83	2179,7	-1,0076	ns	
Icterine Warbler	Hippolais icterina	4	30	40	45	372,29	-0,6644	ns	
Yellowhammer	Emberiza citrinella	6	85	89	58	149062	-1,6940	ns	
Corn Bunting	Miliaria calandra	4	88	94	88	1773392	-2,3029	ns	
Linnet	Carduelis cannabina	6	138	138	27	90,2427	0,0968	ns	
Northern Lapwing	Vanellus vanellus	21	125	134	119	0,3942	1,1575	ns	
Grey Partridge	Perdix perdix	4	100	125	96	9634801	-2,5701	ns	
Reed Bunting	Emberiza schoeniclus	16	50	86	139	2614,95	-1,0739	ns	
Redshank	Tringa totanus	6	188	183	111	1186,16	-0,4883	ns	
Yellow Wagtail	Motacilla flava	11	50	111	141	501,227	-0,5251	ns	
Sedge Warbler	Acrocephalus schoenobaenus	10	25	45	76	0,4507	0,9194	ns	
Stonechat	Saxicola torquata	5	50	104	150	50852,4	-1,5484	ns	
Starling	Sturnus vulgaris	4	75	71	62	4571,61	-1,0901	ns	
Mallard	Anas platyrhynchos	10	113	133	123	29,6433	0,2527	ns	
Marsh Warbler	Acrocephalus palustris	13	50	67	64	0,0032	2,1691	ns	
Reed Warbler	Acrocephalus scirpaceus	13	50	62	69	4288,03	-1,1862	ns	
Black-tailed Godwit	Limosa limosa	7	250	369	315	7826198	-2,3505	ns	
Meadow Pipit	Anthus pratensis	13	50	82	100	1111,88	-0,7998	ns	
Wren	Troglodytes troglodytes	5	50	90	96	0,0053	2,1329	ns	
Chiffchaff	Phylloscopus collybita	5	50	42	40	59,5263	-0,0269	ns	
Non-breeding season									
Carrion/Hooded Crow	Corvus corone	17	0	77	139	5E-09	5,0093	0,033	5,66
Oystercatcher	Haematopus ostralegus	6	15	55	81	3293811	-2,8716	ns	
Common Snipe	Gallinago gallinago	6	325	394	199	911,611	-0,2126	ns	
Coot	Fulica atra	4	138	136	99	1424,8	-0,6019	ns	
Curlew	Numenius arquata	25	200	222	178	236,007	-0,1474	ns	
Skylark	Alauda arvensis	6	0	38	59	0,0021	1,9466	ns	
Finches		14	45	58	59	1,6E-08	4,9391	<0,001	214,39
Geese		15	300	347	230	0,577	1,4018	ns	
Golden Plover	Pluvialis apricaria	24	150	202	190	0,004	3,0760	<0,001	21,14
Grey Heron	Ardea cinerea	7	60	120	170	3739,06	-1,0940	ns	
Northern Lapwing	Vanellus vanellus	36	175	273	390	0,000055	3,4002	<0,001	30,66
Black-headed Gull	Larus ridibundus	16	0	91	205	0,0114	1,7282	ns	
Common Buzzard	Buteo buteo	17	100	76	93	0,6489	0,9307	ns	
Gulls		32	25	120	208	0,3189	1,0722	ns	
Wigeon	Anas penelope	9	300	311	163	661,776	-0,2093	ns	
Wood Pigeon	Columba palumbus	6	100	175	178	4,9E-08	4,7582	ns	
Swans		8	125	150	139	5,4086	0,6210	ns	
Herring Gull	Larus argentatus	5	200	285	323	41,4305	0,2309	ns	
Starling	Sturnus vulgaris	18	0	38	58	0,000033	2,9925	0,036	5,4
Mallard	Anas platyrhynchos	9	200	161	139	1987,79	-0,8288	ns	
Common Gull	Larus canus	7	100	118	139	2,1054	0,7213	ns	
Diving Ducks		12	213	219	122	111,351	0,0673	ns	
Kestrel	Falco tinnunculus	16	0	36	53	2,2685	0,4728	ns	

When assessing the results, it should be remembered that some potentially sensitive species have still only been analysed rarely or not at all. This is particularly the case for the more controversial species (storks, birds of prey, cranes and corncrake) and therefore the list of species sensitive to disturbance is not complete.

As mentioned above, wind farms vary greatly with regard to their impacts on bird populations. It appears that the size of the turbine is at least partly responsible for these differences. The question of how turbine size affects minimum avoidance distances of birds to turbines is also relevant to repowering.

For bird species for which minimum avoidance distances were observed at least four different wind farms (the minimum number needed to obtain a statistically significant result), the relationship between turbine height and minimum avoidance distance was calculated and is presented in Table 3. This report could for the first time (compared with the NABU-BfN report) also include substantially more data relating to larger wind turbines.

Even though the remaining results presented in Tab. 3 are in most cases not statistically significant, overall this analysis still confirms other previous conclusions. Breeding birds were less disturbed by larger wind turbines than by smaller ones. 21 out of 29 species tended to use habitat closer to larger turbines than smaller ones. This was also the case for rather sensitive wader species, such as Black-tailed Godwit, Curlew and Redshank.

Outside the breeding season 16 out of 23 cases showed an increase in minimum avoidance distance with increased turbine size. For Lapwing, Golden Plover, Carrion Crow, Starling and Finches the results were statistically significant (Fig. 4-8).

In seven cases a negative correlation was noticeable, meaning that larger wind turbines had a smaller displacement effect. This also applies to species or species groups, which are more sensitive to disturbance, such as Wigeon, Common Snipe and Curlew.

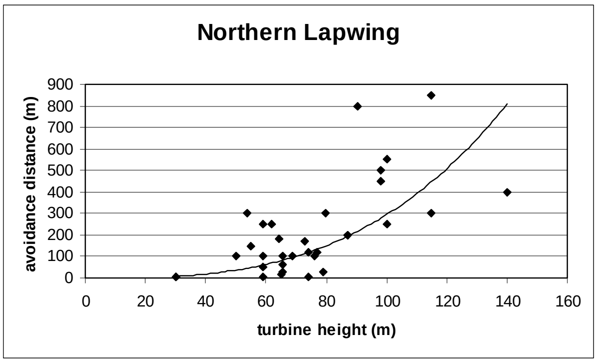

Figure 4*: Relationship between minimum distance kept by Lapwings from wind turbines outside the breeding season in relation to total turbine height.*

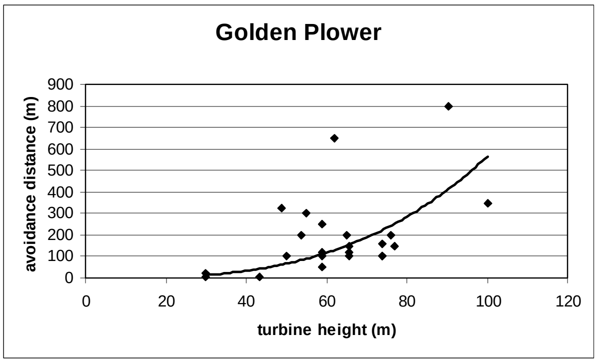

Figure 5*: Relationship between minimum distance kept by Golden Plover from wind turbines outside the breeding season in relation to total turbine height.*

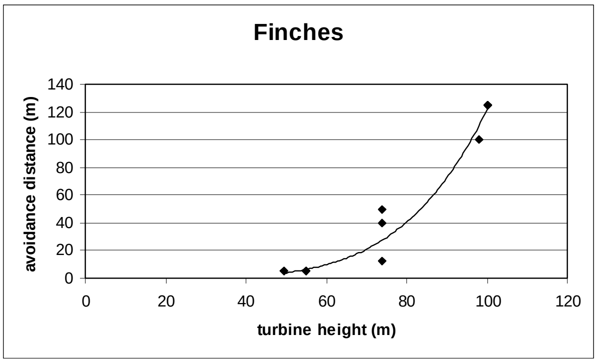

Figure 6*: Relationship between minimum distance kept by Finches from wind turbines outside the breeding season in relation to total turbine height.*

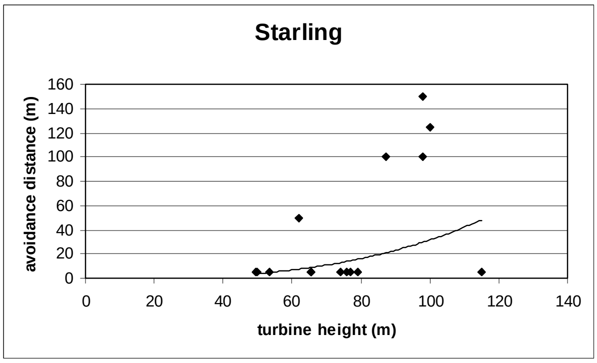

Figure 7*: Relationship between minimum distance kept by Starling from wind turbines outside the breeding season in relation to total turbine height.*

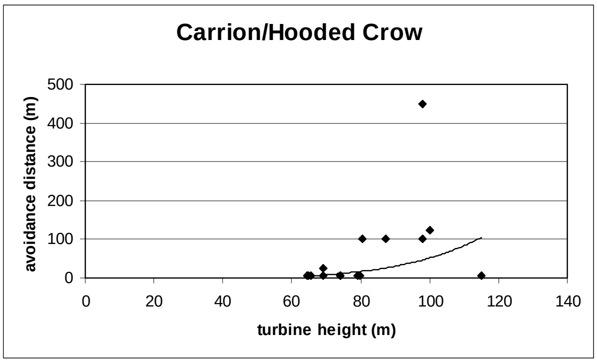

Figure 8*: Relationship between minimum distance kept by Carrion/Hopoded Crow from wind turbines outside the breeding season in relation to total turbine height.*

4.2 Collision of birds and bats with wind turbines

4.2.1 Collision of birds with wind turbines

The NABU-BfN report included mainly observations available from the USA, so it was possible for this report to add some studies from Europe, which had been gathered particularly at relatively large and new wind turbines. Data were only included in the analysis if there were regular controls and if account was taken of the likelihood that carcasses disappeared from the study area (Anderson et al., 1999; Morrison, 2002). The mortality rates of Grünkorn et al. (2005) do not cover the whole year, but were still included in the analysis. Therefore, the data in Tab. 4 tend to underestimate rather than overestimate actual collision rates.

Some wind farms were represented in several studies, so that the present data sets partly overlap with each other. To guarantee the independence of the data sets, each wind farm was included only once in the statistical analysis, using either the most recent report, or that including the most extensive observations.

Collision rates varied greatly between different wind farms. For some wind farms no collisions or nearly none occurred. At other wind farms, collisions occurred at a frequency of more than 60 per turbine per year. Mass collisions, similar to those known from lighthouses or other buildings (Crawford & Engstrom, 2001; Erickson et al., 2002; Manville, 2001; Ugoretz, 2001) could not be identified for individual turbines within wind farms. In most of the studies the casualty rate is one bird per turbine per year; the median was 1.8 and the mean 6.9 victims per turbine per year.

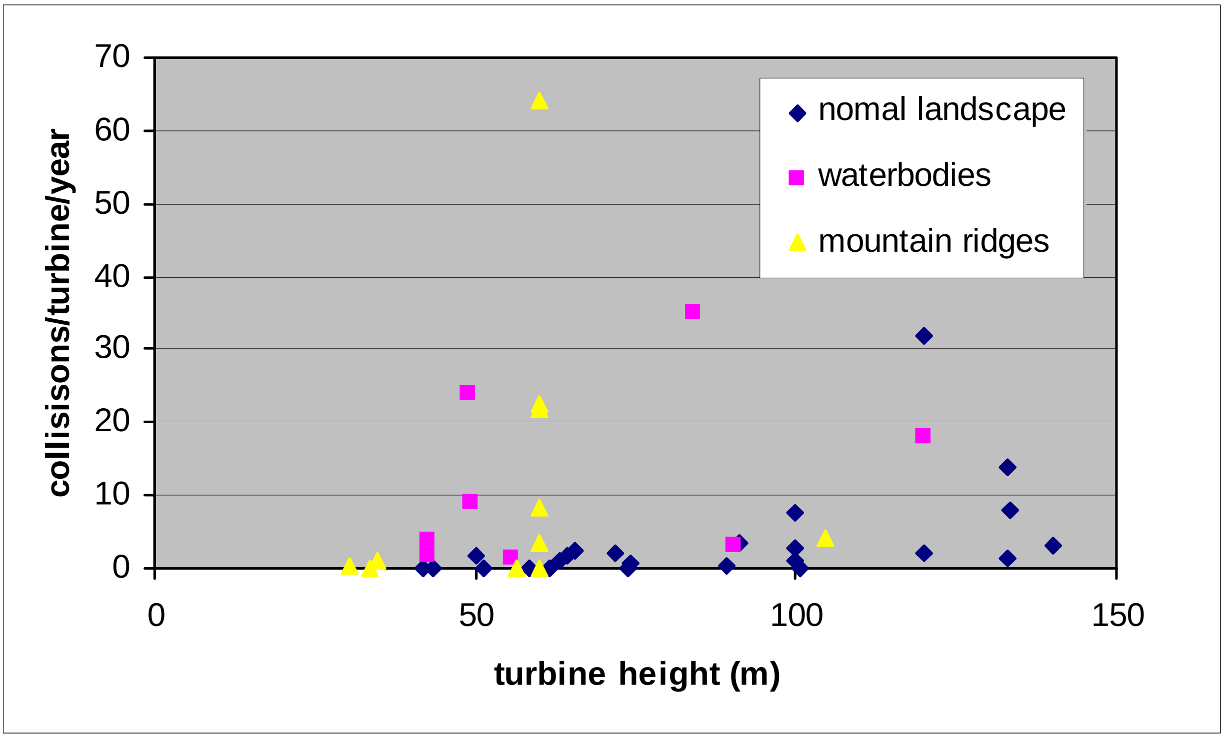

***Figure 9**: Collision rates of birds with wind turbines at different wind farm sites in relation to total turbine height.*

***Table 4**: Collision rates birds (mean number of victims per turbine per year) at different wind farms.*

Country	Wind farm	Habitat	Collisions / Turbine / Year	Comments	Source
Australia	Tasmania	Coast	1,86		Hydro Tasmania
Belgium	Boudewijnkanaal te Brugge	Wetland	35	Other studies in different years	Everaert et al., 2003
Belgium	Elektriciteitscentrale te Schelle	Wetland	18	Other studies in different years	Everaert et al., 2003
Belgium	Gent	Industrial	2		Everaert in litt
Belgium	Kleine Pathoekeweg, Brugge	Industrial	32		Everaert in litt
Belgium	Kluizendok, Gent	Industrial	8		Everaert in litt
Belgium	Nieuwkapelle, Diksmuide	Wet grassland	1		Everaert in litt
Belgium	Oostdam te Zeebrugge	Wetland	24	Other studies in different years	Everaert, Devos & Kuijken, 2003
Denmark	Tjaereborg	Wetland	3		Pedersen & Poulsen, 1991b
Germany	Breklumer Koog	Fields	>7,5	Study period less than 1 year	Grünkorn et al, 2005
Germany	Bremerhaven-Fischereihafen	Wetland	9		Scherner, 1999b
Germany	Friedrich-W ilhelm-Lübke-Koog	Fields	>2,6	Study period less than 1 year	Grünkorn et al, 2005
Germany	Simonsberger Koog	Fields	>2,2	Study period less than 1 year	Grünkorn et al, 2005
Netherlands	Kreekraak sluice	Wetland	3,7		Musters et al., 1996
Netherlands	Oosterbierum	Grassland	1,8		Winkelman, 1992a
Netherlands	Urk	Coast	1,7		W inkelman, 1989
Austria	Obersdorf	Woodland edge, fields	1,49		Traxler et al., 2005
Austria	Prellenkirchen	Fields	13,93		Traxler et al., 2006
Austria	Steinberg-Prinzendorf	Woodland edge, fields	2,99		Traxler et al., 2004
Sweden	Näsudden	Grassland	0,7		Percival, 2000
Spain	Alaiz-Echague	Mountain ridges	3,56		Lekuona, 2001
Spain	E3, Energia Eólica del Estrecho	Mountain ridges	0,03		Barrios & Rodriguez, 2004; SEO, 1995
Spain	El Perdón	Mountain ridges	64,26		Lekuona, 2001
Spain	Guennda	Mountain ridges	8,47		Lekuona, 2001
Spain	Izco-Albar	Mountain ridges	22,63		Lekuona, 2001
Spain	PESUR, Parque Eólico del Sur and	Mountain ridges	0,36		Barrios & Rodriguez, 2004;
	Parque und Parque Eólico de				SEO, 1995
	Levantera				
Spain	Salajones	Mountain ridges	21,69		Lekuona, 2001
Spain	Tarifa		0,03		Janss, 2000
UK	Blyth	Wetland	1,34		Still et al., 1996
UK	Bryn Tytli	Moor, grassland	0		Phillips, 1994
UK	Burgar Hill, Orkney	Moor, grassland	0,15		Percival, 2000
UK	Cemmaes	Moor, grassland	0,04		Percival, 2000
UK	Haverigg, Cumbria	Moor, grassland	0		Percival, 2000
UK	Ovenden Moor	Moor, grassland	0,04		Percival, 2000
USA	Altamont	Mountain ridges	0,87	Other studies in different years	Smallwood & Thelander, 2004
USA	Buffalo Ridge	Grassland	0,98	Other studies in different years	Erickson et al., 2001
USA	Foote Creek Rim	Prairie	1,75	Other studies in different years	Erickson et al., 2001
USA	Green Mt, Searsburg	Mountain ridges	0		Erickson et al., 2001
USA	IDWGP, Algona	Mountain ridges	0		Erickson et al., 2001
USA	Mountaineer	Mountain ridges	4,04		Kerns & Kerlinger, 2004
USA	Nine Canyon W ind Project	Prairie	3,59	Other studies in different years	Erickson et al., 2003
USA	San Gorgino	Mountain ridges	2,31		Erickson et al., 2001
USA	Solano County	Mountain ridges	54		Erickson et al., 2001
USA	Somerset County	Mountain ridges	0		Erickson et al., 2001
USA	Top of Iowa	Prairie	0,415		Koford et al., 2003
USA	Vansycle	Fields, grassland	0,63	Other studies in different years	Erickson et al., 2001

One of the main emphases of this report was the issue of the extent to which collision rates were dependent on turbine size. The worry was that relatively more birds are killed by particularly large wind turbines than at smaller ones. Collision rates correlate significantly with hub and total height (Fig. 9, Tab.5).

It is already know from previous analyses that collision rates were particularly high at certain locations, such as bare mountain ridges and water bodies. It was also possible to confirm these results in this report. Giving equal weight to „habitat“ (category high risk: mountain ridges and water bodies; category low risk: other habitats) and „turbine height“, a GLM-analysis identified both habitat and turbine height as significant ($F_1 = 7.96$; $p = 0.007$) or nearly significant impact parameters ($F_1 = 3.37$; $p = 0.074$), respectively. Wind farms located in low-risk „normal“ landscapes show a relationship between collision rate and the size of wind turbines (Fig. 9) that is statistically significant (Tab.5). If considering the turbine size dependancy of bird casualties within the two habitat-types wetlands and normal landscape, there was no significant result in either case.

In order to address the issue of what species are particularly affected by wind turbines, the comprehensive statistical analyses of T. Dürr (*Staatliche Vogelschutzwarte Brandenburg*) should be pointed out, and the latest version was included in this report. The species composition of collision victims has not fundamentally changed. In Germany, birds of prey dominate with very high numbers of Red Kites and White-tailed Eagles.

4.2.2 Collision of bats with wind farms

***Table 5**: The relationship between collision rates of birds and hub height, rotor diameter and total height of wind turbines. In addition, the relationship between collision rates of birds and total turbine height in different habitat types is included.*

Type	Parameter	n	R^2	Regression equation	F	p
All data	Hub height	43	0,110	$Y = 0{,}0006\ x^{1{,}948}$	0,431	0,030
All data	Rotor diameter	43	0,084	$Y = 0{,}0007\ x^{1{,}966}$	3,75	0,06
All data	Total height	43	0,105	$Y = 0{,}0002\ x^{2{,}022}$	4,78	0,034
“Normal” landscape	Total height	24	0,360	$Y = 0{,}00000017\ x^{3{,}978}$	12,39	0,002
Wetlands	Total height	8	0,167	$Y = 0{,}0303\ x^{1{,}302}$	1,20	0,32
Mountain ridges	Total height	11	0,146	$Y = 0{,}0000032\ x^{3{,}240}$	1,53	0,25

It has been know for some time that bats can also be killed by wind turbines. More recent studies (Brinkmann & Schauer-Weisshahn, 2006) have improved the quality of data. As for the NABU-BfN report, data were only analysed if the number of victims per turbine per year could be calculated. As with the bird analyses, account was also taken of the possibility that bat carcasses could have been removed by scavengers. Because bats were mainly killed in summer and early autumn, only observations from this time period were included. In order to ensure the independence of the data, only one value per wind farm was used, as for the bird analyses.

Collision rates for bats (Tab.6) show even more variation than collision rates for birds (Tab.4). Even though at many wind farms no bats or only a few were killed, other wind farms showed high mortality rates. The results for 34 wind farms ranged between 0 and 134 victims (median: 6.4; mean: 13.3; standard deviation: 13.3 for killed bats per turbine per year), and the highest rates exceed the highest rates for birds.

Table 6*: Collision rates of bats (average number of victims per turbine per year) at different wind farms.*

Country	Windfarm	Habitat	Collisions / Turbine / Year	Source
Australia	Tasmania	Coast	1,86	Hydro Tasmania
Germany	Ettenheim Brudergarten 1	Woodland	35,18	Brinkmann & Schauer Weisshahn, 2005
Germany	Ettenheim Brudergarten 2	Woodland	24,12	Brinkmann & Schauer Weisshahn, 2005
Germany	Ettenheim Brudergarten 3	Woodland/ windthrow	22,04	Brinkmann & Schauer Weisshahn, 2005
Germany	Ettenheim Mahlberg 1	Windthrow	13,02	Brinkmann & Schauer Weisshahn, 2005
Germany	Ettenheim Mahlberg 2	Woodland	9,62	Brinkmann & Schauer Weisshahn, 2005
Germany	Ettenheim Mahlberg 3	Woodland	14,64	Brinkmann & Schauer Weisshahn, 2005
Germany	Freiamt Hohe Eck	Woodland	52,34	Brinkmann & Schauer Weisshahn, 2005
Germany	Freiamt Schillinger Berg 1	Woodland	103,16	Brinkmann & Schauer Weisshahn, 2005
Germany	Freiamt Schillinger Berg 2	Meadow	0	Brinkmann & Schauer Weisshahn, 2005
Germany	Fürstenberg	Meadow	0	Brinkmann & Schauer Weisshahn, 2005
Germany	Horben Holzschlägermatte 1	Woodland	37,56	Brinkmann & Schauer Weisshahn, 2005
Germany	Horben Holzschlägermatte 2	Woodland	8,02	Brinkmann & Schauer Weisshahn, 2005
Germany	Rosskopf	Woodland, mountain ridges	21,5	Behr & Helversen, 2005
Germany	Simonswald Plattenhöfe 2	Meadow/ woodland	7,59	Brinkmann & Schauer Weisshahn, 2005
Germany	Simonswald Plattenhöfe 3	Meadow/ woodland	7,94	Brinkmann & Schauer Weisshahn, 2005
Germany	Simonswald Plattenhöfe 4	Meadow	0	Brinkmann & Schauer Weisshahn, 2005
Germany	St. Peter Plattenhöfe 1	Meadow/ woodland	0	Brinkmann & Schauer Weisshahn, 2005
Austria	Obersdorf	Woodland edge, fields	0	Traxler et al., 2005
Austria	Prellenkirchen	Fields	8	Traxler et al., 2005
Austria	Steinberg-Prinzendorf	Woodland edge, fields	5,33	Traxler et al., 2005
Spain	Alaiz-Echague	Mountain ridges	0	Lekuona, 2001
Spain	El Perdón	Mountain ridges	0	Lekuona, 2001
Spain	Guennda	Mountain ridges	0	Lekuona, 2001
Spain	Izco-Albar	Mountain ridges	3,09	Lekuona, 2001
Spain	Salajones	Mountain ridges	13,36	Lekuona, 2001
USA	Altamont	Mountain ridges	0,0035	Smallwood & Thelander, 2004
USA	Buffalo Ridge	Grassland	2,3	Osborn et al., 1996
USA	Foote Creek Rim	Prairie	1,34	Young et al., 2003a
USA	Mautaineer Wind Energy Facility Blackwater Falls	Woodland	50	Boone, 2003
USA	Meyersdale	Woodland, mountain ridges	25	Kerns et al., 2005
USA	Mountaineer	Woodland, mountain ridges	38	Kerns & Kerlinger, 2004
USA	Nine Canyon Wind Project	Pairie	3,21	Erickson et al., 2003
USA	Top of Iowa	Woodland, mountain ridges	6,432	Koford et al., 2003
USA	Vansycle	Fields, grassland	0,4	Strickland et al., 2001b

Furthermore, there was a statistically significant relationship between the number of bats killed and hub height, rotor diameter and wind turbine height (Fig. 10, Tab. 7). However, if one takes into account the fact that bats are killed more frequently at sites close to woodlands, then the influence of turbine size disappears. A GLM-analysis shows that the factor „habitat“ (woods and other habitats) had an almost significant influence on the collision rates ($F_1 = 3.801$; $p = 0.06$), while turbine height showed no influence ($F_1 = 0.17$; $p = 0.69$). Considering turbine height and collision rates separately for sites close to woodlands and in other locations, then no significant relationship is noticeable (Tab.7).

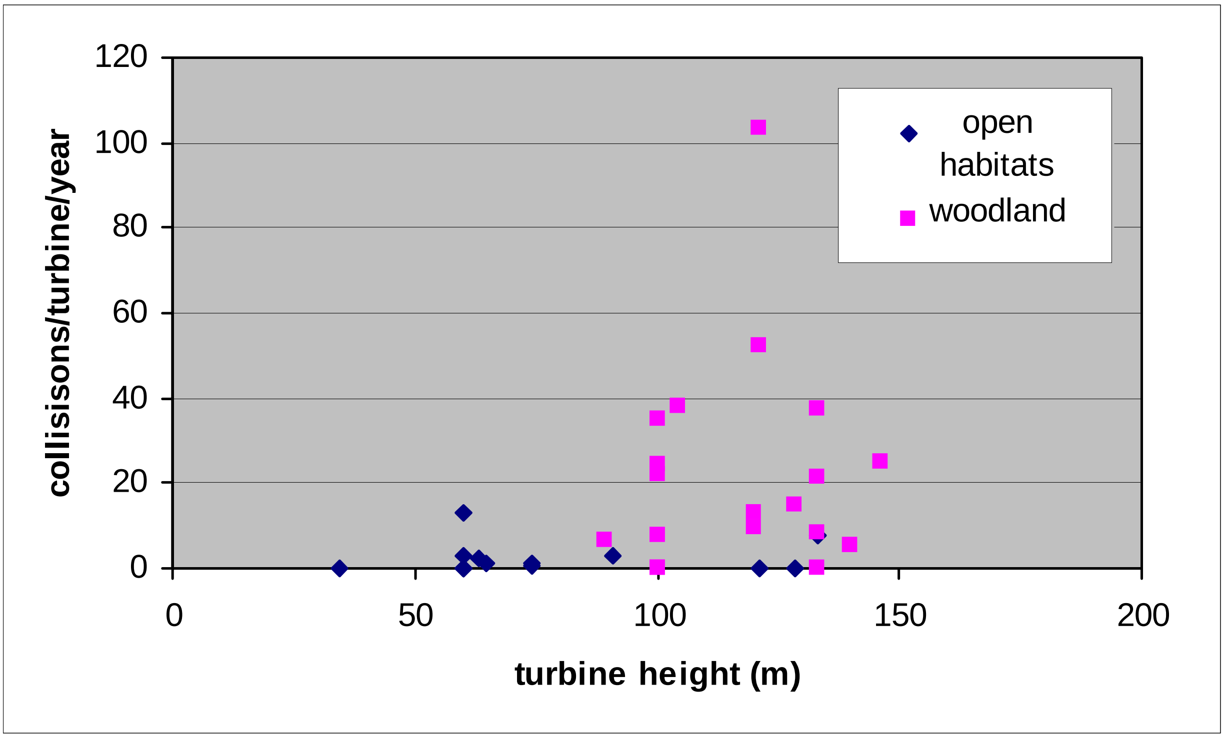

Figure 10*: Collision rates of bats with wind turbines of different total heights.*

Table 7*: Relationship between collision rates of bats and the hub height, rotor diameter and the total height of wind turbines at different wind farms. In addition, the relationship between the collision rate of birds and the total height of wind turbines in different habitat types is included.*

Type	**Parameter**	**n**	**R^2**	**Regression equation**	**F**	**p**
All data	Hub height	34	0,139	$Y = 0{,}0000025\ x^{3{,}180}$	5,17	0,030
All data	Rotor diameter	34	0,165	$Y = 0{,}000000019\ x^{4{,}517}$	6,33	0,017
All data	Total height	34	0,152	$Y = 0{,}000000086\ x^{3{,}674}$	5,75	0,022
Open habitat	Total height	14	0,007	$Y = 0{,}0134\ x^{0{,}679}$	0,09	0,77
Woodland locations	Total height	20	0,022	$Y = 0{,}0000069\ x^{2{,}877}$	0,41	0,53

For further information on the species composition of collision victims, see T. Dürr/ *Staatliche Vogelschutzwarte Brandenburg* (see Appendix). At 14 wind farms, collisions of both bats and birds were analysed and there was no relationship between collision rates ($R^2 = 0.009$, $p = 0.75$).

5 Estimated impacts of repowering

Increasing the amount of electricity produced by wind energy on land will be achieved through repowering, meaning that many small wind turbines will be replaced by larger, more modern and thus more powerful wind turbines. With the help of the results collected so far, this chapter will try to assess the impacts of repowering expected on birds and bats. Displacement impacts of repowering shall be considered, as well as the risk of collisions. Four scenarios were modelled as a first step towards understanding the impacts of repowering. Scenarios 1 and 2 assume that 0.3 MW wind turbines are replaced by 1.5 MW and 2.0 MW turbines respectively, while in scenarios 3 and 4, 0.5 MW turbines are replaced by 1.5 MW and 2.0 MW wind turbines respectively. For each scenario, the model simulates various increases in capacity (ranging between no increase (factor 1) up to a five-times increase).

In order to assess impacts on birds and bats, first of all the expected turbine height was calculated using the relationship between turbine capacity and height (see chapter 3).

5.1 Repowering and disturbance of birds

The relationship between total turbine height and minimum distances birds are found from turbines, combined with the relationship between turbine height and capacity, allows the effects of repowering on the spatial distribution of birds to be estimated. Hence, the following simple hypotheses are assumed:

1. No birds use the area within the radius of the minimum distance (disturbance area); outside this radius turbines have no effect.
2. Scenarios consider single, standalone wind turbines. Because wind farms vary greatly in layout, effects cannot be generalised. The effect of layout must be considered separately for each wind farm.

Impacts can only be estimated by comparing the size of the disturbed areas. For example, at one wind farm 20 x 0.3MW wind turbines shall be replaced by 8 x 1.5MW turbines. The capacity of the wind farm increases by a factor of 2. The repowering has a negative effect for a bird species, if the sum of the disturbance factors from 8 x 1.5MW wind turbines is bigger than the sum of disturbance factors from 20 x 0.3MW turbines.

The disturbance influence radii of wind turbines of different heights can be calculated using the data in Table 3. Examples of model calculations are summarised in Table 8. The results of the different scenarios are not substantially different from each other. In most cases breeding birds reacted positively to repowering, while visiting birds showed a variable picture in which repowering had a negative effect on sensitive species, such as geese, Golden Plover and Lapwing.

***Table 8**: Estimates of disturbance factors for birds after repowering, using model calculations under different scenarios. Positive (+) means a smaller area of disturbance, while negative (-) means a larger area of disturbance after repowering. See text for more details.*

Breeding season; Scenario: 0,3 MW to 1,5 MW

Species	Increase in output (factors):	1	1,5	2	2,5	3	3,5	4	4,5	5
Oystercatcher	*Haematopus ostralegus*	+	+	+	+	+	+	+	+	+
White Wagtail	*Motacilla alba*	+	+	+	+	+	+	+	+	+
Bluethroat	*Luscinia svecica*	-	-	-	-	-	-	-	-	-
Curlew	*Numenius arquata*	+	+	+	+	+	+	+	+	+
Whinchat	*Saxicola rubetra*	+	+	+	+	+	+	+	+	-
Common Whitethroat	*Sylvia communis*	+	+	+	+	+	+	+	+	+
Skylark	*Alauda arvensis*	+	+	+	+	+	+	+	+	+
Finches		+	+	+	+	+	+	+	+	+
Willow Warbler	*Phylloscopus trochilus*	+	+	+	+	+	+	+	+	+
Garden Warbler	*Sylvia borin*	+	+	+	+	+	+	+	+	+
Icterine Warbler	*Hippolais icterina*	+	+	+	+	+	+	+	+	+
Yellowhammer	*Emberiza citrinella*	+	+	+	+	+	+	+	+	+
Corn Bunting	*Miliaria calandra*	+	+	+	+	+	+	+	+	+
Linnet	*Carduelis cannabina*	+	+	+	+	+	+	+	-	-
Northern Lapwing	*Vanellus vanellus*	+	-	-	-	-	-	-	-	-
Grey Partridge	*Perdix perdix*	+	+	+	+	+	+	+	+	+
Reed Bunting	*Emberiza schoeniclus*	+	+	+	+	+	+	+	+	+
Redshank	*Tringa totanus*	+	+	+	+	+	+	+	+	+
Yellow Wagtail	*Motacilla flava*	+	+	+	+	+	+	+	+	+
Sedge Warbler	*Acrocephalus schoenobaenus*	+	+	-	-	-	-	-	-	-
Stonechat	*Saxicola torquata*	+	+	+	+	+	+	+	+	+
Starling	*Sturnus vulgaris*	+	+	+	+	+	+	+	+	+
Mallard	*Anas platyrhynchos*	+	+	+	+	+	+	-	-	-
Marsh warbler	*Acrocephalus palustris*	-	-	-	-	-	-	-	-	-
Reed warbler	*Acrocephalus scirpaceus*	+	+	+	+	+	+	+	+	+
Black-tailed godwit	*Limosa limosa*	+	+	+	+	+	+	+	+	+
Meadow pipit	*Anthus pratensis*	+	+	+	+	+	+	+	+	+
Wren	*Troglodytes troglodytes*	-	-	-	-	-	-	-	-	-
Chiffchaff	*Phylloscopus collybita*	+	+	+	+	+	+	+	+	+

Outside the breeding season; Scenario: 0,3 MW to 1,5 MW

Species	Increase in output (factors):	1	1,5	2	2,5	3	3,5	4	4,5	5
Carrion/Hooded Crow	*Corvus corone*	-	-	-	-	-	-	-	-	-
Blackbird	*Turdus merula*	+	+	+	+	+	+	+	+	+
Oystercatcher	*Haematopus ostralegus*	+	+	+	+	+	+	+	+	+
Common Snipe	*Gallinago gallinago*	+	+	+	+	+	+	+	+	+
Coot	*Fulica atra*	+	+	+	+	+	+	+	+	+
Curlew	*Numenius arquata*	+	+	+	+	+	+	+	+	+
Chaffinch	*Fringilla coelebs*	-	-	-	-	-	-	-	-	-
Skylark	*Alauda arvensis*	-	-	-	-	-	-	-	-	-
Finches		-	-	-	-	-	-	-	-	-
Geese		-	-	-	-	-	-	-	-	-
Golden Plover	*Pluvialis apricaria*	-	-	-	-	-	-	-	-	-
Grey Heron	*Ardea cinerea*	+	+	+	+	+	+	+	+	+
Northern Lapwing	*Vanellus vanellus*	-	-	-	-	-	-	-	-	-
Black-headed Gull	*Larus ridibundus*	-	-	-	-	-	-	-	-	-
Common Buzzard	*Buteo buteo*	+	+	-	-	-	-	-	-	-
Gulls		+	-	-	-	-	-	-	-	-
Wigeon	*Anas penelope*	+	+	+	+	+	+	+	+	+
Wood Pigeon	*Columba palumbus*	-	-	-	-	-	-	-	-	-
Swans		+	+	+	-	-	-	-	-	-
Herring Gull	*Larus argentatus*	+	+	+	+	+	+	-	-	-
Starling	*Sturnus vulgaris*	-	-	-	-	-	-	-	-	-
Mallard	*Anas platyrhynchos*	+	+	+	+	+	+	+	+	+
Common Gull	*Larus canus*	+	+	+	-	-	-	-	-	-
Diving Ducks		+	+	+	+	+	+	+	+	-
Kestrel	*Falco tinnunculus*	+	+	+	+	-	-	-	-	-

Breeding season; Scenario: 0,3 MW to 2,0 MW

Species	Increase in output (factors):	1	1,5	2	2,5	3	3,5	4	4,5	5
Oystercatcher	*Haematopus ostralegus*	+	+	+	+	+	+	+	+	+
White Wagtail	*Motacilla alba*	+	+	+	+	+	+	+	+	+
Bluethroat	*Luscinia svecica*	-	-	-	-	-	-	-	-	-
Curlew	*Numenius arquata*	+	+	+	+	+	+	+	+	+
Whinchat	*Saxicola rubetra*	+	+	+	+	+	+	+	+	+
Common Whitethroat	*Sylvia communis*	+	+	+	+	+	+	+	+	+
Skylark	*Alauda arvensis*	+	+	+	+	+	+	+	+	+
Finches		+	+	+	+	+	+	+	+	+
Willow Warbler	*Phylloscopus trochilus*	+	+	+	+	+	+	+	+	+
Garden Warbler	*Sylvia borin*	+	+	+	+	+	+	+	+	+
Icterine Warbler	*Hippolais icterina*	+	+	+	+	+	+	+	+	+
Yellowhammer	*Emberiza citrinella*	+	+	+	+	+	+	+	+	+
Corn Bunting	*Miliaria calandra*	+	+	+	+	+	+	+	+	+
Linnet	*Carduelis cannabina*	+	+	+	+	+	+	+	+	+
Northern Lapwing	*Vanellus vanellus*	+	-	-	-	-	-	-	-	-
Grey Partridge	*Perdix perdix*	+	+	+	+	+	+	+	+	+
Reed Bunting	*Emberiza schoeniclus*	+	+	+	+	+	+	+	+	+
Redshank	*Tringa totanus*	+	+	+	+	+	+	+	+	+
Yellow Wagtail	*Motacilla flava*	+	+	+	+	+	+	+	+	+
Sedge Warbler	*Acrocephalus schoenobaenus*	+	+	-	-	-	-	-	-	-
Stonechat	*Saxicola torquata*	+	+	+	+	+	+	+	+	+
Starling	*Sturnus vulgaris*	+	+	+	+	+	+	+	+	+
Mallard	*Anas platyrhynchos*	+	+	+	+	+	+	+	+	-
Marsh Warbler	*Acrocephalus palustris*	-	-	-	-	-	-	-	-	-
Reed Warbler	*Acrocephalus scirpaceus*	+	+	+	+	+	+	+	+	+
Black-tailed Godwit	*Limosa limosa*	+	+	+	+	+	+	+	+	+
Meadow Pipit	*Anthus pratensis*	+	+	+	+	+	+	+	+	+
Wren	*Troglodytes troglodytes*	-	-	-	-	-	-	-	-	-
Chiffchaff	*Phylloscopus collybita*	+	+	+	+	+	+	+	+	+

Outside the breeding season; scenario: 0,3 MW to 2,0 MW

Species	Increase in output (factors):	1	1,5	2	2,5	3	3,5	4	4,5	5
Carrion/Hooded Crow	*Corvus corone*	-	-	-	-	-	-	-	-	-
Blackbird	*Turdus merula*	+	+	+	+	+	+	+	+	+
Oystercatcher	*Haematopus ostralegus*	+	+	+	+	+	+	+	+	+
Common Snipe	*Gallinago gallinago*	+	+	+	+	+	+	+	+	+
Coot	*Fulica atra*	+	+	+	+	+	+	+	+	+
Curlew	*Numenius arquata*	+	+	+	+	+	+	+	+	+
Chaffinch	*Fringilla coelebs*	-	-	-	-	-	-	-	-	-
Skylark	*Alauda arvensis*	-	-	-	-	-	-	-	-	-
Finches		-	-	-	-	-	-	-	-	-
Geese		-	-	-	-	-	-	-	-	-
Golden Plover	*Pluvialis apricaria*	-	-	-	-	-	-	-	-	-
Grey Heron	*Ardea cinerea*	+	+	+	+	+	+	+	+	+
Northern Lapwing	*Vanellus vanellus*	-	-	-	-	-	-	-	-	-
Black-headed Gull	*Larus ridibundus*	-	-	-	-	-	-	-	-	-
Common Buzzard	*Buteo buteo*	+	+	-	-	-	-	-	-	-
Gulls		+	-	-	-	-	-	-	-	-
Wigeon	*Anas penelope*	+	+	+	+	+	+	+	+	+
Wood Pigeon	*Columba palumbus*	-	-	-	-	-	-	-	-	-
Swans		+	+	+	+	-	-	-	-	-
Herring Gull	*Larus argentatus*	+	+	+	+	+	+	+	+	-
Starling	*Sturnus vulgaris*	-	-	-	-	-	-	-	-	-
Mallard	*Anas platyrhynchos*	+	+	+	+	+	+	+	+	+
Common Gull	*Larus canus*	+	+	+	-	-	-	-	-	-
Diving Ducks		+	+	+	+	+	+	+	+	+
Kestrel	*Falco tinnunculus*	+	+	+	+	+	-	-	-	-

Breeding season; scenario: 0,5 MW to 1,5 MW

Species	Increase in output (factors):	1	1,5	2	2,5	3	3,5	4	4,5	5
Oystercatcher	*Haematopus ostralegus*	+	+	+	+	+	+	+	+	+
White Wagtail	*Motacilla alba*	+	+	+	+	+	+	+	+	+
Bluethroat	*Luscinia svecica*	-	-	-	-	-	-	-	-	-
Curlew	*Numenius arquata*	+	+	+	+	+	+	+	+	+
Whinchat	*Saxicola rubetra*	+	+	+	+	-	-	-	-	-
Common Whitethroat	*Sylvia communis*	+	+	+	+	+	+	+	+	+
Skylark	*Alauda arvensis*	+	+	+	+	+	+	+	+	+
Finches		+	+	+	+	+	+	+	+	+
Willow Warbler	*Phylloscopus trochilus*	+	+	+	+	+	-	-	-	-
Garden Warbler	*Sylvia borin*	+	+	+	+	+	+	+	+	+
Icterine Warbler	*Hippolais icterina*	+	+	+	+	+	+	+	+	+
Yellowhammer	*Emberiza citrinella*	+	+	+	+	+	+	+	+	+
Corn Bunting	*Miliaria calandra*	+	+	+	+	+	+	+	+	+
Linnet	*Carduelis cannabina*	+	+	+	+	-	-	-	-	-
Northern Lapwing	*Vanellus vanellus*	+	-	-	-	-	-	-	-	-
Grey Partridge	*Perdix perdix*	+	+	+	+	+	+	+	+	+
Reed Bunting	*Emberiza schoeniclus*	+	+	+	+	+	+	+	+	+
Redshank	*Tringa totanus*	+	+	+	+	+	+	+	-	-
Yellow Wagtail	*Motacilla flava*	+	+	+	+	+	+	+	+	-
Sedge Warbler	*Acrocephalus schoenobaenus*	+	-	-	-	-	-	-	-	-
Stonechat	*Saxicola torquata*	+	+	+	+	+	+	+	+	+
Starling	*Sturnus vulgaris*	+	+	+	+	+	+	+	+	+
Mallard	*Anas platyrhynchos*	+	+	+	-	-	-	-	-	-
Marsh Warbler	*Acrocephalus palustris*	-	-	-	-	-	-	-	-	-
Reed Warbler	*Acrocephalus scirpaceus*	+	+	+	+	+	+	+	+	+
Black-tailed Godwit	*Limosa limosa*	+	+	+	+	+	+	+	+	+
Meadow Pipit	*Anthus pratensis*	+	+	+	+	+	+	+	+	+
Wren	*Troglodytes troglodytes*	-	-	-	-	-	-	-	-	-
Chiffchaff	*Phylloscopus collybita*	+	+	+	+	+	-	-	-	-

Outside the breeding season; scenario: 0,5 MW to 1,5 MW

Species	Increase in output (factors):	1	1,5	2	2,5	3	3,5	4	4,5	5
Carrion/Hooded Crow	*Corvus corone*	-	-	-	-	-	-	-	-	-
Blackbird	*Turdus merula*	+	+	+	+	+	+	-	-	-
Oystercatcher	*Haematopus ostralegus*	+	+	+	+	+	+	+	+	+
Common Snipe	*Gallinago gallinago*	+	+	+	+	+	+	-	-	-
Coot	*Fulica atra*	+	+	+	+	+	+	+	+	-
Curlew	*Numenius arquata*	+	+	+	+	+	-	-	-	-
Chaffinch	*Fringilla coelebs*	-	-	-	-	-	-	-	-	-
Skylark	*Alauda arvensis*	-	-	-	-	-	-	-	-	-
Finches		-	-	-	-	-	-	-	-	-
Geese		+	-	-	-	-	-	-	-	-
Golden Plover	*Pluvialis apricaria*	-	-	-	-	-	-	-	-	-
Grey Heron	*Ardea cinerea*	+	+	+	+	+	+	+	+	+
Northern Lapwing	*Vanellus vanellus*	-	-	-	-	-	-	-	-	-
Black-headed Gull	*Larus ridibundus*	+	+	-	-	-	-	-	-	-
Common Buzzard	*Buteo buteo*	+	-	-	-	-	-	-	-	-
Gulls		+	-	-	-	-	-	-	-	-
Wigeon	*Anas penelope*	+	+	+	+	+	+	-	-	-
Wood Pigeon	*Columba palumbus*	-	-	-	-	-	-	-	-	-
Swans		+	+	-	-	-	-	-	-	-
Herring Gull	*Larus argentatus*	+	+	+	-	-	-	-	-	-
Starling	*Sturnus vulgaris*	-	-	-	-	-	-	-	-	-
Mallard	*Anas platyrhynchos*	+	+	+	+	+	+	+	+	+
Common Gull	*Larus canus*	+	-	-	-	-	-	-	-	-
Diving Ducks		+	+	+	+	-	-	-	-	-
Kestrel	*Falco tinnunculus*	+	+	+	-	-	-	-	-	-

Breeding season; scenario: 0,5 MW to 2,0 MW

Species	Increase in output (factors):	1	1,5	2	2,5	3	3,5	4	4,5	5
Oystercatcher	*Haematopus ostralegus*	+	+	+	+	+	+	+	+	+
White Wagtail	*Motacilla alba*	+	+	+	+	+	+	+	+	+
Bluethroat	*Luscinia svecica*	-	-	-	-	-	-	-	-	-
Curlew	*Numenius arquata*	+	+	+	+	+	+	+	+	+
Whinchat	*Saxicola rubetra*	+	+	+	+	+	+	-	-	-
Common Whitethroat	*Sylvia communis*	+	+	+	+	+	+	+	+	+
Skylark	*Alauda arvensis*	+	+	+	+	+	+	+	+	+
Finches		+	+	+	+	+	+	+	+	+
Willow Warbler	*Phylloscopus trochilus*	+	+	+	+	+	+	+	+	+
Garden Warbler	*Sylvia borin*	+	+	+	+	+	+	+	+	+
Icterine Warbler	*Hippolais icterina*	+	+	+	+	+	+	+	+	+
Yellowhammer	*Emberiza citrinella*	+	+	+	+	+	+	+	+	+
Corn Bunting	*Miliaria calandra*	+	+	+	+	+	+	+	+	+
Linnet	*Carduelis cannabina*	+	+	+	+	+	+	-	-	-
Northern Lapwing	*Vanellus vanellus*	+	-	-	-	-	-	-	-	-
Grey Partridge	*Perdix perdix*	+	+	+	+	+	+	+	+	+
Reed Bunting	*Emberiza schoeniclus*	+	+	+	+	+	+	+	+	+
Redshank	*Tringa totanus*	+	+	+	+	+	+	+	+	+
Yellow Wagtail	*Motacilla flava*	+	+	+	+	+	+	+	+	+
Sedge Warbler	*Acrocephalus schoenobaenus*	+	+	-	-	-	-	-	-	-
Stonechat	*Saxicola torquata*	+	+	+	+	+	+	+	+	+
Starling	*Sturnus vulgaris*	+	+	+	+	+	+	+	+	+
Mallard	*Anas platyrhynchos*	+	+	+	+	+	-	-	-	-
Marsh Warbler	*Acrocephalus palustris*	-	-	-	-	-	-	-	-	-
Reed Warbler	*Acrocephalus scirpaceus*	+	+	+	+	+	+	+	+	+
Black-tailed Godwit	*Limosa limosa*	+	+	+	+	+	+	+	+	+
Meadow Pipit	*Anthus pratensis*	+	+	+	+	+	+	+	+	+
Wren	*Troglodytes troglodytes*	-	-	-	-	-	-	-	-	-
Chiffchaff	*Phylloscopus collybita*	+	+	+	+	+	+	+	+	+

Outside the breeding season; scenario: 0,5 MW to 2,0 MW

Species	Increase in output (factors):	1	1,5	2	2,5	3	3,5	4	4,5	5
Carrion/Hooded Crow	*Corvus corone*	-	-	-	-	-	-	-	-	-
Blackbird	*Turdus merula*	+	+	+	+	+	+	+	+	+
Oystercatcher	*Haematopus ostralegus*	+	+	+	+	+	+	+	+	+
Common Snipe	*Gallinago gallinago*	+	+	+	+	+	+	+	+	+
Coot	*Fulica atra*	+	+	+	+	+	+	+	+	+
Curlew	*Numenius arquata*	+	+	+	+	+	+	+	+	-
Chaffinch	*Fringilla coelebs*	-	-	-	-	-	-	-	-	-
Skylark	*Alauda arvensis*	-	-	-	-	-	-	-	-	-
Finches		-	-	-	-	-	-	-	-	-
Geese		-	-	-	-	-	-	-	-	-
Golden Plover	*Pluvialis apricaria*	-	-	-	-	-	-	-	-	-
Grey Heron	*Ardea cinerea*	+	+	+	+	+	+	+	+	+
Northern Lapwing	*Vanellus vanellus*	-	-	-	-	-	-	-	-	-
Black-headed Gull	*Larus ridibundus*	-	-	-	-	-	-	-	-	-
Common Buzzard	*Buteo buteo*	+	+	-	-	-	-	-	-	-
Gulls		+	-	-	-	-	-	-	-	-
Wigeon	*Anas penelope*	+	+	+	+	+	+	+	+	+
Wood Pigeon	*Columba palumbus*	-	-	-	-	-	-	-	-	-
Swans		+	+	-	-	-	-	-	-	-
Herring Gull	*Larus argentatus*	+	+	+	+	+	-	-	-	-
Starling	*Sturnus vulgaris*	-	-	-	-	-	-	-	-	-
Mallard	*Anas platyrhynchos*	+	+	+	+	+	+	+	+	+
Common Gull	*Larus canus*	+	+	-	-	-	-	-	-	-
Diving Ducks		+	+	+	+	+	+	-	-	-
Kestrel	*Falco tinnunculus*	+	+	+	-	-	-	-	-	-

5.2 Repowering and collisions of birds and bats

Following a similar procedure to that in the previous section it is possible to calculate collision rates for the different scenarios, using the relationship between wind turbine capacity and turbine height, and turbine height and collision rates. The estimates presented in Tab. 9 are for wind turbines in „normal“ landscape. As shown in chapter 4.2, considerably higher collision rates of birds and bats would occur at wind farms located close to water bodies or woodlands, respectively. In both habitats, no wind farms should be installed or replaced by repowering and therefore these habitats were not considered further.

The results of modelling show that in all cases repowering has a negative impact on birds – larger wind turbines have higher collision rates than smaller ones (see also chapter 4.2).

Bats show a different picture. The relationship between wind turbine height and the number of casualties is very weak. The extent to which repowering has an impact depends on the factor by which the power capacity is increased. Up to a doubling in capacity, casualties should be less, while larger increases in capacity would result in increased mortality rates.

Table 9: *Assessment of collision rates of birds and bats following repowering using model calculations. Positive impacts (+) mean a reduced collision risk while negative impacts (-) indicate increased risk. For more details see text.*

Collision rates of birds

Changes in collision rates of birds with increased wind farm output (factors)

Scenario	1	1,5	2	2,5	3	3,5	4	4,5	5
0,3 MW to 1,5 MW	-	-	-	-	-	-	-	-	-
0,3 MW to 2,0 MW	-	-	-	-	-	-	-	-	-
0,5 MW to 1,5 MW	-	-	-	-	-	-	-	-	-
0,5 MW to 2,0 MW	-	-	-	-	-	-	-	-	-

Collision rates of bats

Changes in collision rates of bats with increased wind farm output (factors)

Scenario	1	1,5	2	2,5	3	3,5	4	4,5	5
0,3 MW to 1,5 MW	+	+	+	-	-	-	-	-	-
0,3 MW to 2,0 MW	+	+	+	-	-	-	-	-	-
0,5 MW to 1,5 MW	+	+	-	-	-	-	-	-	-
0,5 MW to 2,0 MW	+	+	-	-	-	-	-	-	-

6 Discussion and research requirements

Newly published results regarding the issue of birds, bats and wind farms allow a better understanding of the impacts of larger, more modern wind turbines, which could not be considered previously (e.g. NABU-BfN report (Hötker et al. 2005)). Many previous results were confirmed by this study. It seems that wind turbines have a small impact on breeding birds, apart from particularly sensitive species (waders). However, there is still not much data available to show how other potentially sensitive species, or species of particular nature conservation interest (e.g. large birds and most bird of prey) react to wind turbines.

Wind turbines displace birds from their resting and feeding areas outside the breeding season. This has been confirmed for ducks, geese and some wader species. No new findings have been published regarding minimum displacement distances of birds from wind turbines. Starling and finches, but not Lapwings, showed a significant relationship between turbine height and avoidance distance. The new generation of wind turbines does not have a more disturbing effect on breeding birds than smaller less powerful turbines. This is due to the fact that increases in energy efficiency are proportionally greater than increases in turbine size alone. Among other things, birds, in particular breeding birds, seem to be displaced less by larger turbines than by smaller or middle-sized ones, in contrast to visiting birds, which were more sensitive to larger wind turbines. There was no change to the list of species previously classified as sensitive; the comprehensive case studies were confirmed. However, the particular noticeable results of Brandt et al. (2005b) at the Wybelsumer Polder are in strong contrast to other publications. Unfortunately, the presentation of data in that report did not allow a further analysis and could not be included in the database.

With respect to collision rates, the assumption that the choice of the wind farm site has a significant influence on the impacts of wind turbines was confirmed. High casualty rates for birds occur at wind farms on bare mountain ridges and water bodies, and close to woodlands for bats. Mass mortalities were still not reported for migrating birds. Taking into account the influence of habitat, it can be shown that a clear relationship exists for birds between turbine height and collision rate. A wind turbine 100m high is responsible on average for five bird casualties per year. Despite the better data, no statistically significant relationship between turbine height and mortality rate for bats could be found. Habitat choice is the dominant influence for bats.

Most of the results used in this report are based on only a small number of studies: this applies to avoidance distances as well as to collision rates, and therefore further research is necessary to confirm the results to date. In particular, no data has been published so far which studies the collision rates at large wind turbines at well-known migration hotspots. The numerous existing wind farms in Schleswig-Holstein on migration routes could help to determine whether wind farms have an impact on migrating birds.

Studies analysing the behaviour of large birds particularly birds of prey at wind farms are urgently needed. Birds of prey are strongly affected (see Appendix) and in Germany Red Kites and White-tailed Eagles have especially high number of casualties. Using either automatic recording equipment or targeted observations, it should be possible to determine the situations in which these species are particularly threatened, and thus the collision rates of red kites and sea eagles could hopefully be reduced in the long term.

As there are many wind farms in Schleswig-Holstein, particularly on the grazing marshes at the west coast, it is necessary to study the extent to which the presence of wind farms may already have influenced the habitats of species occupying these areas.

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8 Summary

The impact of repowering of wind farms on birds and bats

The references used by Hötker et al. (2005) in the NABU-BfN report and 45 new studies were analysed in order better to assess the impacts of large, more modern wind turbines on both birds and bats.

This analysis basically confirmed the results of the NABU-BfN report. Wind turbines have small impacts on breeding birds, apart from waders, which were significantly displaced by wind turbines during the breeding season. However, wind turbines have very large impacts on migrant birds outside the breeding season and for ducks, geese and some other waders species a displacement effect could statistically be proven.

Estimates of avoidance distances of larger wind turbines have not changed as a result of this analysis. Birds of open habitats (especially ducks, geese and some waders species) in most cases kept an avoidance distance of several hundred metres from wind turbines. Lapwing, Golden Plover, Carrion Crow, Starling and finches showed significant relationships between turbine height and avoidance distance outside the breeding season. During the breeding season, however, it was not possible to determine whether new generation wind turbines have greater disturbance effects than smaller, less powerful turbines.

Collision rates for birds and bats depend on the choice of wind farm site. Wind farms located close to water bodies or bare mountain ridges were responsible for significantly more bird casualties than others, while wind farms located close to woodlands showed high collision rates for bats. Collision rates at these sensitive sites were many times higher than at other less sensitive sites, so that, for examp-

le, at some wind turbines more than 100 bats were killed per year. Taking habitat choice into account, there was a significant relationship between collision risk and wind turbine height for birds, but not for bats.

With regard to repowering, the results imply that possible disturbance effects need to be assessed differently, depending on the range of bird species occurring on a particular wind farm site. For most breeding birds repowering has a positive effect, while outside the breeding season further species-specific evaluations are necessary, as repowering might increase the collision risk for some birds. If the capacity of a wind turbine is more than doubled, then collision rates for bats should also increase. The differences are, however, minor.

This report also identifies gaps in knowledge, as well as future research requirements.

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10 Appendix

Bird casualties at wind turbines in Germany and casualties of bats at wind turbines worldwide. Total of findings since 1989 (intensive search since 2002). Data from the central card index of the state bird protection office in the Landesumwelt-amt (state environment department) Brandenburg. Compiled by : Tobias Dürr, as of 16.10.2006.

Bird casualties at wind turbines in Germany														
Data from the central card index of the state bird protection office														
In the Landesumweltamt (state environment department) Brandenburg														
Compiled by: Tobias Dürr; as of: 16. October 2006														
		State/*Land*												**Tot.**
Species		**BB**	**ST**	**SN**	**TH**	**MV**	**SH**	**NI**	**HB**	**NW**	**HE**	**SL**	**BW**	
Gavia stellata	**Red-throated Diver**								1					**1**
Phalacrocorax carbo	**Cormorant**								2					**2**
Ciconia ciconia	**White Stork**	4				3	1						1	**9**
Ciconia nigra	**Black Stork**										1			**1**
Cygnus cygnus	**Whooper Swan**						1							**1**
Cygnus olor	**Mute Swan**	2	1			1	1	5						**10**
Anser anser	**Greylag Goose**							1						**1**
Anser fabalis	**Bean Goose**			1										**1**
Anser albifrons	**White-fronted Goose**	1												**1**
Anser fabalis / albifrons	**Bean-/White-fronted Goose**	1	1											**2**
Branta leucopsis	**Barnacle Goose**						6							**6**
Tadorna tadorna	**Shelduck**								1					**1**
Anas crecca	**Teal**								1					**1**
Anas platyrhynchos	**Mallard**	3		1			6	1	2					**13**
Anas clypeata	**Shoveler**						1							**1**
Aythya fuligula	**Tufted Duck**							1						**1**
Haliaeetus albicilla	**White-tailed Eagle**	4	2			9	8	1						**24**
Milvus milvus	**Red Kite**	33	22	8	3	1		2		1	6			**76**
Milvus migrans	**Black Kite**	6		1										**7**
Accipiter gentilis	**Goshawk**	2		1										**3**
Accipiter nisus	**Sparrowhawk**	1		1										**2**
Buteo buteo	**Common Buzzard**	37	14	3	2		1	4		1	1	1		**64**
Buteo lagopus	**Rough-legged Buzzard**		1											**1**
Circus aeruginosus	**Marsh Harrier**	1												**1**
Circus pygargus	**Montagu's Harrier**									1				**1**
Falco subbuteo	**Hobby**	2												**2**
Falco columbarius	**Merlin**	1												**1**
Falco tinnunculus	**Kestrel**	7	7	1						1				**16**
Falconiformes spp.	***Raptor spp..***	1												**1**
Perdix perdix	**Grey Partridge**	1												**1**
Phasianus colchicus	**Pheasant**	1	1					1	1					**4**
Fulica atra	**Coot**					3	1							**4**
Haematopus ostralegus	**Oystercatcher**						2	1						**3**
Pluvialis apricaria	**Golden Plover**		2				8							**10**
Vanellus vanellus	**Northern Lapwing**						3							**3**
Gallinago gallinago	**Common Snipe**						1							**1**
Larus ridibundus	**Black-headed Gull**	4					12	2	2					**20**
Larus argentatus	**Herring Gull**						12	2	1					**15**
Larus fuscus	**Lesser Black-backed Gull**							1						**1**
Larus canus	**Common Gull**	3					6	2	2					**13**
Chlidonias niger	**Black Tern**						1							**1**
Uria aalge	**Guillemot**								1					**1**
Columba livia f. domestica	**Feral Pigeon**	14			1		2							**17**
Columba oenas	**Stock Dove**	3												**3**
Columba palumbus	**Wood Pigeon**	14	2											**16**
Tyto alba	**Barn Owl**	1												**1**
Asio otus	**Long-eared Owl**	1												**1**
Asio flammea	**Short-eared Owl**	2												**2**
Bubo bubo	**Eagle Owl**				2					3			1	**6**
Cuculus canorus	**Cuckoo**	1												**1**
Apus apus	**Swift**	11	2	1						1			2	**17**
Apus melba	**Alpine Swift**												1	**1**
Apus spec.	**Swift sp.**												1	**1**
Picus viridis	**Green Woodpecker**	1												**1**
Dendrocopus major	**Great Spotted Woodpecker**	1												**1**
Nonpasseriformes spec.		1												**1**

		State/*Land*												Tot.
Species		**BB**	**ST**	**SN**	**TH**	**MV**	**SH**	**NI**	**HB**	**NW**	**HE**	**SL**	**BW**	
Alauda arvensis	**Skylark**	19			3									**22**
Lullula arborea	**Woodlark**	1												**1**
Eremophila alpestris	**Shorelark**						1							**1**
Anthus trivalis	**Tree Pipit**	1												**1**
Hirundo rustica	**Barn Swallow**	3					1							**4**
Delichon urbica	**House Martin**	3											3	**6**
Motacilla alba	**White Wagtail**	1												**1**
Motacilla flava	**Yellow Wagtail**	1												**1**
Troglodytes troglodytes	**Wren**	1												**1**
Acrocephalus palustris	**Sedge Warbler**							1						**1**
Hippolais polyglotta	**Melodious Warbler**												1	**1**
Sylvia curruca	**Lesser Whitethroat**	1												**1**
Sylvia atricapilla	**Common Whitethroat**	2												**2**
Regulus regulus	**Goldcrest**	2			1					1				**4**
Regulus ignicapillus	**Firecrest**	1												**1**
Regulus spec.	*Goldcrest/Firecrest.*												1	**1**
Ficedula hypoleuca	**Pied Flycatcher**	3												**3**
Saxicola rubetra	**Whinchat**	1												**1**
Erithacus rubecula	**Robin**	2												**2**
Turdus pilaris	**Fieldfare**	1	1											**2**
Turdus philomelos	**Song Thrush**	1												**1**
Turdus iliacus	**Redwing**						1							**1**
Turdus merula	**Blackbird**	2	1											**3**
Parus major	**Great Tit**	1												**1**
Emberiza calandra	**Corn Bunting**	13												**13**
Emberiza citrinella	**Yellowhammer**	6		1										**7**
Carduelis chloris	**Greenfinch**	2												**2**
Carduelis flavirostris	**Twite**						1							**1**
Fringilla coelebs	**Chaffinch**	2	1		1									**4**
Passer montanus	**Tree Sparrow**	2												**2**
Passer domesticus	**House Sparrow**	1												**1**
Sturnus vulgaris	**Starling**	11	1	1	1		3							**17**
Lanius collurio	**Red-backed Shrike**	1												**1**
Garrulus glandarius	**Jay**	2												**2**
Pica pica	**Magpie**		1											**1**
Corvus corax	**Raven**	10												**10**
Corvus frugilegus	**Rook**		1											**1**
Corvus corone	**Carrion/Hooded crow**	6									1			**7**
Corvus spec.	*Crow spp.*	1						1						**2**
		257	**61**	**20**	**14**	**17**	**80**	**26**	**14**	**9**	**9**	**1**	**11**	**517**

BB = Brandenburg, ST = Sachsen-Anhalt, SN = Sachsen, TH = Thüringen, MVP = Mecklenburg-Vorpommern,
SH = Schleswig-Holstein, NI = Niedersachsen, HB = Hansesatdt Bremen, NW = Nordrhein-Westfalen, HE = Hessen,
SL = Saarland, BW = Baden-Württemberg

Bat casualties at wind turbines

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Species		BB	ST	SN	TH	MV	SH	NI	NW	RP	HE	BW	SL	BY	D ges.	ESP	POR	A	FRA	SWE	USA	AUS	ges.
Nyctalus noctula	Noctule	110	2	29	4	6	5		3					1	**160**	1		3	3	1			**168**
Nyctauls lasiopterus	Greater Noctule														**0**	1							**1**
N. leislerii	Leisler's Bat	9	2	3	1				3			16			**34**	1							**35**
Eptesicus serotinus	Serotine	6		3			1		2			1			**13**	1							**14**
E. nilssonii	Northern Bat			1											**1**					8			**9**
Vespertilio discolor	Parti-coloured Bat	7		7	5						1	2			**22**					1			**23**
Myotis myotis	Mouse-eared Bat														**0**	1							**1**
M. dasycneme	Pond Bat						1								**1**								**1**
M. daubentonii	Daubenton's Bat	1				1	1								**3**								**3**
M. brandtii	Brandt's Bat	1													**1**								**1**
Pipistrellus pipistrellus	Common Pipistrelle	22	2	13	4		6	1	3			101			**152**	1			2	1			**156**
P. nathusii	Nathusius's Pipistrelle	65	4	33	11	1	9	1	1		1				**126**			1	30	5			**162**
P. pygmaeus	Soprano Pipistrelle	6			1										**7**					1			**8**
P. kuhlii	Kuhl's Pipistrelle														**0**	1							**1**
Pipistrellus sp.	Pipistrellus sp.	3					1					4			**8**				4				**12**
Hypsugo savii	Savi's Bat														**0**	3							**3**
Plecotus austriacus	Grey Long-eared Bat	5		1											**6**			1					**7**
Plecotus auritus	Brown Long-eared Bat				1	1									**2**								**2**
Tadarida teniotis	Bulldog Bat														**0**		1						**1**
Miniopterus schreibersi	Schreiber's Long-fingered Bat														**0**	1							**1**
Chiroptera sp.	Bat spez.	2	2	2	1					2		1			**10**	14			1	30	60		**115**
Lasiurus cinereus	Hoary Bat																				637		**637**
L. borealis	Red Bat																				341		**341**
Lasionyteris noctivagans	Silverhaired Bat																				96		**96**
Eptesicus fuscus	Big brown Bat																				22		**22**
spec. ?	Southern Brown Bat																				55		**55**
Myotis luciferus	Little Brown Bat																				88		**88**
M. septentrionalis	Northern Long-eared																				6		**6**
M. evotis	Long Eared																				1		**1**
M. spec.	Myotis sp.																				2		**2**
Pipistrellus subflavus	Eastern Pipistrelle																				108		**108**
Tadarida brasiliensis	Mexican Free-tailed Bat																				1		**1**
Tadarida australis	Australian Free-tailed Bat																					29	**29**
Chalinolobus morio	Chocolate-Wattled Bat																					1	**1**
		236	**13**	**92**	**28**	**9**	**24**	**2**	**12**	**2**	**2**	**125**	**0**	**1**	**546**	**25**	**1**	**5**	**40**	**47**	**1416**	**29**	**2110**

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