WIND TURBINES AND BIRDS IN FLANDERS:
PRELIMINARY STUDY RESULTS AND RECOMMENDATIONS

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Abstract
This article presents some preliminary results from a study on the impact of three wind farms in Flanders (Belgium) on birds. The collision numbers varied from 0 to 125 birds per wind turbine per year. In 2002, the mean numbers for each windfarm were 24, 35 and 18 birds per wind turbine per year. It is important to note that the numbers of victims given must be regarded as an absolute minimum. The number of collisions at the three study sites seems to depend on the number of passing birds, and to a lesser degree on the size of the wind turbine. Most of the victims were locally common birds like gulls, ducks and pigeons but we also found rarer species such as Grey Heron, Peregrine Falcon, Redshank, Common Tern, Little Tern and Stonechat. The chance of a passing bird colliding with a rotor blade was calculated at between 1 in 12000 and 1 in 600.
Most resting or foraging waterbird species kept a distance of 150-300 m from the wind turbines. At one location in the port of Zeebrugge we saw that most gulls and terns, flying between the breeding colonies and feeding areas at sea, crossed the line of wind turbines without mishap. Therefore, in contrast to the situation with birds engaged in seasonal and local migrations, during the breeding season, the wind turbine line posed no problem to these birds. However, this study demonstrates that in areas with many local migrations, there can be relatively high numbers of collisions. The impact on seasonally migrating birds is still unclear, and more research is urgently needed concerning the risk of collision.

Introduction

Wind turbines can have a negative impact on birds. Several European field studies have shown that birds can collide with the turbines during local and seasonal migration, or they can become disturbed in their breeding, resting or feeding areas. A concise review of some study results (including guidance on environmental assessment criteria and site selection issues) was recently published by Birdlife (BirdLife International 2003).
In Flanders (Belgium) there are plans to build a large number of wind turbines, in order to produce 2 % renewable energy from the total electricity production in 2004 (and 5 % in 2010). In September 2000 the policy-letter EME/2000.01 of the Flemish government was performed (Ministerie van de Vlaamse Gemeenschap 2000) in which certain criteria for the implantation of wind turbines were mentioned. Protected nature-area's (including a 250 m buffer around them) for example, are excluded for the placement of wind turbines. In case of specific area's of protection (like Natura 2000 zones) and/or specific species, a buffer of 500-700 m has to be considered. Naturally, area's without any specific protection but with an important ornithological value, also have to be evaluated thoroughly.
In commission by the Ministry of the Flemish Community (Economy administration, Natural Wealth's and Energy department) in May 2000 the Institute of Nature Conservation started a project to study the impact on birds, to produce an atlas of important bird areas and migration routes (Everaert et al. 2003) in order to build up the necessary policy knowledge, and to give counselling support for possible future projects. The results of the preliminary study results (until 2001) were published in a report (Everaert et al. 2002). Some of these results are also presented in this article, including additional results for the number of collision victims in 2002.

Study area and methods

In the period between May 2000 and December 2002 three wind turbine locations were studied: (a) 23 small to medium sized turbines of 200, 400 and 600 kW in two lines of respectively 10, 12 and 1 turbines at the 'East dam' in the port of Zeebrugge (period May 2000 - Dec. 2002), (b1) five medium sized turbines (600 kW) alongside the 'Boudewijn canal' in Brugge (period 2001-2002), (b2) nine medium sized turbines (600 kW) next to the 5 existing turbines at the 'Boudewijn canal' (period 2002), and (c) three large turbines (1.500 kW) in Schelle alongside the Schelde river (period April 2001 - Dec. 2002). The 23 turbines at the East dam are located on a dike along the water. In 2000 and 2001 a peninsula of 5 ha was made for breeding terns, next to the 3 most northern turbines. The wind turbines alongside the Boudewijn canal are surrounded by industrial buildings, unused soil and water. The wind turbines in Schelle are located next to an old electricity power station on unused soil.

There were weekly or twice weekly searches for collision victims under the turbines. Only the certain or most probable collision victims were used to determine the mortality. The range of the search circle was for the small turbines at the East dam in Zeebrugge the same as the tip height of the turbines, for the medium and large wind turbines at the Boudewijn canal and Schelle we used the mast height of the turbines, 60 m and 85 m. Not all collision victims are found, for example because they end up in the water or because they are removed by predators. The estimated number of collision victims (Table 1) was calculated with the use of correction factors for available search area, search efficiency and early predation by animals, deduced from the formula of Winkelman (1992a).

Kleine vogels	**N-geschat= Na*Cz*Cp*Ce**	**Grotere vogels**	**N-geschat= Na*Cz*Ce**
Small birds	*N-estimated= see above*	*Large birds*	*N-estimated= see above*

Table 1. Used formula to determine the estimated number of collision victims (Na=found number of collision victims, Cz=correction factor for search area, Cp=correction factor for predation, Ce=correction factor for search efficiency). The term 'small birds' means everything with a wingspan smaller than a pigeon.

In the further process of the text the 'estimated number of victims' will be presented as the 'number of victims'.

The data of the number of collision victims for 1 month, and the data of the calculated number of locally migrating birds during 1 to 3 full days (extrapolated to one month), were used to determine the collision chance for some species. We made a difference between all migrating birds and those only migrating at rotor height.

The disturbance on resting, foraging, breeding and migrating birds was determined with the use of different methods. With each observation data concerning the species, number, sector, flight direction, flight height, reaction, reaction distance, type of reaction, passageway distance, passageway height, .. was noted on a standardised formulary. The used spatial distribution around the turbines was deduced from the formula of Winkelman (1992a).

Results

Collision victims: numbers and species

The number of collision victims varied between 0 and 125 birds/wind turbine/year. In 2002, the mean number of collision victims for the three locations was 24 (East dam, Zeebrugge), 35 (Boudewijn canal, Brugge) and 18 (Schelle) birds/wind turbine/year (Table 2). In the year 2001 we found comparable numbers on the East dam and for the 5 first implanted wind turbines at the Boudewijn canal. There were clear differences between the locations, but also between groups of wind turbines on the same location. On the East dam in the port of Zeebrugge there were mean collision numbers of 39 and 37 birds per wind turbine per year at the 12 sea-directed wind turbines, and 6 and 9 birds per wind turbine per year at the land-directed cluster of 11 wind turbines (years 2001-2002). At the 5 most southern wind turbines alongside the Boudewijn canal we found an estimated number of 9 birds per wind turbine per year in 2002, whereas the mean number on the 9 more northern wind turbines resulted in 49 birds per wind turbine per year (and for the 4 most northern turbines even 73 birds).

Locatie *Location*	**gevonden aantal** *found number*	**grote vogels** *large birds*	**kleine vogels** *small birds*	**Cz**	**Cp**	**Ce**	**schatting grote vogels** *estimated large birds*	**schatting kleine vogels** *estimated small birds*	**schatting** *total estimated*
Oostdam (haven) *East-dam (Port)* **Zeebrugge** (23 turbines)				var (1,33-9,09)	7,14	±1			
Totaal *Total*	61	58	3				392	153	545
Per turbine							17	7	24
Boudewijnkanaal *Boudewijn-canal* **Brugge** (5+9 turbines)				1,33	4,35	1-2			
Totaal *Total*	210	190	20				253	233	486
Per turbine							18	17	35
Schelle, nabij de Schelde Shelle, *alongside the Schelde river* (3 turbines)				var (1-1,89)	6,67	1-2			
Totaal *Total*	12	11	1				28	25	53
Per turbine							9	8	18

Table 2. Number of collision victims (certain and most probable) per wind farm, during the year 2002. Cz is variable per wind turbine.

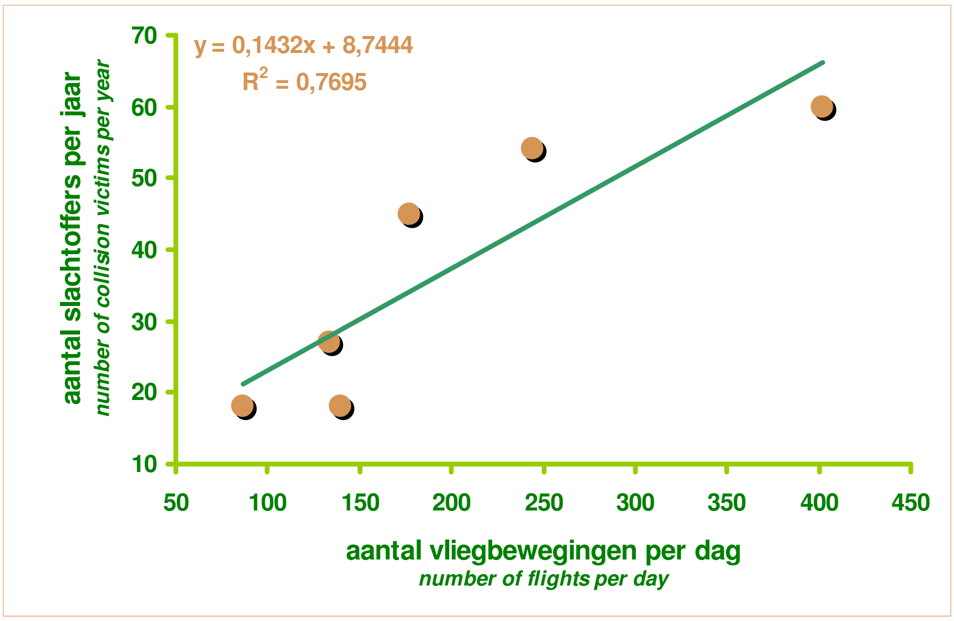


Figure 1. Daily number local flights of large gulls per sector on the East-dam, Zeebrugge (mean of breeding season 2001 and autumn 2001), in relation with the number of gull collision victims per sector (4+3+4+4+4+4+4 turbines).

Figure 1 clearly shows that the number of collision victims is in relation to the number of passing birds in flight. The type of wind turbine seems to be less important (Figure 2).
Most collision victims were abundant present birds, mainly Herring Gull *Larus argentatus*, Lesser Black-backed Gull *L. fuscus* and Black-headed Gull *L. ridibundus*, but also Mallard *Anas platyrhynchos*, Coot *Fulica atra*, and Wood Pigeon *Columba palumbus*. However, there were also – in most cases several collided birds of – rarer species as Grey Heron *Ardea cinerea*, Sparrowhawk *Accipiter nisus*, Common Kestrel *Falco tinnunculus*, Peregrine Falcon *F. peregrinus*, Redshank *Tringa totanus*, Kittiwake *Rissa tridactyla*, Common Tern *Sterna hirundo*, Little Tern *S. albifrons,* Swift *Apus apus* and Stonechat *Saxicola torquata.* At the East-dam in the port of Zeebrugge in 2001 and 2002 the number of collision victims among terns was calculated to be 28 and 26.

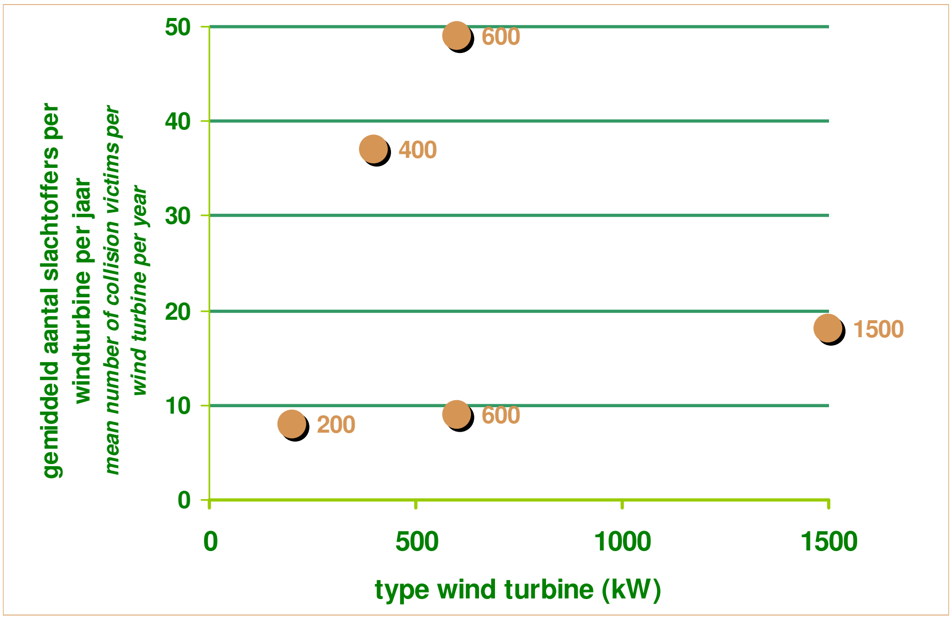


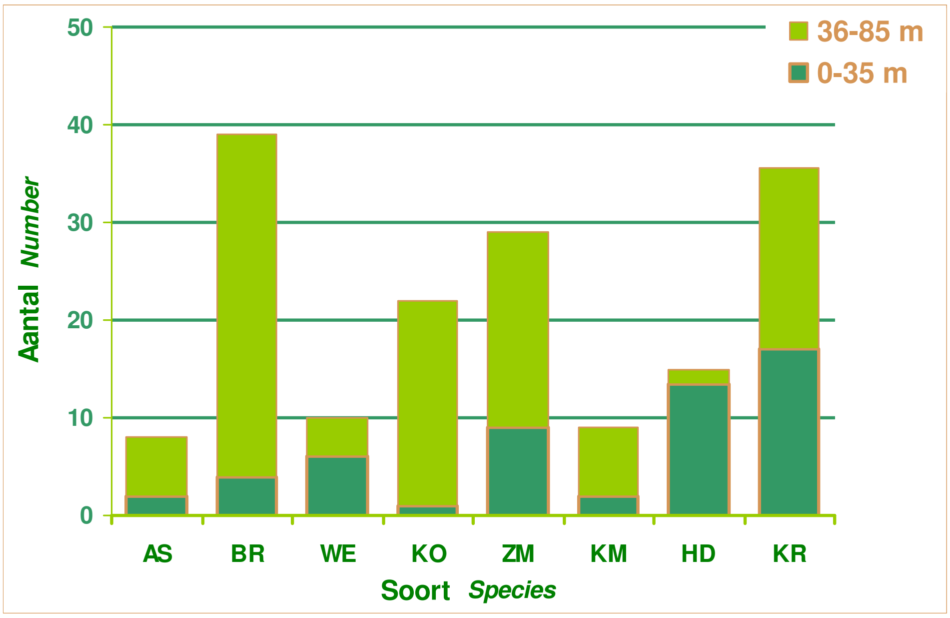
Figure 2. Mean number of collision victims per type of wind turbine in 2002 (200 kW: data from 10 turbines on the East-dam in Zeebrugge, 400 kW: data from 12 sea-directed turbines on the East-dam in Zeebrugge, 600 kW: data from 5 and 9 turbines alongside the Boudewijn-canal in Brugge, 1.500 kW: data from 3 wind turbines in the vicinity of the Schelde river in Schelle.

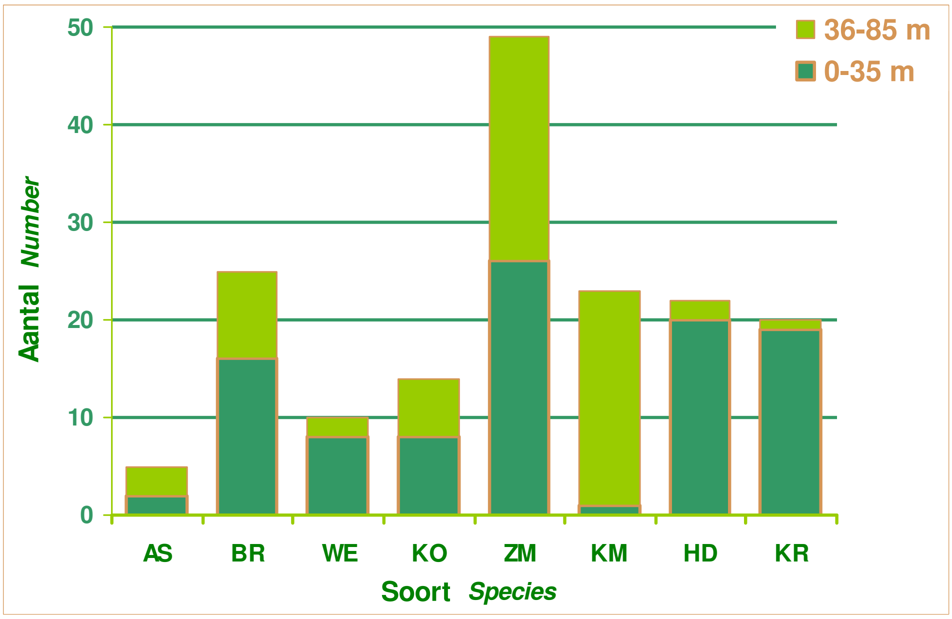
Collision chance

At the East dam in Zeebrugge during the day- and night situation the collision chance for large gulls was around 1 on 3.700 (all heights) and 1 on 2.100 (rotor height) passing birds. During the night the collision chance was 1 on 1.900 (all heights) and 1 on 1.000 (rotor height). At the larger wind turbines alongside the Boudewijn canal during the day- and night situation the collision chance for Herring Gull was 1 on 2.200 (all heights) and 1 on 750 (rotor height) passing birds. For the Little Tern (East dam) the collision chance was 1 on 27.000 (all heights) and 1 on 12.000. A remarkable high collision chance of 1 on 3.000 (all heights) and 1 on 600 (rotor height) was found for the Common Tern.
It wasn't yet possible to investigate how many birds were killed during the day and during the night. But it should be noted that at the wind turbines alongside the Boudewijn canal, there were some accounts from local workers of gulls colliding with the turbines during the day, and some occasional daylight observations (by the author) of near-collisions with large gulls and Grey Herons.

Disturbance and reaction behaviour

Due to the lack of reference situations it was difficult to make conclusions about the amount of disturbance on the three studied locations. Most wintering duck-species certainly held a clear distance of 150 to 300 meters to the turbines, large groups stayed at a wider distance than individual birds. During the month May at the Boudewijn canal for some species we found a decrease in the amount of passing birds after the turbines were constructed. The number of passing Grey Herons decreased by about 42 % after the turbines were constructed. Some species as Black-headed Gull, Herring Gull and Grey Heron also passed lower (below rotor height) then previously (Figures 3 en 4).





Figures 3 & 4. Number of passing birds in flight during 1 day, in May 2000 before the construction of the wind turbines (above), and in May 2001 after the construction (below). 36-85 m = rotor height. Species (left to right): Cormorant, Grey Heron, Mallard, Black-headed Gull, Herring Gull, Lesser Black-backed Gull, Wood Pigeon and Carrion Crow.

The gulls and terns of the breeding colony in the Port of Zeebrugge (West dam) daily undertake thousands of local migration flights for feeding to the sea and back. Most birds fly across the dam on the Westside of the Port, but at the wind turbines on the East dam we also have a few hundred flights daily. Most gulls and terns just crossed the dam flying between the wind turbines. The turbines therefore didn't act as a barrier for these birds. For the Little Tern we found a change of course (reaction; this is a branch off, change in flight altitude or complete return) of only 0,5 % for the number of passing birds at rotor height, and 0,2 % at turbine height. The Common Tern, Lesser Black-backed Gull and Herring Gull showed a reaction of 31,4 %, 26,9 % and 38,2 % for the number of passing birds at rotor height, and 5,9 %, 18,6 % and 17,6 % at turbine height (Table 3). Due to the small amount of passing Sandwich Terns *Sterna sandvicencis* on the East dam, it was impossible to draw conclusions for this species.
Besides, most reacting birds (in some way) just flew between the turbines after their change of course. During the breeding season the number of reactions was positively related with the wingspan (Figure 5). This was also the case at the wind turbines alongside the Boudewijn canal (Figure 6).

Soort *Species*	**Vlieghoogte** *Flight altitude (m)* **H1=0-15 ; H2=16-50 H3=51-65**	**Totaal aantal** *Total number*	**Reacties** *Reactions*	**% Reactie** *% Reaction* **(H1, H2, H3)**	**% Reactie** *% Reaction* **(H1+2)**
Dwergstern *Little Tern*	H1	1010	0	0,0	0,2
	H2	828	4	0,5	
	H3	22	1	4,6	
Visdief *Common Tern*	H1	408	15	3,7	5,9
	H2	35	11	31,4	
	H3	55	6	10,9	
(Grote Stern) *(Sandwich Tern)*	H1	1	1	(100,0)	(66,7)
	H2	2	1	(50,0)	
	H3	8	0	(0,0)	
Kokmeeuw *Black-headed Gull*	H1	13	1	7,7	13,3
	H2	2	1	50,0	
	H3	2	0	0,0	
Zilvermeeuw *Herring Gull*	H1	85	8	9,4	17,6
	H2	34	13	38,2	
	H3	17	7	41,2	
Kleine mantelmeeuw *Lesser Black-headed Gull*	H1	44	6	13,6	18,6
	H2	26	7	26,9	
	H3	11	7	63,6	

Table 3. Number of passing birds and the number of reactions during one day (mean of breeding seasons 2000 and 2001) when approaching one part (400 m sector) of a line of wind turbines at the East dam in Zeebrugge (H2= rotor height ; H1+2= turbine height).

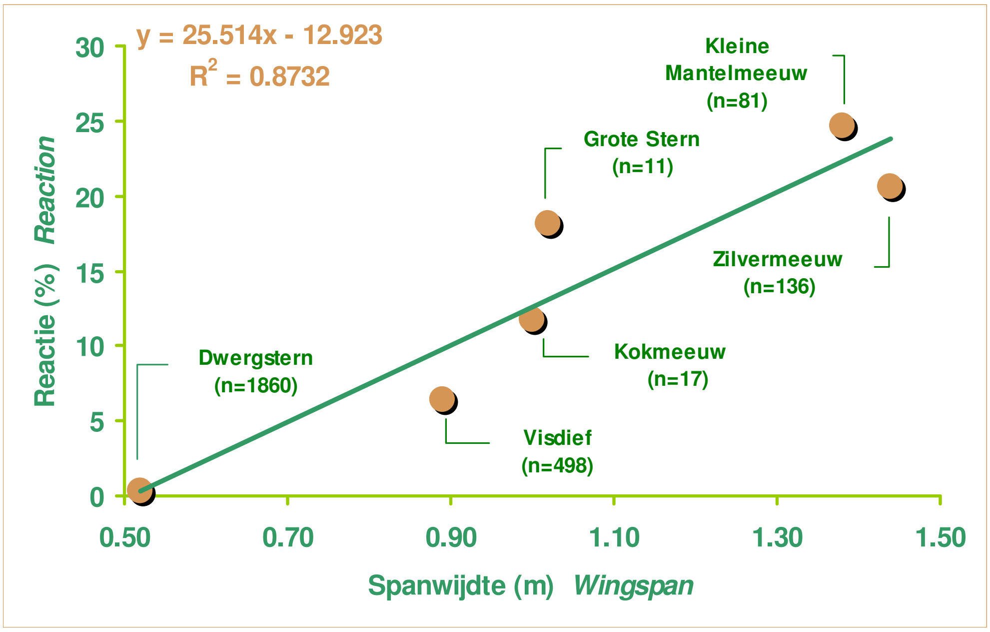


Figure 5. Percentage of reactions from the at all heights passing terns and gulls in flight during one day, in a sector of 400 m, East-dam, Zeebrugge (mean number of the breeding seasons 2000 and 2001), in relation to the mean wingspan of the concerning birds. Species (left to right): Little Tern, Common Tern, Black-headed Gull, Sandwich Tern, Lesser Black-backed Gull and Herring Gull.

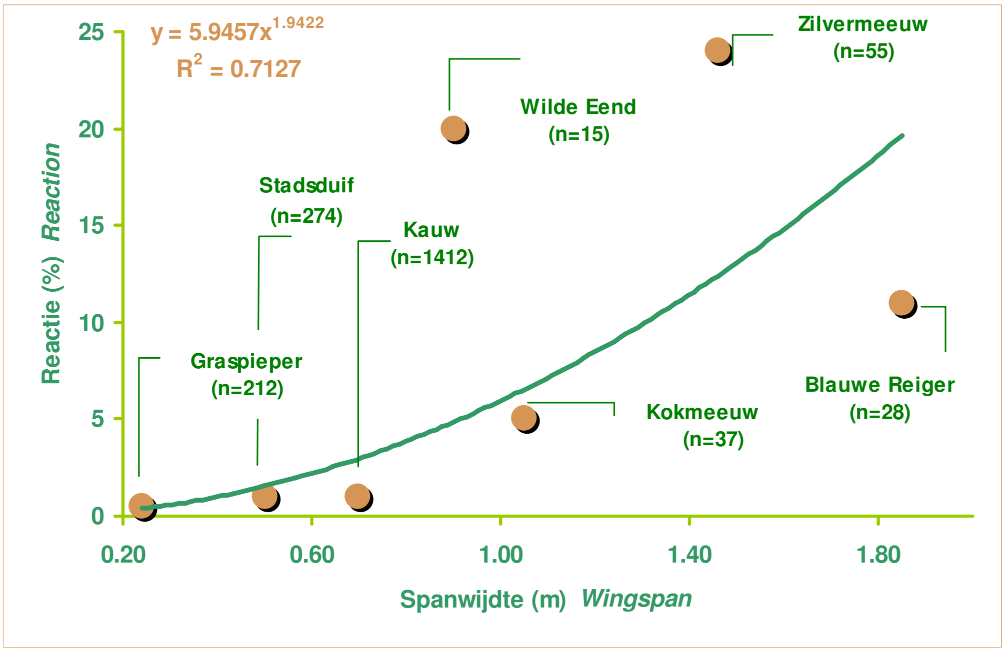


Figure 6. Percentage of reactions from the at all heights passing birds in flight during one day, at 5 wind turbines along the Boudewijn-canal, Brugge (mean number of May 2001 and October 2001), in relation to the mean wingspan of the concerning birds. Species (left to right): Meadow Pipit, Domestic Pigeon, Jackdow, Mallard, Black-headed Gull, Herring Gull and Grey Heron.

Discussion

One of the most comprehensive and best performed studies at small to middle sized wind turbines was conducted in Oosterbierum and Urk (the Netherlands). At these locations, during the spring and autumn migration (March, April, October, November) the number of collision

victims was calculated 0,06 to 0,11 per day per turbine on average (Winkelman 1992a ; Van der Winden et al. 1999).
During the spring and autumn migration (March, April, October, November) for similar wind turbines on the East dam in Zeebrugge, we found an average number of 0,10 (in 2001) and 0,01 (in 2002) collision victims per day per turbine, and for the larger wind turbines alongside the Boudewijn canal 0,06 (in 2001) and 0,09 (in 2002) collision victims per day per turbine.
The 0,01 value at the East dam in 2002 was most probably an exception, the months March, April, October and November had the smallest amount of found collision victims (most in August, September and December). During the whole year 2002 we calculated an average of 0,07 collision victims per day per turbine at the East dam, and 0,10 collision victims per day per turbine for the wind farm alongside the Boudewijn canal.

Extrapolation from the data of the wind farms in Oosterbierum and Urk (open landscape near the coast) learns that an installed capacity of 1.000 MW would give 21.000 (max. 134.000) certain and most probable collision victims on average every year. Inclusive possible victims this would give 46.000 (max. 257.000) collision victims on average every year (Winkelman 1992a). For an installed capacity of 1.000 MW of larger wind turbines near or on the coast, it was estimated that around 100.000 birds would collide every year (Koop 1997).

The estimated 21.000 to 257.000 yearly collision victims is less than the few million of casualties from the traffic road and high tension wires, but relatively the number of victims will be the same per kilometre (Winkelman 1992a). Therefore we cannot ignore the problem. Furthermore, it has to be noticed that 'some' yearly victims of a relatively small population of an endangered species can also have a significant impact, and that an impact will get worse with an increasing amount of wind turbines (BirdLife International 2003). More wind farms means also an extra pressure above the already existing sources of disturbance. In a dense populated region like Flanders, this degrades the total suitability for ecological functions as the presence of bird populations and guarantee for regional or international migration routes.

Plaats *Place*		**Aantal turbines** *Number of turbines*	**Aantal vogels / turbine / jaar** *#birds/turbine/year*	**Studieperiode** *Study period*	**Referentie** *Reference*
Belgium	Schelle	3	18	1 year	This article
	Oostdam, Zeebrugge	23	24	2 years	" & Everaert et al.2002
	Boudewijnkan.Brugge	14	35	1 year	"
Spain, Navarra	Salajones	33	35	1 year	Lekuona 2001
	Izco	75	26	1 year	"
	Alaiz	75	4	1 year	"
	Guerinda	145	8	1 year	"
	El Perdón	40	64	1 year	"
Spain	Basque Country	40	5-7	3 years	Onrubia et al. 2002
Spain	Pesur, Tarifa	190	0,45 (1)	1 year	SEO/Birdlife 1995
	E3, Tarifa	66	0,05 (1)	1 year	"
UK	Blyth	9	1,34	2 years	Still et al. 1996
Netherlands	Zeeland	5	2-7	1 year	Musters et al. 1996
	Oosterbierum	18	22-33 (2)	1 year	Winkelman 1995
	Urk	25	15-18 (2)	1 year	"

Table 4. Mean avian mortality rates from collision at some wind farms in Europe. These studies used correction factors (predator removal and search efficiency rates) to adjust the figures. (1) This is only the number of large sized birds. Small sized birds are not included because they weren't surveyed. (2) These rates were calculated mainly from several days in spring and autumn, originally expressed as birds per turbine per day; the rates over a year long period can be lower.

In table 4 the results from collision (mortality rates) at the 3 Flemish locations are again summarised, together with some results from other countries.
The number of collision victims on the three Flemish locations seems to be particularly dependent on the number of passing birds in flight (Figure 1), and quite probably in much less degree on the type of wind turbine (Figure 2). The results with reference to the collision chance seem to confirm this thesis. However, more data on large wind turbines (≥ 1.500 kW) are necessary. Though, the big differences between reciprocal wind turbines (within one location) demonstrate that 'site selection' can play an important role in limiting the number of collision victims.

Wind turbines don't always operate. Therefore, the mortality per year should also be compared with the number of 'operating hours' per year of the turbines. In 2002, the 23 turbines at the East dam operated 85 % of the time (= connected on the net) and had a production factor (= effective operating at full power) of around 40 % (Neys 2003). In 2002, the 14 turbines alongside the Boudewijn canal operated 81 % of the time, with a production factor of around 23 % (Ackaert & Desender 2003 ; Batardy 2003). In 2002, the 3 more inland placed wind turbines in Schelle operated 76 % of the time, with a production factor of around 18 % (Batardy 2003).
The yearly number of operating hours of wind turbines can of course have an important influence on the mortality, but we presume that this will not be a determining factor for the comparison of mortality between 'normal' operating wind turbines. The 14 turbines along the Boudewijn canal, for example, individually had an almost equal number of operating hours, but a very different number of collision victims.

The results on the Flemish wind farms also demonstrate that rarer species can collide with the turbines. Some researchers abroad reported (almost) only common species (Winkelman 1992a ; Van der Winden et al. 1999). However, the situation is always dependent on the location. The presence of only a few rare birds doesn't always give a guarantee for a low collision chance. In Germany researchers already found 8 White-tailed Eagles *Haliaeetus albicilla* and 28 Red Kites *Milvus milvus* during occasional searches (Hart 2001 ; Dürr 2003). The still growing number of locations with relatively large numbers of protected birds of prey, song-birds and/or bats (as in Tarifa and Navarra (Spain), California, West-Virginia, Wyoming and Minnesota (US)), are examples of poorly sited wind farms (Birdlife International 2003 ; Dürr 2003 ; Windpower Monthly 2003 ; Euskal Herria Journal Navarra 2002 ; Lekuona 2001).

In the literature there are no clear guidelines concerning the necessary search area for collision victims around wind turbines. The search area with radius 50 m applied by Winkelman (1989, 1992a) is frequently mentioned, but it is evident that larger wind turbines also need a bigger search area. Through our own research in Flanders, a search circle of which the radius is equal to the tip height of the wind turbine is advised.

The presented numbers of collision victims in table 4 seem to be 'relatively' low at first sight. Naturally, the real impact depends on the involved species, and the number of wind turbines. Furthermore, these numbers have to be regarded as strict minima because of the fact that more intensive research needs to done to have a better picture of the real number of small (migrating) birds that collide with the wind turbines.

Towards the situation for migrating birds, Kaatz (2002) recently recommended not to build large wind turbines on the coast, because of disturbance (barrier) but especially because of the possible large numbers of collision victims of which the biggest part of the small birds just get squashed totally during a collision with the rotors, whereby they can't be found on the ground. Even for large wind turbines the speed of the rotors goes to a deadly 230 km/h. Therefore, the estimated collision of small birds by use of searching dead birds on the ground (as with most studies) isn't totally reliable, even with corrections for predation and search efficiency. The only – known to us – comprehensive study whereby the collision chance for nocturnal migrating birds was calculated by means of the actual observed collisions (thermal image intensifiers) was performed in the Netherlands (Winkelman 1992b). The results there showed a remarkable high nocturnal collision chance of 1 on 40 (2,5 %) passing birds at rotor height.

In contrast to the daily local migration routes, the seasonal migration movements normally are situated at higher altitudes. But the highest bird densities by the seasonal nocturnal migration are also regularly below 150 meters (Buurma & Van Gasteren 1989).
Above the sea, birds normally fly lower than above the land, but in both landscapes large numbers of birds fly both under and below 150 m (Van der Winden et al. 1999). Because of their high altitude (>100m), large wind turbines of around 1 MW or more can become a real danger for seasonal migrating birds, especially in areas with dense migration near the coast, mountain ridges, forest borders, rivers, etc.
In addition we also have the fact that the anti-collision lights on some wind turbines (>100m, near air fields, ..) can lead to a lot more collision victims because in some situations the birds can become attracted by the light (cf. lighthouse killings) (Buurma & Van Gasteren 1989; Gauthreau & Belser 1999; Manville 2000). This was partially confirmed by the remarkable large number (49) of found collision victims during one night on one temporary lighted wind turbine in Sweden (Karlsson 1983).

Daily searches for collision victims during the migration periods, together with systematic field observations of passing birds, could lead to a better picture of the behaviour and collision chances for small birds. Observation methods by means of night vision devices and/or radar and thermal image intensifiers are a necessity. The recent developments of a full automatic sound- and image detection system for collisions, with contact microphones on the turbine mast in combination with web cams (Verhoef 2003), and the thermal animal detection system (TADS) for estimating collision frequency of migrating birds at wind turbines (Desholm 2003), are also promising.

In comparison with the study results from Oosterbierum in the Netherlands (Table 5), the collision chance for the day and night situation at the East dam in Zeebrugge was quite similar with a calculated 1 on 3.700 passing gulls. For the same situation, the collision chance for the larger wind turbines alongside the Boudewijn canal was a little higher (1 on 2.200 for Herring Gull). Apparently, on the basis of the preliminary results in Flanders, the larger wind turbines don't tend to a lower collision chance.
During the night situation the calculated collision chance for gulls at the East dam (1 on 1.900) was lower than in Oosterbierum. The reason for that is not totally clear. The large amount of background light from the industry at the East dam might be a possible cause.

	dag- en nachtsituatie (alle hoogtes) *day- and night situation (all heights)*	**nachtsituatie (alle hoogtes)** *night situation (all heights)*
Eenden *Ducks*	1 / 2.500	1 / 1.100
Meeuwen *Gulls*	1 / 4.800	1 / 270
Steltlopers *Waders*	1 / 4.800	1 / 770
Zangvogels *Song-birds*	1 / 2.500	1 / 156
Overige soorten *Other species*	1 / 526	?

Table 5. Collision chances (autumn) in Oosterbierum, the Netherlands (Winkelman 1992a), calculated by means of the number of passing birds in comparison to the number of certain, most likely and possible collision victims.

In contrast to gulls, terns don't migrate a lot at night, whereby the collision chance should stay low (Dirksen et al. 1996). The collision chance for Little Tern at the East dam in Zeebrugge (1 on 27.000 ; all heights) seems to confirm that. However, it is remarkable that the collision chance for Common Tern was a lot higher (1 on 3.000 ; all heights). Research during more days and nights is certainly necessary, so that it is possible to work a with a more reliable mean number of passing birds.

The disturbance aspect can also have an important impact in certain areas with wind turbines. Some studies from abroad have demonstrated a significant disturbance of about 400 meters around wind turbines for several bird species, and for some at 600 meters or more. Resting and foraging waterfowl species are especially vulnerable (Kruckenberg & Jaene 1999 ; Osieck & Winkelman 1990 ; Van der Winden et al. 1999 ; Winkelbrandt et al. 2000 ; Winkelman 1989, 1992d). Relatively long lines of wind turbines or large wind farms can also become an important barrier on the local and seasonal migration routes of birds (diving duck's: Van der Winden et al. 1996 ; Wigeon *Mareca penelope*: Poot et al. 2001 ; Common Crane *Grus grus*: Brauneis 2000 ; seasonal migrating birds in general: Albouy et al. 2001 ; Richarz 2002 ; Birdlife International 2003).
On the three Flemish locations it wasn't yet possible to verify and clarify these results from abroad. For certain breeding birds the disturbance on local migration routes could remain limited. Van den Bergh et al. (2002) namely concluded that a line of wind turbines at the Maasvlakte in the Netherlands didn't act as a barrier for the daily migration routes (feeding) of local breeding gulls and terns. Our results at the East dam in Zeebrugge seem to confirm this thesis. At the Maasvlakte, passing gulls (at turbine-height) showed 3,1 % reaction, and terns (Common Tern) 5,3 %. The result for the Common Tern is comparable with that at the East dam in Zeebrugge (5,9 %), at least for the at turbine height passing birds. The Common Terns at the East dam which passed at rotor height reacted at a larger share (31,4 %). In contrast to the Maasvlakte, the turbines at the East dam also had a larger percentage of reactions for gulls at turbine height (18,6 %). There are several study results which seem to sustain the conclusions at the East dam. Research in Oosterbierum (the Netherlands) showed increased sensitivity for thrushes *Turdus spec.* (1 %), Starling *Sturnus vulgaris* (10 %), small song-birds (7-20 %), waders (13-17 %; except Lapwing *Vanellus vanellus* with 32 %), pigeon's (18 %), duck's (19 %) and gulls (24-31 %).
At small wind turbines the fewest reactions acted with waders, thrushes, crows (2-6 %), with duck's and geese (43 %) the most (Winkelman 1992c). Petersen & Nohr (1989) mention plovers (11 %), song-birds (20 %), geese (30 %), swans (34 %) and gulls (35 %) at wind farms with small turbines. Cormorants *Phalacrocorax carbo* also reacted strongly. Böttger et al. (1990) likewise concluded relative little reaction with small birds (song-birds and thrushes) and more reaction with larger birds.
It has to be noticed that most of the reacting birds (from the breeding colonies) at the East dam in Zeebrugge only performed a small change of course, and just flew between the turbines. However, a diminutive barrier doesn't say anything about the number of collision victims. Areas with wind turbines and much (local) migration of gulls and terns can have a large number of collision victims. The study results at the wind farms in Zeebrugge (East dam) and Brugge (Boudewijn canal) clearly show that reasonable amounts of gulls and terns can collide with the wind turbines, despite the limited barrier (Everaert et al. 2002 ; Everaert et al. 2001 ; Everaert & Kuijken 2002).

Conclusions en recommendations

Wind turbines can have an important impact on birds, by direct collision or by habitat disturbance. Through a well performed site selection the biggest problems on a local scale can be avoided. Therefore, it is of the best interest not to build wind farms in the neighbourhood of important bird areas and migration routes.

Cultivated and industrial areas with few birds which are connected to existing buildings or roads have to be explored in the first place. But also in these areas it is important to perform a risk analysis on the possible impact for birds.

The big differences between species and locations makes it difficult to estimate the real impact. Especially the lack of clear data on the impact for seasonal migrating birds (and local raptors in some areas) remains a big problem. It is also important not to forget the possible global impact of wind turbines on birds. Risk analysis only estimate the impact for the one project itself.

That most projects don't have a clear significant impact on bird populations doesn't mean that there can't be an important impact at a larger scale when several projects are taken together. Because of the fact that wind farms are rising very fast in several European countries, it is probable that migrating birds will have to pass several wind farms. Therefore, it is recommended to adjust the plans for wind farms with each other. The determination of the cumulative impact is of course a very complex matter, but there should be a way to develop a working method. At the same time, a large scale cost-benefit analysis should be performed which will lead to a better understanding of the positive effects of wind energy concerning global warming (decrease in CO_2 emissions) and the negative effects of wind turbines on humans, landscape and birds. Scientifically there is still a lot of uncertainty about this issue, and the fear exists that even a limited availability of 'green' energy will not directly stimulate an economy policy for reducing the overflowing energy consumption.

Due to the political, social and economical pressure we are already now faced with many plans for the construction of wind farms. So in this stage it is important that we identify areas where bird species are vulnerable to wind turbines, and these sites have to be avoided in the first place. It should also be clear that the precautionary principle has to be applied, especially around important bird areas and migration routes.

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References

Ackaert J. & Desender L., 2003. Gegevens aantal draaiuren en equivalent vollast uren van het windpark langs het Boudewijnkanaal te Brugge. Mededeling aan het Instituut voor Natuurbehoud.

Albouy S., Dubois Y. & Picq H., 2001. *Suivi ornithologique des parcs éoliens du plateau de Garrigue Haute.* ABIES bureau d'études et la LPO Aude, ADEME, Valbonne, France.

Batardy J., 2003. Gegevens aantal draaiuren en equivalent vollast uren van het windparken te Schelle en langs het Boudewijnkanaal te Brugge. Mededeling aan het Instituut voor Natuurbehoud.

BirdLife International, 2003. *Windfarms and birds: An analysis of the effects of windfarms on birds, and guidance on environmental assessment criteria and site selection issues. Information document for the 23 rd. meeting of the Standing Committee on behalf of the Bern Convention (1-5 December 2003),* Document T-PVS/Inf (2003) 12, Strasbourg. http://www.coe.int/T/E/Cultural_Co-operation/Environment/Nature_and_biological_diversity/Nature_protection/sc23.asp#TopOfPage

Böttger M., Clemens T., Grote G., Hartmann G., Hartwig E., Lammen C. & Vauk-Hentzelt E., 1990. *Biologisch-ökologische Begleituntersuchungen zum Bau und Betrieb von Windkraftanlagen*, Endbericht. NNA-Berichte 3 (Sonderheft):1-124

Brauneis W., 2000. Der Einfluss von Windkraftanlagen auf die Avifauna, dargestellt insb. Am Beispiel des Kranichs *Grus grus*. *Ornithologische Mitteilungen* 52: 410-414

Buurma L.S. & Van Gasteren H., 1989. *Trekvogels en obstakels langs de Zuidhollandse kust. Radarwaarnemingen van vogeltrek en het aanvaringsrisico bij hoogspanningsleidingen en windturbines op de Maasvlakte.* Koninklijke Luchtmacht, sectie Ornithologie, 's Gravenhage.

Desholm M., 2003. *Thermal Animal Detection System (TADS). Development of a method for estimating collision frequency of migrating birds at offshore wind turbines.* National Environmental Research Institute, Denmark. 27 pp.- NERI Technical Report, No. 440. http://faglige-rapporter.dmu.dk

Dirksen S., Spaans A.L. & Van Der Winden J., 1996. Nachtelijke trek en vlieghoogtes van steltlopers in het voorjaar over de Noordelijke Havendam van IJmuiden. *Sula* 10(4): 129-142.

Dürr T., 2003. Kollision von Fledermäuse und Vögel durch Windkraftanlagen. Daten aus Archiv der Staatlichen Vogelschutzwarte Brandenburgs, Buckow.

Euskal Herria Journal Navarra, 2002. Environmental group takes carnage of wind turbines to EU. Environmental News, September 2002. http://www.ehj-navarre.org/news/n_environment_wts0902.html

Everaert J., Devos K. & Kuijken E., 2003. *Vogelconcentraties en vliegbewegingen in Vlaanderen. Beleidsondersteunende vogelatlas – achtergrondinformatie voor de interpretatie.* Rapport Instituut voor Natuurbehoud. R.2003.02., Brussel. (27 pp.)

Everaert J., Devos K. & Kuijken E., 2002. *Windturbines en vogels in Vlaanderen. Voorlopige onderzoeksresultaten en buitenlandse bevindingen.* Rapport Instituut voor Natuurbehoud. R.2002.03., Brussel. (76 pp.)

Everaert J., Devos K., Stienen E. & Kuijken E., 2001. Plaatsing van windturbines langs de Westelijke Havendam te Zeebrugge. Aanbevelingen in het kader van een mogelijke impact op vogels. Instituut voor Natuurbehoud, nota IN.A.2001.82., Brussel.

Everaert J. & Kuijken E., 2002. Bouwen van 14 windturbines langs de Westelijke havendam te Zeebrugge. Aanvullende gegevens bij de adviesnota IN.A.2001.82. Risico-evaluatie met afweging aan de juridische criteria met betrekking tot de avifauna. Instituut voor Natuurbehoud, nota IN.A.2002.139., Brussel.

Gauthreau S.A. & Belser C.G., 1999. The behavioral responses of migrating birds to different lighting systems on tall towers. *Proceedings of the Workshop 'Avian mortality at communication towers'*. Cornell University, August, 11th, 1999.

Hart K., 2001. Windkraftanlagen oder Vögel. Trend online zeitung, ausgabe 10.01.

Kaatz J., 2002. Brandenburger Ornithologe Dr. Jürgen Kaatz: Alle Windanlagen über 100 Meter Nabenhöhe kritisch für Zugvögel / Rotorblätter treffen mit 230 km/Stunde auf Vögel – "da bleibt wenig übrig". WKA Vogelkollisionen und Hinweis auf Fachtagung "Windenergie und Vögel - Ausmaβ und Bewältigung eines Konfliktes". 29-30 Nov. 2001. Technische Universität Berlin. (berichtgeving zie ook http://huegelland.tripod.com/hart4.htm)

Karlsson J., 1983. *Fåglar och vindkraft. Resultatrapport 1977-1982.* Sweden.

Koop B., 1997. Vogelzug und Windenergieplanung. Beispiele für Auswirkungen aus dem Kreis Plön (Schleswig-Holstein). *Naturschutz und Landschaftsplanung* 29 (7): 202-207.

Kruckenberg H. & Jaene J., 1999. Zum Einfluss eines Windparks auf die Verteilung weidender Blässgänse im Rheiderland (Landkreis Leer, Niedersachsen), *Natur und Landschaft* 74: 420-427.

Lekuona J., 2001. *Uso del espacio por la avifauna y control de la mortalidad de aves y murciélagos en los parques eólicos de Navarra durante un ciclo anual. Informe Técnico.* Dirección General de Medio Ambiente. Departamento de Medio Ambiente, Ordenación del Territorio y Vivienda. Gobierno de Navarra. http://www.iberica2000.org/textos/LEKUONA_REPORT.pdf

Manville A.M.II., 2000. The ABCs of avoiding bird collisions at communication towers: the next steps. *Proceedings of the Avian Interactions Workshop, December 2, 1999*, Charleston, SC. Electric Power Research Institute (in press).

Ministerie van de Vlaamse Gemeenschap, 2000. Omzendbrief EME/2000.01. Afwegingskader en randvoorwaarden voor de inplanting van windturbines. *Belgisch Staatsblad*, bl. 30220. Brussel, 01.09.2000.

Musters C.J.M., Noordervliet M.A.W. &.ter Keurs W.J, 1996. Bird casualties by a wind energy project in an estuary. *Bird Study* 43: 124-126.

Neys W., 2003. Gegevens aantal draaiuren en equivalent vollast uren van het windpark aan de Oostdam te Zeebrugge. Mededeling aan het Instituut voor Natuurbehoud.

OC-GIS Vlaanderen, 2003. Geoloket Vogelatlas zie http://www.gisvlaanderen.be/geo-vlaanderen/vogelatlas

Onrubia A., Villasante J., Balmorí A., Sáenz de Buruaga M., Canales F. & Campos M.A., 2002. Estudio de la incidencia sobre la fauna -aves y quirópteros- del parque eólico de Elgea (Alava). Informe inédito de Consultora de Recursos Naturales, S.L. para Eólicas de Euskadi. Vitoria-Gasteiz.

Osieck E.R. & Winkelman J.E., 1990. *Windturbines en vogels in het Klein IJsselmeer*, Vogelbescherming Zeist.

Petersen B.S. & Nohr H., 1989. *Konsekvenser for fluglelivet ved etableringen af mindre vindmoller.* Rapport, Ornis Consult, Kopenhagen.

Poot M.J.M., Tulp I., Schekkerman H., Van Den Bergh L.M.J. & Van Der Winden J., 2001. *Effect van mist op vogelvlieggedrag bij het windpark Eemmeerdijk.* Bureau Waardenburg, Culemborg/Alterra, Wageningen.

Richarz K., 2002. *Erfahrungen zur Problembewältigung des Konfliktes Windkraftanlagen – Vogelschutz aus Hessen, Rheinland-Pflatz und das Saarland. Tagungsband, Fachtagung "Windenergie und Vögel - Ausmaß und Bewältigung eines Konfliktes".* 29-30 Nov. 2001. Technische Universität Berlin.

Still D., Little B. & Lawrence S., 1996. *The Effect of Wind Turbines on the Bird Population at Blyth Harbour, Northumberland*. ETSU W/13/00394/REP

Van den Bergh L., Spaans A. & Van Swelm N., 2002. Lijnopstellingen van windturbines geen barrière voor voedselvluchten van meeuwen en sterns in de broedtijd. *Limosa* 75: 25-32.

Van der Winden J., Dirksen S., van den Bergh L. & Spaans A., 1996. *Nachtelijke vliegbewegingen van duikeenden bij het windpark Lely in het IJsselmeer.* Bureau Waardenburg rapport 96.34, Bureau Waardenburg, Culemborg/Instituut voor Bos- en Natuuronderzoek (IBN-DLO), Wageningen.

Van der Winden J., Spaans A., Tulp I., Verboom I., Lensink R., Jonkers D., van den Haterd R. & Dirksen S., 1999. *Deelstudie Ornithologie MER Interprovinciaal Windpartk Afsluitdijk.* Bureau Waardenburg rapport 99.002, Bureau Waardenburg, Culemborg/Instituut voor Bos- en Natuuronderzoek (IBN-DLO), Wageningen.

Verhoef H., 2003. Betere meting van aanvaringen vogels op windturbines. Energieonderzoek Centrum Nederland, ECN Nieuwsbrief februari 2003. http://www.ecn.nl/nwsbrf/article/0132.html

Windpower Monthly, 2003. Bat kills a sudden and unexpected problem. *Windpower Monthly* Okt. 2003. http://www.wpm.co.nz/oct03/cont.htm (see also http://www.birdingonthe.net/mailinglists/WVBD.html#1068554304)

Winkelbrandt A., Bless R., Herbert M., Kröger K., Merck T., Netz-Gerten B., Schiller J., Schubert S. & Schweppe-Kraft B., 2000. *Empfehlungen des Bundesamtes für Naturschutz zu naturschutzverträglichen Windkraftanlagen.* Bundesamt für Naturschutz, Bonn.

Winkelman J.E., 1989. *Vogels en het windpark nabij Urk (NOP): aanvaringsslachtoffers en verstoring van pleisterende eenden, ganzen en zwanen.* RIN-rapport 89/1. Rijksinstituut voor Natuurbeheer, Arnhem.

Winkelman J.E., 1992 a-d. *De invloed van de Sep-proefwindcentrale te Oosterbierum (Fr) op vogels, 1: aanvaringsslachtoffers, 2: nachtelijke aanvaringskansen, 3: aanvlieggedrag overdag, 4: verstoring.* RIN-rapport 92/2-5. Instituut voor Bos- en Natuuronderzoek (IBN-DLO), Arnhem.

Winkelman J.E., 1995. Bird/wind turbine investigations in Europe. Proc. National Avian-Wind Power Meetings, Denver Colorado, 20-21 July 1994. pp. 43-48.