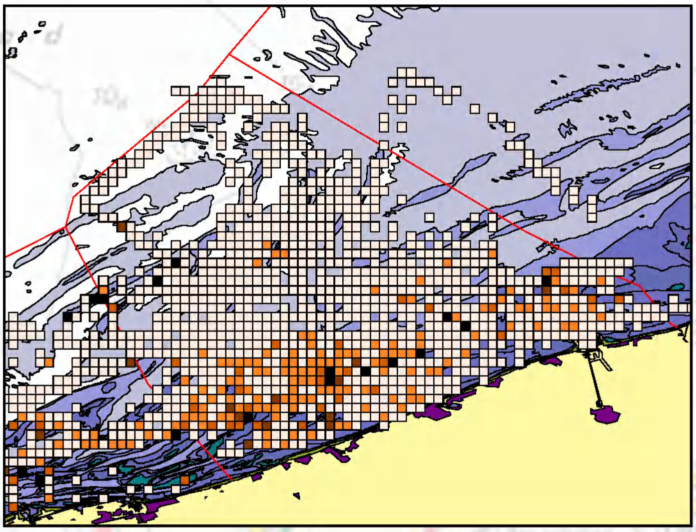
SEABIRDS AT THE NORTHERN PART OF "DE VLAKTE VAN DE RAAN"

ENVIRONMENTAL IMPACT STUDY ON THE EFFECTS OF AN OFFSHORE WINDFARM ON SEABIRDS

Report under the authority of
Fina Eolia N.V.

**Eric W.M. Stienen, Jeroen Van Waeyenberge &
Eckhart Kuijken**



Report IN.A.2002.213
November 2002

*Institute of Nature Conservation
Brussels*

CONTENT

1. BACKGROUND OF THE STUDY

In 2001 Fina Eolia, a branch of TOTALFINAELF, had submitted an application document for the domain concession and exploiting of a windfarm at the Vlakte van de Raan. Within this framework this licence request must contain an environmental impact study (EIS). As a result of this Fina Eolia NV had asked in 2001 the Institute of Nature Conservation (IN) to conduct a EIS in which:

(1) the reference situation of the avifauna (migrating, staging and foraging birds) at the Vlakte van de Raan were discribed,
(2) the potential effects during construction and exploitation phase based upon bibliography were discribed,
(3) the gaps in knowledge were cited and the mitigating measures were proposed and
(4) a description of the necessary monitoring before and after construction phase and during the operational phase.

This avifauna-part of the EIS had delivered begin April 2002 to incorporate into the entire EIS-report (Stienen *et al.* 2002).

Fina Eolia had recent submitted a new request to obtain a consession for building and exploiting a windfarm just north of the Vlakte van de Raan. This modified project consist of the location of 36 turbines within a concession area like a parallelogram with sides of ± 2,5 by ± 3,7 km (total surface area 8711 km^2). In compliance with the safety distance of 500 m the total area claimed would be 15 668 km^2. The turbines are setted up in four lines perpendicular to the coastline, each line consist of 9 turbines. The distance between these 4 rows is ± 720 m. Within one row the distance between the turbines is ± 450 m. The distance from the coast is ± 16 up to 20 km. The project are equiped with turbines of 3 up to 3,6 MW, the total capacity is minimal 108 and maximal 129,6 MW. The turbines have a pilon height of more or less 70 m above sea level and with a rotor diameter of 90 up to 100 m.

Within the scope of this new request the IN is asked to adapt the previous report (Stienen *et al.* 2002) to the modified project and to complete it with new information (counts and literature).

2. METHODOLOGY

2.1. Target area and frame of reference

Because of the high mobility of seabirds it is not sufficient for an environmental impact assessment to focus on a relatively small area like the area in which the windfarm is planned. In addition, the limited number of counts of marine birds performed at the windfarm site might bias the data so that an unrealistic picture of the ornithological importance of the area could arise. Therefore, the report also takes account of a certain buffer zone in which seabird densities are considered. The buffer zone encloses the entire northern part of the Vlakte van de Raan on Belgian territorial waters as well as a segment of the deeper waters adjacent to this and partly extents to the Dutch Continental Shelf to the east (Figure 1). In the following part the term target area will designate this buffer zone. The demarcation of the target area was done in a way that the physiological and biological conditions resemble those at the windfarm site. The exact borders of the target area were, however, drawn arbitrary. It is not to be expected that small changes in the size or shape of the target area will strongly affect the results. The importance of the target area is considered for each bird species by comparing the on-site seabird densities to those on the entire Belgian Continental Shelf (BCS). As far as possible and if relevant, also the importance of the area for migrating seabirds is evaluated.

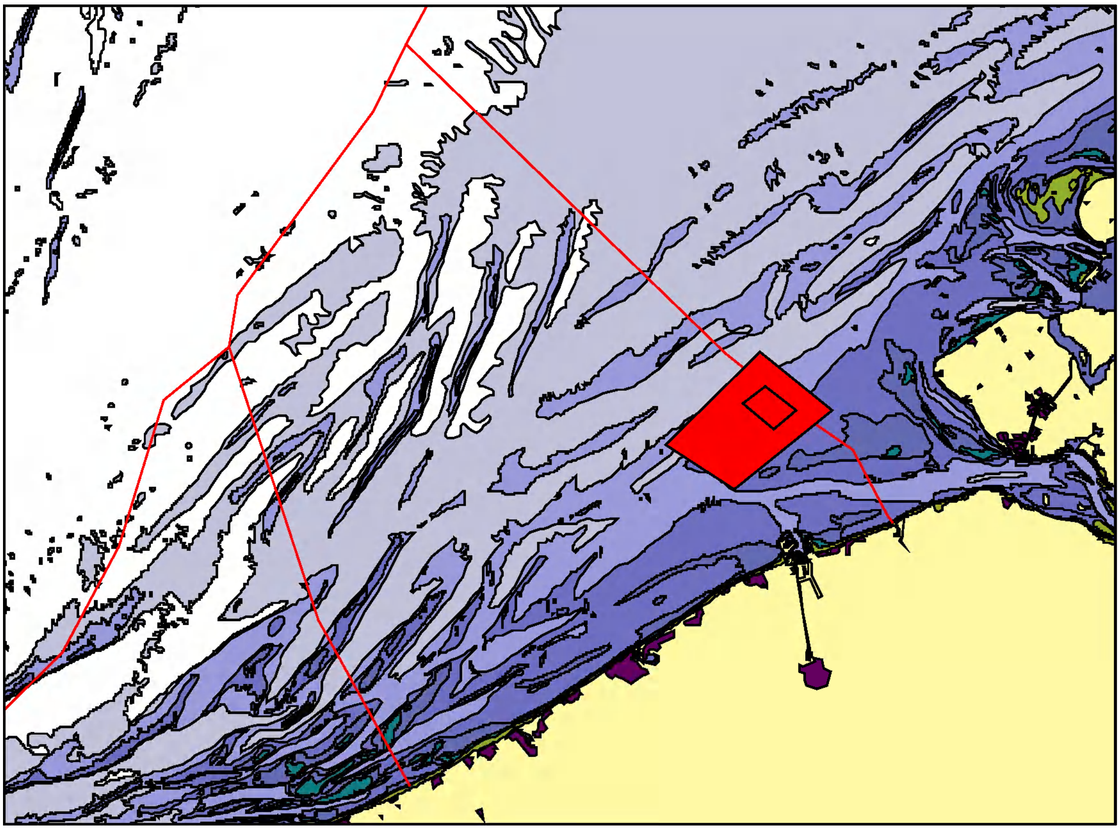


Figure 1. Situation and demarcation of the windfarm site (solid red area) and the target area (area dotted in red). The red lines delineate the Belgian Continental Shelf.

2.2. Method of counting and data processing

In order to evaluate the importance of the site to the marine avifauna, an extensive database on the distribution of marine birds on the Belgian Continental Shelf and its immediately surrounding area was used. The database consists of standardised counts of the marine avifauna, carried out from ships in the period from January 1992 to October 2002 by the Institute of Nature Conservation. The counts were performed using the so-called transect method, in which all swimming birds present within a distance of 300 m from the vessel and in an angle of 90° from the bow of the vessel are counted during successive periods of 10 minutes (see Tasker *et al.* 1984 for a comprehensive description). For standardised counting of flying birds the snapshot method was used (Komdeur *et al.* 1992), in which all flying birds that are within a distance of 300 m and in an angle of 90° from the ship are counted every minute. Estimation of the distance was calibrated between observers. To calculate seabird density the numbers were corrected in accordance with internationally accepted correction factors (Offringa *et al.* 1996), which take account of the fact that some birds are difficult to see at greater distances. During the counts, birds that were seen at > 300 m from the ship were also noted. The latter observations were not used to determine densities, but for a number of uncommon species maps showing all sightings often provide a better picture of actual distribution than maps based on bird density.

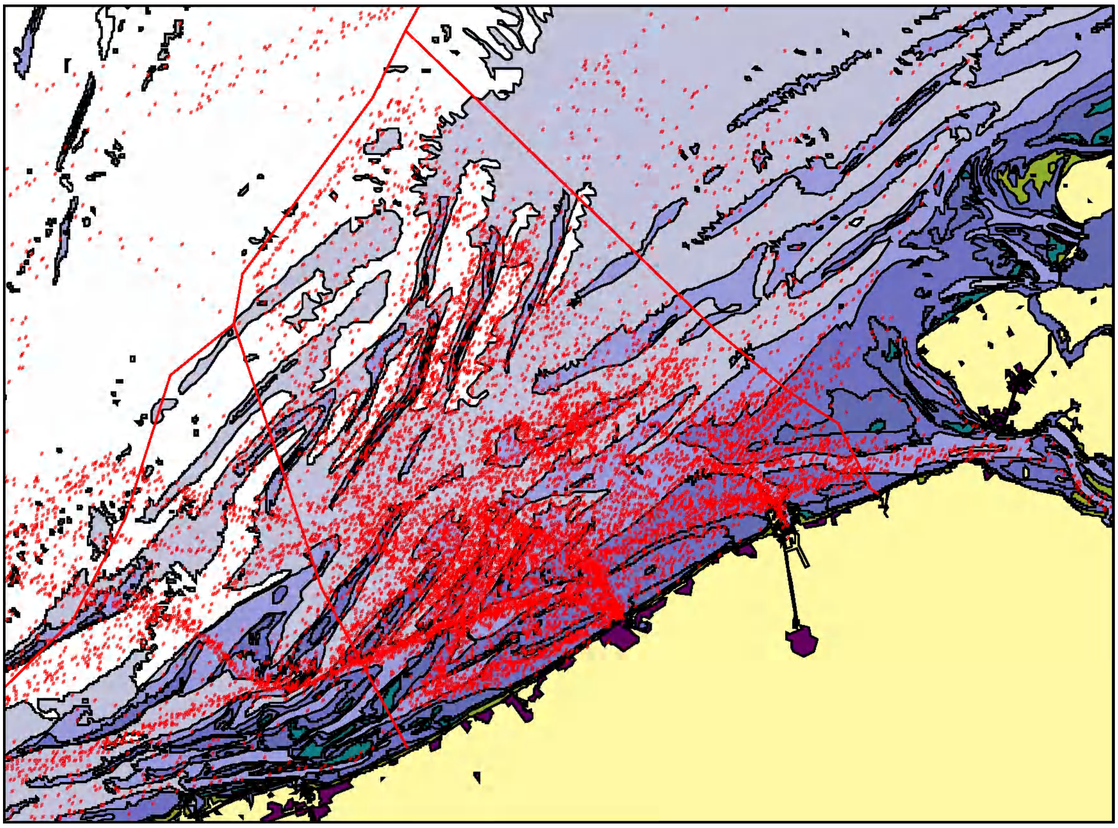


Figure 2. Positions on the BCS (red dots) where counts of seabirds were performed.

The ship-based counts were performed from on board the vessels 'Belgica', 'Zeeleeuw', 'Zeehond', 'Zeearend' and 'Ter Streep' and from ferries on the Zeebrugge-Dover and Ostend-Ramsgate routes. The counts give virtually complete coverage for the BCS (Figure 2). Only in the deep-water zone, along the Belgian-English boundary and the area bordering on the Dutch Continental Shelf were the counts less intensive. Also at the windfarm site the number of counts is relatively low. For this reason a rather large but homogeneous area was demarcated as a target area (Figure 1) so that a reliable picture of the use of the area by marine avifauna could be obtained.

For each bird species (or in some cases group of species) the average density (number of birds per km^2) within each 1′ x 1′ – square at the BCS was calculated. Since the occurrence of many seabirds varies strongly with the season, the average density per season is considered (whereby autumn = September – November, winter = December – February, spring = March – May and summer = June – August). Next the densities of all 1′ x 1′ – squares that partly or entirely belong to either the BCS or the target area were averaged to become a reliable figure for seabird density. By averaging the data twice (first per 1′ x 1′ – square and next per area) possible outliers in the data (*e.g.* extremely high values because of clusters of birds that were found behind fishing vessels) do less affect the results.

This analysis is primarily intended to single out the species for which problems with regard to the windfarm might be expected. However, the average densities per season do not always do justice to the actual densities that may be found at a particular moment. Many species are only temporary guests, the numbers of which show brief peaks in specific months. By using seasonal averages the numbers can be a gross underestimate of the peak values.

3. DESCRIPTION OF REFERENCE SITUATION

3.1. General specification

In general, seabird densities in the target area are very much comparable to those on the BCS (Figure 3). Both in the target area and on the BCS low densities were measured during summer (< 3.1 birds per km^2), while during the remainder of the year average densities always exceeded 8.0 birds per km^2. Compared to the BCS, the target area holds lower densities of seabirds during winter, while in the autumn on-site seabird density is higher than on the BCS. Note that the presented figures represent average densities. Maximum densities can be much higher and can reach more than 700 birds per km^2. Such high densities of more than 100 birds per km^2 are usually the result of birds being attracted by fishing vessels. All species of gulls, for example, regularly forage in large groups behind fishing boats, where they pick up the fish and fish residue thrown overboard (Camphuysen 1993, 1994, Offringa *et al.* 1996, Seys 2001).

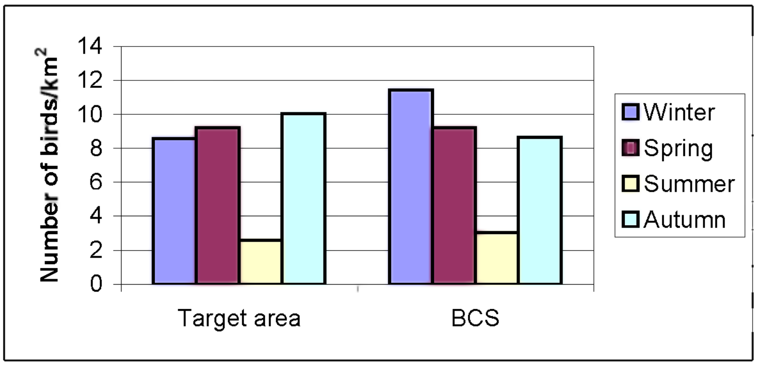


Figure 3. *The average density of marine birds in the target area and on the BCS during the various seasons.*

3.2. Species composition

During winter, the species composition at the target area very much resembles that at the BCS (Figure 4). Most dominant species at the target area then is Guillemot/Razorbill (42% of all species), followed by Herring Gull (15%), Kittiwake (13%) and Common Gull (8%). In the spring there are remarkable differences in species composition between the target area and the BCS. The target area is then dominated by Herring Gull (39%) and Lesser Black-backed Gull (32%), while also Little Gull (9%) and Common Gull (9%) are common species. In the summer Lesser Black-backed Gull (42%), Great Black-backed Gull (21%) and Common/Arctic Tern (15%) are strongly represented in the target area. A strong dominance of Lesser Black-backed Gull (48%) is also found in autumn, while also Herring Gull (13%), Great Crested Grebe (11%) and Great Black-backed Gull (10%) are important species in this season.

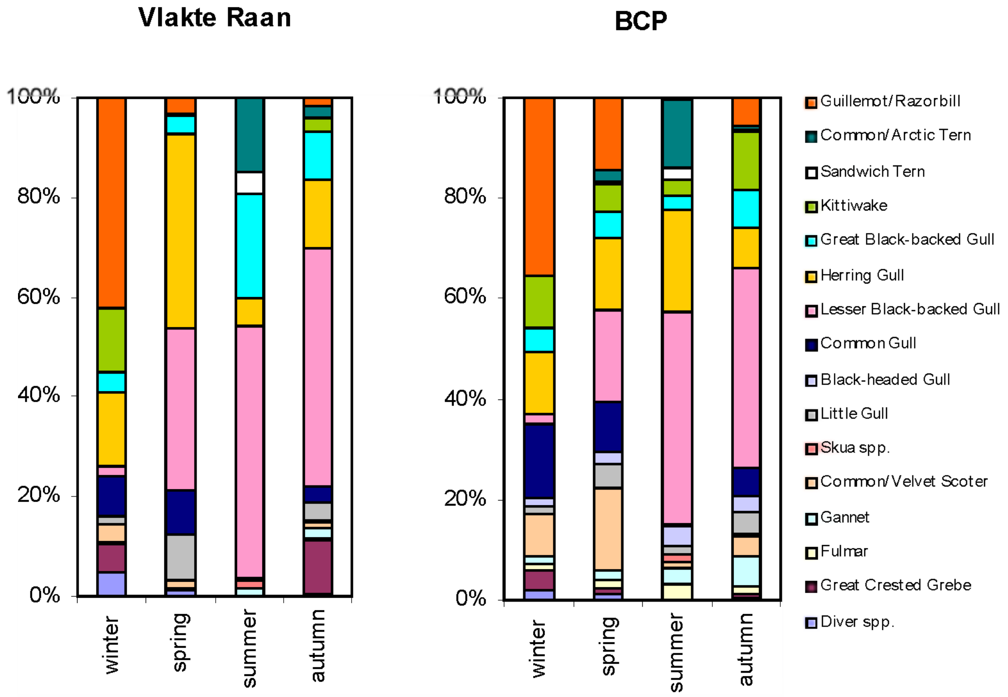


Figure 4. The relative importance of the various seabirds in the target area compared with the BCS.

3.3. Potential problem species

3.3.1. General

The species composition in combination with the average densities of seabirds provides an indication for the possible impact of the windfarm and which species will probably be most affected. After all, studies at terrestrial wind turbines have shown that the number of casualties is related to the number of birds present at the site (among others Musterts *et al.* 1991, Eveleart et al. 2002). However, only discussing the most numerous bird species at the site certainly does no justice to rare species, which can nevertheless be very important from the point of view of protection. Moreover, it does give no information on the relative importance of the site for a particular species. Although a specific species can reach high densities at the windfarm site, the impact of the windfarm on a species level can still be insignificant if for example the species is widely distributed over the BCS. On the other hand, if a species occurs strongly clustered in one or several areas (e.g. Common Scoter) one must be extremely careful to interfere with any bird activity in such areas.

For a reliable picture of the relative importance of the windfarm site one must therefore compare the local densities at the site to those on the BCS as a whole. The result of such analysis is shown in Table 2. By using these figures one can identify species that might cause potential problems. In this study potential problem species will be defined as follows:

1) species that in a particular season reach a higher density in the target area than on the BCS (figures given in red in Table 2),
2) species that are common or very common in the target area in one a particular season (figures underlined in Table 2) and
3) species that reach relatively high densities in the target area in the season of peak occurrence on the BCS (exclamation marks in Table 2).

Table 2. The average density of seabirds (number/km^2) and the number of 1′ x 1′- squares used for averaging in the target area and on the entire Belgian Continental Shelf (BCS) in the summer, autumn, winter and spring on the basis of ship-based counts in the period 1992-2002. When in a particular season the density of a species in the target area exceeds or equals that on the BCS the density is indicated in red. If in a particular season a species is common (0.5 birds/km^2 ≤ density < 1.0 birds/km^2) or very common (≥ 1.0 birds/km^2) in the target area the figure is underlined either single or double. An exclamation mark behind the target value denotes that the species occurs in the target area in relatively high densities (value target area ≥ 0.5 x the value on the BCS).

	Winter		*Spring*		*Summer*		*Autumn*	
	Target area	*BCS*	*Target area*	*BCS*	*Target area*	*BCS*	*Target area*	*BCS*
Diver spp. *Gavia stellata/arctica*	0.41!	0.25	0.12!	0.12	0.00	0.00	0.04	0.02
Great Crested Grebe *Podiceps cristatus*	0.48!	0.44	0.01	0.09	0.00	0.00	1.10	0.09
Fulmar *Fulmarus glacialis*	0.04	0.14	0.00	0.15	0.00	0.10	0.02	0.12
Gannet *Sula bassana*	0.01	0.19	0.01	0.20	0.04	0.10	0.23	0.54
Common/Velvet Zee-eend *Melanitta nigra*	0.29	0.95	0.15	1.50	0.00	0.03	0.09	0.34
Skua spp. *Stercorarius sp.*	0.00	0.01	0.00	0.00	0.04!	0.04	0.07!	0.04
Little Gull *Larus minutus*	0.13	0.18	0.86!	0.45	0.01	0.05	0.33!	0.38
Black-headed Gull *Larus ridibundus*	0.01	0.18	0.01	0.22	0.00	0.12	0.00	0.26
Common Gull *Larus canus*	0.70	1.67	0.80!	0.89	0.00	0.01	0.35	0.49
Lesser Black-backed Gull *Larus fuscus*	0.18	0.21	2.98!	1.68	1.31!	1.29	4.80!	3.45
Herring Gull *Larus argentatus*	1.25!	1.43	3.60!	1.35	0.14	0.62	1.35	0.68
Great Black-backed Gull *Larus marinus*	0.35!	0.55	0.32!	0.47	0.54	0.08	0.98!	0.67
Kittiwake *Rissa tridactyla*	1.11!	1.19	0.02	0.49	0.00	0.10	0.29	1.00
Sandwich Tern *Sterna sandvicensis*	0.00	0.00	0.02	0.06	0.12!	0.08	0.00	0.01
Common/Arctic Tern *Sterna hirundo/paradisaea*	0.00	0.00	0.00	0.20	0.38!	0.41	0.24	0.09
Guillemot/Razorbill *Uria aalge/Alca torda*	3.60!	4.04	0.31	1.33	0.00	0.01	0.15	0.47
Total	8.56	11.43	9.21	9.20	2.58	3.05	10.04	8.65
Number of 1′ X 1′ - squares	52	1074	61	892	30	713	54	926

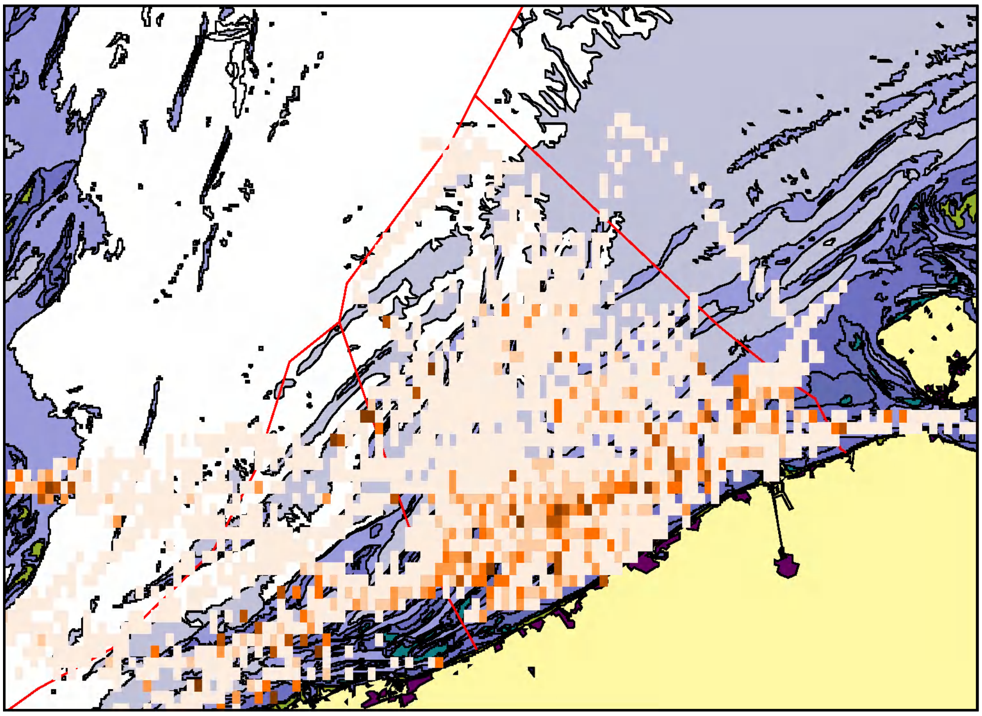
In this section, for each species the importance of the target area is considered using the current knowledge on its temporal and spatial distribution pattern on the BCS. As the occasion arises a detailed distribution map is presented, showing the average density of a species in 1' x 1' – squares (e.g. Figure 5). In each distribution map the density is classified into the following six categories: 0.00-0.49, 0.50-0.99, 1.00-1.49, 1.50-1.99, 2.00-4.99 and > 5.00 birds per km^2 for Great Crested Grebe, Gannet, Common/Velvet Scoter, Little Gull, Black-headed Gull, Common Gull and Guillemot/Razorbill and 0.00-0.09, 0.10-0.49, 0.50-0.99, 1.00-1.99, 2.00-4.99 en > 5.00 birds per km^2 for all other species (an increasing colour intensity is related to increasing densities). For some species that occur in low densities at the BCS (e.g. skuas and terns) maps are shown on which all observations (including those outside the transect) can be seen, rather than the densities. These maps are strongly influenced by the number of counts performed at a particular site, but give a good general picture of the distribution of these scarce species.

3.3.2. Discussion of species/taxa

- **Diver spp.** *Gavidae spp.*

Since the determination of divers in the field is not easy, in the present document the entire taxon is discussed without making a distinction between the various species. However, based on the specimens found dead along the Belgian coast and the divers that were determined to the level of species it can be assumed that the majority (86%) in this case were Red-throated Divers *Gavia stellata* (Seys 2001). Divers are generally found swimming on the water. All species of diver are extremely sensitive to disturbance. Indeed, they often fly off when an approaching ship is only more than a kilometre away (own observation IN).

Figure 5. Distribution of divers on the BCS in winter.



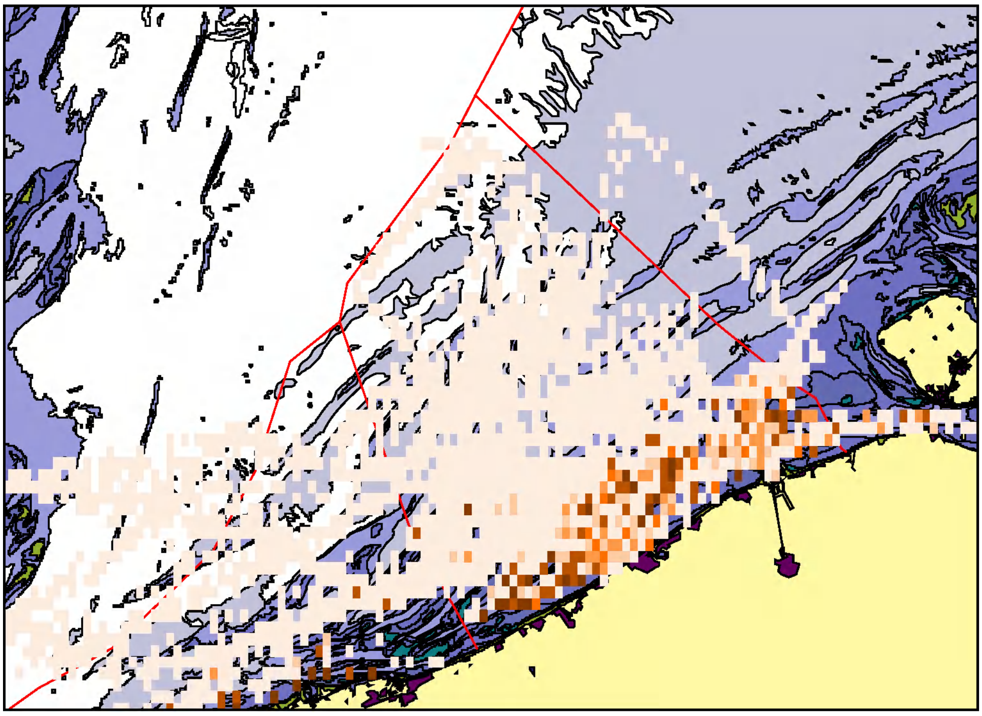
Divers are typical winter guests, which visit the BCS between November and March. On the BCS divers are typical inshore species, predominately occur within a small band located between 4 and 20 km from the coastline (Figure 5). During winter, lower densities can also be found further from the coast at the Flemish Banks, Hinder Banks and Goote Bank. The windfarm site is located within the band of highest densities and for this reason divers emerge as potential problem species from Table 2. During winter and autumn densities in the target area are much higher than on the BCS, whereas during spring densities in the two areas are very much comparable. However the density in autumn is low compared to the winter and spring period. The Vlakte van de Raan and its surroundings can be designated as an important wintering area for this taxon, although more extensive wintering areas with even higher densities are to be found on the western coastal banks and Flemish Banks.

- **Great Crested Grebe** *Podiceps cristatus*

The Great Crested Grebe is a typical winter visitor at the BCS, found here particularly between November and May. Like divers, Great Crested Grebes are also mostly found swimming on the water. However, they are less sensitive to disturbance than divers and, when a vessel approaches, usually move away at a distance of less than 100 m (own observation IN). Even more than divers, Great Crested Grebes are typically inshore species of which highest densities are found within 12 km from the coastline (Figure 6).

In autumn and in winter the densities in the target area are higher than the densities on the BCS. From the distribution map it can be deduced that the Vlakte van de Raan and the surrounding areas are important for wintering Great Crested Grebes (Figure 6). Similar concentrations can found along the entire coastline. In 2001, this species reached extremely high numbers off the Belgian coast. On 30 January 2001 4945 individuals were counted from land (own observation IN), which is 3.3% of the total northwest-European population. The most important concentrations were then found close to the coast between Ostend and De Panne (4788 individuals). However, the numbers at sea can substantially differ between years, because severe winters force grebes to move from fresh water to the sea.

Figure 6. Distribution of Great Crested Grebe on the BCS in winter.



- **Skua spp.** *Stercorarius spp.*

Although skuas occur in low densities at the BCS (Table 2), the area is of international significance for the Great Skua *Stercorarius skua* in particular (Seys 2001). Like Arctic Skua *Stercorarius parasiticus*, Pomarine Skua *Stercorarius* pomarinus and Long-tailed Skua *Stercorarius longicaudus*, also Great Skuas are seen here primarily during the autumn (Spanhove 2001). In the autumn more than 1% of the biogeographical population of Great Skua is found in Belgian marine waters (Seys 2001). The great majority (80-100%) of the flyway population of Arctic Skua uses the southern North Sea as a migration corridor (Seys 2001). Great Skuas are kleptoparasites that steal fish from other birds. On the BCS they are often found in association with large gulls and Gannets or behind fishing boats, where they kleptoparasitise on gulls or forage for fish and fish remains thrown overboard.

In summer and autumn the average densities in the target area are equal to or exceed those at the BCS (Table 2). For scarce species like skuas the use of densities may not be the best method to interpret the importance of the area. For this reason a map showing all records (including those at larger distance from the ship) of Great Skua is included in this section (Figure 7). It is obvious that such maps are biased by the number of times an area is visited (see Figure 2). Nevertheless, Figure 7 clearly shows that in particular during autumn and winter Arctic Skuas are widely scattered over the BCS. Somewhat elevated densities are found on the Flemish Banks, the Hinder Banks and to a lesser extent the Zeeland Banks (Goote Bank). In summer, most Arctic Skuas were seen further from the shore in particular on the Hinder Banks. The few records in spring stress the importance of the Flemish Banks during this season. Apart from Great Skuas, also other skuas are frequently observed on the Hinder Banks and the Zeeland Banks (Spanhove 2001). One can conclude that the target area seems of minor importance to skuas. The fact that Table 2 still shows relatively high densities in some seasons is probably the result of the low number of counts performed here in combination with the scarcity of the species.

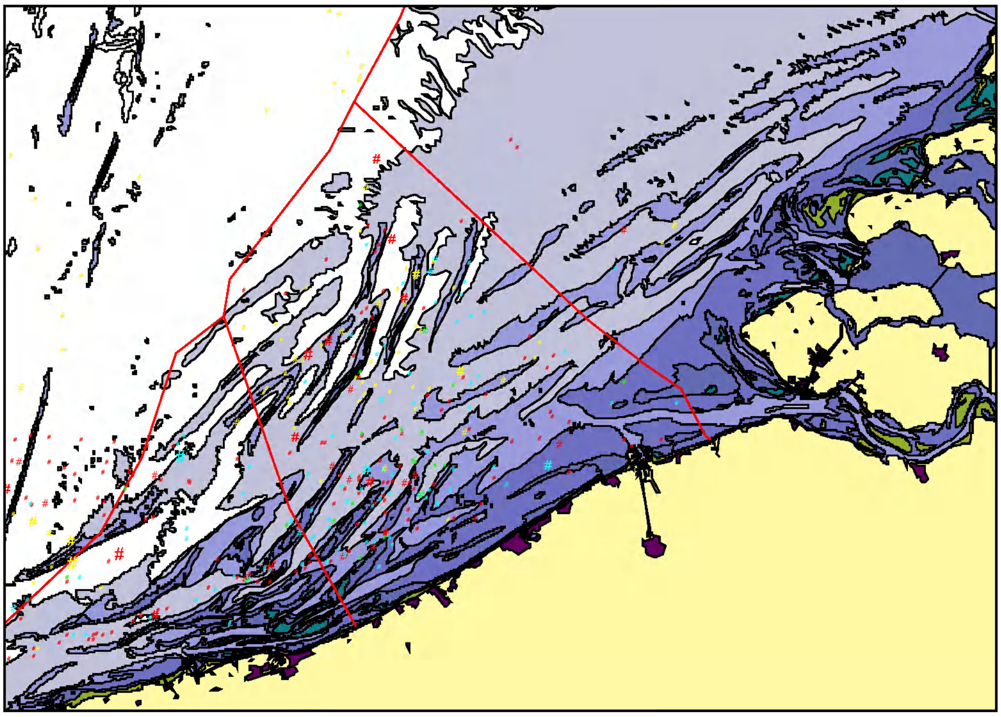


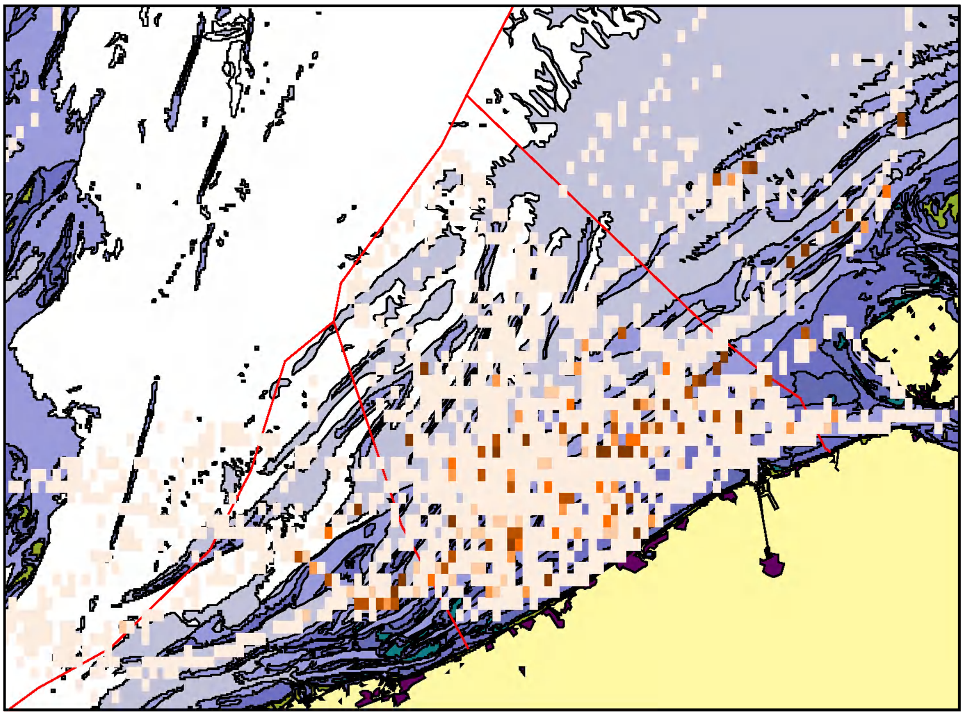
Figure 7. All sightings of Great Skua on the BCS in winter (blue dots), spring (green), summer (yellow) and autumn (red). The size of the dots denotes the numbers of individuals spotted (1-5).

- **Little Gull** *Larus minutus*

Little Gulls are typical migrants at the BCS. The densities show strong peaks in March-April and September-October. The southern North Sea plays a crucial role as a migration corridor for the species. An estimated 40-100% of the total biogeographical population passes through the southern North Sea each autumn (Seys 2001). Except for the area between the Thornton Bank and the Goote Bank, in autumn most Little Gulls migrate within 15 km from the coastline. A smaller number of birds is present on the BCS during winter. The birds then concentrate around the Goote Bank, the western Flemish Banks and the entrance of the harbour of Ostend. During spring migration the species is less tied to the coast and most Little Gulls are then found scattered within 30 km from the coast.

In the target area too there is a strong influx of Little Gulls in autumn and spring (Table 2). Very high densities were found here in spring, when migration is situated further from the coast than in autumn. In spring highest densities occurred in the area north of the Vlakte van de Raan, but also the Goote Bank and the Flemish Banks (Figure 8). During the remainder of the year the target area is less important, although it holds relatively high densities also during autumn.

Figure 8. Distribution of Little Gull on the BCS in spring.



- **Common Gull** *Larus canus*

The Common Gull is encountered on the BCS virtually exclusively in the period November-March. Common Gulls are widespread across a large part of the BCS, but hardly at all on open sea. They frequently forage behind fishing boats. On the BCS 31% of all birds are found behind fishing vessels (Offringa *et al.* 1996).

Both in winter and spring there are no clear areas of concentrated use, although in both seasons the eastern coastal area holds higher densities than the western part of the BCS. In the target area, too, the species is common (average density up to 0.8 birds/km^2) in winter and spring, but in neither season the densities did exceed those on the BCS. Although the target area can accommodate large numbers of Common Gull, it is not a marked area of concentration for this species. Therefore, the target area can be labelled as moderately important for this species.

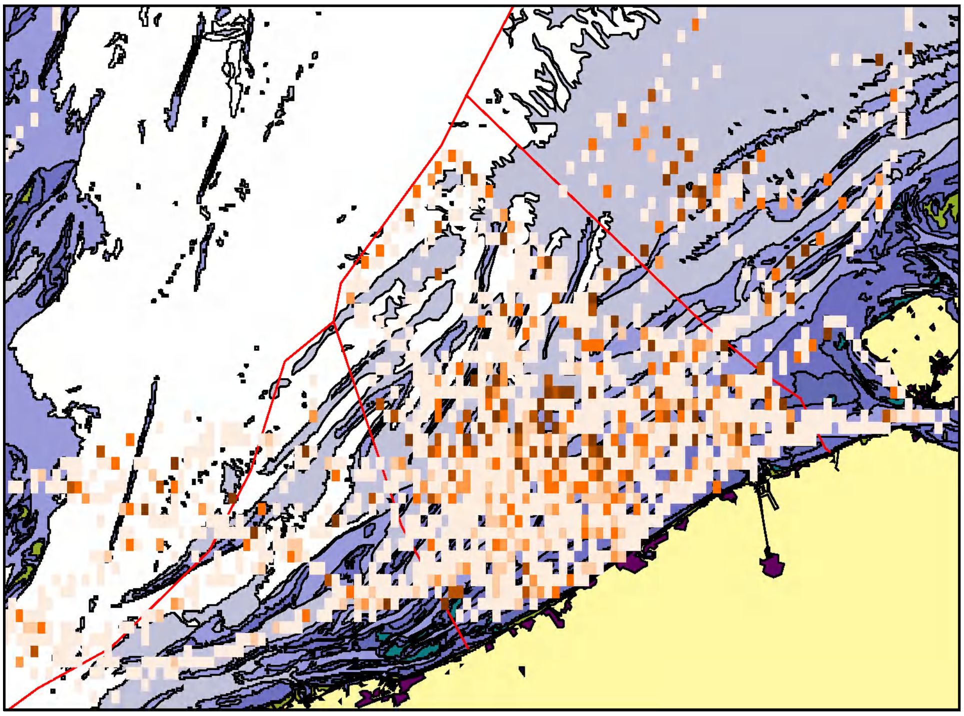
- **Lesser Black-backed Gull** *Larus fuscus*

The Lesser Black-backed Gull is found in high densities on the BCS throughout the year except from December-February. Except during winter it is the most numerous species on the BCS (Figure 4, Table 2). The densities peak in March-April and in July-September, indicating migration from and to the wintering areas. In the autumn an estimated 28% of the total biogeographical population migrates through the southern North Sea to the wintering areas in southern Europe and northern Africa (Seys 2001). On the BCS 50% of all birds are found behind fishing vessels (Offringa *et al.* 1996).

The species is much less tied to the coast than the closely related Herring Gull. Particularly in spring, Lesser Black-backed Gulls are found relatively far from the coast. They are then found scattered over the entire BCS with no marked areas of concentrated use (Figure 9). In the summer months the coastal area in front of the harbour of Zeebrugge is important as a result of the presence of a large breeding colony (3400 pairs in 2002; own data IN) in the outer harbour. Highest densities are then found within a radius of 30 km from the colony. During autumn migration Lesser Black-backed Gulls are more tied to the coast than in the spring and most are found within 20 km from the coast (Figure 10).

The figures shown in Table 2 stress the numerical dominance of this species in the target area throughout large parts of the year (see also Figure 4). Average densities recorded in the target area can reach 4.8 birds per km^2. Nevertheless the area is not of marked importance for the species. It lies at the border of the foraging area during the breeding season and has no major importance as a migration corridor.

Figure 9. Distribution of Lesser Black-backed Gull on the BCS in spring.



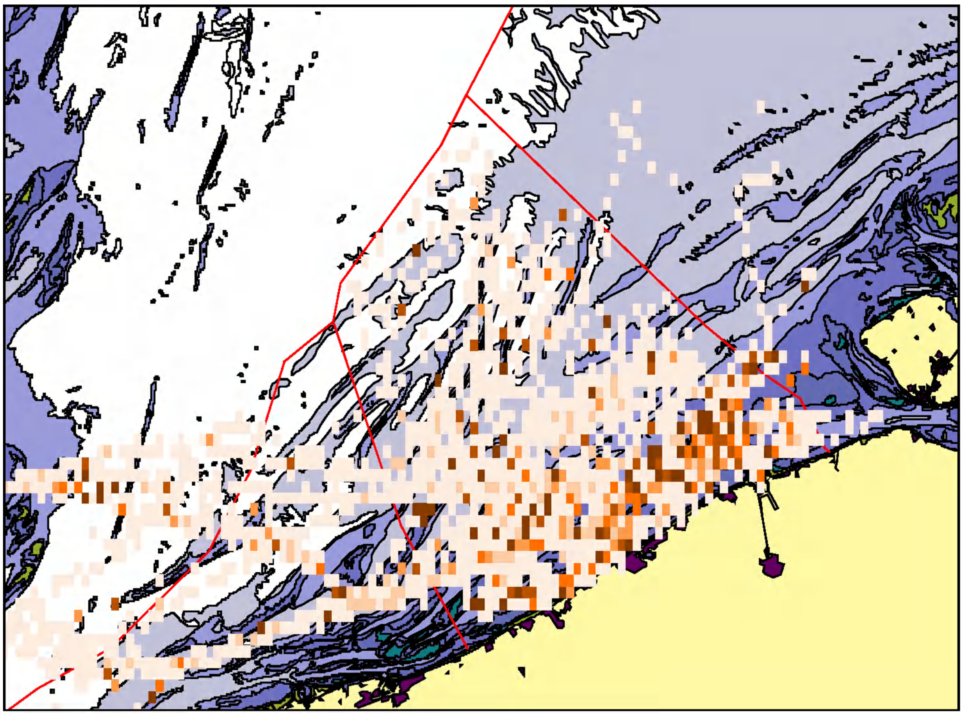


Figure 10. Distribution of Lesser Black-backed Gull on the BCS in autumn.

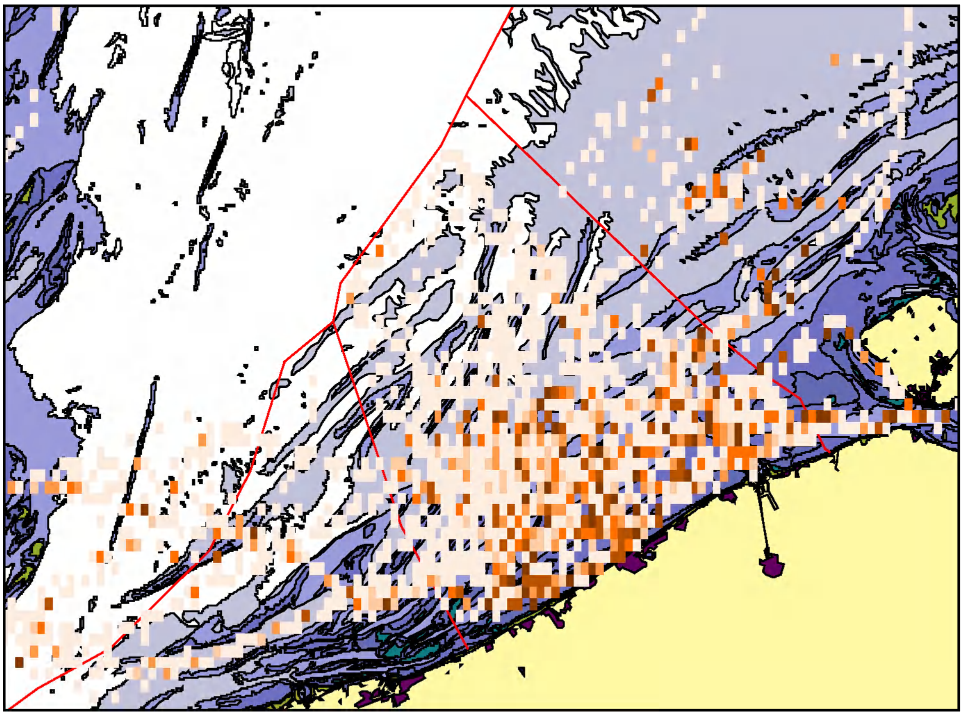
- **Herring Gull** *Larus argentatus*

The Herring Gull is encountered in high densities throughout the year on the BCS, with highest densities measured in winter and spring (Table 2). As with the Lesser Black-backed Gull, the distribution of this species depends strongly on the presence of fishing vessels. On the BCS more than one third of all birds are encountered behind fishing vessels (Offringa *et al.* 1996), where they scavenging for fish and fish residue thrown overboard.

In general the species is more tied to the coast than the closely related Lesser Black-backed Gull. This is most obvious during summer and autumn when the majority of the birds is found within 20 km from the coast. An important breeding colony is established in the outer harbour of Zeebrugge in the summer (maximum of 1184 pairs in 2001, Van Waeyenberge *et al.* 2001a and b). In spring (majority within 30 km from the coast, Figure 11) and in particular in winter (within 45 km) the species is also found further at sea. Throughout the year there are no clear areas of concentrated use within the borders given above, although in winter the deeper waters in the eastern part of the BCS hold fewer Herring Gulls than the remaining parts.

The target area may hold large numbers of Herring Gulls with highest densities recorded in spring (on average 3.6 birds per km^2), but is still of minor importance for the species. The species is widely scattered over large parts of the BCS (Figure 11). Also during the breeding season there are no clear indication that the area has an important function as a foraging area for the gulls breeding in Zeebrugge.

Figure 11. Distribution of Herring Gull on the BCS in spring.



- **Great Black-backed Gull** *Larus marinus*

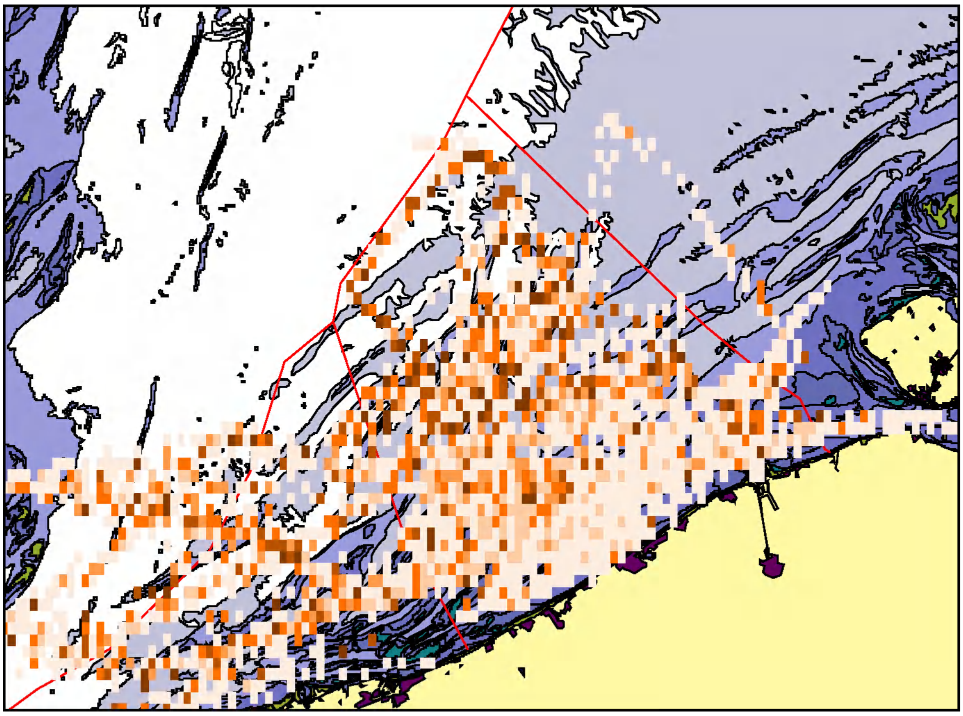
The Great Black-backed Gull is a common winter visitor on the BCS, the highest densities are recorded in December. In winter the species is widely distributed across the entire BCS with no areas of concentration use. In autumn and at the beginning of winter the species is rather more tied to the coast, with concentrations around Zeebrugge and in the western corner. Great Black-backed Gulls are frequently encountered behind fishing vessels (46% according to Offringa *et al.* 1996). In the case of this species of gull, too, although a relatively large number of the birds is found in the target area (Table 2), the area is not of marked importance for the species. The relatively high densities found here in summer are probably the result of a bias caused by the small sample size in the target area.

- **Kittiwake** *Rissa tridactyla*

Kittiwakes are real seabirds that visit the BCS between late autumn and the onset of spring. Except for the surroundings of the Zeebrugge harbour, the species largely avoids the coastal waters (Figure 12). Otherwise the birds are widely distributed over the entire BCS with no marked areas of concentrated use, although somewhat higher densities are found on the Hinder Banks. Kittiwakes are common as scavengers behind commercial trawlers. In the southern North Sea nearly half (48%) of all recorded birds is found behind fishing vessels (48% volgens Offringa *et al.* 1996).

Although the target area holds relatively large numbers of Kittiwakes in winter (Table 2), the scattered occurrence on the BCS gives no rise to designate this area as important for the species.

Figure 12. Distribution of Kittiwake on the BCS in winter.



- **Sandwich Tern** *Sterna sandvicensis*

The Sandwich Tern is present on the BCS from March to October, but markedly higher densities are recorded in the period April-July. An estimated 67% of the total biogeographical population uses the southern North Sea as a migration corridor (Seys 2001). In spring, migration takes place along a relatively wide area that stretches from the coast to the Hinder Banks, although the majority migrates within 25 km from the coast (Figure 14). In autumn, migrating birds are found much closer to the coast (largest distance recorded 27 km, but majority within 15 km). The individuals found on the BCS in May-June on the BCS (Figures 13 and 14) are from the breeding colonies in the outer harbour of Zeebrugge (maximum of 1650 pairs in 1993, Van Waeyenberge *et al.* 2001a), at the Hooge Platen in the Dutch Delta area (3100 pairs in 2001, De Kraker & Derks 2002) and Oye-Plage in France (770 pairs in 2001, De Kraker & Derks 2002). The foraging area of the Zeebrugge Sandwich Terns extends from over the Dutch border as far as the French border. Particularly to the north and west of Zeebrugge, on both sides of the Scheur, to the north of the Wenduine Bank, on the western coastal banks, on the Flemish Banks and on the Goote Bank individuals are regularly seen foraging in the summer (Figures 13 and 14).

The target area is an important foraging area for Sandwich Terns breeding in Zeebrugge and at the Hooge Platen (own observation IN, Arts & Meininger 1995, Offringa & Meire 1997). In summer, local densities in the target area average much higher than those on the BCS (Table 2). Although the figures shown in Table 2 suggest otherwise - but these are probably biased by the scarceness of the species - Figure 14 stresses the importance of the area as a migration corridor especially during autumn migration.

Figure 13. Distribution of Sandwich Tern on the BCS in summer.

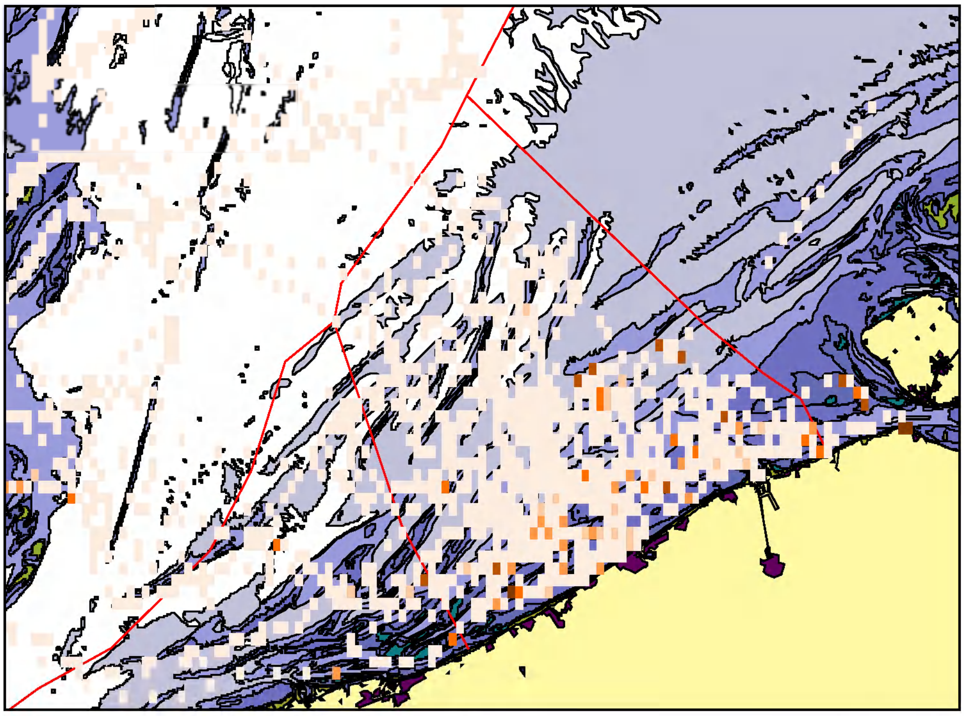
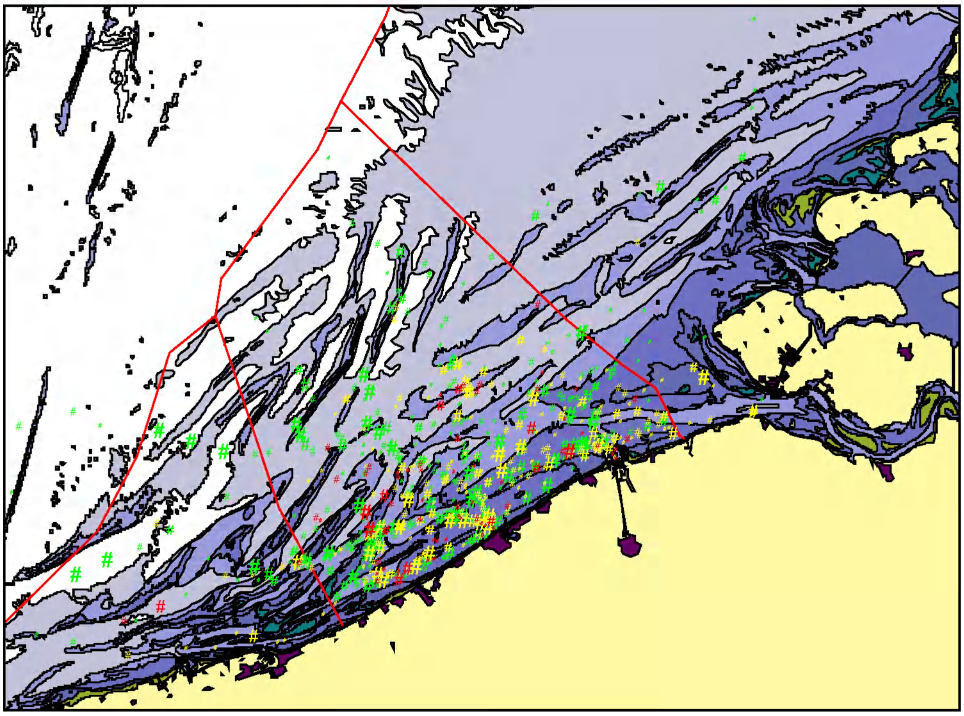


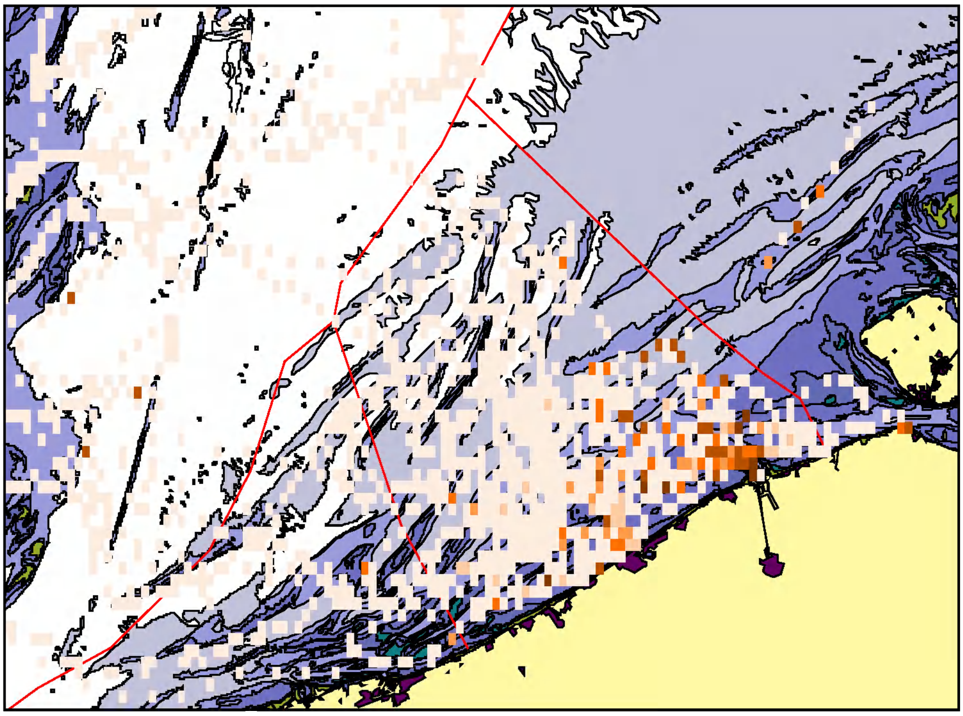
Figure 14. All sightings of Sandwich Tern on the BCS in spring (green dots), summer (yellow) en autumn (red). The size of the dots gives an indication for the number of birds seen (1-5).



- **Common/Arctic Tern** *Sterna hirundo/paradisaea*

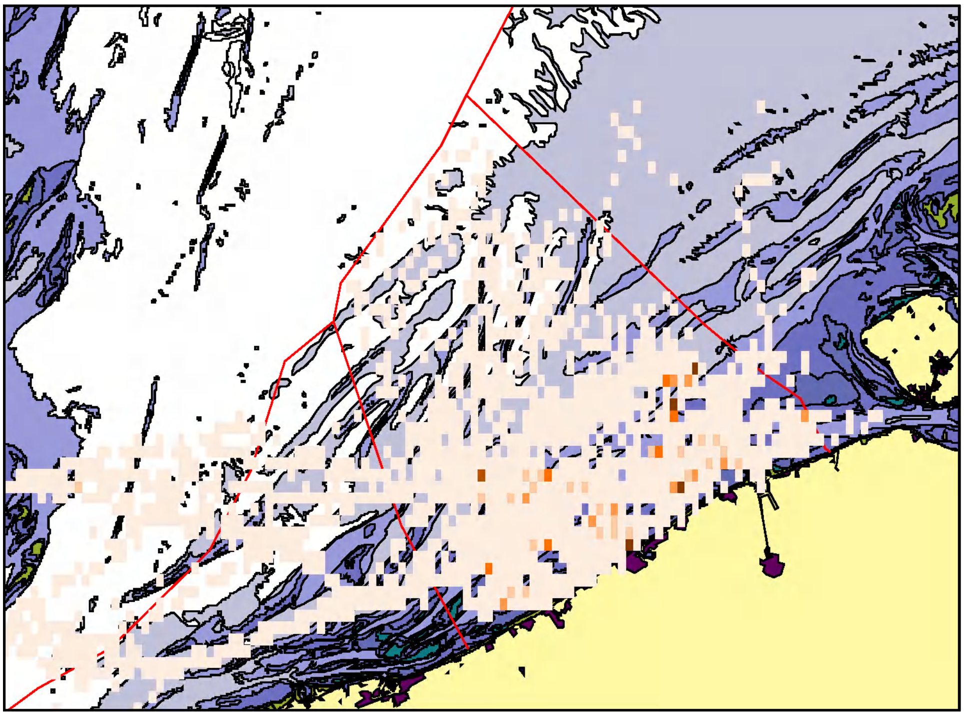
Under normal field conditions it is difficult to distinguish Common Terns from Arctic Terns. However, it is highly probable that in more than 80% of the cases these are Common Terns (Offringa *et al.* 1996). On the BCS Common/Arctic Terns are observed from April to November, with peaks in density in May and July as a result of migration. The southern North Sea is extremely important as a migration pathway for Common Terns. An estimated 56% of the total flyway population passes through the southern North Sea each spring and autumn (Seys 2001). In spring concentrated migration takes place closely inshore (majority within 10 km from the shoreline), while in autumn migrating Common/Arctic Terns are also found somewhat further at sea (but still the majority is found within 20 km from the coast, Figure 16). Around the harbours of Ostend and Zeebrugge, particularly in May, large groups are present, but at that time many passing individuals are also seen elsewhere in the coastal zone. In the summer months the outer harbour of Zeebrugge supports one of Europe's largest colonies (maximum of 2450 pairs in 2002, own data IN). Research into the foraging activity of Common Terns shows that a significant proportion of the Zeebrugge breeding population forages in the port itself or in its immediate vicinity (Rossaert *et al.* 1993, Manhout 1999, Van Waeyenberge *et al.* 2000). Foraging Common Terns are often encountered behind ferries and to a less extent behind other vessels. The western side of the harbour in particular is an important foraging area (Figure 15). However, concentrations of foraging Common Terns have also frequently been observed on and around the Vlakte van de Raan (Arts & Meininger 1995, Offringa & Meire 1997). Most birds were, however, seen within 10 km from Zeebrugge (Figure 15), although some individuals might perform foraging flights of up to 15 km (Beijersbergen 1980, Stienen & Brenninkmeijer 1992, Arts & Meininger 1995).

Figure 15. Distribution of Common/Arctic Tern on the BCS in summer.



In the target area high densities were found in summer and autumn (Table 2). The importance of the windfarm site as a foraging area for terns breeding in Zeebrugge and Het Zwin is not entirely clear, but seems negligible because it is located at more than 15 km from the colonies. On the other hand, the area is very important for migrating Common/Arctic Terns in particular during autumn when migration occurs somewhat further from the shore (Figure 16).

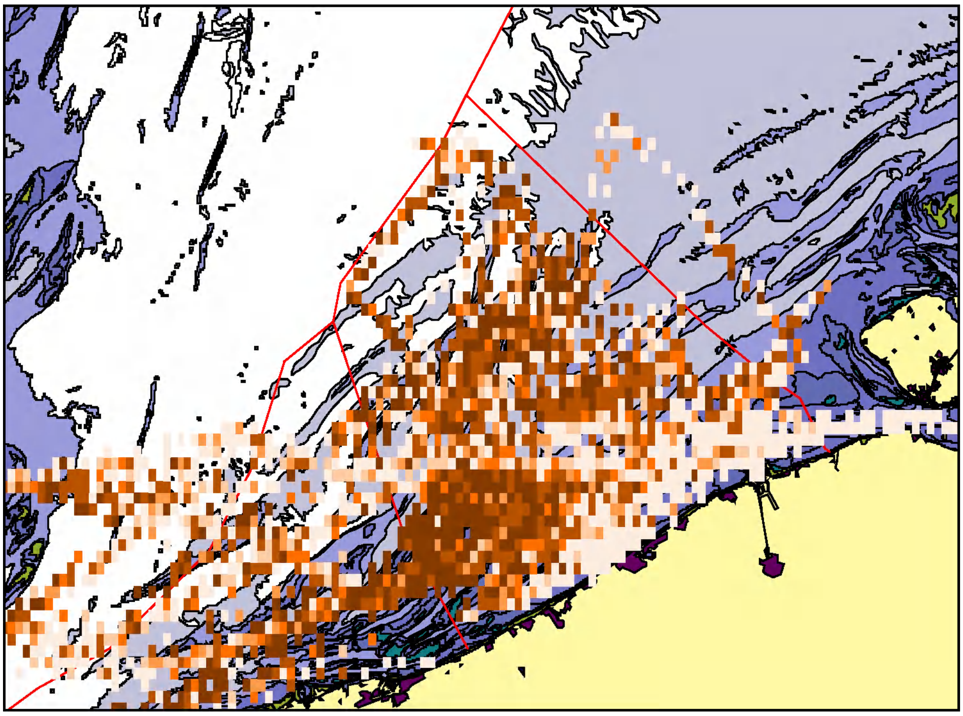
Figure 16. Distribution of Common/Arctic Tern on the BCS in autumn.



- **Guillemot/Razorbill** *Uria aalge/Alca torda*

Both Guillemots and Razorbills are winter guests, which visit the BCS between October and March. The highest densities are recorded in January-February, when this taxon is the most common seabird present in the area. More than 75% of all records refer to Guillemots. Guillemots and Razorbills generally avoid the immediate coastal waters (Figure 17). Except for the west coast, where high densities are also found closer to the shoreline, Guillemot/Razorbill were primarily found at more than 10 km from the coast. Important wintering areas are found on the Flemish Banks, Hinder Banks as well as the Zeeland Banks, but also in the gullies and deeper waters Guillemots/Razorbills are frequently encountered.

Figure 17. Distribution of Guillemot/Razorbill on the BCS in winter.



Notwithstanding the fact that the average density at the target area is very high in winter (Table 2) and Guillemot/Razorbill make up 42% of all species (Figure 4), the area is not of exceptional importance for this taxon because both Guillemots and Razorbills are widespread over large parts of the BCS.

3.4. Importance of southern North Sea for migrating birds

3.4.1. General

Many migratory birds use the coastline for orientation during migration to and from their breeding grounds. In spring and autumn this results in high densities of migratory birds along the coast. Both along the Belgian and Dutch coasts migration has been intensively monitored by seabird watchers for many years (incl. Camphuysen & Van Dijk 1983, Borrey *et al.* 1986, Van Westrienen 1988, Platteeuw *et al.* 1994), thus we know that typical coastal species and waders are dominant during migration along the coasts of the southern North Sea.

For most migratory species these counts show clear patterns throughout the year. Depending on the species there may be a concentrated spring or autumn migration. A few species also show a moulting migration (for example Shelduck). In addition to these patterns, the migration of birds along the coast often depends on wind direction and strength. In certain weather conditions a strongly propelled migration along the coast can take place. In autumn for instance, a strongly concentrated migration can be observed when there is a strong wind from the north-west. At times of strong north-westerly wind, also offshore birds are driven closer to the coast.

3.4.2. Seawatches

Depending on the season and the species the number of birds migrating along the coast can be very high. During observations at Ostend (1978-1983) the following species (or groups of species) reached peak averages of more than 10 birds per hour: Greylag Goose, Brent Goose, Wigeon, Common Scoter, Wader spp., Oystercatcher, Lapwing and Sterna spp. (Borrey *et al.* 1986). In particular Common Scoters (maxima of 266 birds per hour) and Common Terns/Arctic Terns (maxima of 52 birds per hour) can reach very high averages per hour. Typical offshore species (like e.g. Fulmar, Kittiwake and Auk) are seen only in low numbers along the coast. The more common Laridae-species (Black-headed Gull, Common Gull, Herring Gull, Lesser Black-backed Gull and Great Black-backed Gull) have not been counted systematically, so no good data exists on their migratory movements.

Generally, counts of the number of birds passing along the coast of South Holland (The Netherlands) give the same results of the predominant species (Camphuysen & Van Dijk 1983, Platteeuw *et al.* 1994). However, in contrast to the observations at Ostend, some species (Great Crested Grebe, Gannet, ducks, Little Gull and Kittiwake) did reach peak numbers of more than 10 birds per hour along coast of South Holland. Here the number of migratory movements of Laridae was recorded and Black-headed Gull, Common Gull, Herring Gull and Lesser Black-backed Gull all achieved peak averages of more than 10 passing birds per hour, running up to a maximum of 140 birds per hour (Camphuysen & Van Dijk 1983, Platteeuw *et al.* 1994). The total number of birds that migrate along the Dutch coastline in spring is in the order of 3.5 million and in the autumn in the order of 2.5 million. Approximately the same migration intensity will occur along the Belgian coast.

3.4.3. Radar studies

Knowledge of migratory movements of birds further offshore is very limited (Lack 1960, 1963, Louette 1971a, 1971b, Buurma 1987). Generally it can be stated that in autumn during the daytime migration takes place close to the coast, with the highest densities of migratory birds being located in a narrow band along the coast. The few sea migration observations from oil platforms and ships confirm that a much lower density of migratory birds is found over the open sea (Report of the Club of Sea migration observers, quoted in Buurma & Van Gasteren 1989).

However, it appears from a radar study of the spring and autumn migration of birds along the Belgian coast that the north-south oriented migration can also still be very intensive far from the coast (Louette 1971a). In addition, strong movements in an east-west direction were sometimes visible on the radar, indicating migration to and from England. Since the width of the migration zone is not accurately known, on the basis of radar observations (Louette 1971a, Buurma 1987, Buurma & Van Gasteren 1989) a distance of 15 to 20 km from the coast could be the estimated zone within which concentrated migration occurs. Not only is the distance from the coast at which the various species pass by virtually unknown, there is also a virtual no information on flying height and nocturnal migration. A radar study near the Maasvlakte (The Netherlands) shows that in the autumn, migration takes place throughout the night in the lower strata of the air (< 150 m; Buurma & Van Gasteren 1989). Also during night numerous species use the coast as a guideline at night, although strong concentrations of birds seem to occur less than at daytime. Still this results in relatively high densities of migratory birds in the lower air layers over a zone the width of a few kilometres (Lack 1960, 1963, Buurma 1987, Buurma & Van Gasteren 1989). A radar study of the intensity of nocturnal bird migration along the Belgian coast (Louette 1971a, 1971b) confirms this picture.

3.4.3. Importance of BCS as migration route

The southern North Sea, including the BCS, has an important function as a migration route for a number of marine birds. Looking at the map of the southern North Sea it is clear that cuneiform entrances to the Strait of Dover may act as a fyke net within which seabirds become temporarily concentrated when they leave or enter the southern North Sea (Stienen *et al.* in prep). An estimated 1-1.3 million marine birds use this narrow corridor as a migration route each year (Seys 2001). For a number of seabirds a very significant percentage of the total biogeographical population migrates through this area (Seys 2001, 2002). For Great Skua and Little Gull in particular this is a very important migration route (40-100% of the total biogeographical population). An estimated 30-70% of the total flyway population of the Lesser Black-backed Gull and summer resident terns (Little, Common and Sandwich Tern) migrate via the Channel. In addition, 10-20% of the flyway population of Red-throated Diver and Great Crested Grebe may pass this bottleneck, and 3-10% of the *Larus*-gulls (excepte Little Gull), Northern Gannets and Common Scoters. The majority of these species are very much tied to the coast (except Great Skua and Northern Gannet) and migrate at less than 20 km from the coast (Offringa *et al.* 1996, Seys 2002, Stienen *et al.* in prep.). A number of species (including Red-throated Diver, terns and possibly also some other species) are also known to migrate during night or during crepuscular hours (Cramp & Simmons 1977, Camphuysen & Van Dijk 1983, Allein & Boudolf 1998).

All seabirds are known as k-strategists (long life span, small clutch size and delayed maturity), making them extremely sensitive to changes in the mortality of adult birds. A small increase in adult mortality rate can have disastrous consequences for the population as a whole. Because of their longevity the impact on the population may only become evident after a number of years (and sometimes after more than 20 years). For this reason and because of the international importance of southern North Sea as a migration pathway for many seabirds, particularly in this area one must be very careful to situate constructions that might affect survival probabilities of seabirds.

3.5. Conclusions

In order to draw conclusions on the importance of the target area and the expected effect for the various species/taxa one must weigh up several factors of importance. In this report the following factors were considered:

- whether or not the species/taxon is included in the highest priority lists of European legislative instruments, being the EC-Birds Directive (Annex I species), the Bern Convention (appendices I or II) and the Bonn Convention (appendices I or II).
- whether or not the species/taxon has a threatened status either in Europe or in Belgium.
- the importance of Belgian marine waters as a migration pathway for the species concerned.
- whether or not the numbers found in Belgian marine waters are of international importance (i.e. they exceed the 1% level of their respective biogeographical population)
- the importance of the target area for the species, which is a weighing up of (1) the local densities compared to those on the BCS, (2) the area being a specific area of concentrated use and (3) the importance of the area as a migration corridor for the species.

The results of this exercise are listed in Table 3. Note that the analysis is made on a species-specific basis. If the case that in the above sections the entire taxon was described (e.g. diver spp., skua spp. etc.) Table 3 only treats the most dominant species within this taxon. A summary of the most important issues evident from this table and from the above is given below.

- The importance of the windfarm site for wintering **Red-throated Diver** is not to be neglected. Relatively high densities are found here in autumn, winter and spring. The BCS and in particular the coastal zone including the target area plays an important role as a migration corridor for the northwest-European flyway population. Since the species migrates in relatively high densities in a narrow band close to the coastline, the impact of a windfarm within this migration pathway might be large. Since the species is also highly sensitive to disturbance, is listed as vulnerable within Europe, is included in Europe's highest priority lists for conservation and the maximum numbers recorded in Belgian marine waters exceed the 1%-level of the total flyway population the integrated importance of the windfarm site can be judged as ***very high***.

- The windfarm site is very important for wintering **Great Crested Grebes**. The coastal zone of the BCS is an important corridor for migrating Great Crested Grebes. Even more than is the case in Great Crested Grebe this species migrates in a narrow band close to the coast. The windfarm site is situated at the northern border of this band. The species is not considered as threatened within Europe or in Flanders and is not included in Europe's highest priority lists for conservation, but the maximum numbers wintering in Belgian marine waters well exceed the 1%-level. Weighing up these considerations the importance of the windfarm site for Great Crested Grebes can be judged as ***high***.

- The site is very important for the **Little Gull** during the spring and autumn migration. Especially in autumn when concentrated migration occurs close to the coast, the windfarm site constitutes a relatively large part of the migration corridor of Little Gulls. The species' sensitivity for collision and disturbance is, however, unknown. The total European population of this species is showing a decline, the species is listed on Europe's highest priority lists for conservation, the BCS forms a very important migration corridor for Little Gulls and the numbers on the BCS well exceed the 1%-level of the total flyway population. For those reasons the importance of windfarm site is considered as ***very high***.

- During the breeding season the site is important as a foraging area for **Sandwich Terns** breeding at the out port of Zeebrugge and at the Hooge Platen (The Netherlands). Although the BCS as a whole is an important migration route for Sandwich Terns, certainly during spring passage when Sandwich Terns are widely distributed over large parts of the BCS, the windfarm site constitutes only a small part of the species' migration corridor. A more significant impact might be expected during autumn migration when the species is more tied to the coast, but the species' sensitivity for collision is unknown. The Sandwich Tern is included in Europe's highest priority lists for conservation, the European population is declining, the species is threatened with extinction in Flanders and the numbers in Belgian marine waters exceed the 1%-level of the total flyway population. This leads to an integrated importance of the windfarm site that can be judged as ***moderate.***

- The windfarm site is situated outside the normal foraging range of **Common Terns** breeding along the Flemish coast. Still the site holds significant numbers of Common Terns during summer and autumn, stressing its importance as a migration corridor. If consideration is also given to inclusion into the highest priority lists for conservation in Europe, the threatened status in Flanders, the importance of BCS as a migration pathway for the flyway population and the numbers in Belgian marine waters exceeding the 1%-level of the total flyway population, the integrated importance of the windfarm site is judged as ***moderate***.

- The most common seabirds present at the windfarm site are **Guillemot/Razorbill** (winter), **Lesser Black-backed Gull** (spring through autumn) and **Herring Gull** (spring). Only for the Lesser Black-backed Gull the area is an important migration corridor. In particular during autumn passage when the latter species is more tied to the coast, the windfarm site constitutes a significant part of the migration corridor of this species. Since none of the three species or species groups are listed on European highest priority lists for conservation or are considered threatened within Europe and the site is not of particular importance for any of these species the integrated importance of the windfarm site is judged as ***minor***.

Table 3. Schematic representation of the inclusion of a species in European legislative instruments (the species is represented in red if it is included as an Annex I species in the EC-Birds Directive, appendices I or II of the Bern or Bonn Convention), the international status (according to Heath et al. 2000, localized = population larger than 10,000 breeding birds, of which 90% at less than 10 locations), the status within Flanders (derived from the Red List of breeding birds in Flanders, Kuijken 1999), the importance of the BCS as a migration corridor (- = of little or no importance, + = of some importance, ++ = of great importance, +++ = of very great importance), the proportion of the total biogeographical population present on the BCS (given in red if more than 1% of the species is present on the BCS in a particular season, according to Seys 2001) and the importance of the target area relative to the BCS (- = of little or no importance, + = of some importance, ++ = of great importance, +++ = of very great importance). For each species the function of the target area as foraging (F), resting (R) or migration (M) area is denoted.

Species	*Status in Europe*	*Status in Flanders*	*Function as a migration corridor*	*Maximum % observed on BCS*	*Importance of target area*	*Function of target area*
Red-throated Diver	vulnerable	not breeding	++	2.5%	+++	FMR
Great Crested Grebe	secure	not threatened	++	*3.2%	+++	FMR
Fulmar	secure	not breeding	-	0.0%	-	F
Gannet	localized	not breeding	+	0.4%	-	FR
Common Scoter	secure	not breeding	+	1.0%	-	FR
Great Skua	secure	not breeding	+++	1.6%	+	FMR
Little Gull	declining	not breeding	+++	4.9%	+++	FMR
Black-headed Gull	secure	not threatened	+	0.1%	-	F
Common Gull	declining	rare	+	0.4%	+	FR
Lesser Black-backed Gull	secure	vulnerable	++	3.5%	++	FMR
Herring Gull	secure	vulnerable	+	1.4%	+	FR
Great Black-backed Gull	secure	not breeding	+	1.2%	+	FR
Kittiwake	secure	not breeding	-	0.1%	-	F
Sandwich Tern	declining	threatened with extinction	+++	2.2%	++	FM
Common Tern	secure	threatened	+++	*2.7%	++	FMR
Little Tern	declining	threatened with extinction	++	2.5%	+	M
Guillemot	secure	not breeding	-	0.7%	-	FR
Razorbill	secure	not breeding	-	0.8%	-	FR

* = figures of Seys 2001 were amended according to the new data collected by the IN

- The report did not account for a possible impact of the windfarm on **Little Terns** because this species is hardly ever encountered at sea. The windfarm is located well outside the foraging range of Little Terns breeding along the Flemish coast. However, the southern North Sea including the BCS ***could be*** of ***high*** importance for the species as a migration pathway. There are indications that this species predominantly migrates during night, which would explain why it is hardly ever encountered during daytime. Also other seabirds might show nocturnal migration but the extent of it remains unknown (see also paragraph 3.5.3.).

4. AUTONOMOUS DEVELOPMENT

It is to be expected that, if wind turbines are not installed, the ornithological value of the northern part of the Vlakte van de Raan will remain essentially the same. Apart from natural variations in numbers that can be sometimes very large (for example Great Crested Grebes that are mainly found in high numbers at sea during strong winters), there are no indications that major shifts in species composition or numbers are taking place in the area. Only the number of Herring Gull, Lesser-Black-backed Gull, Sandwich Tern and Common Tern present in the area during summer were undoubtedly strongly linked to the number of birds breeding in the outer harbour of Zeebrugge and will remain doing so in the future. It is possible that the significance of the site as a foraging area for Common Terns and/or Sandwich Terns may fluctuate somewhat from year to year since annual changes and movements occur in their food stocks (Herring, Sprat and Sandeel).

5. ASSESSMENT OF POTENTIAL EFFECTS

5.1. Descriptive bibliography

5.1.1. Introduction

Throughout Europe wind turbines have been mainly installed on land and in semi-offshore areas nowadays. Research on the effects of wind turbines on birds has therefore largely been limited to the land or coastal situation (see Winkelman 1989, 1992a, 1992b, 1992c, Musters *et al.* 1991, Everaert *et al.* 2002). Virtually no research is available on the offshore situation (Cristensen *et al.* 2001, 2002, Guillemette *et al.* 1998, 1999). However, parts of the terrestrial studies are also relevant for the offshore situation. The following paragraphs provide a summary of the main results of research relating to medium-sized and large wind turbines. A summary overview of the current understanding appeared in Spaans *et al.* (1998a,b, 1999) and Van der Winden *et al.* (1999).

Research projects were recently started in Flanders studying the effects of windfarms on land and in coastal areas on birds (Everaert *et al.*, 2000, 2001a, 2001b, 2001c, 2002, Seys *et al.* 1999b). The study focussed on the two largest wind-turbine locations in Flanders, namely in the outer harbour of Zeebrugge (23 small to medium-sized wind turbines on the eastern jetty and the transverse dam) and along the Boudewijn canal in Bruges (14 medium-sized turbines). In May 2001, a third location in Schelle (3 large turbines) is added to the study. The situation along the eastern jetty at Zeebrugge (see Everaert *et al.* 2001b, 2001c, 2002, Seys *et al.* 1999b) resembles most to the situation at the Vlakte van de Raan and will be discussed in more detail in the next sections. However large differences exist in size of windturbines, rotation speed, distance between the turbines, density of bird population and the different areal caracteristics of the area compared to the offshore site north of the Vlakte van de Raan.

5.1.2. Description of potential effects

Birds can be troubled in two ways by wind turbines. First they can collide with parts of the turbines (primarily the rotor blades) resulting in being killed or injured (*collision aspect*). In addition, birds can be disturbed by the turbines, where a distinction has to be made between direct effects like loss of suitable breeding, foraging and resting areas as a result of direct use of the space or restriction of the birds' flying and migration routes, and indirect effects resulting from disturbance by the presence, movement or sound of the turbines (*disturbance aspect*).

5.1.3. Collision

General

Birds collide with wind turbines virtually exclusively at night and at twilight (Crockford 1992, Winkelman 1985, 1992a). Casualties occurring during the daytime are largely restricted to birds of prey, heron and pigeons, the numbers of which at sea are negligibly small. During the day, in certain weather conditions (such as fog, strong wind, spray or rain) birds' sight is limited to such an extent that the probability of a collision increases substantially (Winkelman 1995). Although visibility conditions play an important part, illuminating the obstacles is more likely to have a negative effect. In conditions of poor visibility many birds are in fact attracted by illumination. There are various examples in the literature in which massive collisions with obstacles have taken place in a single night, so-called disaster nights (summary in Winkelman 1992a). However, real disaster nights only occur in the case of high obstacles. Low towers and masts (less than 150 m) only result in disaster nights on very incidental occasions (Winkelman 1992a, 1995).

Collision risk

Only a small proportion of the birds present run the risk of colliding with a wind turbine. Research at the windfarm in Oosterbierum (The Netherlands) shows that an average of 0.10-0.22% of the nocturnal migrants collide with a turbine (Winkelman 1992a). If movements during daylight are also considered, an average of 0.01-0.02% of passing birds become casualties. For resident birds the number of casualties averaged 0.06-0.12 birds per day. The large-scale research at Oosterbierum was based on the number of birds present at a distance of 500 m around the windfarm and related to 18 medium-sized wind turbines (35 m high, three rotor blades and a maximum power of 300 kW), positioned at intervals of 150-300 m. In the operational phase an average of 0.02-0.12 birds per day per wind turbine are killed as result of a collision. The variation in the data from Oosterbierum (Winkelman 1992a) is the result of including or not including the number of possible collision casualties (*i.e.* taking account of the fact that a number of casualties were not found because they were taken away by predators). At a windfarm in the Noordoostpolder (The Netherlands) the number of casualties was of the same order of magnitude as at Oosterbierum (Winkelman 1989). In the case of the windfarm near the Kreekrak locks (the Netherlands) the number of collision casualties was almost ten times lower (Musters *et al.* 1991). Such differences can be associated among other things with the vicinity of other landscape elements, such as high-voltage cables, roads, spinneys and rows of trees (Van der Winden *et al.* 1999). So the number of collision casualties can differ clearly by location. The maximum rate at any windfarm site in North America was 0.005 birds/day/turbine (Strickland *et al.* 1998, Dillon Consulting Ltd. 2000). In big windfarms in the United States (California) with more than 2000 turbines between 0.03 and 0.15 birds/year/turbine are killed by collision (Dillon Consulting Ltd. 2000). The studies at Oosterbierum and in the Noordoostpolder both refer to an open landscape with only small lightening of the horizon, which is more comparable with the offshore situation.

Follow Winkelman (1992b) some birds were swept down during night throught the wake behind the rotor of the wind turbines. These accidents seems to happen only with birds approaching the turbine with tailwind and therefore direct after passage dealing with unexpected air turbulences. Only some of these accidents are mortal.

Number of casualties

The mean number of casualties per kilometre of small to medium sized wind turbines is comparable with the number of casualties per kilometre of a busy road or power transmission line (Winkelman 1992a, 1995). 1000 MW of installed wind-turbine capacity in land and coastal locations would in the case of small to medium-sized wind turbines cause an average of approximately 21,000 to 46,000 casualties annually (Winkelman 1992a).). The same study compares this to other annual total human-related bird-mortality in the Netherlands: road kills 2.000.000 - 8.000.000, power line kills 1.000.000 - 2.000.000 and hunting kills: 650.000. For 1000 MW of installed capacity of medium-sized wind turbines Koop (1997) arrived at a higher estimate of approximately 60,000 to 100,000 casualties a year. Less casualties are currently being recorded in the case of a number of large wind turbines (0-10/year/turbine), but additional research at several locations is still required to confirm this figure (Musters *et al.* 1996, Percival 1999).

Belgian research results

The research results of the number of collision casualties along the eastern jetty at Zeebrugge during the spring and autumn migration (March-April and October-November) give a similar estimate (average 0.10 casualties/day/turbine) to the research carried out by Winkelman (1992a) and Van der Winden *et al.* (1999). A higher risk of collision for the cluster on the seaward side compared to landward cluster exists at this location. The number of casualties is related to the number of flight movements at a particular wind turbine. Collisions along the eastern jetty occur particularly among gulls (Everaert *et al.* 2001b, 2001c, 2002), which are present at Zeebrugge in high numbers (eg. 8260 breeding individuals in 2000, based upon Van Waeyenberge *et al.* (2001b); average wintering numbers not known and also non-breeding birds during breeding season not included).

Collision casualties

A positive relationship between the number of birds present and the number of collision casualties was also found in the windfarm near the Kreekrak locks (The Netherlands) (Musters *et al.* 1991). So there is ample evidence that the number of collision casualties primarily depends on the number of birds present in the area around a windfarm (see also Musters *et al.* 1996, Winkelman 1995). Several studies have shown, however, that the risk of collision can differ by species (Musters *et al.* 1991, Winkelman 1992a, Still *et al.* 1995, Everaert *et al.* 2002). During the daytime most casualties are found among birds of prey, heron and pigeons. At night it is primarily songbirds and ducks that are lost, but also Lesser Black-backed Gulls and Great Black-backed Gulls have a relatively high risk of collision. Research in England has shown that the risk of collision for Eider Ducks can also be relatively high (Still *et al.* 1995, Van der Winden *et al.* 1999). In this English study Cormorants, Herring Gulls and Black-headed Gulls had a relatively low probability of collision. Several foreign researchers noted only common birds are casualties of wind turbines (Winkelman 1992a, Van der Winden *et al.* 1999). In recent studies in Germany and at Zeebrugge also rare species like White-tailed Eagle, Peregrine Falcon, Red Kite and Little tern are identified as collision victims (Harte 2001, Everaert *et al.* 2002, Ostsee-Zeitung 2002). Information on species-specific collision risk is, however, scarce and sometimes confusing, so that no general conclusions can be drawn yet. Especially for seabirds there is very limited information on this subject.

Flight altitude

It seems inevitable that collision risk of a bird very much depends on its flying altitude. The majority of nocturnal and local daylight flight movements that have been recorded took place between 50 and 150 metres, which corresponds with the height of the current generation of wind turbines (pile height up to 80-100 m, rotor diameter up to 100 m). These studies include local flight movements of diving ducks and Spoonbills between resident (ducks) or breeding (Spoonbills) areas and foraging grounds (Dirksen *et al.* 1996b, 1998, Van der Winden *et al.* 1998), migration of waders along the coast (Dirksen *et al.* 1995, 1996a), flight movements of waders and ducks related to the tide (Van der Winden *et al.* 1997, 1998, 1999, Spaans *et al.* 1996, 1998a, 1998b), local flight movements of geese (Spaans *et al.* 1998a, Van der Winden *et al.* 1998) and seasonal migration (Buurma & Van Gasteren 1989). At night birds seem to fly higher than during daylight (Spaans *et al.* 1996, Dirksen *et al.* 1998).

5.1.4. Disturbance

Habitat loss and disturbance distance

Various studies have shown that wind turbines can cause disturbance among foraging and resident birds, both on land (Petersen & Nøhr 1989, Winkelman 1989, 1992b, Bach *et al.* 1999, Kruckenberg & Jaene 1999, Schreiber 1999) and in wetlands (Winkelman 1989, 1992b). Here too, there are substantial differences between species and groups of species in terms of the distance and the degree to which the disturbance occurs (van den Bergh *et al.* 2002). In open agricultural area ducks, waders and gulls in particular felt a clearly disturbing effect, in contrast to Corvidea and Starlings. Depending on the species, the distance at which disturbance occurred varied between 100 and 800 meters (Osieck & Winkelman 1990, Winkelman 1992d, Schreiber 1993, 1999, Percival 1998, Kruckenberg & Jaene 1999). Within these zones the reduction in numbers of the different species in relation to the reference situation (i.e. before installation of the windfarm) was between 60 and 95% (Winkelman 1992d, Van den Bergh *et al.* 1993). The number of resident and foraging birds that use an area can decline substantially after installation of wind turbines. The disturbing effect is greatest when the windfarm is operational, but is already measurable in the non-operational phase.

In a recent study in Germany a clearly disturbing effect on White-fronted Geese was found. Before installation of the wind turbines large numbers of White-fronted Geese rested in the area. After installation of the turbines no White-fronted Geese were observed in a zone of 400 m around the turbines, and in a zone of 400 to 600 m around the turbines a reduction of 50% was recorded (Kruckenberg & Jaene 1999). Large windfarms with small wind turbines in Denmark caused disturbance distances of 400 m for the Pink-footed Goose (Osieck & Winkelman 1990). Birds staying on the water are also disturbed by wind turbines standing on the edge of or in the water. Disturbance distances for various species of waterbirds (primarily ducks) extend to 400 metres (Winkelbrandt *et al.* 2000, Van der Winden *et al.* 1999, Winkelman 1989). For resident and feeding Common Pochards, Tufted Ducks and Goldeneyes an average reduction of 80% was recorded in a zone of 150 m around the turbines. In the case of the Mallard and most other swimming ducks a reduction in numbers of 60% in a zone 300 m around the turbines could be establised. Most waders show a reduction in numbers of approximately 90% within a zone 100 m around the turbines; for the Curlew this is the case up to 500 m from the turbines (Van der Winden *et al.* 1999, Winkelman 1989, 1992d). Similar disturbance distances were also measured for water birds near large windfarms in Denmark.

There are also differences of disturbance between breeding and non-breeding birds around windmill parks about their distribution and numbers at the site (van den Bergh *et al.* 2002). For most of the studies there are no clear indications so far for a disturbed influence on breeding birds, despite the size of the wind turbines (Vauk 1990, Winkelman 1992b, Meek *et al.* 1993, Bach *et al.* 1999, Thomas 2000, Everaert *et al.* 2002, van den Bergh *et al.* 2002). Only Handke et al. (1999) and Sachslehner & Kollar (1997) found significant negative effects on Lapwings breeding close to wind turbines, even also for Meadow Pipits and Sky Larks. These results indicate that during the breeding period birds are less sensitive to disturbance for windmills. In contrast to the situation outside the breeding season, local breeding birds might get used to this obstacles (van den Bergh *et al.* 2002). Little if any information is known about the effect on songbirds that sometimes also resident in large groups outside the breeding season.

Behavioural response to and barrier effect of wind turbines

Also passing birds respond to wind-turbine farms. During the day the birds' response depends on whether or not the turbines are operating and the density of wind turbines (Winkelman 1992c). When the wind turbines were not operating 2% of the passing birds reacted to the wind-turbine farm in Oosterbierum. When the wind turbines were turning 11-18% of the birds responded. Again substantial differences between species were found. The larger birds, such as ducks and gulls, respond more strongly to wind turbines than smaller birds (like songbirds). When spacing is less than five times the rotor diameter the proportion of birds showing a response is much greater than when spacing is more than eight times the diameter. Also the research in the out port of Zeebrugge provided indications that the behavioural response to the presence of wind turbines is related to the wingspan of the birds (Everaert *et al.* 2001b, 2001c, 2002). Nevertheless, terns such as the Common Tern and Sandwich Tern seemed to be more sensitive to disturbance than the larger gulls (Everaert *et al.* 2001b, 2001c, 2002). In the Netherlands, two short line-up of wind turbines at a coastal breeding site (Maasvlakte) of gulls and terns showed that during the breeding period almost no reaction could be observed from these breeding birds (van den Bergh *et al.* 2002).

With long line-up or clusters of wind turbines a serious barrier effect can be caused by turbines (van den Bergh *et al.* 2002). This is the case during migration or for local movements as well as for birds flying above land or water (Karlsson 1987, Winkelman 1992a, 1992b, van der Winden *et al.* 1996, Spaans *et al.* 1998a, Tulp *et al.* 1999, Brauneis 2000, Poot *et al.* 2001). Two types of response can be identified, namely changing flight direction in order to avoid the windfarm and temporarily adjusting the flight altitude in order to fly over the windfarm. A large proportion of the birds will not fly into the windfarm or will leave it again quickly. Generally avoidance of the turbines occurs at a short distance. Groups of birds that pass a windfarm often bunch together in response to the wind turbines (Winkelman 1992d). Other studies also show that migrating birds avoid the windfarms, as a result of which there can be a substantial reduction in the number of birds passing. A study in Sweden suggests a reduction to 4% of the expected migration (Karlsson 1987). Other foreign studies assume a reduction of more than 75% up to even 100% of the number of birds passing (overview of the literature in Winkelman 1992d).

A line-up of wind turbines parallell to the birds' main migration direction is preferable to a clustered configuration, however this can be disadvantageous for staging birds. If a line-up configuration perpendicular to the flight direction is established, this will act as a barrier particularly at night (Van der Winden *et al.* 1996, Spaans *et al.* 1998a).

5.1.5. Offshore situation

Disturbance and behavioural response to wind turbines

The current knowledge about possible effects of wind turbines on birds in the offshore situation is very limited (Van der Winden *et al.* 1997). In particular research into collision risks and disturbance effects during twilight and at night is scarce, as is knowledge about nocturnal flying movements of various groups of species. However, the risk of collision is actually greatest at night. The only study on this subject contains research into the nocturnal flying activity of scoters (Common Eiders and Common Scoters) near an offshore windfarm in the Baltic Sea (Tunø Knob) (Tulp *et al.* 1999*)*. Nocturnal flight movements have been recorded for both of these seaduck species. The nocturnal activity was found to be greatest in moonlight conditions and during twilight. During their nocturnal flight movements, and particularly on moonlit nights, Common Eiders partially avoided the wind turbines. Negative effects on the number of flight movements were recorded up to a distance of 1500 m from the windfarm. The recorded decline both in the flying activity and the number of flying movements indicates a barrier effect of offshore windfarms for species that are active at night. Particularly in the case of larger windfarms this could represent a significant limitation for the use of food resources and the accessibility of resting areas. However the results of the research by Tulp *et al.* (1999) are applicable to offshore areas with large concentrations of seaducks and can therefore not be extrapolated to the Belgian situation. A study of the local situation is essential in order to establish a correct assessment of the disturbance effects on site.

In the same Danish windfarm research was also conducted into the disturbing effects on Common Eiders during daylight (Guillemette *et al.* 1998). This provided no indications that during the day disturbing effects occur to foraging Common Eiders as a result of the wind turbines. Although less birds landed in the immediate vicinity of the windfarm, the birds swam towards it from a substantial distance in order to forage. However, the flocks of seaducks investigated during this study were relatively small and sensitivity to disturbance may significantly differ in large flocks. The Tunø Knob windfarm is also small (only 10 turbines of 500kW) and is therefore not comparable to the present situation.

Flight altitude

Information on flight altitude for coastal and marine birds is scarce. During systematic sea migration counts in the autumn of 1999 on the East Friesian island of Wangerooge, observations were collected on the flight altitude of coastal birds in relation to wind direction and speed (Krüger & Garthe 2001). In the case of Red-throated Diver, Common Eider and Common Scoter the proportion of birds flying low (0 to 1.5 m) against the wind increased with increasing wind speed. With tail wind, the proportion of low-flying birds decreased with increasing wind speed, while the proportion of higher-flying birds (1.5 to 25 m) increased. Regardless of the wind speed the proportion of individuals flying against the wind was highest in the case of the Red-throated Diver, Shelduck, Common Eider and Common Scoter. Sandwich Tern and Common Tern/Arctic Tern show the same pattern, though at a greater height. With tail wind the majority of these species flew markedly higher. This study suggests that daytime migration of the observed coastal birds takes place relatively. Most important conclusions that can be drawn from this study are 1) that daytime migration predominantly takes place low above the sea level (up to 25 m, sometimes up to 50 m, seldom higher; so at wind turbine height), 2) flight altitude is species-dependent and 3) flight altitude depends on meteorological conditions.

Falls

The phenomenon of so called falls of migrating (land)birds (like starlings, trushes and finches) is something to keep in mind. These falls could be explained as high numbers of migrants (up to 100.000 individuals) suddenly enter an area. In most cases as a result of the weather conditions that getting worse (like fog, heavy rainfall, low clouds, hard head wind) during migration (see Lensink *et al.* 1999). From own observations we can say that at open sea such phenomenon can happen during migration and mainly due to heavy fog. At this circumstances several songbirds are observed on and around the ship, who in other cases not or seldom be seen like they come out of the sky. The chance of collisions with wind turbines is higher in this specific case. But the frequency of occurrence of such a phenomenon is low and difficult to predict.

5.1.6. Conclusions

- Particularly at night and in conditions of poor visibility birds collide with wind turbines. The number of collision casualties in this context depends on the number of birds present, the number of birds passing, the composition of the birds in terms of species and the presence of other landscape elements and light. The probability of collisions is highest at places where large numbers of birds pass at wind-turbine height.

- Wind turbines can have highly disturbing effects on resident and migrating birds. Locally the number of birds passing and staging can decline by more than 50% in relation to the undisturbed situation. The disturbing effect of wind turbines differs from one bird species to another, with larger birds in particular being strongly affected by wind turbines.
- Data from other areas cannot simply be extrapolated to new locations. For each new location the use of the site by resident, foraging and migrating birds should be investigated in order to establish a good assessment of the effects. Nocturnal movements in particular should be examined in this context.

5.2. Potential effects during construction phase

During the construction phase there will be significant disturbance of the marine avifauna as a result of the activities. Consequently, species that are sensitive to disturbance, such as Red-throated Divers and Great Crested Grebes (Seys *et al.* 1999a) will temporarily avoid the area. Other species (including gulls and terns) may benefit from the activities as a result of the temporary availability of food (because of the seabed being churned up and the increased ship activity). A barrier effect for migrating and passing birds may already be present during the construction. Collisions with the masts may already occur during the non-operational phase, although the chance of collisions will be much smaller than in the operational phase. Considering the temporary nature of the activities the effect on marine avifauna is considered to be moderately negative. If the activities are carried out during spring and summer (May-July), the effect on species sensitive to disturbance will be negligible.

5.3. Potential effects during operating phase

5.3.1. Foraging and resident birds

The northern part of the Vlakte van de Raan is characterised by a seabird density that is very much comparable to average densities found on the entire BCS (Figure 3). Except for the winter, large gulls dominate the species composition in the area (in particular Lesser Black-backed Gull are very common, Figure 4), which species are known to be sensitive to collision (Everaert *et al.* 2002). Therefore most casualties must be expected among large gulls. However, it should be stated here that the distribution of most species of *Larus*-gulls depends to a large part on the presence of fishing vessels. Because fishing vessels will avoid the windfarm, this will have a negative effect on the presence of gulls. Therefore, the number of collision casualties might be significantly lower than what might be expected on the basis of the current numbers present in the area.

In the winter, the area is predominantly used by Guillemots/Razorbills and gulls (Figure 4). Guillemot/Razorbill are not particularly sensitive to disturbance by boats (own observation IN) and will probably also not be troubled much by the presence of a windfarm. As far as less numerous but internationally important species are concerned, the area is of great importance for Red-throated Diver (winter), Great Crested Grebe (winter), Little Gull (spring and autumn), Sandwich Tern (summer) and Common Tern (summer and autumn). For wintering Great Crested Grebes and Red-throated Divers that are both known to be respectively fairly and highly sensitive to disturbance, the disturbing effect of a windfarm can be assessed as large. For these species a significant reduction in the numbers can already be expected during the construction of the windfarm. Because it is to be expected that these species will largely avoid the windfarm, we can assume the number of collision casualties will be fairly small. For foraging Little Gulls, Sandwich Terns and Common Terns the disturbing effect will probably be low, but on the other hand terns frequently collide against wind turbines (Everaert *et al.* 2002). The windfarm therefore might have a significant effect on the mortality rate of adult terns breeding in the colonies at Zeebrugge and the Hooge Platen (The Netherlands) and might in the long term affect their population size.

5.3.2. Migrating birds and local movements

Based on the current knowledge of the numbers of migratory birds on the one hand and on the effects of wind turbines on the birds on the other, there is sufficient reason to state that there is a relatively high risk of collisions for birds in the coastal area. Moreover, a windfarm of such a size could be a barrier for birds migrating along the coast. The BCS is of major importance for migrating Litlle Gulls, Sandwich Terns, Common Terns and probably also for Little Terns. These species all migrate close to the coast and the windfarm area constitutes a relatively large part of their migration corridor at the BCS, so that a significant effect on their respective biogeographical populations can not be excluded. The proposed clustered of the windfarm will diminish the barrier effect of the windfarm, but will still block at least 3.4 km of the migration corridor. In order to reduce the barrier effect it is advisable to reserve a gap between groups of wind turbines. No reliable information is available on the size of such gaps, though a minimum distance of 800 - 1000 m would be desirable.

In addition to migratory movements to and from the wintering areas it is important to know the local (nocturnal) flight movements. It is to be expected, for example, that movements of gulls will occur in the target area at twilight. The coast of Belgium and the southern coast of the Netherlands is an important wintering region for Herring Gulls (Devos & Debruyne 1990, 1991, Meininger *et al.* 1994, Spanoghe 1999, Vercruijsse 1999). A significant proportion of these gulls use rubbish tips located inland as foraging areas or live off the food that is present locally (Spanoghe 1999, Vercruijsse 1999). This species will therefore not experience any adverse impact from an offshore windfarm. Another important proportion of the Herring Gull population along the coast makes use of the coastal waters as a feeding area, with a lot of foraging taking place behind fishing vessels. Also most other gull species are frequently found foraging at sea during the day and often behind fishing vessels. Around sunset some of these gulls will probably move to the coast to sleep, with a proportion of them passing through the target area. Gulls are also attracted to fishing vessels at night (Garthe & Hüppop 1996), where they forage for fish residue behind the illuminated fishing vessels.

Nocturnal flight movements of breeding terns only occur in highly exceptional cases. Nocturnal collisions may occur during migration because they are well known nocturnal migrants. In addition, the (nocturnal) flight movements of the internationally important species that occur in high densities in the area (Red-throated Diver, Great Crested Grebe and Little Gull) should also be examined.

5.3.3. Evaluation of cumulative effects

Cumulative effects might occur as a result of the interference at a particular trophic level of the ecosystem that has its effects on a higher level as well. Because of the limited knowledge on the functioning of the marine ecosystem as a whole and because of the complexity and diversity of the ecological relations within this ecosystem, it is virtually impossible to assess the cumulative effects across different trophic levels. For example, effects of local changes in water turbidity (as a result of the construction works) on the behaviour and occurrence of prey fish as well as the direct impact of changes in water clarity on fish-eating seabirds is largely unknown, thus making it impossible to assess its cumulative effect. Also the presence of the foundations of the turbines might indirectly have an effect on seabirds, but the direction of this effect can not be predicted. Assuming that the building material used in the foundation is suitable for it, the foundations will act as an artificial reef resulting in an increase of the biological richness of the area. They might provide a suitable surface for algae, anemones, bivalves etc. to attach to and a hiding place for fish larvae. The windfarm might potentially function as a spawning and nursing area for fish, which in term will have positive effects on the food abundance for seabirds. However, it will be impossible to predict beforehand what effects this will have on the seabird densities and species composition in the area. That will totally depend on the autonomous development of the underwater ecosystem (*e.g.* species composition and abundance of the prey fish will be important factors) and the response of the various seabird species (*e.g.* species sensitive to disturbance will avoid the windfarm even if food abundance increases).

In the near future, inshore migrants will encounter several windfarms during their flight along the European coasts and their populations will have to face the accumulated impact of a chain of wind parks. There is, however, insufficient knowledge on the effect of offshore windfarms on seabirds to precisely assess the impact on their distribution or mortality rate, not to mention on the accumulated effect of a series of windfarms. Nevertheless it is obvious that if any negative effect exists, there will also be an accumulated effect of a series of windfarms that might be even larger than the sum of the effects of each individual windfarm. In the first place, there might be the accumulated effect of a series of windfarms acting on the mortality rate of seabirds. However, up to now for offshore species no information on species-specific collision rates exists, which makes it impossible to predict the impact on the population level of the various seabirds. Likewise an accumulated barrier effect is to be expected but again it is impossible to assess the accumulated impact because of a major lack on scientific information on this matter. In the specific case of a windfarm north of the Vlakte van de Raan, the accumulated effect for migrating seabirds might be large because it is located close to an optional windfarm at the Droogte van Schooneveld (project 'Seanargy'). Together these two windfarms will make up a large part of the migration corridor for Red-throated Diver, Great Crested Grebe, Little Gull, Sandwich Tern, Common Tern and possibly also for Common Scoter, Lesser Black-backed Gull and Little Tern. Studies in terrestrial situations suggest that the reservation of a space of about 800 – 1000 m between clusters of wind turbines may already provide a suitable corridor for passing birds. Since such a space is available between the two windfarms, for the time being there is no reason to assume that the two windfarms at the Vlakte van de Raan will constitute a barrier for seabirds of which the cumulative effect will be larger than the added effect of the two windfarms.

5.4. Conclusions

Based on current knowledge about the function and importance of the site for marine resident, foraging and migrating birds, on the literature review and on the potential effects during construction and operating phase it is possible to make a *provisional* overal best judgement of the effects to be expected (Table 4).

For the assessment of the disturbing effect of the windfarm on a species (1) the importance of the area for feeding, resting or migration (derived from Table 3) and (2) the sensitivity of the species for disturbance is considered. For the assessment of the collision effect (1) the function of the area as a part of the species' migration corridor (derived from Table 3), (2) the function of the area for local movements like foraging flights or roosting movements and (3) the expected sensitivity of the species for collision were taken into account. Finally, the integrated effect is a weighing up of the disturbance and collision effect and also takes account for the national and international status of the species and the inclusion in Europe's highest priority lists for conservation (derived from Table 3). By using the latter consideration it is possible (e.g. in the case of Lesser Black-backed Gull) that the disturbance and collision effect is expected to be high or very high while the integrated effect might only be moderate. It has to be pointed out in this context, however, that the extent to which each species is sensitive to disturbance or is prone to collision is not known for all species, so that an estimate has been made for this purpose on the basis of the best expert knowledge. The quasi-absence of knowledge about nocturnal flight movements and flight altitude also makes a good scientific evaluation impossible.

The integrated impact of the windfarm at the northern part of the Vlakte van de Raan is moderately high or very high for five of the 16 possible problem species/taxa of the BCS (Table 4, see also Table 2): Red-throated Diver, Great Crested Grebe, Little Gull, Sandwich Tern and Common Tern. For the other 11 species listed in Table 4 the integrated effect is expected to be moderate.

- The ***strong negative*** effect that must be expected for **Red-throated Diver** is based on the very high importance of the windfarm area for wintering as well as for migrating birds, the high sensitivity of the species for disturbance, its protected status in Europe and the inclusion in all three of Europe's highest priority lists for conservation.
- For **Great Crested Grebe** the integrated effect is assessed as ***negative*** because of the very important function of the windfarm area for wintering and migration, but on the other hand the species is probably less sensitive to disturbance than the Red-throated Diver and has no internationally protected status.
- The sensitivity of **Little Gulls** to disturbance and collision is insufficiently known to draw specific conclusions. Based on information in the literature about other gulls, strongly negative effects on this species can certainly not be ruled out. Because of the very high importance of the windfarm area during migration and the international protected status the integrated effect is judged as ***strongly negative***.

Table 4. Schematic presentation of the possible expected impact on marine avifauna of the wind-farm site in the northern part of the Vlakte van de Raan. In assessing the effect of disturbance and risk of collision the number of birds of each resident species has been taken into consideration. Whether or not a species enjoys international protection status has also been taken into consideration in the integrated assessment (see Table 3). The assessment of the risk of collision does not take nocturnal migratory movements into account (- = no or little effect, + = moderately negative effect, ++ = negative effect and +++ = strongly negative effect, ? = not known as a result of possible strong nocturnal migration).

Species	*Disturbance*	*Collisions*	*Integrated effect*
Red-throated Diver	+++	++	**+++**
Great Crested Grebe	++	++	**++**
Fulmar	-	-	-
Gannet	-	-	-
Common Scoter	-	-	-
Great Skua	+	-	+
Little Gull	+++	+++	**+++**
Black-headed Gull	-	-	-
Common Gull	+	++	**+**
Lesser Black-backed Gull	++	+++	**+**
Herring Gull	+	++	**+**
Great Black-backed Gull	+	++	**+**
Kittiwake	-	++	-
Sandwich Tern	++	++	**++**
Common Tern	++	++	**++**
Little Tern	+	?	**?**
Guillemot/Razorbill	+	++	-

- The windfarm area is important for foraging **Sandwich Terns** from Belgian and Dutch colonies and has an important function as a migration pathway. The species has a protected status in Flanders and in Europe and is listed on all three of Europe's highest priority lists for conservation. The disturbing effect for foraging terns will probably be low, but collisions with the turbines and a barrier effect can be expected during migration, so that the integrated effect is assessed as ***negative***.
- The windfarm area is of minor importance as a foraging area for **Common Terns** breeding along the Belgian coast, but constitutes an important part of the migration pathway of this species. The species listed on two out of three of Europe's highest priority lists for conservation and has a threatened status in Flanders (but not in Europe). Collisions with wind turbines are known to frequently occur and a barrier effect can not be excluded, so that the integrated effect is assessed as ***negative***.

6. GAPS IN KNOWLEDGE AND MITIGATING MEASURES

6.1. Gaps in knowledge

- The necessary knowledge about migratory movements of birds during spring and autumn and flight altitudes, which is required for a correct assessment of the impact of an offshore windfarm, is lacking. Similarly the knowledge concerning nocturnal migration and other nocturnal flight movements (flights for resting and foraging) does not exist.
- There is a major lack in knowledge on the species-specific sensitivity to disturbance and collision by windfarms.
- There is an absence of any understanding of the cumulative effects of windfarms on seabirds. Since windfarms will be installed along the coasts of the entire Europe, the migratory routes of many birds will be blocked at several locations. The effects of an individual windfarm are already insufficiently known, let alone the combined effects of a chain of windfarms along the entire migratory route.

6.2. Mitigating measures

6.2.1. Configuration

Correct configuration of the wind turbines, with sufficient space reserved for passing birds, can substantially reduce the risk of collision (Everaert *et al.* 2002). However, this demands a thorough understanding of the local flight movements and is strongly determined by local circumstances. It is important to pay thorough attention to the area's function for birds (migration, foraging, resting; see Table 3 for this study), and to adapt the configuration of the windfarm accordingly. Depending on the function it may be decided to choose open rather than closed clusters of wind turbines. The orientation of the cluster in relation to predominant flying directions also determines the probability of collision to a significant extent. Compact clusters are less dangerous for birds in terms of migration than long line-ups if these are build perpendicular to the dominant migration direction (S/SW – N/NE).

6.2.2. Warning signals

Some authors make specific suggestions to install warning signals on the turbines. These suggestions include sound signals with a frequency above the limit of human hearing, sounding the alarm calls of the bird species themselves and applying silhouettes of birds of prey and other striking markings. However, since after a time the birds become accustomed to such signals, this will not result in a permanent solution.

Total illumination of the wind turbines is more likely to have a negative impact on the probability of collision since this attracts birds, particularly in poor weather conditions and where there is little background light (Buurma & van Gasteren 1989). By marking turbines the disturbance effect may increase in proportion to the intended reduction of the possibility of collisions. Flying birds can be captured in in the beams of light so collisions are more likely to occur. However, increased visibility of the turbine for the birds will also have detrimental effects in terms of the visual aspect for people.

Illuminating the rotor blades with anti-collision-lights (for the purpose of aviation) appears to have more prospects, but there are no scientific data in this respect. Buurma & van Gasteren (1989) and Gauthreau & Belser (1999) suggest that even these relative weak lights could lead to more collision casualties. This suggestion are also be confirmed by the discovery of a great number (49) of collision victims during one night under a temporarily illuminated windturbine in Sweden (Karlsson 1983). The retina of a birds eye is much more sensitive for the red or infrared range than a human eye. Red lights can be attract migrants to the source of light and/or the magnetic compass of the birds can be desorientated. Some results show the most problems would be expected with fixed and pulsated red lights (Gauthreau & Belser 1999). There are some indications that the duration of the flashes would be the most determing factor and to a lesser extent the colour. The longer the phase between two flashes, the lesser the chance to attract birds (Manville 2000). If installing anti-collision-lights is necessary for other purposes than birds, it is best to use only white stroboscopic lights during night and in small number as possible and with a minimum of intensity and number of flashes per minute.

6.2.3. Examples of mitigation

The wind turbines could temporarily be switched off to prevent bird catastrophes during bad sight conditions (mist, dark nights, heavy rainfall) and periods of strong bird migration or marked foraging activity (*e.g.* breeding season for terns).

Given the specific biotope and the favourable location in relation to the breeding colonies in the outer harbour of Zeebrugge, offsetting the loss of foraging area for terns does not appear immediately possible. As an alternative, however, providing protected areas for nesting might compensate the loss of foraging areas. Thought can also be given to allocating protected resting and foraging areas elsewhere for Red-throated Divers, Great Crested Grebes and Little Gulls. In addition, good co-ordination with other current and planned windfarms may be advisable.

7. MONITORING

In monitoring of the avifauna on the one hand a distinction should be made between the pre-construction, construction and operational phase and on the other hand between the potential effects on resident and migrating birds.

7.1. Monitoring of collision casualties

During both the construction and operating phases of the windfarm collisions may occur with the masts or the rotor blades of the turbines. Monitoring of the number of casualties is a common and well-developed practice in the terrestrial situation. At sea monitoring of the number of casualties is difficult because victims disappear in the water. To deal with this problem consideration can be given to placing a net under a number of turbines to collect casualties. However, the possibility can not be excluded that such a net may hinder birds (birds may avoid the net) or produce additional casualties (predators or passing birds may get caught in the net), so that the number of casualties will not be entirely representative. A more independent method may be to place cameras on the wind turbines to record collisions. In addition to conventional cameras, infrared cameras can be positioned to record nocturnal collisions. If the cameras are correctly positioned, this method delivers highly reliable measurements of the number of casualties. However, this method is highly labour intensive (viewing the tapes afterwards takes a lot of time) and only one camera can observe one or maximal two wind turbine (short distance recording necessary). In order to reduce the time of interpretation of these tapes cameras can be setted to only recording when differences in temperature on the picture are found. At the same time mitigating effects can be examined in the research, varying from painting the rotor blades with conspicuous colours to shutting the wind turbines down temporarily to prevent bird catastrophes.

In the case of birds found dead it is possible to establish whether they have been in contact with wind turbines (own observation IN). Beach-bird-surveys can therefore provide more insight into the number of collision casualties and the species-specific sensitivity to collisions. However, research on birds that have washed up on the beach is not very suitable for obtaining an understanding of localised effects since dead birds often cover many kilometres before washing up on the beach (Seys 2001).

As far as monitoring of collision casualties is concerned a preliminary study has already been carried out in Denmark. According to a working document of the Danish NERI-institute (Desholm 2001) the major conclusions are as follows:

- Since most collisions occur at night and in conditions of poor visibility (mist, dusk, rain), the equipment must be capable of recording collisions under these conditions.
- Given the low frequency of the collisions a fully automatic system should be used while data can be acquired without the presence of an operator.
- Since the probability of collision differs from one bird species to another, the system used must be capable of distinguish species or groups of species.
- The system must be suitable for marine conditions.

7.2. Barrier effect of wind turbines

Research in terrestrial situations has shown that windfarms can act as a significant barrier for passing birds. Flying birds respond to a wind turbine by adapting their flight altitude or changing their route. It is recommended that immediately after completion of the windfarm a study will be carried out into the barrier effect and the behavioural response of flying birds. When the ecosystem below the sea surface has stabilised after a number of years such a study may be repeated. The study should consist of visual observations (during the day) from a fixed point in the immediate vicinity of the windfarm (possibly on board of a vessel), and recording with a standardised method the behaviour of birds approaching the windfarm. Using radar equipment the behavioural response during the night can be investigated. A conventional ship radar is suitable for this purpose, with a combination of one horizontally and one vertically oriented radar being advantageous. To measure the effect of the turning rotors an on/off experiment can be carried out, in which the turning rotor blades are compared to the rotor blades standing still. Naturally a platform has to be provided from which the observations can be carried out.

7.3. Monitoring of resident avifauna

Monitoring of the resident avifauna should be carried out in accordance with a so-called BACI-design (Before-After-Control-Impact). In the case of such a test the situation before installation of the turbines is compared with that after the installation. An important feature of the BACI-design is that one or preferably more control areas are included, so that any changes not attributable to installation of the windfarm can be excluded with reasonable certainty. Ideally such monitoring should start before the construction phase and also take place during the construction phase. Completion of the windfarm is followed by an initial phase of intensive monitoring (monthly), after which a frequency of about four times per year will be sufficient. The monitoring should be continued until the marine ecosystem has fully stabilised. It is advisable to monitor not only the avifauna but also the food on which the birds are dependent. This is because, even when using the above-mentioned BACI-design, it ca not be completely excluded that changes in the bird population are unrelated to local shifts in the availability of their prey. In order to monitor the evolution of the entire marine ecosystem, samples of the seabed structure, benthos and fish should be taken on a regular basis.

It is advisable to conduct monitoring of the bird population in accordance with European standards. An example of this is the ESAS (European Seabirds At Sea) standard for counting birds from ships (Tasker *et al.* 1984, Komdeur *et al.* 1992). For this purpose there must also be a possibility of performing counts inside the windfarm. Counts performed from aircraft can also serve for monitoring marine birds, provided the aircraft flies at a low height (preferably < 80 m). In addition, swimming marine birds in particular can be counted from fixed objects, such as a platform set up for this purpose or transformer platforms.

7.4. Phasing

According to marine legislation monitoring should take place during the entire operational phase. In this paragraph only monitoring until fifth year after the onset of the operational phase is mentioned (Table 5).

Table 5. Phases of monitoring of the number of collision casualties, the behavioural response of birds approaching the windfarm and the resident avifauna up to the fourth year after completion of the windfarm. The necessary monitoring is indicated in black, while monitoring considered very desirable is in the grey-coloured blocks.

Type of monitoring	**Pre-construction phase**	**Construction phase**	**Operational phase**			
			Year 1	Year 2	Year 3	Year 4
Collision casualties		▒	■	■	▒	▒
Behavioural response			■			■
Counting avifauna	▒	■	■	▒	▒	■

Monitoring of the number of collision casualties should preferably start during the construction of the windfarm. Particularly in the first and second year after completion of the windfarm, monitoring should be performed intensively (throughout the year). At a later stage a phased monitoring that takes place only during the migration period in combination with monitoring under adverse weather conditions will be sufficient. The approach behaviour of birds in flight should be investigated during the first year after completion of the windfarm. In the fourth year this research should be repeated in order to investigate whether habituation occurs in relation to the windfarm. It is advisable to begin with counting of the avifauna before the construction phase, so that a comparison can be made afterwards. These counts should be repeated during the construction phase as well as in the first and fourth years after completion of the windfarm. However, given the strongly dynamic nature of the marine ecosystem, it is desirable also to carry out monitoring during the second and third years. In this case it is sufficient to perform a count once during each of the four seasons. Only in the first year following construction is a more intensive counting frequency (monthly) necessary.

8. CONCLUSIONS

For the description of the reference situation at the proposed windfarm site we can conslude that for at least ten possible problem species the area around the northern part of the Vlakte van de Raan plays a role as a migratory pathway, foraging area and resting place (see Table 3). Taking their conservation status into account, the windfarm site is of relative great importance for Red-throated Diver, Great Crested Grebe, Little Gull, Lesser Black-backed Gull, Sandwich and Common Tern (see Table 3). However, not all these species are at equal risk to be disturbed by or collide with wind turbines. Based upon the best professional judgement including sensitivity for disturbance, collision risk and the results from Table 3, the integrated impact of the windfarm could be high or very high for five species: Red-throated Diver, Great Crested Grebe, Little Gull, Sandwich and Common Tern (see Table 4).

In general, the current knowledge on the intensity of bird migration on the BCS is largely insufficient to be able to precisely evaluate the integrated impact of this windfarm. Given the important function of the BCS as a migration pathway for seabirds in combination with the bottleneck shape of the area as well as the poor knowledge on (nocturnal) movements and collision risks of seabirds, countries bordering the southern North Sea should be very careful to establish offshore windfarms in their coastal and even more offshore areas. Given the importance of the BCS as a migration corridor for several seabirds, it is therefore advisable to closely monitor bird migration patterns, local fight patterns, (nocturnal) migratory behaviour and collision rates after the construction of the windfarm. Extensive and carefully designed monitoring of the accumulated effect (species-specific sensitivity to disturbance and collision risk) is advisable in all windfarm areas. Also long-term monitoring in combination with population modelling would certainly not be out of place. Because of the longevity and delayed maturity of seabirds effects on the population level may become visible only after a long period of time.

9. LITERATURE

Allein, S. & L. Boudolf (1998). Mijden Dwergsterns *Sterna albifrons* de Belgische kust tijdens de voorjaarstrek en verkiezen ze die tijdens de najaarstrek? Mergus 12: 111-125 (with English summary).

Arts, F.A. & P.L. Meininger (1995). Foeragerende sterns in het Westerschelde estuarium: een verkenning in verband met de verdieping. RIKZ Werkdocument OS-95.835X. Rijksinstituut voor Kust en Zee, Middelburg.

Bach, L., K. Handke & F. Sinning (1999). Einfluss von Windenergieanlagen auf die Verteilung von Brut- und Rastvögeln in Nordwest-Deutschland – erste Auswertung verschiedener Untersuchungen. Bremer Beiträge für Naturkunde und Naturschutz 4: 107-121.

Beijersbergen, J. (1980). Vergelijking van de broedplaatsen van verschillende soorten sterns. Sterna 24: 100-104.

Borrey, J., L. Dewulf, D. Raes, R. Tahon & B. Vercruijsse (1986). 5 jaar zeevogelwaarnemingen te Nieuwpoort.

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

Buurma, L.S. (1987). Patronen van hoge vogeltrek boven het Noordzeegebied in oktober. Limosa 60: 63-74.

Buurma, L.S. & H. van Gasteren (1989). Trekvogels een obstakels langs de Zuid-Hollandse kust. Rapport Koninklijke Luchtmacht, Den Haag.

Camphuysen, C.J. & J. van Dijk (1983). Zee- en kustvogels langs de Nederlandse kust, 1974-79. Limosa 56: 83-211.

Camphuysen, C.J. (1993). Scavenging seabirds behind fishing vessels in the Noth-east Atlantic. NIOZ-Report 1993-1. Netherlands Institute for Sea Research, Texel.

Camphuysen, C.J. (1994). Scavenging seabirds at beamtrawlers in the southern North-Sea, distribution, relative abundance, behaviour, prey selection, feeding efficiency, kleptoparasitism and the possible effects of 'protected areas'. NIOZ-report 1994. Netherlands Institute for Sea Research, Texel.

Christensen, T.K., I. Clausager & I.K. Petersen (2001). Base-line investigations of birds in relation to an offshore wind farm at Horns Rev: results and conclusions 2000/2001. National Environmental Research Institute, Denmark. Neri Report, 21 pp.

Christensen, T.K., I. Clausager & I.K. Petersen (2002). Status report of seabird surveys at Horns Rev, 2000-2001. National Environmental Research Institute, Denmark. Neri Report, 24 pp.

Cramp, S. & K.E.L. Simmons (1977). Birds of the western Palearctic. Vol. I. Oxford University Press, Oxford.

Crockford, N.J. (1992). A review of the possible impacts of windfarms on birds and other wildlife. Joint Nature Conservation Committee, JNCC Report no. 27, Peterborough, UK.

De Kraker, K. & P.J.T. Derks (2002). Verslag Hompelvoet/Markenje – 2001. Ecologisch adviesbureau Sandvicensis, Burgh-Haamstede, Nederland.

Desholm, M. (2001). First phase of the project "Development of method for estimating the collision frequency between migrating birds and offshore wind turbines" – the choice of equipment. Work report National Environmental Research Institute, Rønde.

Devos, K. & R. Debruyne (1990). Overwinterende meeuwen langs de Vlaamse kust: een totaaltelling in december 1989. Mergus 4: 2-13.

Devos, K. & R. Debruyne (1991). Overwinterende meeuwen langs de Vlaamse kust in juni en september 1990. Mergus 5: 97-108.

Dillon Consulting Ltd. (2000). Wind Turbine Environmental Assessment for the Toronto Waterfront. Draft Screening Document, TREC-Toronto Hydro.

Dirksen, S., A.L. Spaans & J. van der Winden (1995). Nachtelijke trek en vlieghoogtes van steltlopers over de noordelijke havendam van IJmuiden, voorjaar 1995. Rapport 95.26. Bureau Waardenburg, Culemborg.

Dirksen, S., A.L. Spaans & J. van der Winden (1996a). Nachtelijke trek en vlieghoogtes van steltlopers in het voorjaar over de noordelijke havendam van IJmuiden. Sula 10: 129-142.

Dirksen, S., A.L. Spaans, J. van der Winden & L.M.J. van den Bergh (1996b). Vogelhinder door windturbines. Landelijk onderzoekprogramma, deel 2: nachtelijke vlieghoogtemetingen van duikeenden in het IJsselmeergebied. Rapport 96.18. Bureau Waardenburg, Culemborg.

Dirksen, S., A.L. Spaans, J. van der Winden & L.M.J. van den Bergh (1998). Nachtelijke vliegpatronen en vlieghoogtes van duikeenden in het IJsselmeergebied. Limosa 71: 57-68.

Everaert, J. (ongepubliceerd). Voorlopige onderzoeksresultaten voor de windturbinelocaties te Brugge en Schelle, Project: Interactie tussen locaties voor windturbines en vogelbestanden in Vlaanderen. Instituut voor Natuurbehoud.

Everaert, J., K. Devos & E. Kuijken (2001b). Plaatsing van 2 windturbines op de noordoostelijke havendam te Zeebrugge. Aanbevelingen in het kader van een mogelijke impact op vogels. Instituut voor Natuurbehoud, nota IN.A.2001.27., Brussel.

Everaert, J., K. Devos & E. Kuijken (2001c). Plaatsing van 2 bijkomende windturbines op de Oostdam te Zeebrugge. Aanbevelingen in het kader van een mogelijke impact op vogels. Nota IN.A.2001.160, 25 pp.

Everaert, J., K. Devos & E. Kuijken (2002). Windturbines en vogels in Vlaanderen: voorlopige onderzoeksresultaten en buitenlandse bevindingen. Rapport Instituut voor Natuurbehoud 2002.03, Brussel.

Everaert, J., K. Devos & J. Van Waeyenberge (2000). Plaatsing van windturbines op de westdam van Zeebrugge. Aanbevelingen in het kader van een mogelijke impact op vogels. Nota IN.A.2000.90, 4 pp.

Everaert, J., K. Devos, E. Stienen & E. Kuijken (2001a). Plaatsing van windturbines langs de Westelijke havendam te Zeebrugge. Aanbevelingen in het kader van een mogelijke impact op vogels. Nota IN.A.2001.82, 32 pp.

Garthe, S. & O. Hüppop (1996). Nocturnal scavenging by gulls in the southern North Sea. Colonial Waterbirds 19: 232-241.

Gauthreau, S.A. & C.G. Belser (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. http://www.towerkill.com/workshop/proceedings/index.html

Guillemette, M., J.K. Larsen & I. Clausager (1998). Impact assessment of an offshore wind park on sea ducks. NERI Technical Report 227. National Environmental Research Institute, Kalø.

Guillemette, M., J.K. Larsen & I. Clausager (1999). Assessing the impact of the Tunø Knob wind park on sea ducks: the influence of food resources. National Environmental Research Institute, Denmark. Neri Technical Report No 263, 21 pp.

Handke, K., H. Kulp, M. Reichenbach, M. Rode, B. Schuchardt & F. Sinning (1999). Vögel und Windkraft. Bremer Beitrage fur Naturkunde und Naturschutz, band 4. Bund Landesverband Bremen.

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

Heath, M., C. Borggreve & N. Peet (2000). European bird populations: estimates and trends. BirdLife Conservation Series No. 10. BirdLife international, Cambridge.

Karlsson, J. (1983). Fåglar och vindkraft. Resultatrapport 1977-1982.

Karlsson, J. (1987). Fågler och vindkraft. Kompletterande resultatredovisnung. Intern rapport. University of Lund, Lund.

Komdeur, J., J. Bertelsen & G. Cracknell (1992). Manual for aeroplane and ship surveys of waterfowl and seabirds. IWRB Special publication 19. IWRB, Slimbridge.

Koop, B. (1997). Vogelzug und Windenergieplanung. Beispiele für Auswirkungen aus dem Kreis Plön. Naturschutz und Landschaftsplanung 29 (7): 202-206.

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

Krüger, T. & S. Garthe (2001). Flight altidudes of coastal birds in relation to wind direction and speed. Atlantic Seabirds 3(4): 203-216.

Kuijken, E. (1999). Natuurrapport 1999. Toestand van de natuur in Vlaanderen: cijfers voor het beleid. Mededelingen van het Instituut voor Natuurbehoud 6. Instituut voor Natuurbehoud, Brussel

Lack, D. (1963). Migration across the Southern North Sea studied by radar, part 4. Autumn. Ibis 105: 1-54.

Lack, D. (1960). Migration across the North Sea studied by radar. Part 2. The spring departure 1956-1959. Ibis 102: 26-55.

Lensink, R., C.J. Camphuysen, D.A. Jonkers, M.F. Leopold, H. Schekkerman & S. Dirksen (1999). Falls of migrant birds, an analysis of current knowledge. Bureau Waardenburg, report 99.55, 75pp.

Louette, M. (1971a). Différence d’intensité de migration entre la zone cotière Belge et l’interieur du pays, vue par radar. Aves 8: 41-55.

Louette, M. (1971b). Radargegevens over de herfststrek in 1969 en 1970 over N.W.-België (Trekrichting). De Wielewaal 37: 345-350.

Lowther, S. (2000). The European perspective: some lessons from case studies. Proc. National Avian-Wind Power Planning Meeting III, San Diego, California, USA, May 1998.

Manhout, J. (1999). Vergelijkende studie van de broedbiologie van de Visdief *Sterna hirundo* in kolonies langs de Belgische kust en de Westerschelde: analyse van de interactie tussen broedparameters en de factoren die het broedsucces bepalen. Licentiaatsscriptie. Universiteit Gent, Gent.

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). http://www.birdweb.net/arklowbank.html#AnchorAlManville

Meek, E.R., J.B. Ribbands, W.G. Christer, P.R. Davy & I. Higginson (1993). The effects of aero-generators on moorland bird populations in the Orkney Islands, Scotland. Bird Study 40: 140-143.

Meininger, P.L., C.M. Berrevoets & R.C.W. Strucker (1994). Watervogeltellingen in het zuidelijk Deltagebied 1987-91. Rapport RIKZ-94.005. Rijksinstituut voor Kust en Zee, Middelburg.

Musters, C.J.M, G.J.C. van Zuylen & W.J. ter Keurs (1991). Vogels en windmolens bij de Kreekraksluizen. Rapport vakgroep Biologie. Rijksuniversiteit Leiden, Leiden.

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

Offringa, H. & P. Meire (1997). Verslag van tellingen van zeevogels die zijn verricht onder contract 13/05/96 van het Ministerie van Sociale Zaken, Volksgezondheid en Leefmilieu. Intern rapport. Instituut voor Natuurbehoud, Brussel.

Offringa, H., J. Seys, W. van den Bossche & P. Meire (1996). Seabirds on the Channel doormat. De Giervalk 86: 3-71.

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

Ostsee-Zeitung (2002). Brandenburger Artenexperte Tobias Dürr: Jetzt sogar streng geschützte Fledermäuse und Rotmilande tot unter Windkraftanlagen gefunden/Aufruf an Umweltschützer zu systematischer Nachsuche unter Windkraftwerken, Ostsee Zeitung.de, 2/3 Februar, 2002.

Percival, S.M. (1998). Birds and wind turbines: managing potential planning issues. Proc. 20th British Wind Energy Assoc. Conf., 1998. Ecology Centre, Univ. Sutherland, UK, pp. 345-350.

Percival, S.M. (1999). Birds and wind turbines: can they live together ? Wind directions, Apr. 1999, pp. 18-20.

Petersen, B.S. & H. Nøhr (1989). Konsekvenser for fuglelivet ved etableringen af mindre vindmøller. Rapport Ornis Consult, Kopenhagen.

Platteeuw, M., N.F. van der Ham & J.E. den Ouden (1994). Zeetrektellingen in Nederland in de jaren tachtig. Sula 8: 1-203.

Poot, M.J.M., I. Tulp, H. Schekkerman, L.M.J. van den Bergh & J. van der Winden (2001). Effect van mist op vogelvlieggedrag bij het windpark Eemmeerdijk. Bureau Waardenburg Rapport nr. 01-072. Bureau Waardenburg, Culemborg/Alterra, Wageningen.

Rossaert, G., S. Dirksen, T.J. Boudewijn, P.M. Meire, T. Ysebaert, E.H.G. Evers & P.L. Meininger (1993). Effects of PCBs, PCDDs and PCDFs on reproductive success, and morphological, physiological and biochemical parameters in chicks of Common Terns (*Sterna hirundo*). Report A93.31. Institute for Nature Conservation, Brussels.

Sachslehner, L. & H.P. Kollar (1997). Vogelschutz und Windkraftanlagen in Wien. Endbericht. Verein für Ökologie und Umweltforschung.

Schreiber, M. (1993). Zum Einfluss von Störingen auf die Rastplatzwahl von Watvögeln. Inform. d. Naturschutz Niedersachs. 13: 161-169.

Schreiber, M. (1999). Windkraftanlagen als Störingsquelle für Gastvögel am Beispiel von Blessgans (Anser albifrons) und Lachmöwe (Larus ridibundus). Bremer Beitr. Naturk. Natursch. 4: 39-48.

Seys, J. (2001). Sea- and coastal bird data as tools in the policy and management of Belgian marine waters. Proefschrift Universiteit Gent. Universiteit Gent, Gent.

Seys, J. (2002). Estimates of the number of seabirds residing in and migrating through the southern North Sea. Report IN.D.2002.2. Institute of Nature Conservation, Brussels.

Seys, J., H. Offringa, J. van Waeyenberge, P. Meire & E. Kuijken (1999a). Ornithologische belang van de Belgische maritieme wateren: naar een aanduiding van kensoorten en sleutelgebieden. Nota In A74. Instituut voor Natuurbehoud, Brussel.

Seys, J., K. Devos & E. Kuijken (1999b). Windmolens en vogels: evaluatie impact huidige en geplande site in de voorhaven van Zeebrugge. Nota Instituut voor Natuurbehoud, A.99.106., Brussel.

Spaans, A.L. , L.M.J. van den Bergh, S. Dirksen & J. van der Winden (1999). Windturbines en vogels: hoe hiermee om te gaan? De Levende Natuur 99: 115-121.

Spaans, A.L., J. van der Winden, L.M.J. van den Bergh & S. Dirksen (1996). Nachtelijke vliegbewegingen van watervogels rond het Oosterscheldebekken. Sterna 41:2-8.

Spaans, A.L., J. van der Winden, R. Lensink, L.M.J. van den Bergh & S. Dirksen (1998a). Vogelhinder door windturbines. Landelijk onderzoeksprogramma, deel 4: nachtelijke vliegbewegingen en vlieghoogtes langs de Afsluitdijk. Rapport 98.015. Bureau Waardenburg, Culemborg.

Spaans, A.L., J. van der Winden, R. Lensink, L.M.J. van den Bergh & S. Dirksen (1998b). Vogelhinder door windturbines. Landelijk onderzoeksprogramma, deel 5: nachtelijke vliegbewegingen en vlieghoogtes van getijdentrek langs de Friese waddenkust. Rapport 98.066. Bureau Waardenburg, Culemborg.

Spanhove, T. (2001). Distributie van vogels in de zuidelijke Noordzee. Verslag eerste licentie biologie. Universiteit Gent, Gent.

Spanoghe, G. (1999). Aantallen, verspreiding, gedrag en habitatkeuze van meeuwen (Laridae) aan de Vlaamse kust in het winterhalfjaar. Scriptie Faculteit der Wetenschappen. Universiteit Gent, Gent.

Stienen, E.W.M. & A. Brenninkmeijer (1992). Ecologisch profiel van de Visdief (*Sterna hirundo*). RIN-rapport 92/18. Instituut voor Bos- en Natuuronderzoek, Arnhem.

Stienen, E.W.M., J. Seys, J. Van Waeyenberge & E. Kuijken (in prep.). Trapped within the corridor of the southern North Sea: the potential impact of offshore wind farms on seabirds.

Stienen, E.W.M., J. Van Waeyenberge & E. Kuijken (2002). Studie naar te verwachten impact van windmolenparken op zee ten aanzien van de mariene avifauna in het kader van een MER voor plaatsing van windturbines thv de Vlakte van Raan. Deelstudie 'avifauna' van MER 'TotalFinaElf'-project. Adviesnota IN.A.2002.179, Instituut voor Natuurbehoud, Brussel.

Still, D., B. Little & S. Lawrence (1995). The effect of wind turbines on the bird population at Blyth. ETSU Report W/13/00394, Haugh Lane Industrial Estate, Hexham.

Strickland, M.D., G.D. Johnson & W.P. Erickson (1998). Avian use, flight behaviour and mortality on the Buffalo Ridge, Minnosota Wind Resource Area.

Tasker, M.L., P.H. Jones, T.J. Dixon & B.F. Blake (1984). Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized approach. Auk 101: 567-577.

Thomas, R. (2000). An assessment of the impact of wind turbines on birds at ten windfarm sites in the UK. Sustainable Development International 1: 215-219.

Tulp, I., H. Schekkerman, J.K. Larsen, J. van der Winden, R.J.W. van de Haterd, P. van Horssen, S. Dirksen & A.L. Spaans (1999). Nachtelijke vliegbewegingen van zee-eenden bij het windpark Tunø Knob in de Oostzee. Rapport 99.30. Bureau Waardenburg, Culemborg.

van den Bergh, L.M.J., A.L. Spaans & J.E. Winkelman (1993). De mogelijke hinder van een 25MW windpark voor vogels op twee potentiële lokaties in Noord-Groningen. IBN-rapport 016. Instituut voor Bos- en Natuuronderzoek, Arnhem.

van den Bergh, L.M.J., A.L. Spaans & N.D. van Swelm (2002). Lijnopstelling van windturbines geen barrière voor voedselvluchten van meeuwen en sterns in de broedtijd. Limosa 75: 25-32.

van der Winden, J., A.L. Spaans, I. Tulp, B. Verboom, R. Lensink, D.A. Jonkers, R.J.W. van de Haterd & S. Dirksen (1999). Deelstudie Ornithologie MER Interprovinciaal Windpark Afsluitdijk. Rapport 99.002. Bureau Waardenburg, Culemborg.

van der Winden, J., A.L. Spaans, L.M.J. van den Bergh & S. Dirksen (1997). Vogelhinder door windturbines. Landelijk onderzoekprogramma, deel 3: nachtelijke vlieghoogtemetingen van getijdetrek in het Deltagebied. Rapport 97.27. Bureau Waardenburg, Culemborg.

van der Winden, J., A.L. Spaans, L.M.J. van den Bergh, I. Tulp & S. Dirksen (1998). Nachtelijke vliegbewegingen van duikeenden, ganzen en Lepelaars in en rond Pampushaven. Bureau Waardenburg Rapport nr. 98.030. Bureau Waardenburg, Culemborg/Instituut voor Bos- en Natuuronderzoek (IBN-DLO), Wageningen.

van der Winden, J., S. Dirksen, L.M.J. van den Bergh & A.L. Spaans (1996). Nachtelijke vliegbewegingen van duikeenden bij het Windpark Lely in het IJsselmeer. Rapport 96.34. Bureau Waardenburg, Culemborg.

Van Waeyenberge, J. & J. Seys (2000). Sternen- en meeuwenkolonies in de Voorhaven van Zeebrugge. Documentatiemap IN.D.2000.11. Instituut voor Natuurbehoud, Brussel.

Van Waeyenberge, J., E. Stienen & J. Seys (2001a). Sternen- en meeuwenkolonies in de Voorhaven van Zeebrugge. Documentatiemap IN.D.2001.9. Instituut voor Natuurbehoud, Brussel.

Van Waeyenberge, J., E.W.M. Stienen & J. Seys (2001b). Broedbiologisch onderzoek bij sternen en meeuwen in de Zeebrugse voorhaven : waarom, wat en hoe ? Vogelnieuws, ornithologische nieuwsbrief van het Instituut voor Natuurbehoud, Nr 1 (juni 2001) : 15-20.

Van Waeyenberge, J., Manhout J, Seys J., Offringa H., Meire P. & Kuijken E. (2000). Reproductive success of Common Terns Sterna hirundo in colonies along the Belgian coast and the Westerschelde. Lecture abstract, 7th Seabird Group Conference, 17-19 March 2000, Wilhelmshaven, Germany, p 39.

van Westrienen, R. (1988). Zichtbare trek langs de Zeeuws-Vlaamse kust. In: Buisse, M.A. & F.L.L. Tombeur (eds.). Vogels tussen het Zwin en Saeftinghe. De avifauna van Zeeuws-Vlaanderen. pp. 55-62.

Vauk, G. (1990). Biological and ecological study of the effects of construction and operation of wind power sites. Jahrgang/Sonderheft, Endbericht. Norddeutsche Naturschutzakademie, Germany.

Veen, J, E.W.M. Stienen, A. Brenninkmeijer, H. Offringa, P. Meire & J. Van Waeyenberge (1997). Ecologische randvoorwaarden voor de aanleg van een broedplaats voor sterns in de voorhaven van Zeebrugge. Rapport IN 97/15. Instituut voor Natuurbehoud Brussel.

Vercruijsse, H.J.P. (1999). Zilvermeeuwen uit de duinen van Schouwen. Verspreiding, sterfte en broedbiologie. Vercruijsse, Tilburg.

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

Winkelman, J.E. (1985). Bird impact by middle-sized wind turbines – on flight behaviour, victims, and disturbance. Limosa 58: 117-121.

Winkelman, J.E. (1989). Vogels en het windpark nabij Urk (NOP): aanvaringsslachtoffers en verstoring van pleisterende eenden, ganzen en zwanen. RIN-rapport 89/15. Rijksinstituut voor Natuurbeheer, Arnhem.

Winkelman, J.E. (1992a). De invloed van de SEP-proefwindcentrale te Oosterbierum (Fr.) op vogels. 1. Aanvaringsslachtoffers. RIN-rapport 92/2. DLO-Instituut voor Bos- en Natuuronderzoek, Arnhem.

Winkelman, J.E. (1992b). De invloed van de SEP-proefwindcentrale te Oosterbierum (Fr.) op vogels. 2. Nachtelijke aanvaringskansen. RIN-rapport 92/3. DLO-Instituut voor Bos- en Natuuronderzoek, Arnhem.

Winkelman, J.E. (1992c). De invloed van de SEP-proefwindcentrale te Oosterbierum (Fr.) op vogels. 3. Aanvlieggedrag overdag. RIN-rapport 92/4. DLO-Instituut voor Bos- en Natuuronderzoek, Arnhem.

Winkelman, J.E. (1992d). De invloed van de SEP-proefwindcentrale te Oosterbierum (Fr.) op vogels. 4. Verstoring. RIN-rapport 92/5. DLO-Instituut voor Bos- en Natuuronderzoek, 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.