SEABIRDS & OFFSHORE WIND FARMS: MONITORING RESULTS 2008

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Photo: Misjel Decleer

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Summary

In 2008, n.v. C-Power started up the construction of the first offshore wind farm at the Belgian Part of the North Sea (BPNS). This wind farm will be located on the shallows of the Thorntonbank, about fifteen nautical miles offshore. At the time of writing six windmills are erected of which two are in operation, but in the near future the wind farm will comprise of 60 turbines in total, each with a capacity of 5MW. Following the reference study (Vanermen *et al.* 2006), this report presents an update of the reference situation and the results of the year-1 monitoring of the avifauna at the Thorntonbank. To assess possible impacts on seabirds, we implement a methodology based on the BACI-principles. Hence the before-situation (2005-2007) is compared with the situation in 2008, during which the first construction works took place. Possible changes in avian densities are put in perspective by performing the same before-after comparison in a control area (see Vanermen *et al.* 2006).

Based on intensive monitoring in 2005-2007, it seems that Annex I species Little gull, Sandwich tern and Common tern all occur in increased densities at the Thorntonbank wind farm site. On the other hand, Vanermen *et al.* (2006) overestimated the importance of the area to Great skuas. Next to this, we set up a ranking of seabird species according to their suitability for monitoring. Auks seems the most suitable species, followed by Little gull, Sandwich tern and Common tern. Hence, future monitoring will focus on these 5 species. A comparison of the monitoring results of the reference period (2005-2007) and the first construction year do not yet show clear effects.

Meanwhile, n.v. Belwind has received their license for the construction and exploitation of a wind farm comprising of 110 3MW turbines on the Blighbank, 24 nautical miles offshore. Analogous to Vanermen *et al.* (2006), the Research Institute for Nature and Forest (INBO) carried out a reference study on the ornithological importance of the wind farm site at the BB, and selected a suitable control area.

Based on intensive seabird monitoring, we know that the area is characterised by a typical offshore and relatively species-poor bird community. Black-legged kittiwakes and Common guillemots occur in high densities, while there are signs of increased densities of rarer species like Little gull and Great skua. As a control area, we selected an area including the rest of the Blighbank and the Oosthinderbank.

Finally, we made a preliminary estimation of the number of collision victims at the future wind farm site at the Thorntonbank, based on flux counts, flying height observations and model calculations. Northern gannets and especially large gulls are most at risk. Meanwhile, this was an inventory of the needed (and lacking) parameters. It appears that radar research will be indispensable for determining data on bird movements, flying heights as well as avoidance behaviour.

Samenvatting

Gedurende het afgelopen jaar werden de eerste zes windmolens gebouwd op de Thorntonbank. Bovendien zal binnenkort ook aanvang genomen worden met de bouw van een windmolenpark op de Blighbank. Het Instituut voor Natuur en Bosonderzoek (INBO) voert een onderzoek uit naar de effecten van de bouw en exploitatie van deze windparken op zeevogels. In het onderhavige rapport worden de monitoringsresultaten voor 2008 voorgesteld.

In navolging van de referentiestudie Vanermen *et al.* (2006), werd de referentiesituatie op de Thorntonbank beschreven zoals die werd opgemeten in de periode 2005-2007. Ook op basis van de bijkomende gegevens blijken Bijlage 1 soorten Dwergmeeuw, Grote stern en Visdief tijdelijk in verhoogde aantallen voor te komen in het windparkgebied. Vanermen *et al.* (2006) bleken het voorkomen van Grote jager echter te hebben overschat. Daarnaast werd een ranking opgesteld van soorten volgens hun geschiktheid voor monitoring. Criteria hiervoor zijn een homogene verspreiding over windpark- en controlegebied en een zo min mogelijke associatiegraad met visserij. Alkachtigen blijken het meest geschikt voor monitoring, onmiddellijk gevolgd door de Bijlage 1 soorten Dwergmeeuw, Grote stern & Visdief. Toekomstige monitoring zal zich dan ook in de eerste plaats toespitsen op deze 5 soorten. Een vergelijking van de monitoringsresultaten voor de referentieperiode (2005-2007) en het eerste constructiejaar 2008 laten nog geen duidelijke effecten zien.

Voor het eerst werd ook intensief geteld op de Blighbank, dat nog verder in zee ligt dan de Thorntonbank. Het gebied wordt gekarakteriseerd door een pelagische en vrij soortenarme zeevogelgemeenschap. Drieteenmeeuwen en Zeekoeten komen er echter in hoge dichtheden voor en er zijn ook aanwijzingen van verhoogde aantallen Grote jager en Dwergmeeuw. Als referentiegebied werd een zone geselecteerd die onder meer de rest van de Blighbank en de Oosthinderbank omvat.

Tenslotte werd een inschatting gemaakt van het aantal aanvaringsslachtoffers, op basis van fluxgegevens, waargenomen vlieghoogten en modelberekeningen. Uit deze resultaten blijkt dat de meeste slachtoffers zullen vallen onder Jan van genten en grotere meeuwen. Tegelijk vormde deze oefening een inventarisatie van de benodigde en nog ontbrekende parameters. Zo zal het toekomstige radaronderzoek onmisbaar blijken voor het nader bepalen van vogelbewegingen (flux) door het windpark, alsook voor de bepaling van vlieghoogtes en vermijdingsgedrag.

1 Seabirds at the Belgian part of the North Sea

1.1 Monitoring seabirds

Each month, the Research Institute for Nature and forest (INBO) performs standardized seabird counts along fixed monitoring routes across the Belgian part of the North Sea (BPNS) (Figure 1). These monitoring routes are chosen such that both the future wind farm sites at the Blighbank (BB) and Thorntonbank (TTB) are covered, as well as the control area for the TTB (Vanermen *et al.* 2006) and a preliminary control area for the wind farm site at the BB (see Chapter 6).
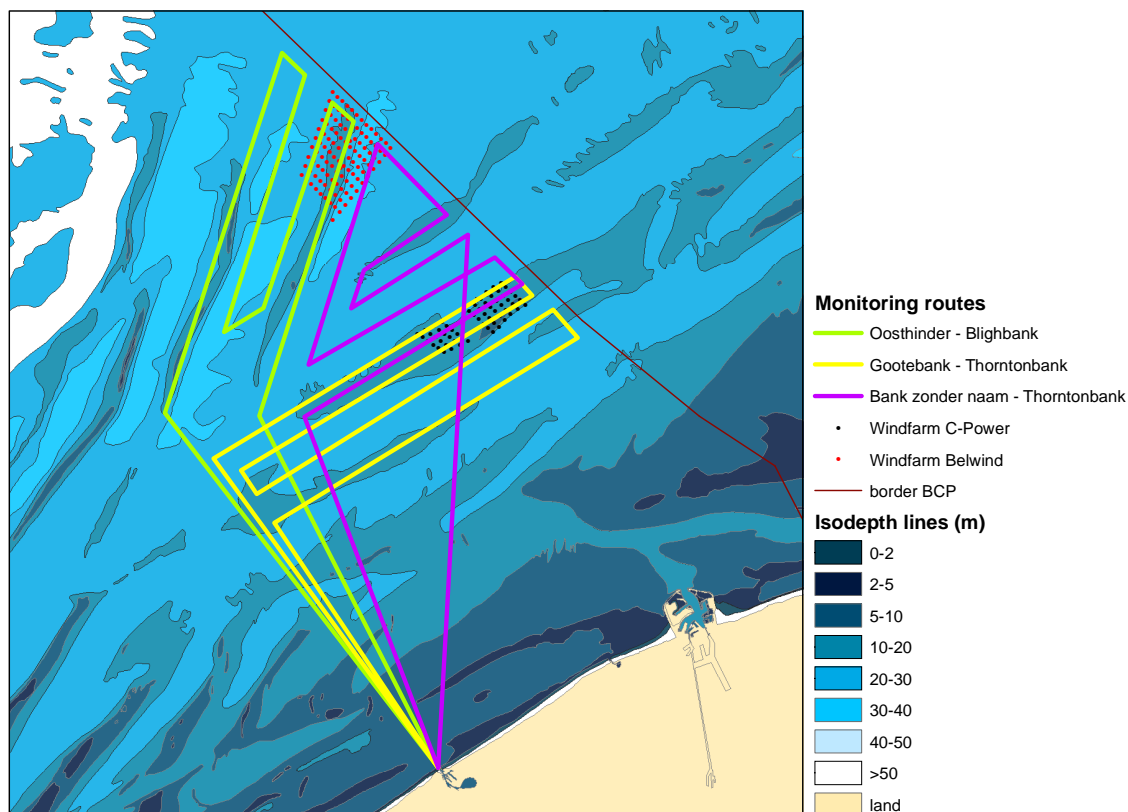
Figure 1. Monthly monitoring routes since April 2008.

The ship-based seabird counts are conducted according to a standardized and internationally applied method, as described by Tasker *et al.* (1984). While steaming, all birds in touch with the water (swimming, dipping, diving) located within a 300m wide transect along one side of the ship's track are counted ('transect counts'). For flying birds, this transect is divided in discrete blocks of time. During one minute the ship covers a distance of approximately 300m, and at the start of each minute all birds flying within a quadrant of 300 x 300 m are counted ('snapshot count'). The results of these observations are grouped in periods of ten minutes, resulting in so-called 'ten-minute counts'.

Taking the velocity of the ship in calculation, the count results can be transformed to seabird densities with specified X- en Y-coordinates (at the geographical middle point of each ten-minute count). The observed densities of most seabirds are corrected according to correction factors presented by

Offringa *et al.* (1997). This accounts for the fact that small and dark birds are more difficult to detect at greater distances.
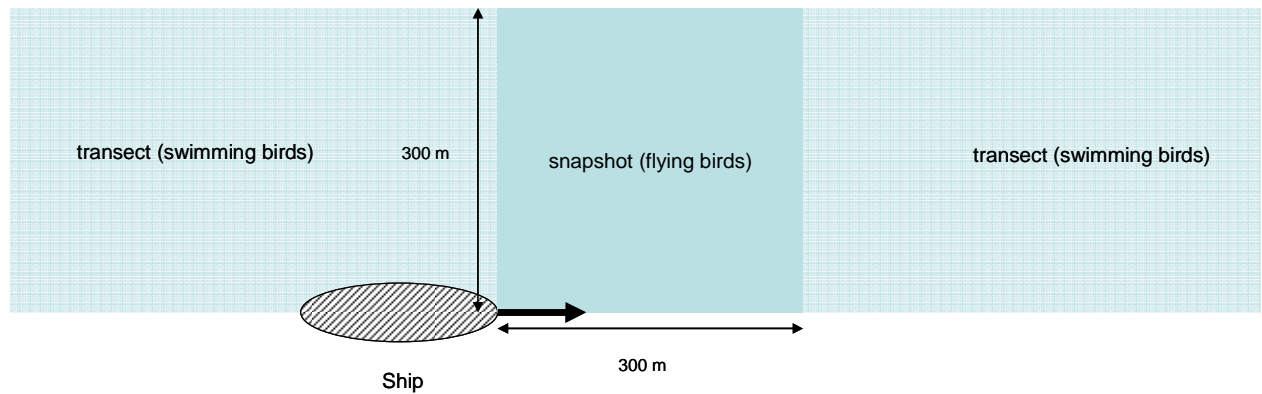
Figure 2. Methodology of standardized seabird counts using a 300m wide transect for swimming birds, and 'snapshot' counts (each minute) for flying birds.

Eventually, the original database is transformed to a database with observed densities of sixteen common seabirds (see §1.1) at more than 20,000 locations within the BPNS. Analogous to the reference study for the TTB (Vanermen *et al.* 2006), the following species will be included in the analysis: Red-throated diver, Crested grebe, Northern fulmar, Northern gannet, Common scoter, Great skua, Little gull, Common gull, Herring gull, Lesser black-backed gull, Greater black-backed gull, Black-legged kittiwake, Sandwich tern, Common tern, Common guillemot and Razorbill (see §1.2).

During the counts, birds observed outside the 'transect' and outside the 'snapshots' were noted too. These observations were not used for actual density calculations (n/km²), but when the total number of observed birds is divided by the number of sailed kilometres, this too provides a standardized measure of seabird density (n/km). In case of rare species, this kind of data, although much more biased, may provide a better insight in the birds' true distribution.

1.2 Seabirds at the BPNS: species discussion

In this chapter we discuss 16 seabird species commonly occurring at the BPNS. These species are all considered to be 'seabirds' since a significant part of their populations strongly depends on the marine environment during one or more seasons.

Red-throated diver (*Gavia stellata*)
(Conservation status: Annex I Birds Directive, Appendix II Bonn Convention, Appendix II Bern Convention)
The Red-throated diver is an inland and coastal breeder of N Europe, Russia and North America, wintering in shallow inshore or coastal waters. A large proportion of the NW European breeding population (50,000 to 150,000 pairs) spends the non-breeding season in the North Sea, along the coasts of Belgium, the Netherlands, Germany and Denmark (Cramp 1977, Stone *et al*. 1995, Wetlands International 2006).

Great crested grebe (*Podiceps cristatus*)
The Great crested grebe is an inland breeder, but lots of birds spend the non-breeding season in shallow marine waters near shore. Wintering numbers at sea are highly variable and are highest during prolonged periods of frost. In the North Sea, most Crested grebes are found along the continental coast from Belgium up to Denmark (Cramp 1977, Stone *et al*. 1995).

Northern fulmar (*Fulmaris glacialis*)
This true seabird has a widespread distribution across the northern hemisphere, and the NE Atlantic population holds an estimated 2.3 to 3.7 million breeding pairs. The species typically breeds on grassy cliffs, and spends most of its time at sea where it feeds on a variety of marine foods. It is one of the most numerous seabirds in the North Sea, with highest densities generally occurring above 54°N (Cramp 1977, Camphuysen & Leopold 1994, Stone *et al*. 1995, Mitchell *et al*. 2004).

Northern gannet (*Morus bassanus*)
The Northern gannet's breeding range is confined to the N Atlantic. The world population holds an estimated 390,000 breeding pairs, of which no less than 230,000 pairs breed on the British Isles. Northern gannets breed in large colonies (so-called gannetries) on inaccessible offshore islands, and to a lesser extent on imposing mainland cliffs. Across the North Sea, Northern gannets occur widespread throughout the year (Cramp 1977, Stone *et al*. 1995, Mitchell *et al*. 2004).

The southern North Sea is particularly important to Northern gannets during their southbound migration in autumn, and also as a wintering area for adults (Camphuysen & Leopold 1994). Stienen *et al*. (2007) estimated that annually 4 to 7% of the NE Atlantic biogeographical population migrates through this part of the North Sea.

Common scoter (*Melanitta nigra*)
Common scoters are inland breeders across N Europe, Russia and North America. The species winters in a marine environment, where it prefers shallow inshore waters to feed on benthic prey. In the North Sea their distribution is largely confined to waters close to land, along the coasts of Belgium up to Denmark (Cramp 1977, Stone *et al.* 1995).

Great skua (*Stercorarius skua*)
The world population of Great skua is confined to merely 16,000 breeding pairs, and no less than two-thirds of the whole world population breed on the Shetland and Orkney Isles. However, numbers have been increasing since 1900, and the species is progressively extending its breeding range (Mitchell *et al.* 2004).

During early summer and autumn internationally important numbers reside in the southern North Sea. During this part of their southward migration fishery discards are an important food source, but they are also frequently observed kleptoparasitising Northern gannets, gulls and terns (Camphuysen & Leopold 1994). Each autumn, an estimated 60% of the NW European population (Icelandic birds excluded) migrates through this part of the North Sea (Stienen & Kuijken 2003).

Little gull (*Larus minutus*)
(Conservation status: Annex I Birds Directive, Appendix II Bern Convention)
The European biogeographical population breeds across N Scandinavia, the Baltic states, W Russia, Belarus & Ukraine, and counts 24,000 to 58,000 breeding pairs. This population winters in W Europe and NW Africa (Wetlands International 2006).

During autumn most birds migrate via the Baltic Sea towards the North Sea and further on, while during spring an indefinable percentage of the population migrates north over land (Cramp 1983). An estimated 40 to 100% of the total European biogeographical population annually migrates through the bottleneck of the southern North Sea and the Strait of Dover. Since autumn migration is concentrated along the continental coast, the BPNS a very important area to this species (Camphuysen & Leopold 1994, Stone *et al.* 1995, Stienen *et al.* 2007).

Common gull (*Larus canus*)
Common gulls breed throughout Europe, Asia and North America, mainly above 50°N. Three quarters of the world population breed on the British Isles and Scandinavia (300,000 breeding pairs, Mitchell *et al.* 2004). The subspecies *canus*, breeding in NW Europe east to the White Sea, winters in W Europe, inland as well as at sea. The southern North Sea, and more particular the coastal strip along its continental coast, is a very important wintering area to this species (Cramp 1983, Camphuysen & Leopold 1994, Stone *et al.* 1995, Mitchell *et al.* 2004).

Lesser black-backed gull (*Larus fuscus*)
The distribution of Lesser black-backed gull is limited to the shores of W & NW Europe and N Russia. The breeding population of the subspecies *graelsii* (W Europe, SW Greenland, Iceland & Faeroer isles) numbers around 180,000 pairs, and winters along the Atlantic coasts of France, Spain and NW-Africa. The subspecies *intermedius* breeds in S Norway, W Sweden, Denmark, Germany, the Netherland & Spain (100,000-150,000 breeding pairs) and also migrates through the southern North

Sea, towards the same winter quarters in W Europe and W Africa (Cramp 1983, Mitchell *et al.* 2004, Wetlands International 2006).

The southern North Sea, and in particular its continental coast, is of great significance to this species. The Belgian port of Zeebrugge harbours a large colony of up to 4,573 breeding pairs in 2006 (data INBO). Campuysen & Leopold (1994) estimated that 18% of the NE Atlantic population resides in Dutch waters during April and May, and Stienen *et al.* (2007) state that each autumn 28% of the *graelsii* population migrates through the Strait of Dover.

Herring gull (*Larus argentatus*)
Herring gulls (ssp. *argentatus* & *argenteus*) breed widespread in W and N Europe, the Baltic states, the Faeroer isles and Iceland. These populations are estimated to hold 800,000 to 1,400,000 breeding pairs. In the north of their range, Herring gulls are mainly migratory, in contrast to the W European breeding birds which are largely sedentary or dispersive (Cramp 1983, Van Waeyenberge *et al.* 2002, Wetlands International 2006).

In the North Sea highest spring and summer densities occur in coastal waters near the breeding colonies. In Belgium, a large breeding colony is located in Zeebrugge, with up to 1,986 breeding pairs in 2004 (data INBO). During winter however, the species occurs more widespread and in higher densities, since resident birds are joined by large numbers originating from northern breeding colonies (Stone *et al.* 1995).

Great black-backed gull (*Larus marinus*)
Great black-backed gulls breed along the coasts of the N Atlantic, with an estimated 110,000-180,000 breeding pairs in the NE Atlantic region. The most northern breeding birds are migratory, wintering south to the Atlantic shores of Spain and Portugal (Cramp 1983, Wetlands International 2006).

Outside the breeding season, Great black-backed gulls occur widespread across much of the North Sea (Stone *et al.* 1995). Camphuysen & Leopold (1994) state that the southern North Sea is a very important wintering area, with more than 13% of the NE Atlantic population residing in the Dutch Part of the North Sea in late autumn. Accordingly, a mean number of 5,400 Great Black-backed gulls resides in the BPNS during winter (Table 1), which exceeds the 1% level of the NE Atlantic biogeographical population.

Black-legged kittiwake (*Rissa tridactyla*)
Kittiwakes breed across the northern hemisphere, in the N Atlantic as well as the N Pacific. The NE Atlantic population counts 2.0–2.7 million breeding pairs. Outside the breeding season, these birds occur throughout the N Atlantic Ocean, north of 30°N (Cramp 1983, Mitchell *et al.* 2004, Wetlands International 2006).

In the North Sea, the summer distribution of Black-legged kittiwake is concentrated in NE English & Scottish waters near the main breeding colonies. During winter however, the species occurs widespread across the North Sea, with a preference for pelagic habitat. In the southern part of the North Sea, the species is most common during autumn (Camphuysen & Leopold 1994, Stone *et al.* 1995).

Sandwich tern (*Sterna sandvicensis*)
(Conservation status: Annex I Birds Directive, Appendix II Bonn Convention, Appendix II Bern Convention)
The Sandwich tern breeds scattered along the coasts of the Atlantic and the Mediterranean. The European breeding population comprises of an estimated 55,000–57,000 breeding pairs, and winters along W and S African coasts (Cramp 1985, Wetlands International 2006).

Summer densities of Sandwich tern in the Southern North Sea are highest along the continental coasts, especially near the Frisian Isles and the German Bight (Stone *et al.* 1995). The port of Zeebrugge (Belgium) harbours an internationally important breeding colony of up to 4,067 breeding pairs (2004). Because of a strong interchange between several colonies along the North Sea coasts, breeding numbers in this colony show strong interannual variation. The BPNS is undoubtedly of high value to Sandwich tern, as a foraging area for breeding birds of the colonies of Zeebrugge, Oye-Plage (France) and the Delta Area (the Netherlands), but also as it is part of an important migration route through the southern North Sea. An estimated 67% of the total European population migrates through this area (Stienen *et al.* 2007).

Common tern (*Sterna hirundo*)
(Conservation status: Annex I Birds Directive, Appendix II Bonn Convention, Appendix II Bern Convention)
This species breeds widespread across the northern hemisphere, along coasts as well as inland. In Europe, an estimated number of 270,000–570,000 breeding couples occur. While the breeding population of W & S Europe winter along W African coasts, most of the N & E European breeding birds spend the winter more south near W to S African coasts. Both populations however migrate along the western coasts of the European continent (Cramp 1985, Stone *et al.* 1995, Wetlands International 2006).

The BPNS is very important as a foraging area for birds of the internationally important breeding colony located in the harbour of Zeebrugge (3,052 breeding pairs in 2004, data INBO). Furthermore, the BPNS is of exceptional importance as it is part of the migration bottleneck of the southern North Sea. According to Stienen *et al.* (2007), an estimated 56% of the total W & S European biogeographical population migrates through this area.

Common guillemot (*Uria aalge*)
Common guillemots breed on cliffs above 40°N, in the N Atlantic as well as the N Pacific. The NE Atlantic population comprises of 2.3–2.4 million breeding pairs (Cramp 1985, Mitchell *et al.* 2004).

From August onwards, Common guillemots arrive in the southern North Sea. In late autumn an estimated number of 240,000 birds reside in Dutch territorial waters. On the BPNS more than 12,000 individuals occur in winter (Table 2). The southern part of the North Sea is especially important as a wintering area for birds from the E Britain colonies, like Flamborough Head (Camphuysen & Leopold 1994, Stone *et al.* 1995).

Razorbill (*Alca torda*)

In contrast to the Common guillemot, the Razorbill's distribution is limited to the N Atlantic (above 40°N). NW Europe holds an estimated number of 530,000 breeding pairs (Cramp 1985, Mitchell *et al*. 2004).

Razorbills arrive a little later in the southern North Sea compared to Common Guillemots. Its maximum densities are reached in early spring (February-March), when an estimated number of 44,000 birds resides in Dutch territorial waters (Camphuysen & Leopold 1994). On the BPNS maximum numbers are also observed during February with a mean of 2,600 residing individuals (Table 2).

1.3   Seabirds at the BPNS: International context

Despite its limited surface, the Belgian Part of the North Sea (BPNS) holds internationally important numbers of seabirds. The area is exploited by birds in a number of ways, and its specific importance varies throughout the year. During winter, the offshore bird community is dominated by auks and kittiwakes, while important numbers of grebes, scoters and divers reside inshore. During summer, large numbers of terns and gulls exploit the area in support of the large breeding colony located in the port of Zeebrugge. Furthermore, the BPNS is part of a very important migration route through the southern North Sea: during autumn and spring, an estimated number of no less than 1.0 to 1.3 million seabirds annually migrate through this 'migration bottleneck' (Stienen *et al.* 2007).

Table 1 & Table 2 show the results of a conservative extrapolation of the observed densities at the BPNS, and give insight in the number of birds residing in Belgian territorial waters. To account for skewed counting efforts in different parts of the BNPS, mean densities were calculated separately for each one of three subzones, namely an inshore (< 16 km), a midshore (16 – 32 km) and an offshore zone (> 32 km). The resulting mean densities per subzone were multiplied with the respective zone's surface and then summed. The resulting numbers are also shown as a percentage of their total biogeographical populations. For Lesser black-backed and Herring gull, as well as Common tern, mean densities in the BPNS are compared to the 1% levels of two biogeographical populations, since birds of both populations migrate through the BPNS.

In general, mean numbers of seabirds residing at the BPNS are rather small compared to their biogeographical populations. Nevertheless, both Little gull and Great black-backed gull occur in numbers higher then the 1% level published by Wetlands International (2006) (Table 1). Take notice of the fact that these numbers are mean values resulting from observations over a period of 16 years, and need to be interpreted as such. Hence, maximum numbers residing at the BPNS are temporarily much higher than the presented values. For example, in years with good breeding numbers of terns in the port of Zeebrugge, the 1% level of Sandwich tern is easily exceeded (4,067 breeding pairs in 2004), which is clearly not reflected in the extrapolated numbers in Table 1.

Table 1. Mean numbers of birds residing at the BPNS during the season with highest densities, compared to the 1% level of relevant biogeographical populations according to Wetlands International (2006) – species in bold occur in mean numbers higher than the 1% level.

Species	Subspecies / Biogeographical population	1% Level	BPNS		
			Season	Mean number	% of Biog. Pop.
Red-throated diver	NW Europe	3,000	Winter	730	0.24%
Great crested grebe	N & W Europe	3,600	Winter	1,300	0.36%
Common scoter	ssp. *nigra*	16,000	Spring	1,900	0.12%
Little gull	N, C & E Europe	1,230	Spring	**2,400**	**1.95%**
Common gull	ssp. *canus*	20,000	Winter	5,100	0.26%
Lesser black-backed gull	ssp. *graellsii* + *intermedius*	5,500 + 3,800	Spring	9,000	0.97%
Herring gull	ssp. *argenteus* + *argentatus*	5,900 + 20,000	Summer	3,000	0.12%
Great black-backed gull	NE Atlantic	4,400	Winter	**5,400**	**1.23%**
Black-legged kittiwake	NE Atlantic	20,000	Winter	5,800	0.29%
Sandwich tern	W Europe	1,700	Summer	1,000	0.59%
Common tern	S & W Europe + N & E Europe	1,900 + 11,000	Spring	3,100	0.24%

Table 2. Mean numbers of birds residing at the BPNS during the season with highest densities, compared to their NE Atlantic populations (Mitchell *et al*. 2004) – population sizes are calculated by multiplying the number of breeding pairs by three.

Species	Biogeographical population	Number of breeding pairs	BPNS		
			Season	Mean number	% of Biog. Pop.
Northern fulmar		2,300,000 – 3,700,000	Autumn	3,200	0.04%
Northern gannet		310,000	Autumn	3,300	0.35%
Great skua	NE Atlantic	16,000	Autumn	150	0.31%
Common guillemot		2,300,000 – 2,400,000	Winter	12,200	0.17%
Razorbill		570,000	Winter	2,600	0.15%

The mean densities in Table 1 and Table 2 represent a static situation but give no insight in the turnover rate of the birds. Nevertheless, we have strong reasons to believe that these turnover rates may temporarily be very high, especially during migration seasons. Migrating seabirds do not rapidly fly through the area, but in contrast, exploit the area for sleeping as well as foraging. Stienen & Kuijken (2003) made estimations of the percentage of the biogeographical populations of seabirds annually migrating through the southern North Sea (Table 3). This estimation is based on the numbers in wintering areas, the position of breeding grounds in respect to these wintering areas and the number of birds seen during land-based observations (seawatch data). The numbers presented in Table 3 show the extreme high importance of the southern North Sea towards Great skua, Little gull, Common tern and Sandwich tern.

Table 3. Percentage of the biogeographical seabird populations [(1) Wetlands International (1997), (2) Lloyd *et al.* (1991), (3) Harris (1997) and (4) Hildén & Tasker (1997)] migrating through the southern North Sea.

Species (English)	Biogeographical population / Subspecies	% migrating through the Southern North Sea
Red-throated diver	(1) NW Europe (non-br)	<1
Great crested grebe	(1) N & W Europe (non-br)	10-20
Northern fulmar	(2) NE Atlantic	<1
Northern gannet	(2) NE Atlantic	4-7
Common scoter	(1) ssp. *nigra*	4-5
Great skua	(2) NW Europe (excl. Iceland)	>60
Little gull	(1) N, C & E Europe (br)	40-100
Common gull	(1) ssp. *canus*	3-6
Lesser black-backed gull	(1) ssp. *graellsii*	28
Herring gull	(1) ssp. *argentatus*	5
Great black-backed gull	(1) NE Atlantic	5
Black-legged kittiwake	(1) E Atlantic	<1
Sandwich tern	(1) ssp. *sandvicensis*, W Europe (br)	67
Common tern	(1) ssp. *hirundo*, S & W Europe (br)	56
Common guillemot	(3) NW Europe (excl. Iceland)	<1
Razorbill	(4) NW Europe (excl. Iceland)	<2

1.4 Seabirds at the BPNS: Seasonal and spatial distribution

Seabirds densities at the BNPS show strong seasonal fluctuations (Figure 3). Maximum densities occur during winter season, when on average more than 42,000 seabirds are present at the BPNS, and minimum densities during summer (17,000 birds present). These totals are calculated through extrapolation of mean zonal densities (see §1.3).
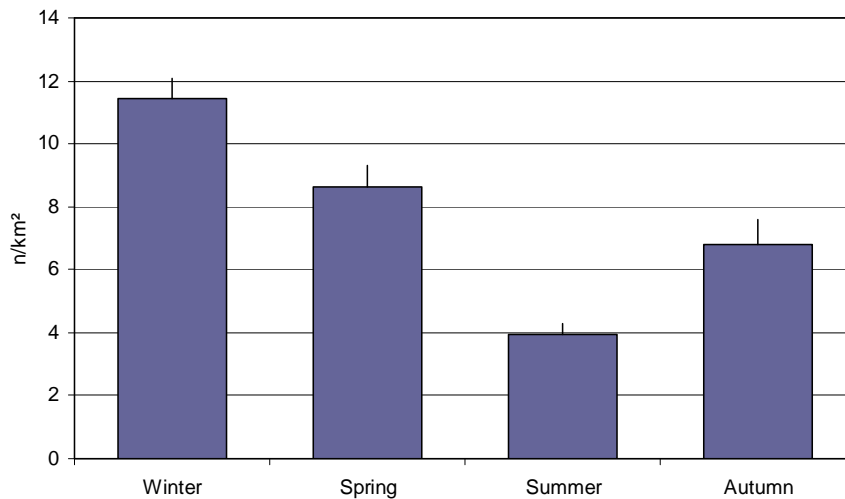

Figure 3. Seasonal variation in seabird densities at the BPNS (+SE).

Seabird community composition also shows strong seasonal variation (Figure 4). During winter, Common guillemot, Razorbill and Black-legged kittiwake account for more than 50% of the total bird density. Less important numbers of wintering gulls, grebes and divers occur. In the course of spring, most of these species leave the area and large numbers of Lesser black-backed gulls arrive at the BPNS, together with migrating Little gulls and Common scoters. The summer community in its turn is strongly dominated by local breeding birds like Lesser black-backed gull, Herring gull, Common tern and Sandwich tern. Terns leave the BPNS at the end of summer, and in autumn, Northern fulmar and Northern gannet migrate in large numbers, and the first wintering auks and kittiwakes arrive.

With the seasonal changes in species composition, seabird distribution patterns change accordingly. While some birds occur widespread, others show marked preference for the shallow inshore waters or clearly avoid the coast as illustrated in Figure 5.
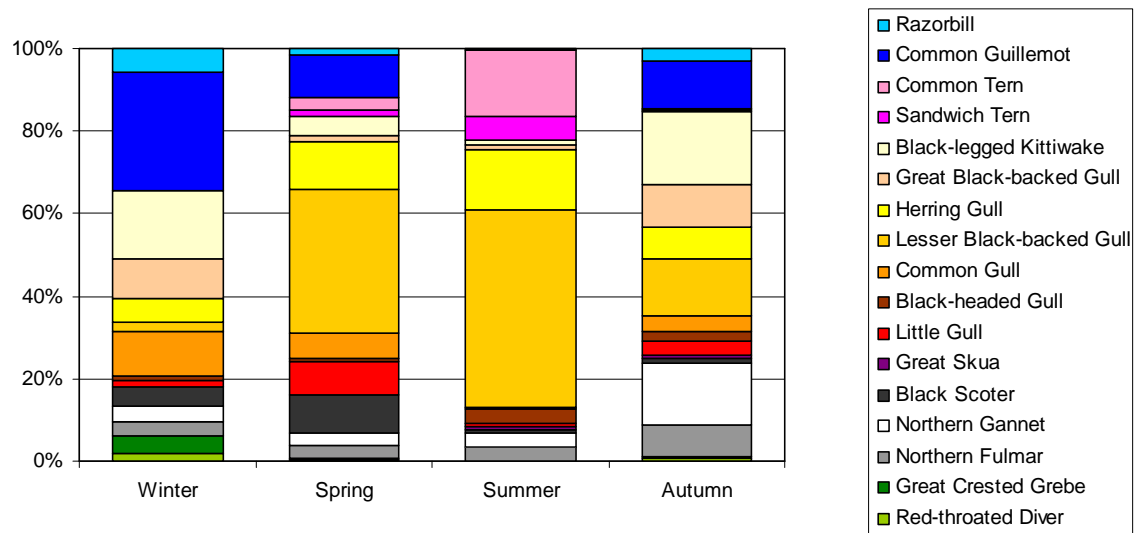
Figure 4. Seasonal variation in seabird community (blue = auks; pink = terns; yellow-orange-red = gulls; purple = Great skua; black = Common scoter; white = Northern gannet; grey = Northern fulmar; green = divers & grebes).
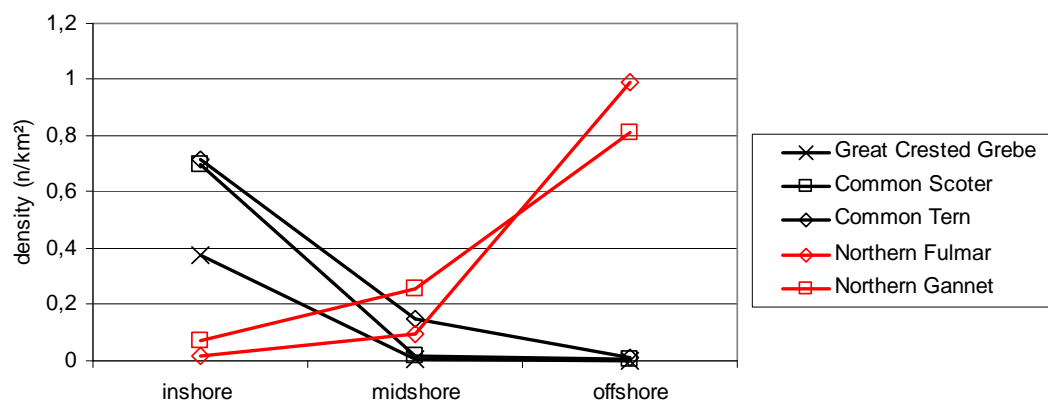

Figure 5. Seabird densities in relation to the distance from the coast, with typical inshore (black) and offshore species (red).

2 Avian importance of the Thorntonbank wind farm area

2.1 Methodology

In Vanermen *et al.* (2006), densities on the TTB were compared to densities on the BPNS as a whole. Relatively few data were available at that time, but already, some preliminary conclusions could be drawn. Several species, like Red-throated diver, Great crested grebe and Common scoter mainly occur inshore and thus the wind farm area is situated outside their normal distribution. Other species, like for example Northern gannet, Black-legged kittiwake and Common guillemot, did occur in high densities at the TTB, mainly during migration periods. But considering their wide distribution across the North Sea, the area could not be acknowledged as being particularly important to these species. On the other hand, Vanermen *et al.* (2006) found that several vulnerable species appeared in relatively high densities at the TTB. Based on the sparse data available, they alerted that the area could play an important role in the migration of four species, being Great skua, Little gull, Sandwich tern and Common tern.

Here we present an update of the results Vanermen *et al.* (2006) based on intensive monitoring of the TTB area during the period 2005-2007. Table 4 compares the mean seasonal densities of 16 species of seabird in the impact area of the wind farm (WFA-TTB) with the mean density on the BPNS as a whole. Since there is substantial seasonal variation in numbers as well as species composition, the dataset was first split into seasons:
- Winter: December – February
- Spring: March – May
- Summer: June – August
- Autumn: September – November

The impact area WFA-TTB corresponds to the wind farm area surrounded by a buffer zone of 3km. The width of this buffer zone was chosen based on literature research. Extensive radar and visual observation studies in Denmark and Sweden showed that migrating birds may already show avoidance behaviour from up to 3 km (Christensen *et al.* 2004, Kahlert *et al.* 2005, Pettersson *et al.* 2005). Hence, a buffer zone of 3 km assures that potential effects are limited to the impact zone exclusively. Thereafter, the BPNS was overlaid by a grid of 2x2 km cells. Every grid cell overlapping for at least one third of its surface with the impact area was assigned to the subzone WFA-TTB, while all grid cells with their centroid within the boundaries of the Belgian part of the North Sea were assigned to the subzone BPNS (Figure 6). The mean densities in the WFA-TTB and the BPNS were calculated by first calculating the means for each grid cell, before calculating the means per subzone. This way, we compensated for the skewed counting effort throughout the area.
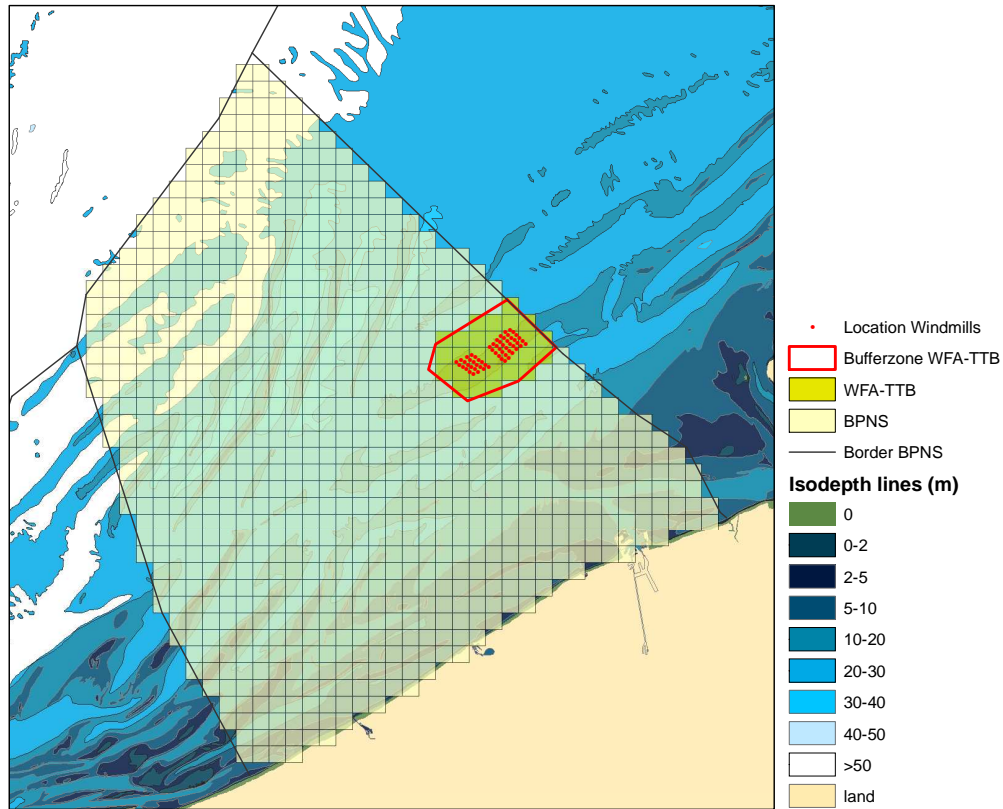
Figure 6. Grid of 2x2km cells used as a base for comparison of seabird densities in the impact area WFA-TTB and the BPNS.

2.2 Avian importance of the Thorntonbank wind farm area

2.2.1 General

Compared to the preliminary results in Vanermen *et al.* (2006), some species are slightly more abundant in this study (Table 4). This is the case for Lesser black-backed gull, Great black-backed gull, Black-legged kittiwake, Common guillemot and Razorbill.

The importance of the WFA-TTB towards Little gull, Sandwich tern and Common tern, is now confirmed by recent monitoring. The Little gull occurs concentrated in the WFA-TTB during winter months and the area is also part of its south bound autumn migration route (Figure 7 & Figure 9). Densities are highest during winter with 0.84 Little gulls per km². Significant numbers of terns occur in the WFA-TTB during summer months and especially during migration, from the end of July onwards to August (§2.2.2). On the other hand, densities of Great skua were seemingly overestimated in Vanermen *et al.* (2006), and the WFA-TBB now seems to be rather insignificant for this species.

Table 4. Seasonal bird densities (n/km²) in the future wind farm area at 'Thorntonbank' (WFA-TTB) compared to densities at the BPNS as a whole (1992-2007).

(species marked in bold meet one of following criteria: density in the WFA exceeds 1 bird/km² during one or more seasons; density in the WFA exceeds 0,25 bird/km² during one or more seasons in case of a protected species (*); WFA-density is at least 50% higher than the BPNS-density)

	Winter		Spring		Summer		Autumn	
	WFA-TTB	BPNS	WFA-TTB	BPNS	WFA-TTB	BPNS	WFA-TTB	BPNS
Number of grid cells	26	769	23	649	23	602	27	726
Red-throated diver	0,12	0,24	0,02	0,04	0,00	0,00	0,02	0,04
Great crested grebe	0,00	0,44	0,00	0,04	0,00	0,00	0,00	0,05
Northern fulmar	0,15	0,39	0,13	0,21	0,20	0,14	0,70	0,52
Northern gannet	0,18	0,39	0,36	0,25	0,17	0,13	**1,14**	1,04
Common scoter	0,07	0,57	0,00	0,86	0,00	0,05	0,00	0,08
Great skua	0,00	0,01	0,00	0,00	0,02	0,02	0,00	0,04
Little gull*	**0,81**	0,16	**0,40**	0,57	0,00	0,04	**0,43**	0,25
Common gull	**2,56**	0,98	0,07	0,59	0,00	0,01	0,04	0,27
Lesser black-backed gull	0,06	0,12	**21,64**	2,79	**4,42**	1,93	0,18	0,97
Herring gull	0,38	0,60	0,37	1,07	0,02	0,64	0,01	0,53

	Winter		Spring		Summer		Autumn	
	WFA-TTB	BPNS	WFA-TTB	BPNS	WFA-TTB	BPNS	WFA-TTB	BPNS
Great black-backed gull	**2,73**	1,05	0,04	0,14	**0,21**	0,05	**3,25**	0,80
Black-legged kittiwake	**5,97**	1,79	0,09	0,39	0,00	0,04	**5,24**	1,37
Sandwich tern*	0,00	0,00	0,11	0,16	**0,59**	0,25	0,02	0,02
Common tern*	0,00	0,00	0,02	0,26	**0,38**	0,66	0,02	0,03
Common guillemot	**4,42**	3,23	0,65	0,94	0,00	0,01	**3,67**	0,90
Razorbill	**1,33**	0,69	0,08	0,14	0,00	0,00	**0,58**	0,21

2.2.2 Species discussion

Little gull (*Larus minutus*)

In Vanermen *et al.* (2006), it was already suggested that the WFA-TTB was important to Little gulls, mainly during autumn migration. It has now become clear that relatively high densities occur in the area from September until April. Densities are even higher than initially calculated by Vanermen *et al.* (2006).

In general, the Little gull's distribution at the BPNS is concentrated within a 40km wide band along the coast, including the WFA-TTB. Especially during winter, Little gulls occur concentrated in the impact area (Figure 7). In autumn however, highest concentrations occur near the ports of Zeebrugge and Ostend, while the WFA-TTB shows increased densities too (Figure 9).
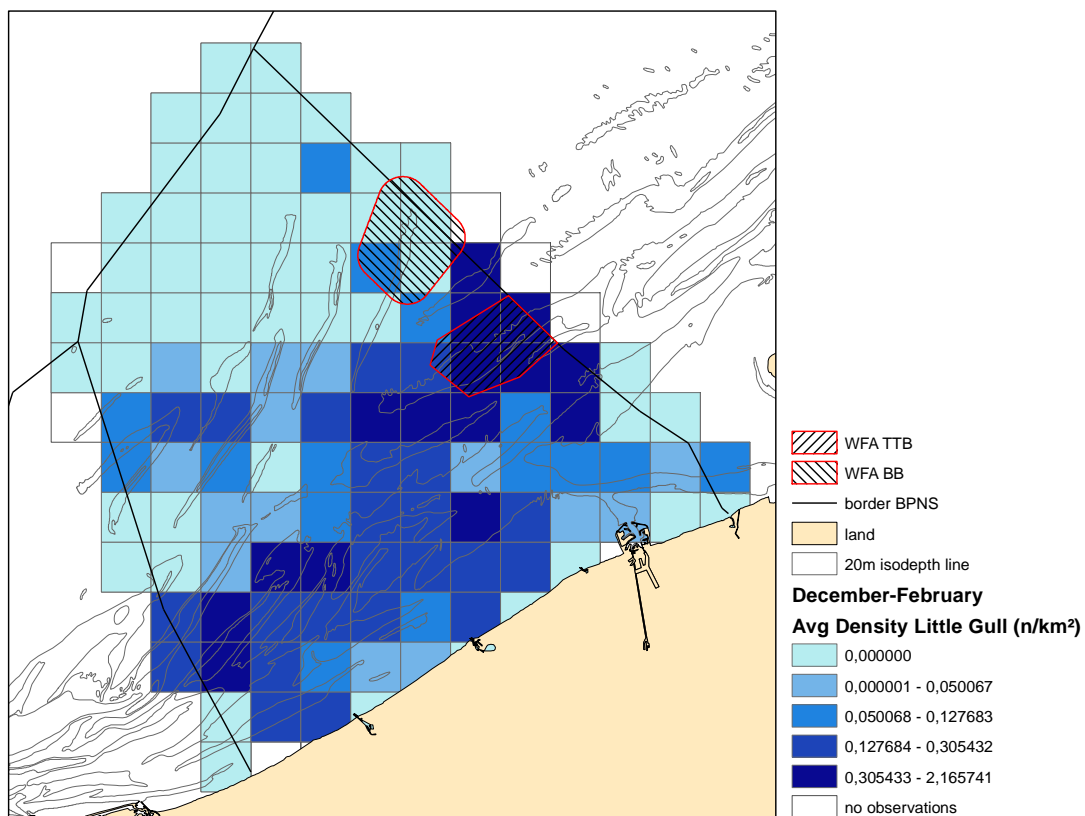
Figure 7. Winter distribution of Little gull on the BPNS (number per km²).
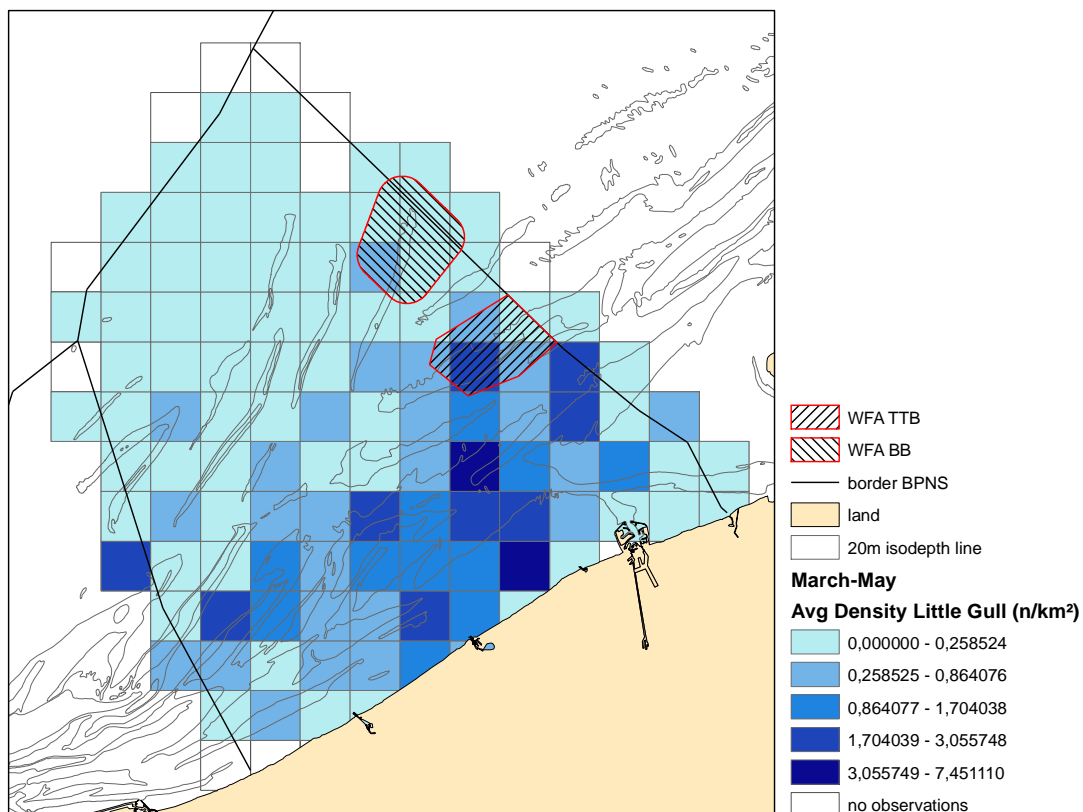
Figure 8. Spring distribution of Little gull on the BPNS (number per km².).
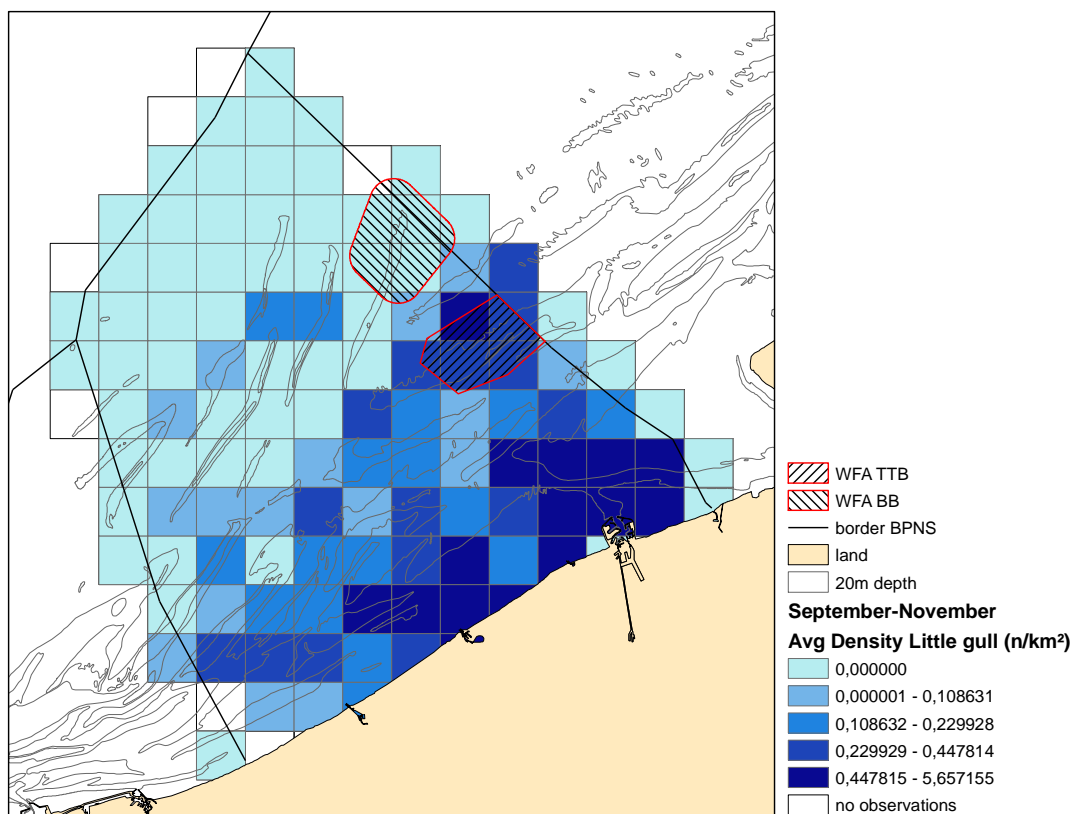
Figure 9. Autumn distribution of Little gull on the BPNS (number per km².).

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Sandwich tern (*Sterna sandvicensis*)

Following the discussion in Chapter 1 of Vanermen *et al.* (2006), the distribution maps shown are based on an adapted seasonal classification: March-April (spring migration), May-June (breeding season) and July-August (autumn migration). In spring, migration occurs widespread across the BPNS, with equally high densities near shore and further offshore (Figure 10). During the breeding season, highest densities occur near shore, with a clear concentration of Sandwich terns within 15km of the breeding colony in Zeebrugge (Figure 11). Table 4 suggests that mainly during summer, the WFA-TTB holds important numbers of Sandwich tern. This is illustrated by the distribution map in Figure 12, which shows that Sandwich terns concentrate near the port of Zeebrugge and within the WFA-TTB during July to August.
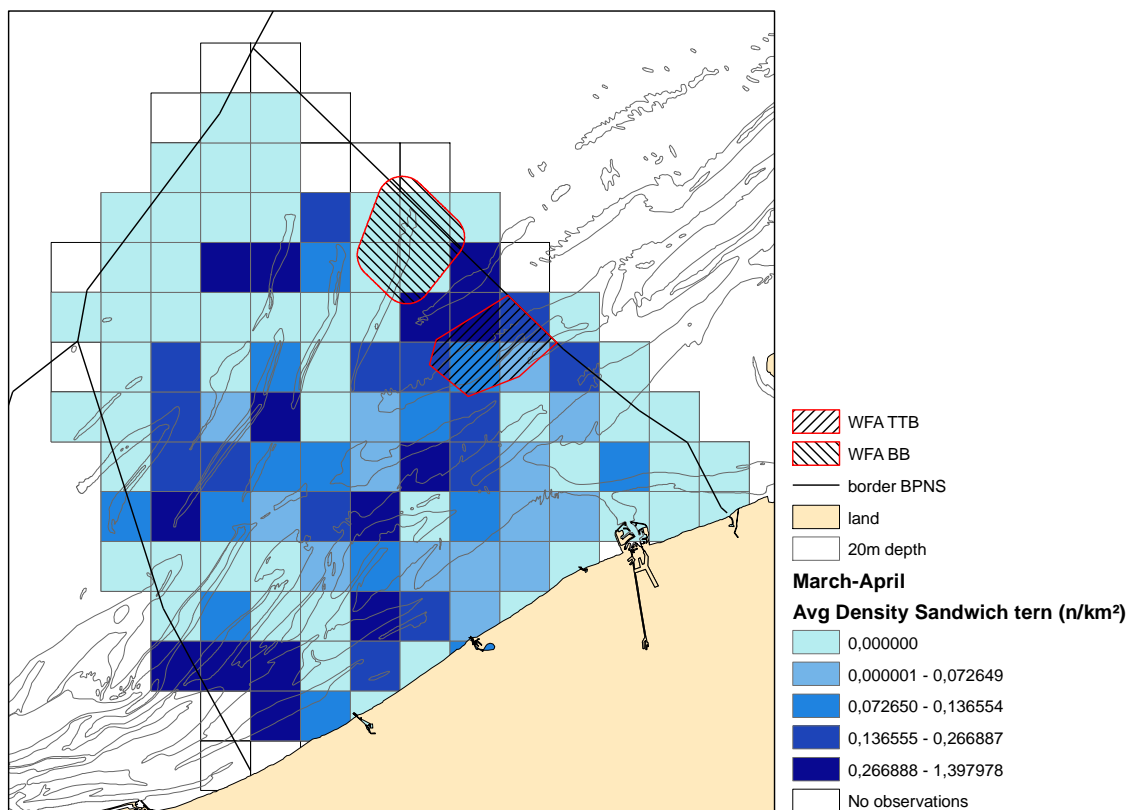
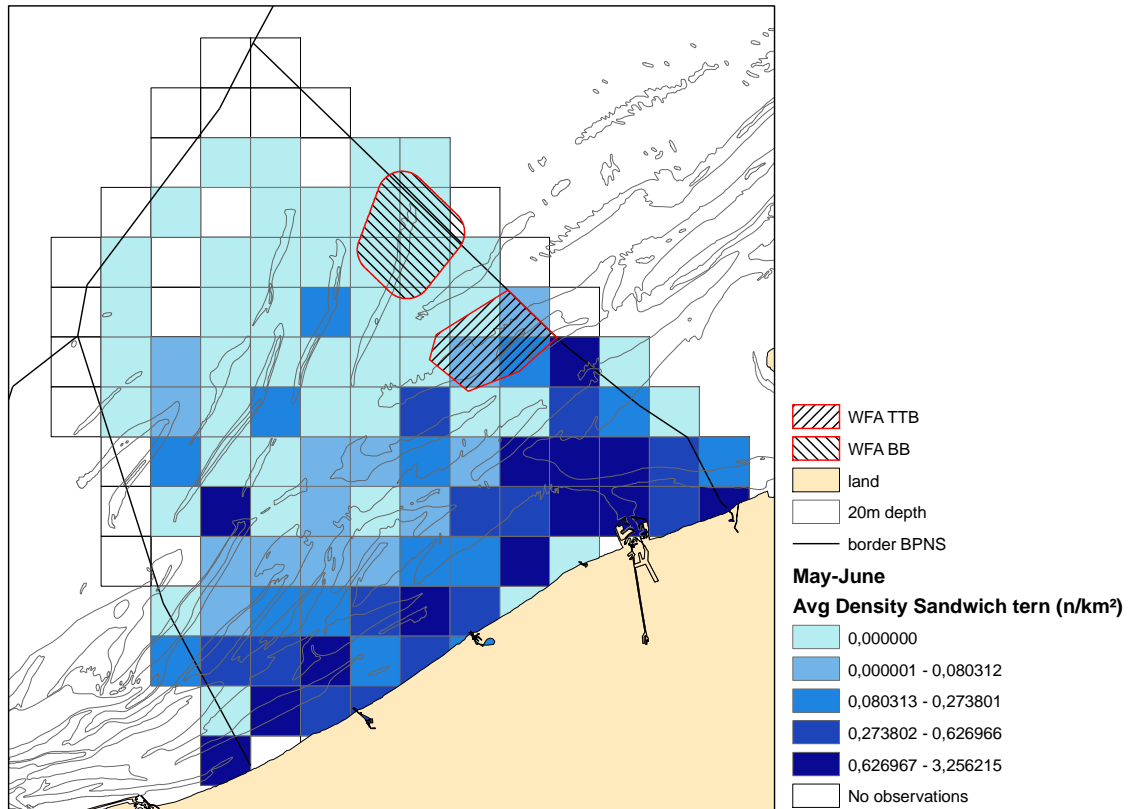**Figure 10. Distribution of Sandwich tern on the BPNS during spring migration (March-April).**

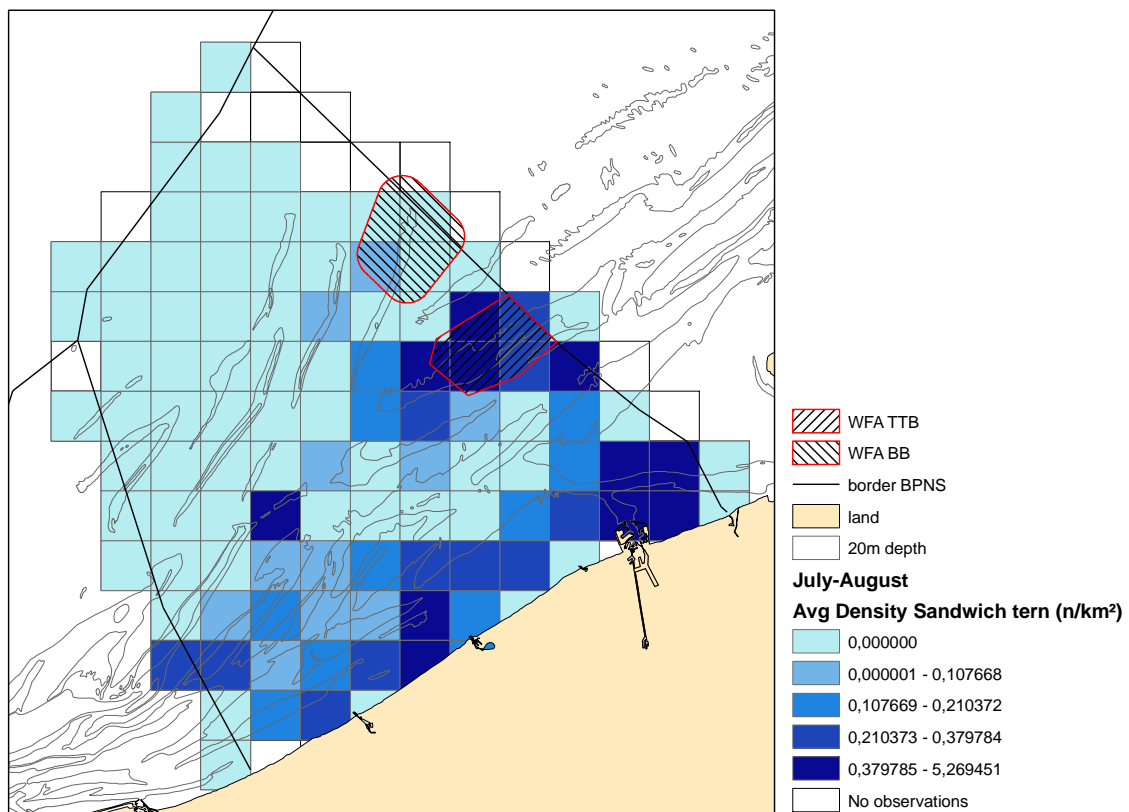**Figure 11. Distribution of Sandwich tern on the BPNS during breeding season (May-June).**

Figure 12. Distribution of Sandwich tern on the BPNS during summer (July-August).

Common tern (*Sterna hirundo*)

In early spring Common terns occur scattered around the BPNS, with high densities already building up near the ports of Zeebrugge and Ostend. In that period, Common terns are observed as far offshore as the 'Hinderbanken'. In contrast, the species is limited to the near shore zone during breeding season, with very high densities near the breeding colony of Zeebrugge. More than 20km offshore zero densities are standard. The foraging range of breeding Common tern usually does not exceed 15 km, and hence the WFA-TTB is not important to the birds of Zeebrugge. The species already takes on its southbound migration in late summer (July-August). That period, the species' distribution is most widespread and the WFA-TTB holds increased densities (Table 4 & Figure 15).
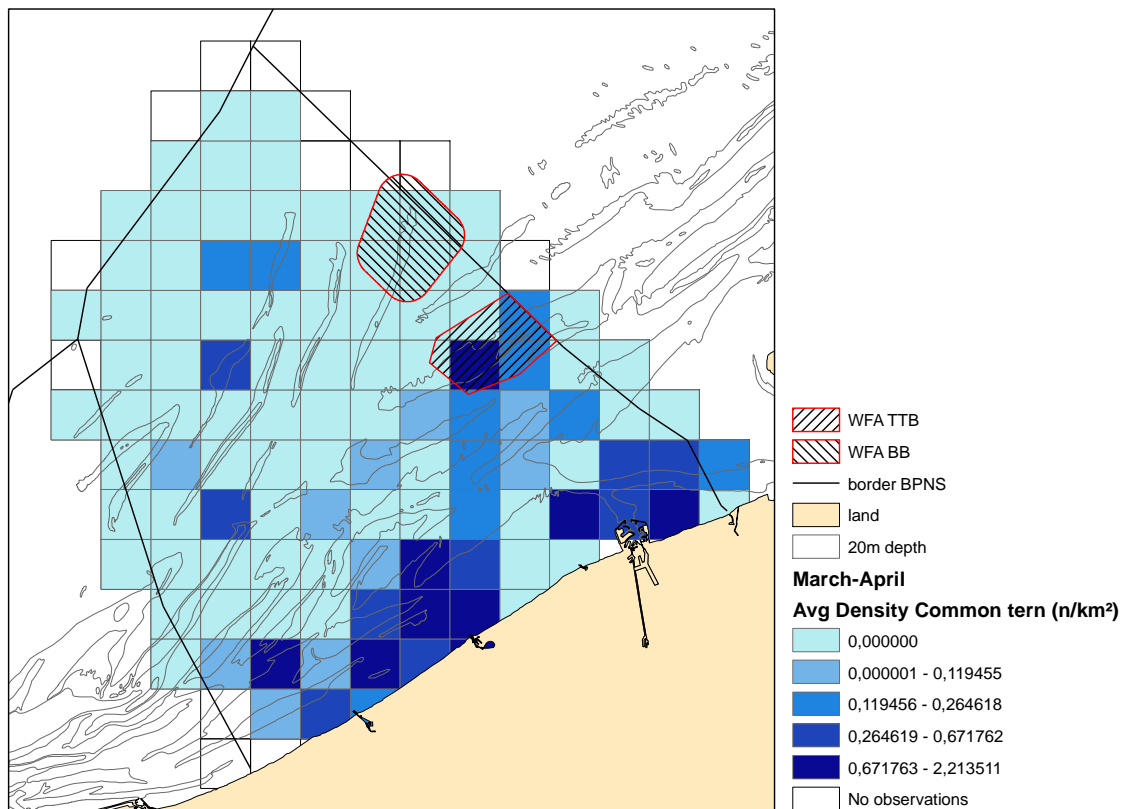

Figure 13. Distribution of Common tern on the BPNS during spring migration (March-April).
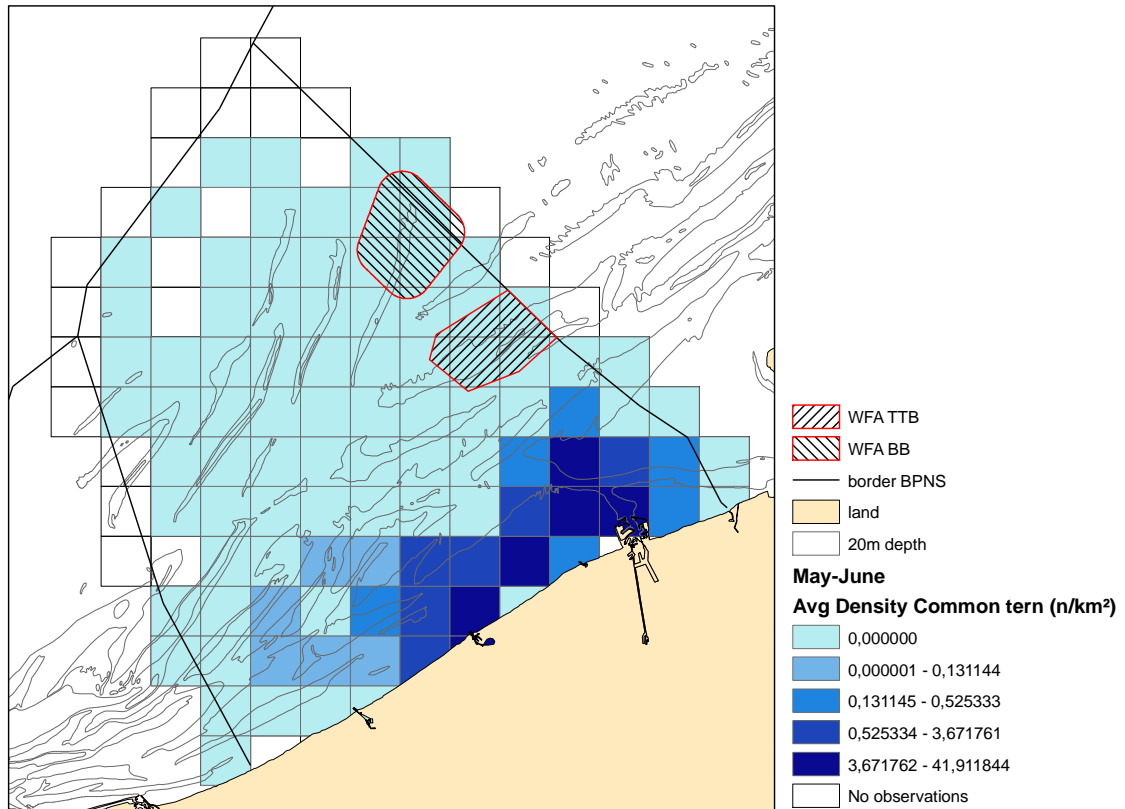
Figure 14. Distribution of Common tern on the BPNS during breeding season (May-June).
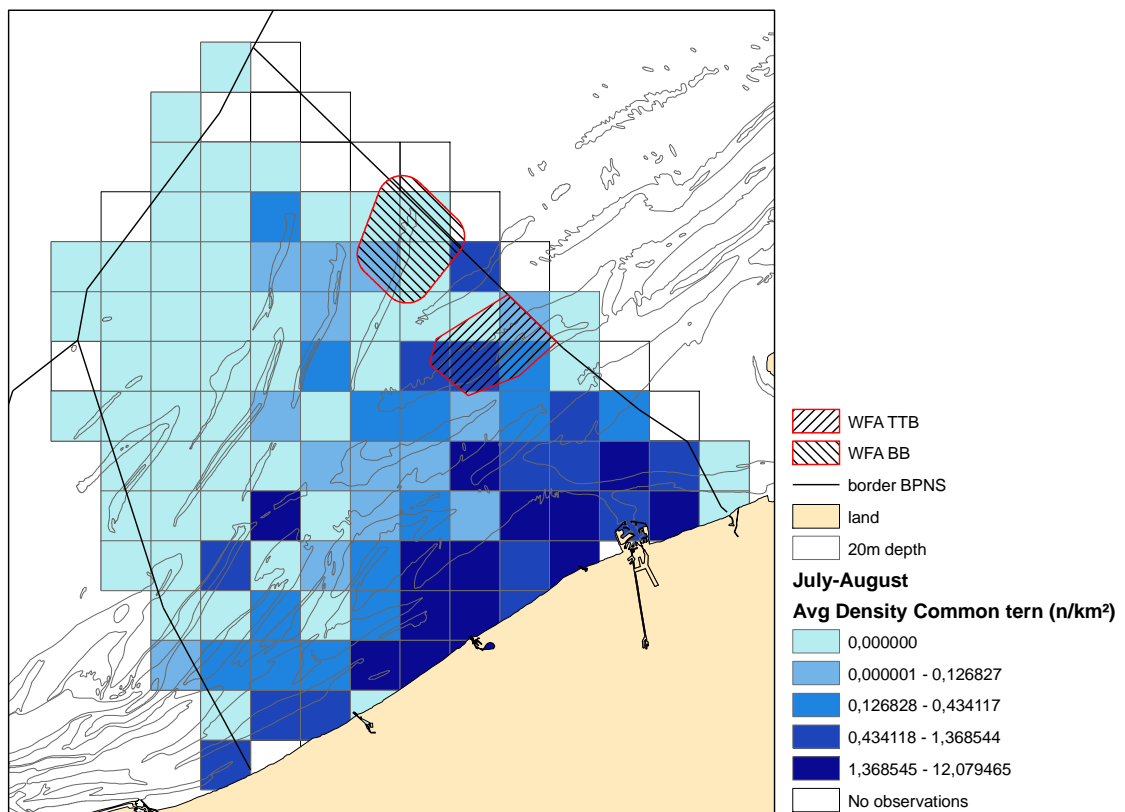

Figure 15. Distribution of Common tern on the BPNS during summer (July-August).

2.2.3   Conclusion

Based on the information gathered during three years of intense monitoring (2005-2007), we conclude that:

- The WFA-TTB is has no particular value to Red-throated diver, Great crested grebe, Northern fulmar, Common scoter, Great skua and Herring gull

- The WFA-TTB is not particularly valuable to the following species, although high densities may occur: Northern gannet, Common gull, Lesser black-backed gull, Great black-backed gull, Black-legged kittiwake, Common guillemot, Razorbill

  → *Considering their high densities in the reference period, these species are well suitable for monitoring regarding displacement effects by the future wind farm.*

- The WFA-TTB is of particular value to **Little gull**, **Sandwich tern** and **Common tern**

  → *To accurately assess possible effects of the future wind farm, migration behaviour and occurrence of these birds in the TTB-WFA needs to be investigated in detail. Research should also focus on displacement through avoidance behaviour, as well as migration flux and collision risk.*

3 Evaluation of the control area of the Thorntonbank wind farm area

To accurately assess the impact of human structures at sea, it is not sufficient to perform a before-after comparison. Ideally, the changes in the impact area are put in perspective by comparing them with possible changes in a control area. Naturally, changes in bird community and densities are not necessarily induced by local changes in the marine environment, and might as well be induced by larger scale processes. Such large scale events include temporary influxes of seabirds due to specific weather conditions or food availability elsewhere, as well as changes in population level.

In the reference study (Vanermen *et al.* 2006), a control area was delineated for the future wind farm site at the Thorntonbank (WFA-TTB). Obviously, the bird community in this area had to correspond as much as possible to that occurring in the WFA-TTB. Additionally, the chosen control area had to account for the fact that seabird distribution and densities are highly variable on a temporal as well as a spatial scale. Hence, several logistic considerations had to be made. Since seabird occurrence is highly variable even on a short time scale, it was necessary to choose a control area that could be monitored the exact same day as the wind farm area itself. Secondly, the control area should not suffer from adverse effects caused by the wind farm, which was countered by applying a 3km wide buffer zone (Christensen *et al.* 2004, Kahlert *et al.* 2005, Pettersson *et al.* 2005). Finally, the area had to be large enough to be able to include sufficient data for statistical analysis. This is especially important for scarce species like terns, Little gull and Great skua.

After analysing the local seabird densities and taking in account the aforementioned logistic and practical considerations, one single control area (CA-TTB) was delimited for year-round monitoring. The chosen control area largely surrounds the WFA-TTB, extending from the Dutch border to the southwest tip of the Gootebank, measuring 329 km². The WFA-TTB itself measures 105 km², the 3km wide buffer zone included (Figure 16). Vanermen *et al.* (2006) compared the seabird densities in the WFA-TTB and CA-TTB based on monitoring results of the year 2005. In this chapter we perform a likewise analysis for the data obtained during the period 2005-2007, and evaluate the suitability of the control area.

3.1 Methodology

3.1.1 Selectivity Index

Analogous to the monitoring programmes performed in Denmark (e.g. Christensen *et al.* 2004, Kahlert *et al.* 2005), the Jacobs selectivity index (Jacobs 1974) was used as a base for comparison between WFA-TTB and CA-TTB. The Jacobs selectivity index (JSI) is calculated as follows:

$$D = (r - p) / (r + p - 2rp)$$

With

r = % of birds in the WFA-TTB compared to the number of birds in the total study area;

p = % of the count effort (see §3.1.2) in the WFA-TTB compared to the effort in the total study area.

The index obtained through this formula results in values ranging from -1 to +1. When birds occur homogeneously dispersed throughout both areas, a value of 0 is obtained. In contrast, a value of +1 stands for 100% preference to the WFA, and -1 for complete preference to the CA. During the reference period, the JSI should be as small as possible.

3.1.2 Count effort

Figure 16 shows the count locations for the period 1992-2007, which makes clear that prior to 2005 counting effort was strongly skewed in favour of the CA-TTB. Therefore, only count results of the years 2005-2007 were included in the analysis, and Figure 17 compares the count effort in the CA-TTB and the WFA-TTB for this period. The count effort is expressed as the number of square kilometres monitored (km²), which is calculated by multiplying the sailed kilometres with the transect width (0.3km). In autumn, the area monitored in the CA-TTB was more than twice the area monitored in the WFA-TTB. Otherwise, despite the large dimensions of the CA-TTB compared to the WFA-TTB, the count effort was relatively well partitioned between both areas.
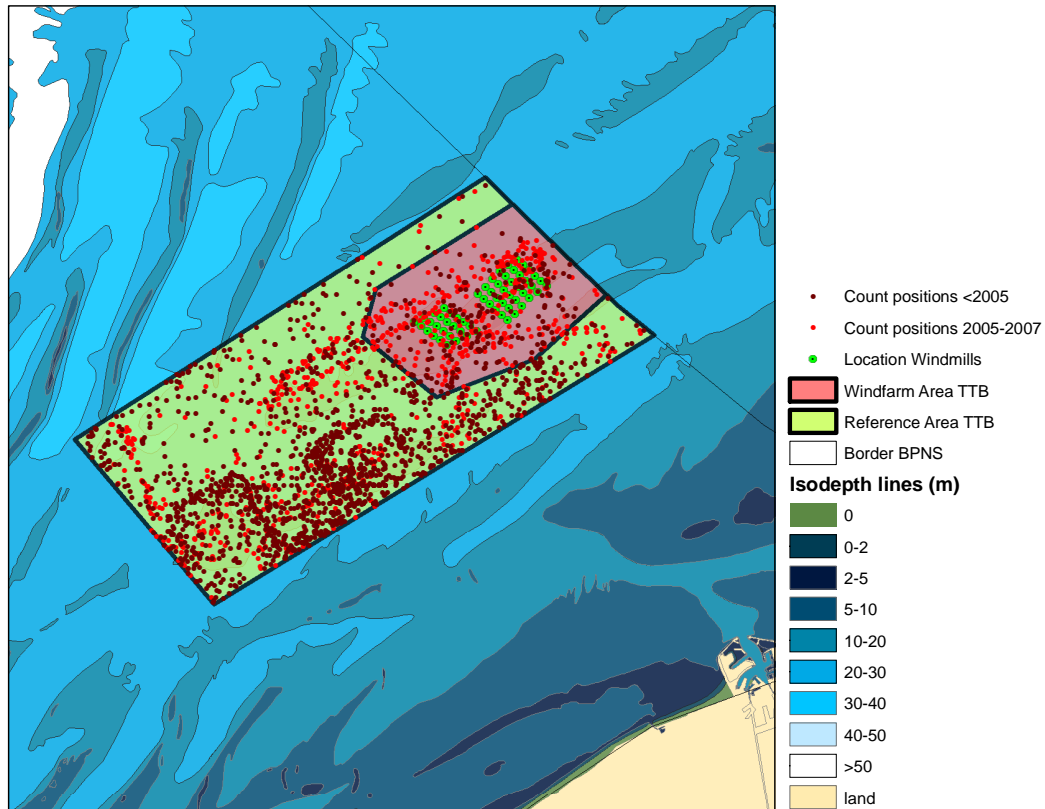
Figure 16. The control area (CA-TTB) and wind farm area (WFA-TTB) at the Thorntonbank – the brown dots represent all count locations prior to 2005, the red dots those from 2005 to 2007.
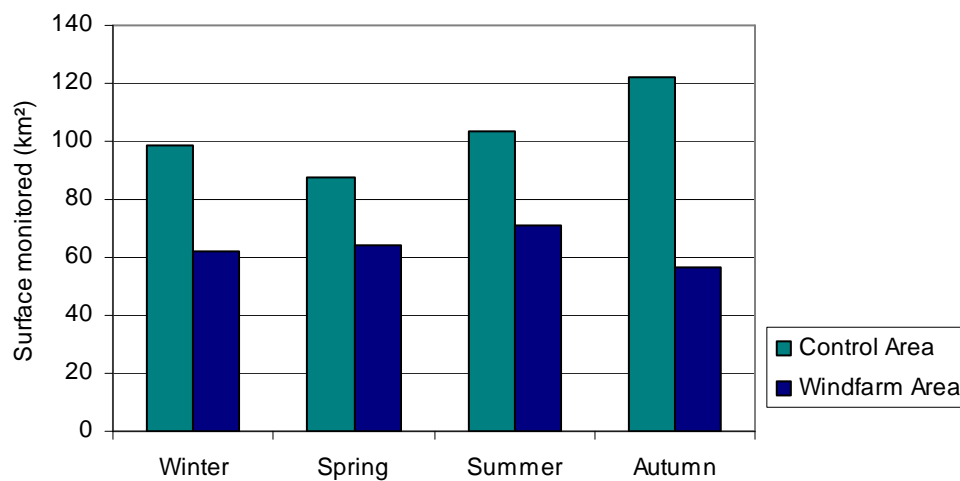

Figure 17. Count effort in the control area (CA-TTB) compared to the impact area (WFA-TTB) at the 'Thorntonbank', expressed in km² of area monitored (2005-2007).

3.2 Results

Northern gannet (*Morus bassanus*)

Northern gannets occur in relatively high densities, with highest numbers during autumn. The species occurs in well corresponding numbers in both subzones, which is confirmed by a JSI of 0.11. Nevertheless, seasonal densities show poor correspondence.
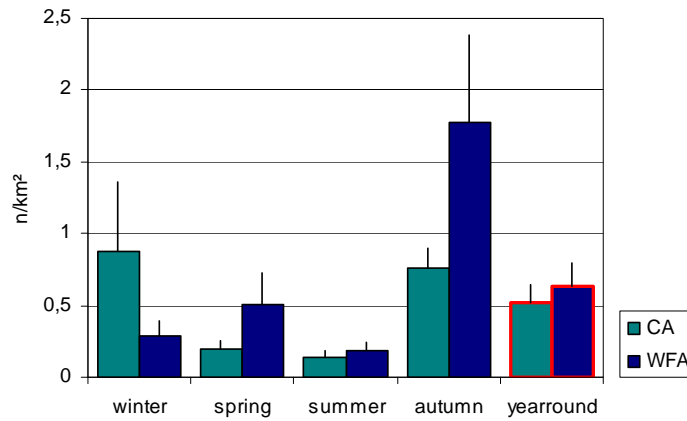

Figure 18. Seasonal and year-round densities of Northern gannet in the CA-TTB compared to the WFA-TTB (+ std. error) (2005 – 2007).

Little gull (*Larus minutus*)

Both the WFA-TTB and CA-TTB hold moderately high densities of Little gulls (Figure 19). In contrast to the BPNS as a whole, where the species is most common during spring, densities of Little gull are highest during winter months. Year-round densities indicate a preference to the WFA-TTB (JSI = 0.25), mainly resulting from high densities observed there during winter.
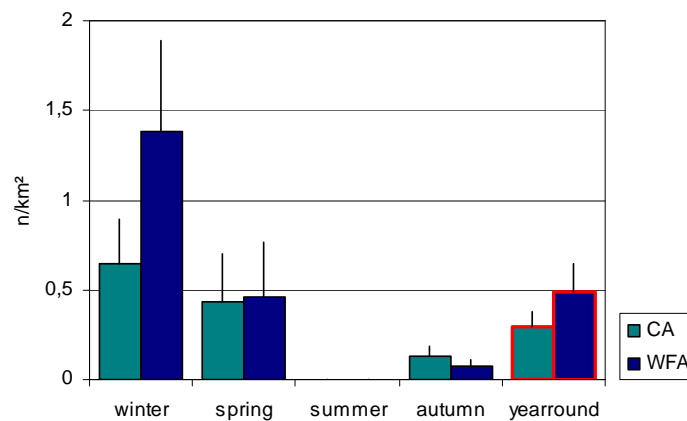

Figure 19. Seasonal and year-round densities of Little gull in the CA-TTB compared to the WFA-TTB (+ std. error) (2005 – 2007).

Common gull (*Larus canus*)

In our study area, Common gulls were almost exclusively observed during winter months, with densities of more than 3 birds per km² in the WFA-TTB as well as the CA-TTB. This results in a fairly low selectivity index of -0.13.
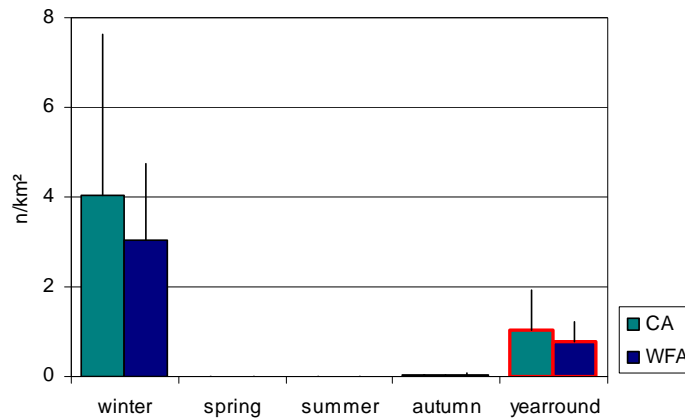

Figure 20. Seasonal and year-round densities of Common gull in the CA-TTB compared to the WFA-TTB (+ std. error) (2005 – 2007).

Lesser black-backed gull (*Larus fuscus*)

Lesser black-backed gulls show a selectivity index strongly in favour of the WFA-TTB (JSI = 0.55). Since gulls often aggregate in large numbers around fishing vessels, these results need to be interpreted with care. In the study area, densities of more than 150 birds/km² were observed at five locations, of which four were within the WFA-TTB. Such large concentrations are inevitably associated with nearby fishing activities, and on such a small scale encounters with a towing fishing vessel mainly rely on coincidence.
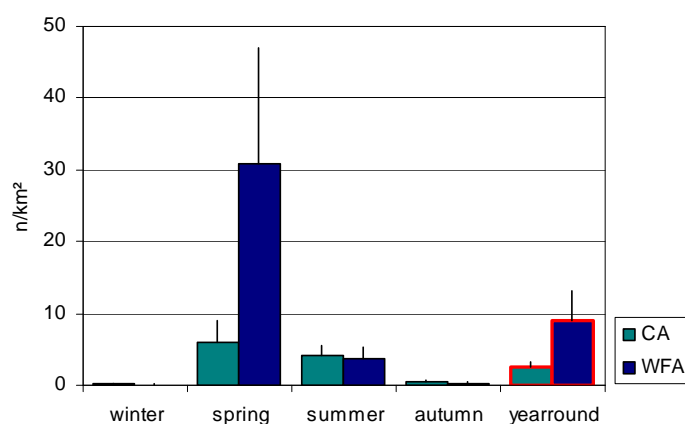

Figure 21. Seasonal and year-round densities of Lesser black-backed gull in the CA-TTB compared to the WFA-TTB (+ std. error) (2005 – 2007).

Great black-backed gull (*Larus marinus*)

In the study area, the Great black-backed gull is a winter visitor which is present in high numbers during winter and autumn. Mean densities amount up to 9 birds per km² in the CA-TTB, and up to 6 birds per km² in the WFA-TTB. While the seasonal densities in both subzones show poor correspondence (especially in autumn), the overall selectivity appears to be very low (-0.01). Great black-backed gulls too show high association with fishing activity, which makes the species unsuitable for a reliable 'control area' versus 'impact area' comparison.
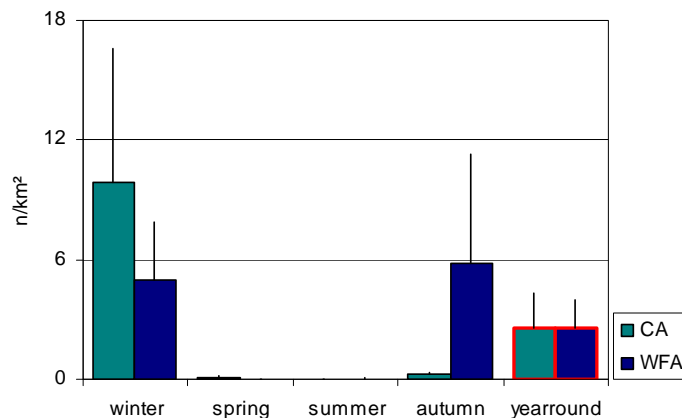

Figure 22. Seasonal and year-round densities of Great black-backed gull in the CA-TTB compared to the WFA-TTB (+ std. error) (2005 – 2007).

Black-legged kittiwake (*Rissa tridactyla*)

Black-legged kittiwakes are winter and autumn visitors in the study area. While winter densities correspond well, the autumn density in the WFA-TTB is much higher than in the CA-TTB. Resulting, the selectivity index is in favour of the WFA-TTB (0.27).
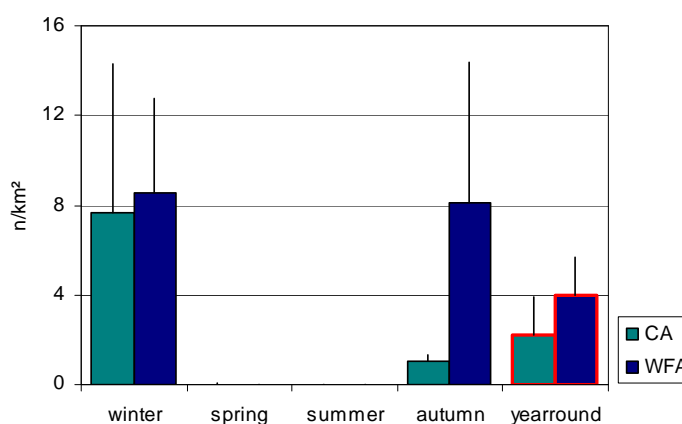

Figure 23. Seasonal and year-round densities of Black-legged kittiwake in the CA-TTB compared to the WFA-TTB (+ std. error) (2005 – 2007).

Sandwich tern (*Sterna sandvicensis*)

Sandwich terns occur in low densities in the study area, mainly during spring and summer. While the seasonal densities show poor correspondence between WFA-TTB and CA-TTB, the overall selectivity appears to be very low (-0.05).
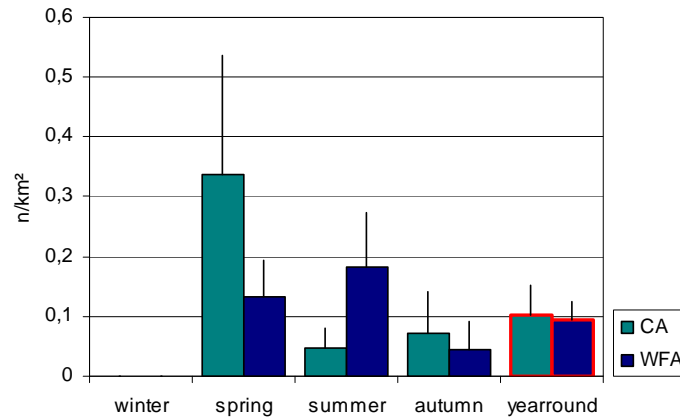

Figure 24. Seasonal and year-round densities of Sandwich tern in the CA-TTB compared to the WFA-TTB (+ std. error) (2005 – 2007).

Common tern (*Sterna hirundo*)

As well as the previous species, Common terns are mainly present during spring and summer. Numbers in both areas correspond well, resulting in a fairly low JSI-value of 0.14.
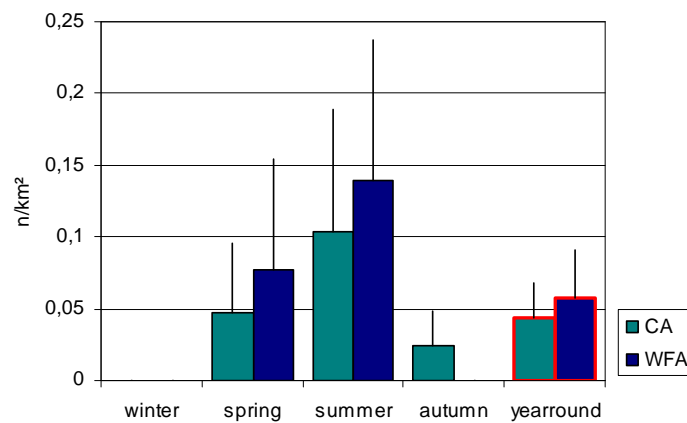

Figure 25. Seasonal and year-round densities of Common tern in the CA-TTB compared to the WFA-TTB (+ std. error) (2005 – 2007).

Common guillemot (*Uria aalge*)

Common guillemots are present in high numbers in both subzones during winter and autumn. During both seasons the species is more numerous in the WFA-TTB compared to the CA-TTB, with densities amounting up to 7 birds per km². This results in a selectivity index of 0.23, in favour of the WFA-TTB.
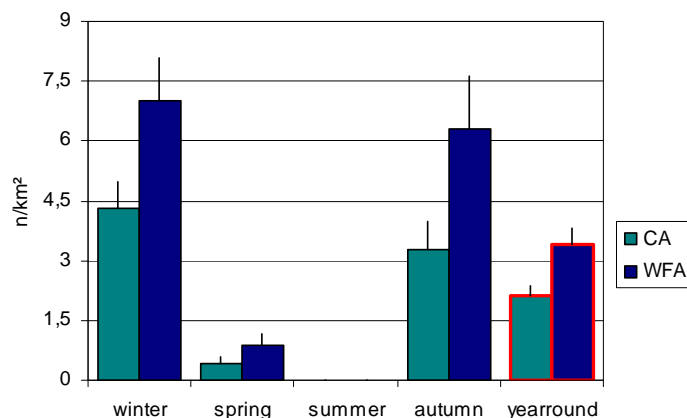

Figure 26. Seasonal and year-round densities of Common guillemot in the CA-TTB compared to the WFA-TTB (+ std. error) (2005 – 2007).

Razorbill (*Alca torda*)

While numbers are insignificant during spring and summer, densities of more than 1 Razorbill per km² occur during winter and autumn. There is good agreement in densities of Razorbill in the WFA-TTB and CA-TTB, resulting in a low selectivity index of 0.05.
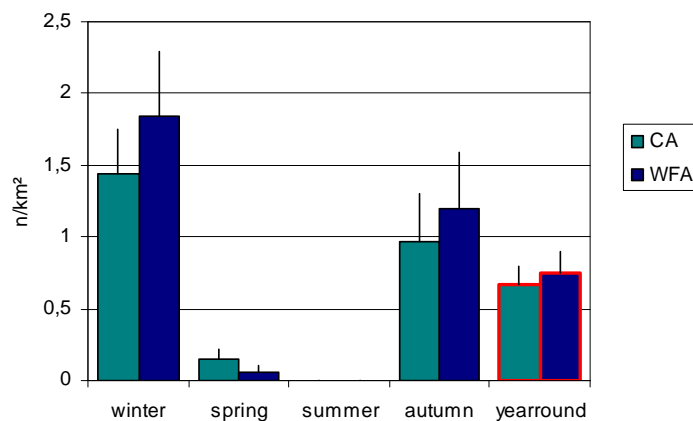

Figure 27. Seasonal and year-round densities of Razorbill in the CA-TTB compared to the WFA-TTB (+ std. error) (2005 – 2007).

3.3 Summary

In this chapter we calculated the Jacob's selectivity index (JSI) of ten species of seabird, as a measure for the deviation of densities in the control area (CA-TTB) compared to the impact area (WFA-TTB). During the reference period, JSI-values are favourably close to zero.

We calculated the index for two periods, 1992-2007 and 2005-2007. Since 2005, the monthly monitoring routes covered both the WFA-TTB and the CA-TTB, which results in smaller JSI's (Figure 28). Based on the generally good agreement in seabird occurrence in both areas we regard the CA-TTB proposed by Vanermen *et al.* (2006) as suitable for future monitoring.
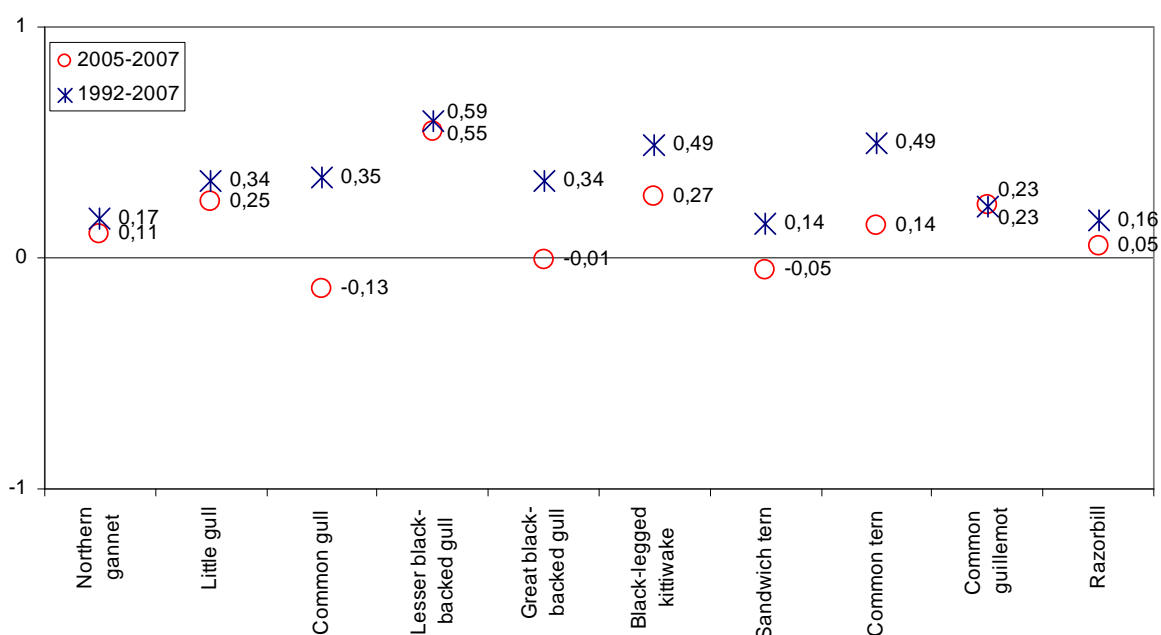

Figure 28. Results for two different JSI calculations (+1 = 100% preference to the WFA-TTB / -1 = 100% preference to the CA-TTB).

In chapter 1 we selected 10 out of 16 species of seabirds on which future monitoring should be focused on, based on their conservational value and/or abundant occurrence in the WFA-TTB. The information gathered in this chapter allows us to further determine the remaining species' suitability.

Suitable monitoring species should agree on the following criteria. A reliable 'control area' versus 'impact area' comparison requires highly comparable seabird densities in both areas during the reference period and hence, a small JSI. For data as variable as seabird densities, it will never be possible to obtain zero JSI-values. Therefore, future monitoring will mainly focus on the procentual changes in the WFA and CA, rather than on absolute differences in densities between both areas (see §4.1). Nevertheless, large JSI-values during the reference period may be a reflection of a high and unwanted spatial variability in the species' occurrence, due to, for example fishing activities.
Secondly, Figure 28 shows the JSI's for the whole reference period 2005-2007. However, a low JSI does not necessarily result from a good agreement in seasonal densities (in Great black-backed gull

for example, Figure 22). Therefore we calculated the standard deviation of the (relevant) seasonal JSI's, as a measure of seasonal variation in selectivity.

Lastly, for each species we calculated a percentage of association with fisheries. As already mentioned, monitoring of species with a strong association with fishing activities is less reliable. Obviously, the encounter with a large number of birds concentrated near fishing activities is highly coincidental. Moreover, the observed distribution reflects the distribution of fishing activity rather than it reflects an inherent preference to a certain marine area.

Each of these three parameters was ranked from low to high and split up in three categories. The three lowest values were scored as 0 and the three highest as 2, the four remaining 'middle' values were scored as 1 (Table 5). These categorical values were then summed, resulting in one value based on which we are able to sort the species according to their suitability for future monitoring. As expected, specialists like auks, terns and Little gulls are better suited compared to generalists like gulls. While the specialists occur relatively homogeneously dispersed, generalists concentrate more aggregated, resulting in strongly skewed JSI's.

Table 5. Ranking of the species' suitability for future monitoring.

Species	Association with fishery (%) (1)	JSI (absolute value) (2)	SD of seasonal JSI (3)	(1)	(2)	(3)	Σ [(1),(2),(3)]
Razorbill	0.00	0.05	0.01	0	0	0	**0**
Common guillemot	0.00	0.23	0.05	0	1	0	**1**
Common tern	0.06	0.14	0.06	1	1	0	**2**
Little gull	0.02	0.25	0.33	0	2	1	**3**
Sandwich tern	0.06	0.05	0.72	1	0	2	**3**
Common gull	0.20	0.13	0.24	2	1	1	**4**
Northern gannet	0.13	0.11	0.52	1	1	2	**4**
Black-legged kittiwake	0.16	0.27	0.49	1	2	1	**4**
Great black-backed gull	0.33	0.01	0.86	2	0	2	**4**
Lesser black-backed gull	0.39	0.55	0.49	2	2	1	**5**

4 Results of the year-1 monitoring in the Thorntonbank wind farm area

In 2008, C-Power started up the construction works in the wind farm area at the Thorntonbank (WFA-TTB). At the time of writing, six wind turbines are in place, of which two are in operation. Clearly, construction works were conducted at a relatively small scale, considering the fact that upcoming years another 54 wind turbines will be build. In this chapter, we investigated whether changes in seabird densities have already taken place, and if so, if these could be assigned to the construction activities in the wind farm area.

Based on the results in Table 5, we focus our results on 6 species of seabirds, namely Northern gannet, Little gull, Sandwich tern, Common tern, Common guillemot and Razorbill.

4.1 Species discussion

Northern gannet *(Morus bassanus)*

While densities in the WFA-TTB were almost halved, densities in the control area remained the same, suggesting a negative effect due to the construction of the windmills. In reality however, Northern gannets did not seem to bother much about the presence of the turbines, and more than once they were observed flying through the wind farm.
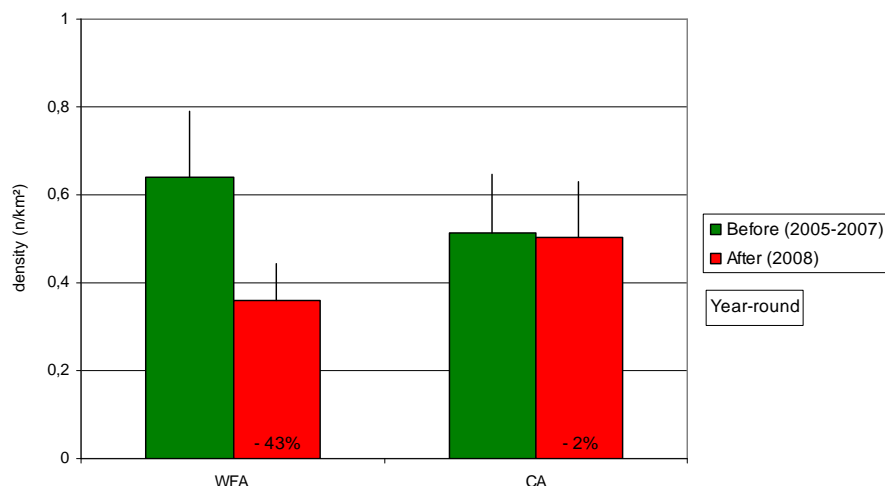

Figure 29. Comparison of the year-round densities of Northern gannet in the WFA-TTB and the CA-TTB during the reference period 2005-2007 and 2008 (+ std. error).

Little gull (*Larus minutus*)

Compared to the reference period, Little gull densities in the WFA-TTB were higher in 2008. However, a comparative change in densities has occurred in the control area, suggesting that in 2008, Little gulls were more common throughout the area.
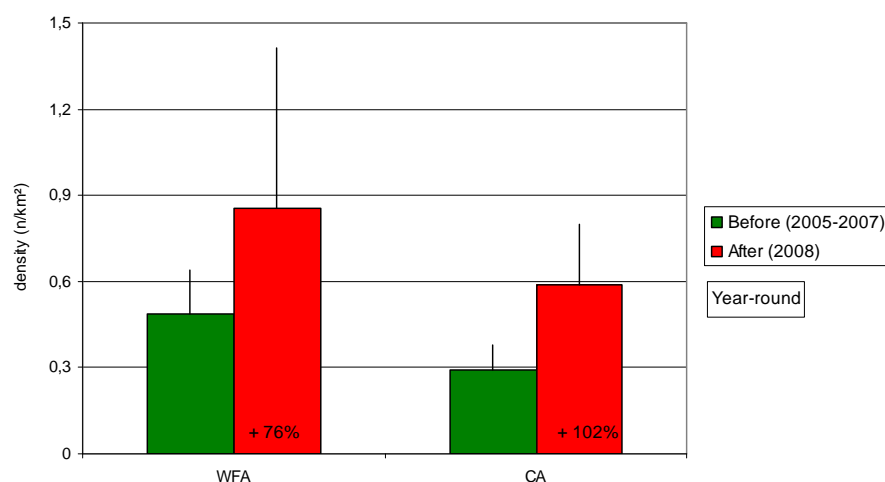

Figure 30. Comparison of the year-round densities of Little gull in the WFA-TTB and the CA-TTB during the reference period 2005-2007 and 2008 (+ std. error).

Sandwich tern (Sterna sanvicensis)

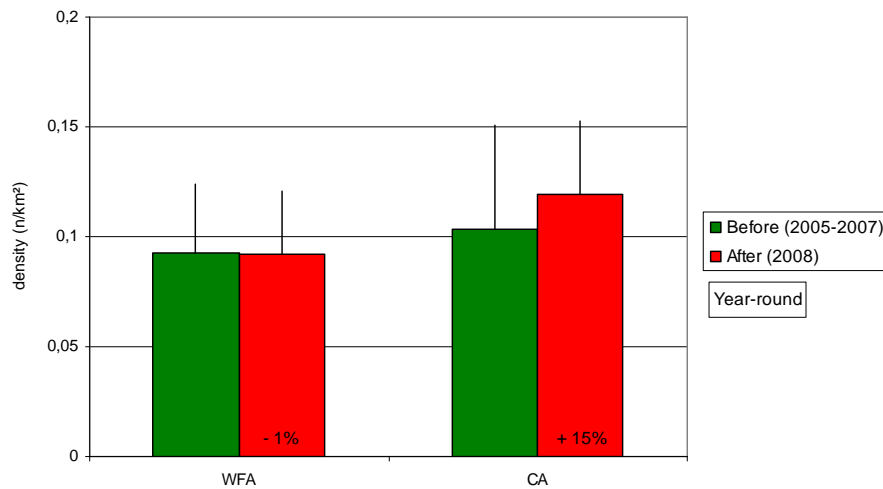In the WFA-TTB as well as the CA-TTB, densities of Sandwich tern stayed more or less the same.

Figure 31. Comparison of the year-round densities of Sandwich tern in the WFA-TTB and the CA-TTB during the reference period 2005-2007 and 2008 (+ std. error).

Common tern (*Sterna hirundo*)

In 2008 densities in the WFA-TTB increased with a factor 5. The increased density in the WFA-TTB is due to a very high density of Common terns observed at one location in April 2008, and is probably rather coincidental. However much less dramatic, an increase in densities was noticed in de CA-TTB too.
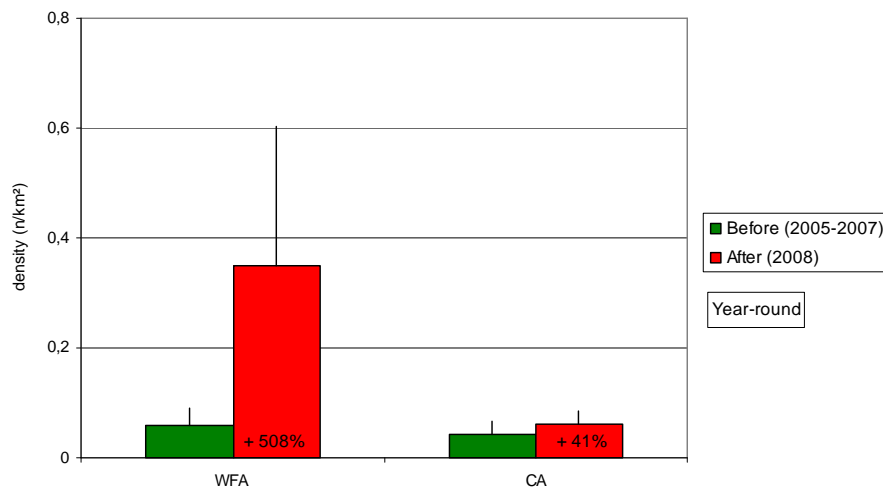

Figure 32. Comparison of the year-round densities of Common tern in the WFA-TTB and the CA-TTB during the reference period 2005-2007 and 2008 (+ std. error).

Common guillemot (*Uria aalge*)

Compared to the reference period, numbers of Common guillemot have dropped considerably in 2008. However, an equally dramatic change in densities has occurred in the CA-TTB, suggesting that the Common guillemot was far less common throughout the area as a whole. Hence, the drop in numbers can not be assigned to the construction of the first wind turbines.
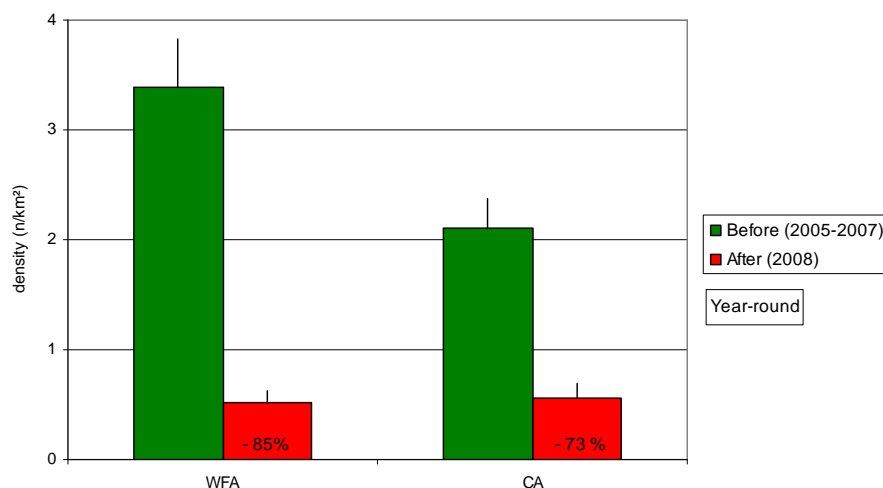

Figure 33. Comparison of the year-round densities of Common guillemot in the WFA-TTB and the CA-TTB during the reference period 2005-2007 and 2008 (+ std. error).

Razorbill (*Alca torda*)

The pattern in Razorbill shows strong comparison to that of its relative the Common guillemot, with a strong decrease in numbers in the WFA-TTB as well as in the CA-TTB.
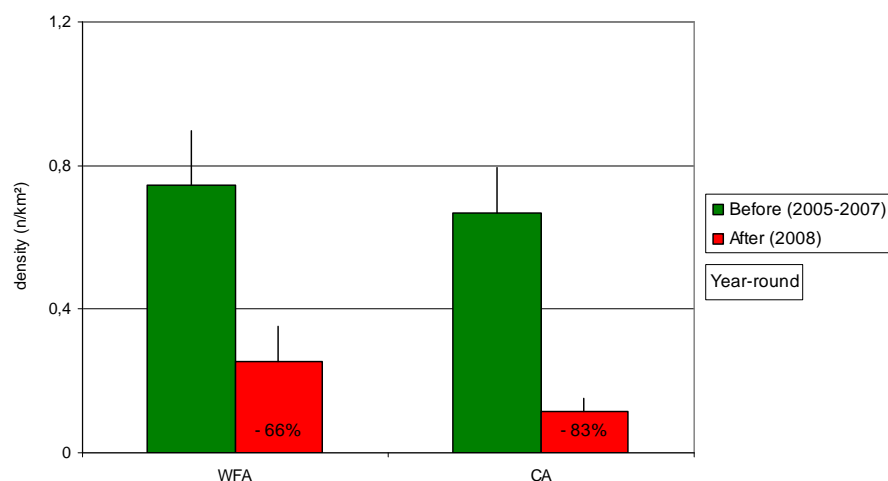

Figure 34. Comparison of the year-round densities of Razorbill in the WFA-TTB and the CA-TTB during the reference period 2005-2007 and 2008 (+ std. error).

4.2 Summary

Except for Sandwich tern there were clear changes in seabird densities in 2008 compared to the reference period. However, in the case of Little gull, Common guillemot and Razorbill, these changes must have taken place on a wider scale than the wind farm area since comparable changes were observed in the control area. Densities of Northern gannet in the WFA-TTB were almost halved which was not the case in the CA-TTB. Future monitoring must reveal if this decrease is in fact due to the presence of the wind farm. Contrastingly, densities of Common terns in the WFA-TTB increased strongly. This was due to a single observation and therefore should be considered with care.

Up until now, there was a major logistic shortcoming since it was prohibited to enter the wind farm itself. Resulting, the presented WFA-TTB densities reflect seabird presence in the immediate surroundings of the first wind turbines (buffer zone), rather than occurrence inside the wind farm. In terms of reliable monitoring, it is absolutely necessary that in coming years, we are allowed to enter the wind farm.

5 Avian importance of the Blighbank wind farm area

5.1 Introduction

In this chapter we discuss the ornithological importance of the future wind farm area at the Blighbank (BB). Before April 2008 very few information was available regarding seabird presence in this part of the BPNS. From April 2008 onwards however, the BB and its immediate surroundings were included in the monthly seabird counts performed by the Research Institute for Nature and Forest (INBO) (Figure 1). This discussion will include all available data up until December 2008.

To assess the relative importance of the future wind farm site at the BB, we compare the observed seabird densities in the area with the mean densities at the rest of the BPNS. Since there is substantial seasonal variation in numbers as well as species composition, the dataset was first split into seasons:

- Winter: December – February
- Spring: March – May
- Summer: June – August
- Autumn: September – November

Analogous to the methodology in Chapter 2, the 'impact area' (WFA-BB) corresponds to the wind farm area surrounded by a buffer zone of 3km. The width of this buffer zone was chosen based on literature research. Extensive radar and visual observation studies in Denmark and Sweden showed that migrating birds may already show avoidance behaviour from up to 3 km (Christensen *et al.* 2004, Kahlert *et al.* 2005, Pettersson *et al.* 2005). Hence, a buffer zone of 3 km around the wind farm area makes relatively sure that potential impacts are limited to this zone exclusively. Thereafter, the BPNS was overlaid by a grid of 2x2 km cells. Every grid cell overlapping for at least one third of its surface with the impact area was assigned to the subzone WFA-BB, while all grid cells with their centroid within the boundaries of the Belgian part of the North Sea were assigned to the subzone BPNS (Figure 35). The mean densities in the WFA-BB and the BPNS were calculated by first calculating the mean for each grid cell, before calculating the means per subzone. This way, we compensated for the skewed counting effort throughout the area. Take notice of the fact that part of the WFA-BB falls on Dutch territorial waters. In this part of the WFA-BB very few counts took place since counts were only to be conducted on Belgian territory.
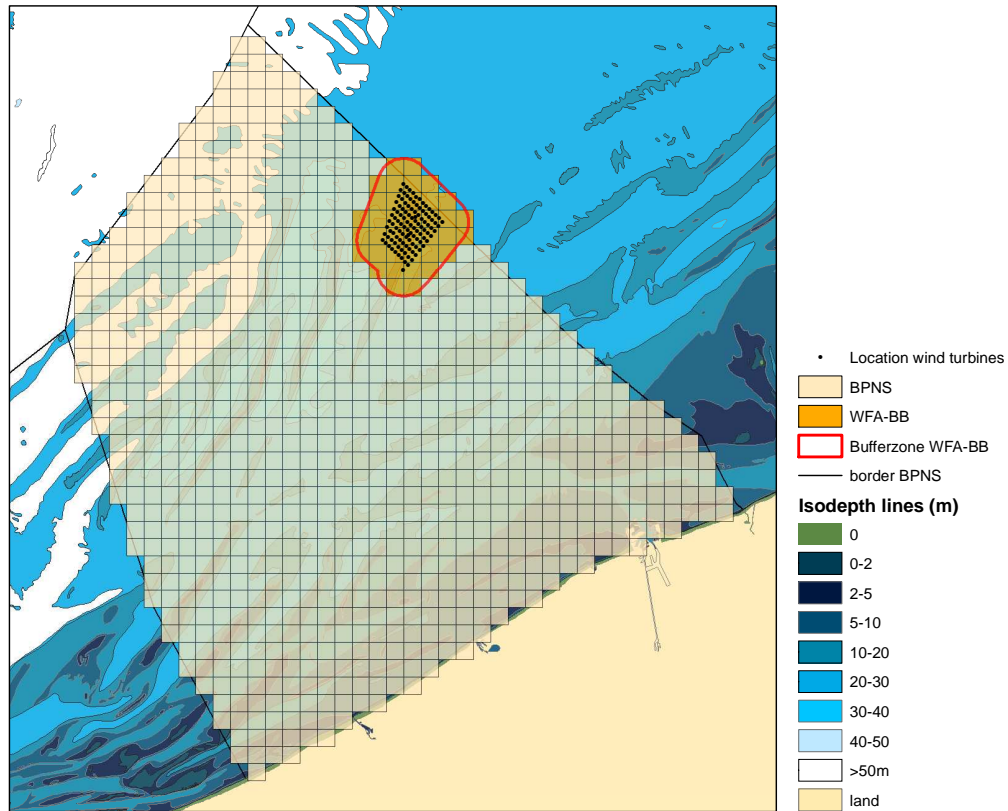
Figure 35. Grid of 2x2 km cells used as a base for comparison of seabird densities in the impact area WFA-BB and the BPNS.

5.2 Seabird densities at the Blighbank

5.2.1 General

Throughout the year, mean densities in the WFA-BB never exceed those on the BPNS as a whole (Figure 36). During spring and summer months, densities in the WFA-BB are very low. This is not surprising since that time of year, the seabird community is largely dominated by coast bound species like gulls and terns. In contrast, densities are relatively high during autumn and especially winter, when the area holds seabird densities of respectively 5 and 8 birds per km².
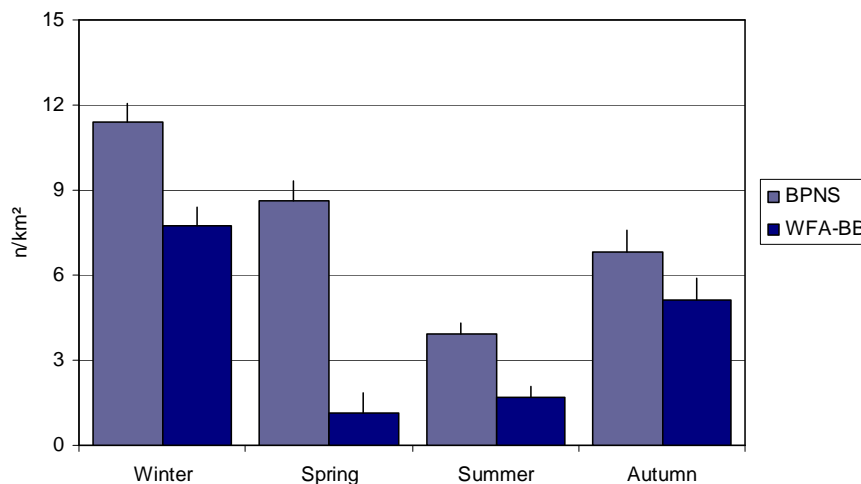

Figure 36. Seabird densities (n/km²) at the WFA-BB compared to the BPNS as a whole.

Figure 37 shows the composition of the seabird community in the WFA-BB (compare with Figure 4). The species composition is generally spoken less rich compared to that on the BPNS. Inshore birds like Common scoter, Great crested grebe and Black-headed gull are completely absent in the impact area. Other inshore birds like terns and divers were observed occasionally, but in much lower densities compared to the inshore zone.

Diversity is at its highest during winter months, when Northern gannet, Kittiwake, Common guillemot and several species of gull dominate the seabird community. In spring, the seabird densities are generally low, but small numbers of Little gull, Common guillemot and Lesser black-backed gull occur. Densities remain low during the course of summer, with Lesser black-backed gull being the most common species. In autumn, large numbers of 'true' seabirds arrive and migrate through, especially Black-legged kittiwake and Northern gannet.
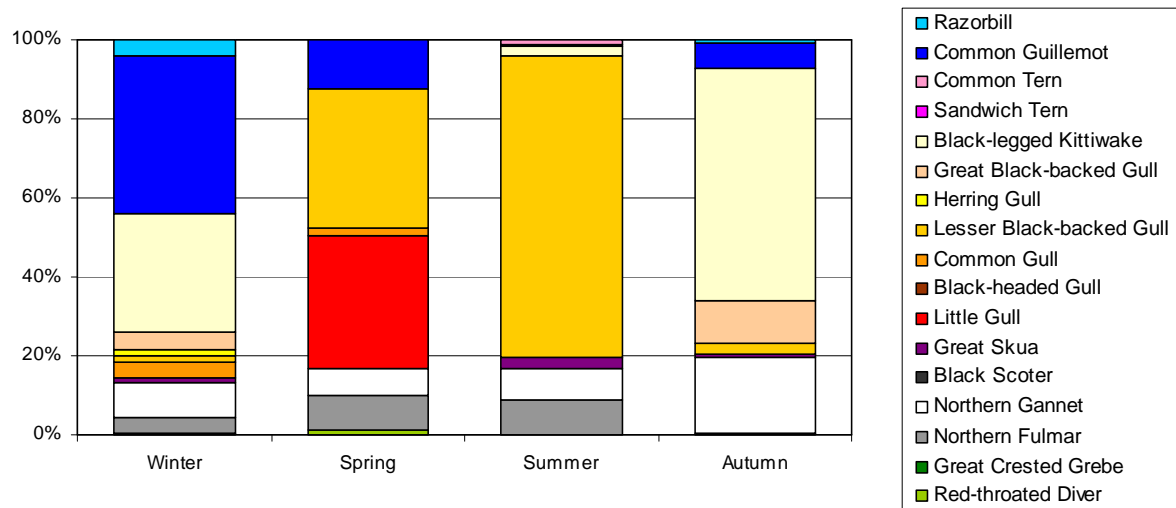
Figure 37. Seasonal variation in seabird community (blue = auks; pink = terns; yellow-red = gulls; purple = Great skua; black = Common scoter; white = Northern gannet; grey = Northern fulmar; green = divers & grebes).

Table 6 compares seasonal densities in the WFA-BB and the BPNS. Seen its far shore location, the WFA-BB is of no importance to divers, grebes, scoters and terns. Six seabird species do occur in relatively high densities, namely Northern gannet, Great skua, Little gull, Lesser black-backed gull, Black-legged kittiwake and Common guillemot. These are discussed in detail in §5.2.2.

Table 6. Seasonal bird densities (n/km²) in the future wind farm area at the Blighbank (WFA-BB) compared to densities at the BPNS as a whole (1992-2008).

(species marked in bold meet one of following criteria: density in the WFA exceeds 1 bird/km² during one or more seasons; density in the WFA exceeds 0,25 bird/km² during one or more seasons in case of a protected species (*); WFA-density is at least 50% higher than the BPNS-density)

	Winter		Spring		Summer		Autumn	
	WFA-BB	BPNS	WFA-BB	BPNS	WFA-BB	BPNS	WFA-BB	BPNS
Number of grid cells	27	778	17	676	25	642	29	736
Red-throated diver	0,02	0,23	0,01	0,03	0,00	0,00	0,00	0,04
Great crested grebe	0,00	0,46	0,00	0,04	0,00	0,00	0,00	0,05
Northern fulmar	0,31	0,43	0,10	0,25	0,15	0,14	0,02	0,51
Northern gannet	**0,67**	0,42	0,08	0,27	0,14	0,13	0,98	1,02
Common scoter	0,00	0,53	0,00	0,78	0,00	0,04	0,00	0,08
Great skua	**0,10**	0,01	0,00	0,01	**0,05**	0,03	0,04	0,05
Little gull*	0,00	0,17	**0,38**	0,70	0,00	0,03	0,00	0,25
Common gull	0,32	1,24	0,02	0,53	0,00	0,01	0,01	0,26
Lesser black-backed gull	0,12	0,27	0,40	3,00	**1,29**	1,89	0,13	0,95
Herring gull	0,13	0,63	0,00	0,98	0,00	0,56	0,00	0,51
Great black-backed gull	0,34	1,12	0,00	0,15	0,00	0,05	0,56	0,70
Black-legged kittiwake	**2,31**	1,87	0,00	0,38	0,05	0,04	**2,99**	1,22
Sandwich tern*	0,00	0,00	0,00	0,15	0,01	0,23	0,00	0,01
Common tern*	0,00	0,00	0,00	0,26	0,02	0,64	0,00	0,02
Common guillemot	**3,10**	3,26	0,14	0,88	0,00	0,01	0,34	0,80
Razorbill	0,30	0,67	0,00	0,13	0,00	0,00	0,04	0,20

5.2.2 Species discussion

Northern gannet (*Morus bassanus*)

Densities at the BPNS peak in October – November, and resulting, the BPNS holds a mean of 1.02 gannets per km² during autumn. Meanwhile, the WFA-BB holds a corresponding number of Northern gannets (0.98 ind./km²). During winter, the density of Northern gannets in the WFA-BB (0.67 ind./km²) exceeds the BPNS density (0.42 ind./km²).

The distribution maps in Figure 39 & Figure 40 show that Northern gannets generally occur homogenously dispersed outside the near shore zone, with a concentration around the Hinderbanken. Considering this, the WFA-BB cannot be designated as being particularly important to this species.
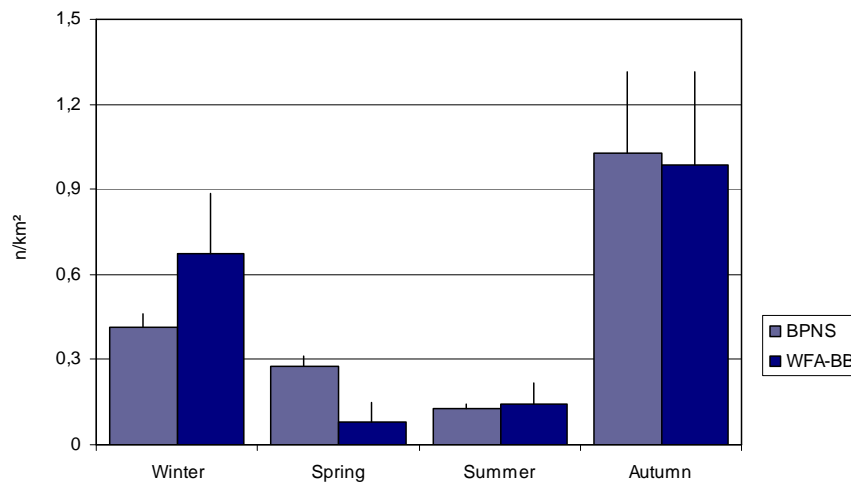

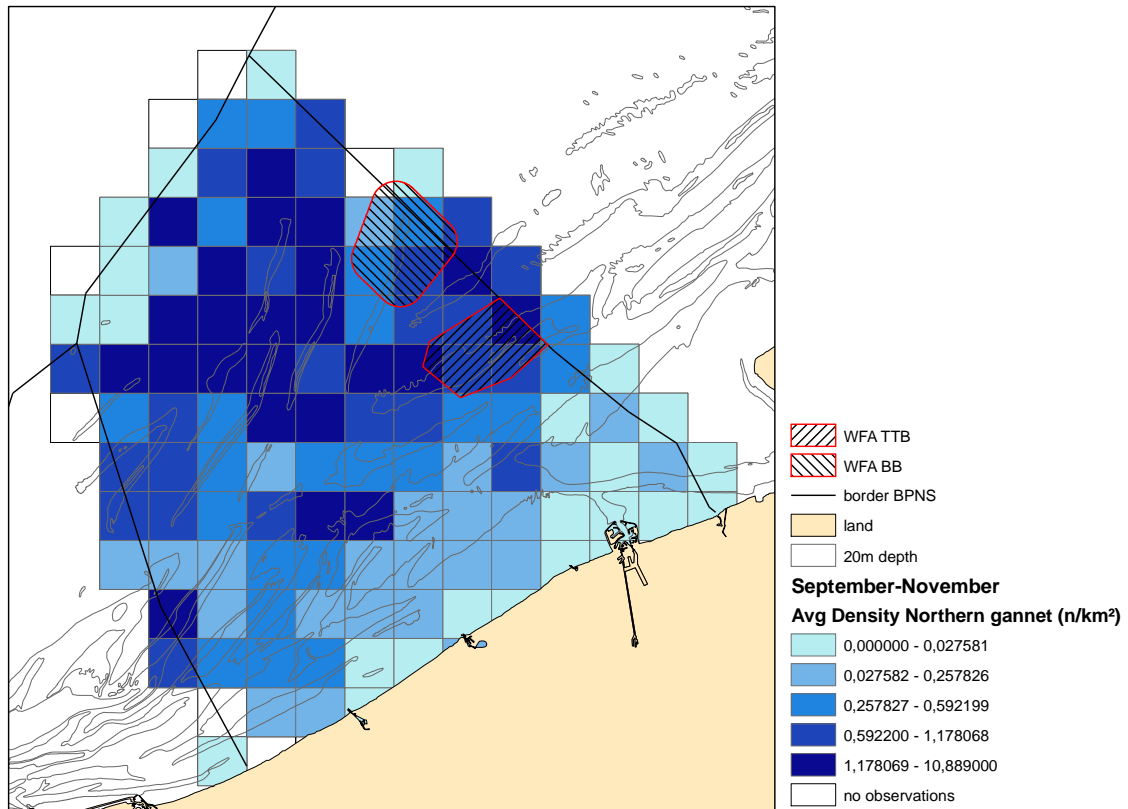**Figure 38. Seasonal densities of Northern gannet in the BPNS and in the WFA-BB (+ std. error).**

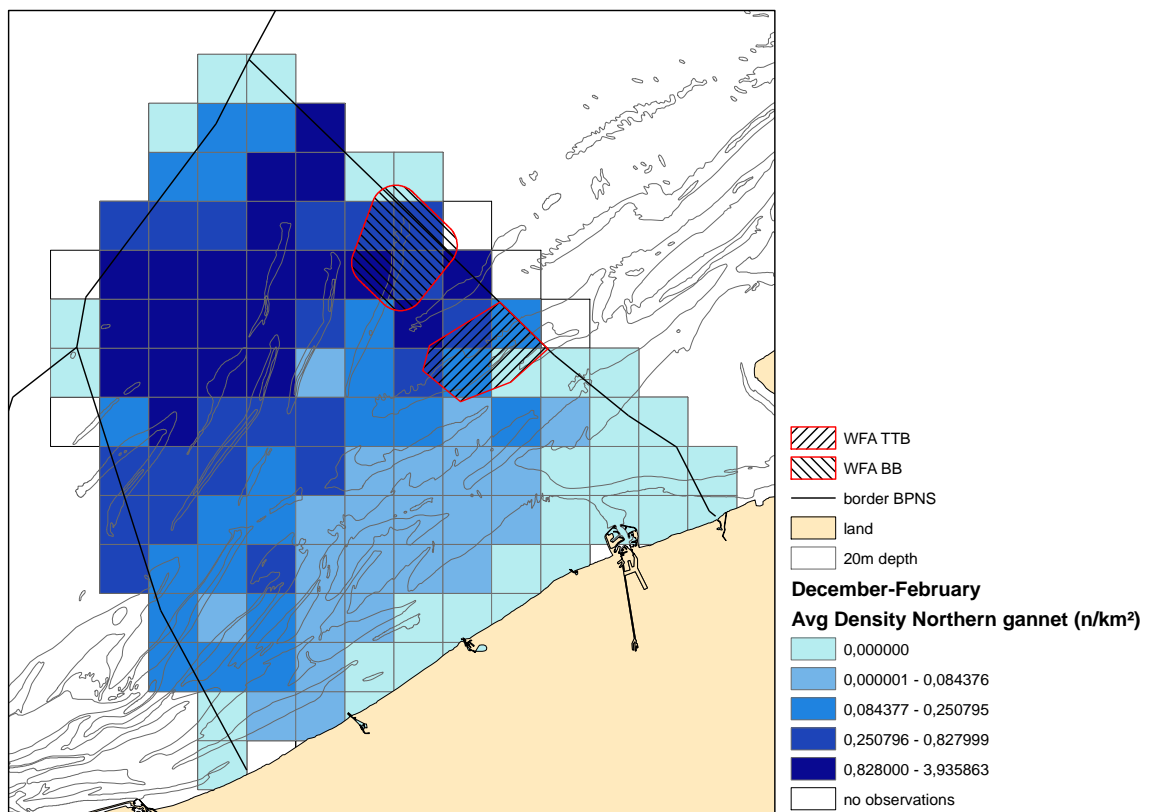**Figure 39. Autumn distribution of Northern gannet in the BPNS.**

Figure 40. Winter distribution of Northern gannet in the BPNS.

Great skua (*Stercorarius skua*)

Great skuas occur in low to very low densities throughout the BPNS. It is most common during autumn, with a mean of 0.05 individuals per km². At the WFA-BB, this rare and vulnerable species is present in increased numbers during winter and summer, when it holds a mean of 0.10 and 0.05 individuals per km² respectively.

The winter distribution map (Figure 42) shows that Great skuas are concentrated in two areas, one in the southwest of the BPNS (Vlaamse banken) and one in and around the WFA-BB. Because of this, we will pay careful attention to the occurrence of Great skuas in the WFA-BB in future monitoring years.
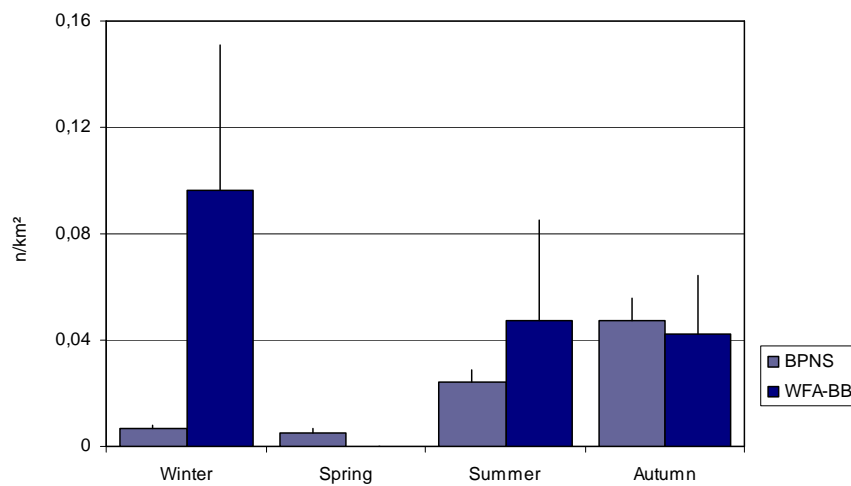

Figure 41. Seasonal densities of Great skua in the BPNS and the WFA-BB (+ std. error).
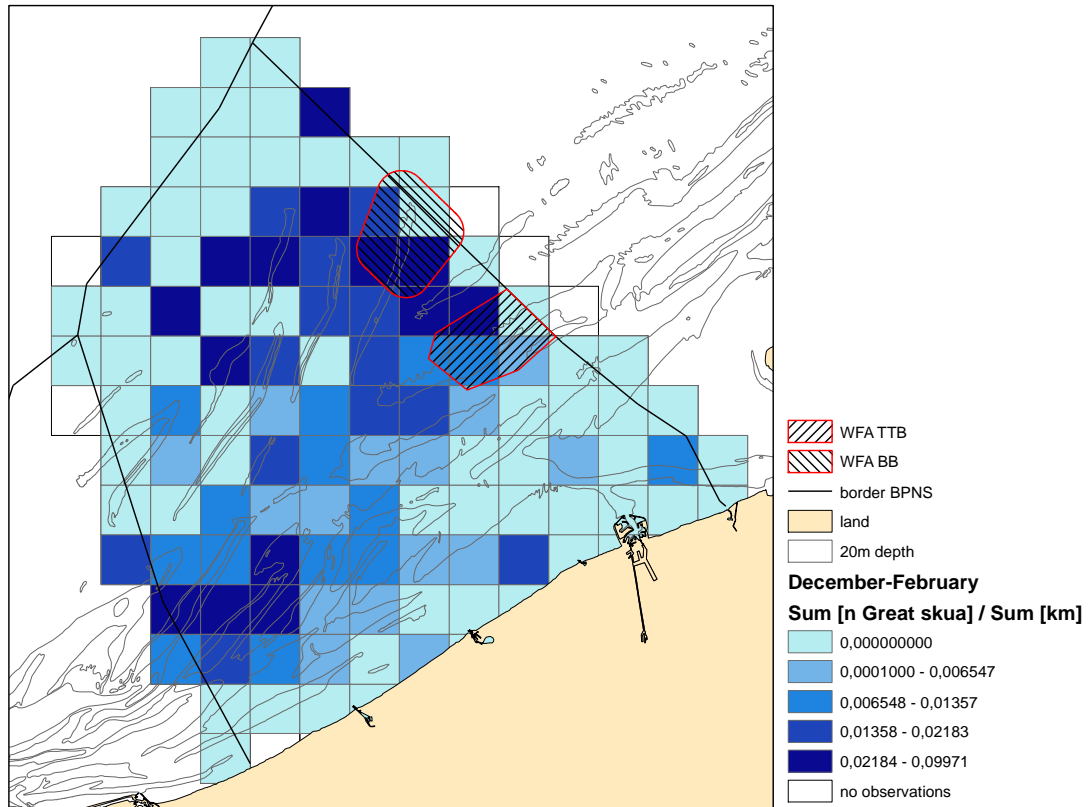
Figure 42. Numbers of observed Great skuas per km sailed (n/km) during winter months.

Little gull (*Larus minutus*)

At the BPNS, Little gulls are present almost year round, with marked seasonal variation. Highest densities are present during spring and autumn migration periods, mainly in April and September. Mean seasonal density reaches 0.70 individuals per km² during spring months. During the same period, the mean density at the WFA-BB amounts up to 0.38 individuals/km². Apparently this protected species migrates through the area during spring.

The spring distribution map (Figure 8) however shows that migration is mainly confined to a 40km wide band along the coast and the WFA-BB is located just outside this migration corridor. Nevertheless, considering the species' protection status, the occurrence of Little gulls in the WFA-BB will be further monitored.
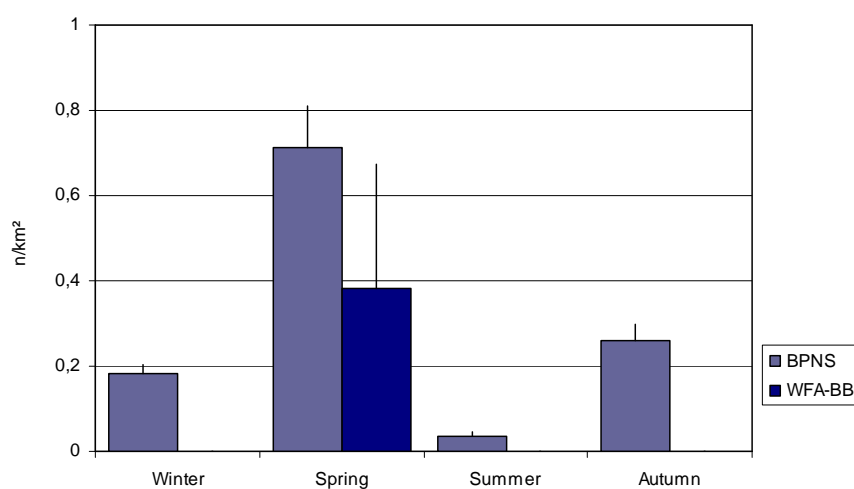

Figure 43. Seasonal densities of Little gull in the BPNS and the WFA-BB (+ std. error).

Lesser black-backed gull (*Larus fuscus*)

This gull species is the most common seabird at the BPNS during spring and summer, with mean densities of more than 3.0 birds per km². The species is less coast bound compared to the closely related Herring gull, and especially during spring migration Lesser black-backed gulls occur widespread across the BPNS. The WFA-BB holds relatively high densities during summer with a maximum density of 1.29 birds per km². The WFA-BB appears to be located right on the edge of the species' main summer distribution within 40km from the coast (Figure 45). However, the densities in the WFA-BB never exceed those on the BPNS as a whole, and the area cannot be considered to be of particular value to this species.
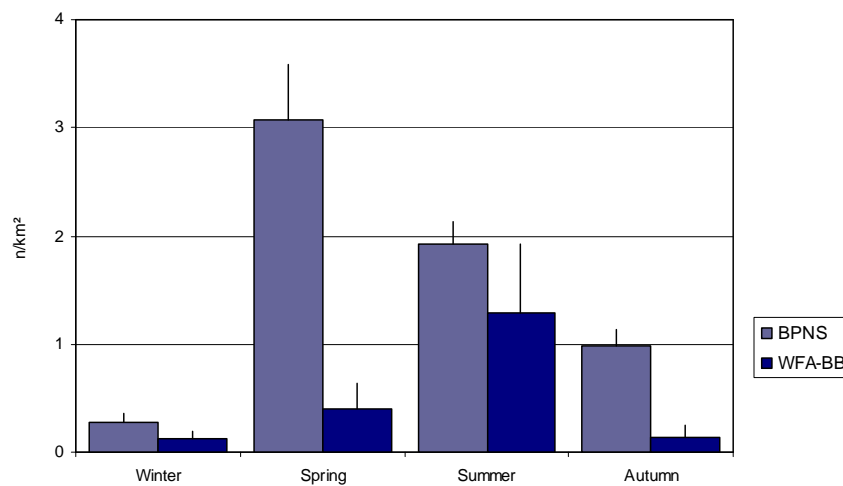

Figure 44. Seasonal densities of Lesser black-backed gull in the BPNS and the WFA-BB (+ std. error).
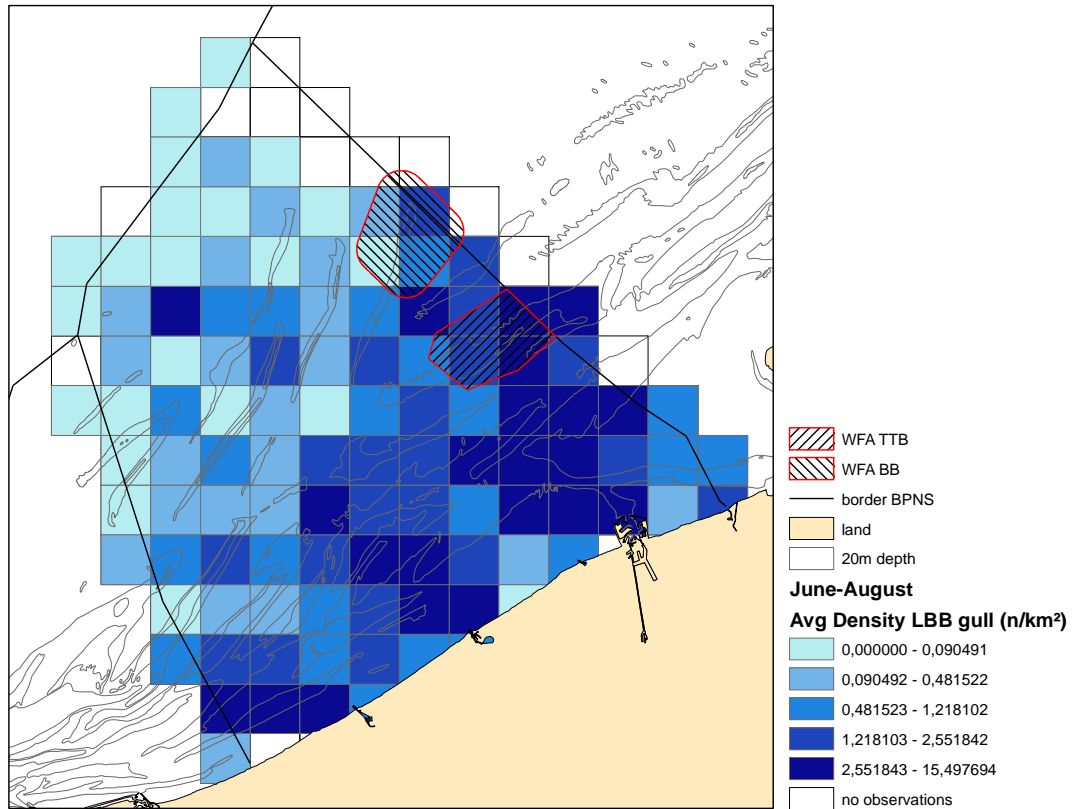
Figure 45. Summer distribution of Lesser black-backed gull in the BPNS.

Black-legged kittiwake (*Rissa tridactyla*)

This offshore species is present at the BPNS in highest numbers during autumn and winter (respectively 1.31 and 1.87 individuals per km²). While during winter, corresponding numbers are present in the WFA-BB and the BPNS, Black-legged kittiwakes appear to be much more common in the WFA-BB during autumn.

Based on the distribution maps in Figure 47 & Figure 48, Black-legged kittiwakes occur relatively homogenously dispersed outside the near shore zone, and the WFA-BB cannot be acknowledged to be more important compared to other offshore areas. Therefore, the WFA-BB is of no particular value to this species.
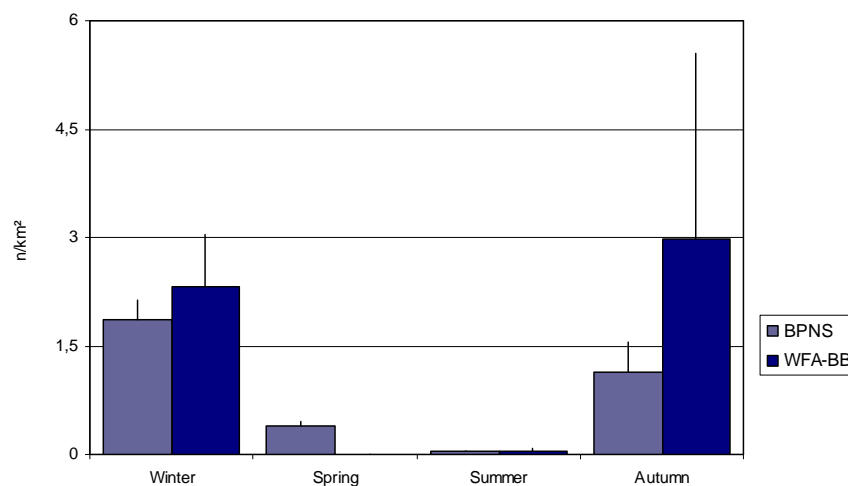

Figure 46. Seasonal densities of Black-legged kittiwake on the BPNS and the WFA-BB (+ std. error).
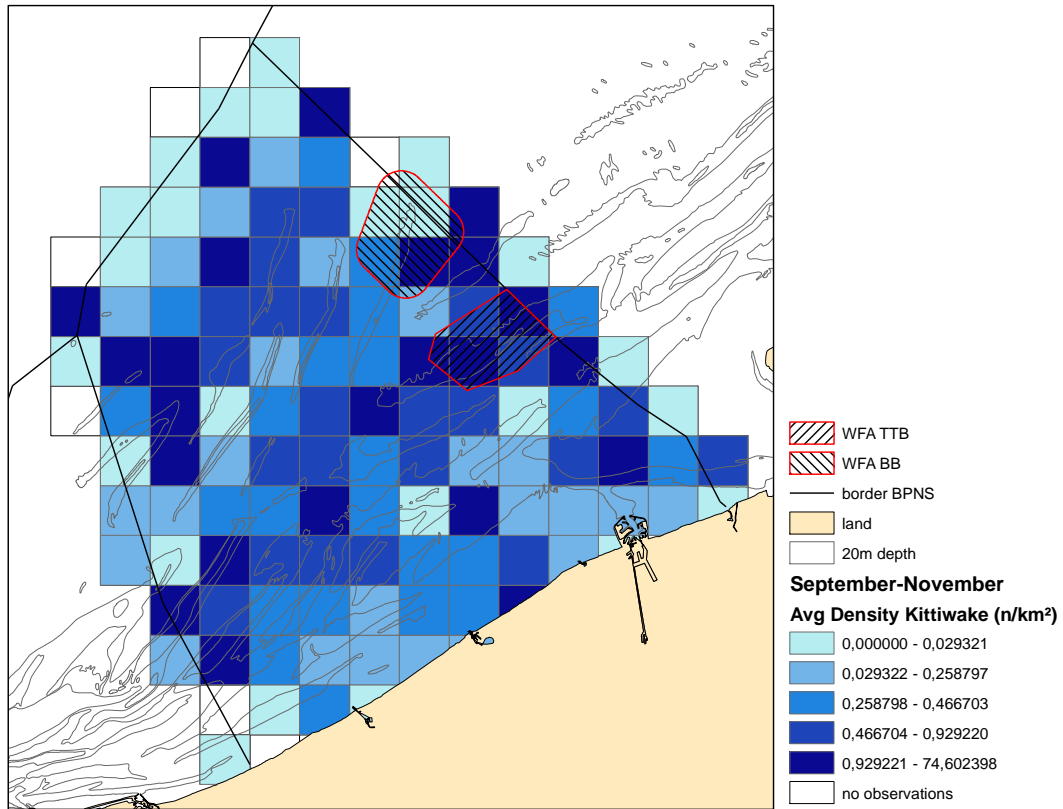
Figure 47. Autumn distribution of Black-legged kittiwake on the BPNS.

September-November
Avg Density Kittiwake (n/km²)
- 0,000000 - 0,029321
- 0,029322 - 0,258797
- 0,258798 - 0,466703
- 0,466704 - 0,929220
- 0,929221 - 74,602398
- no observations

WFA TTB
WFA BB
border BPNS
land
20m depth
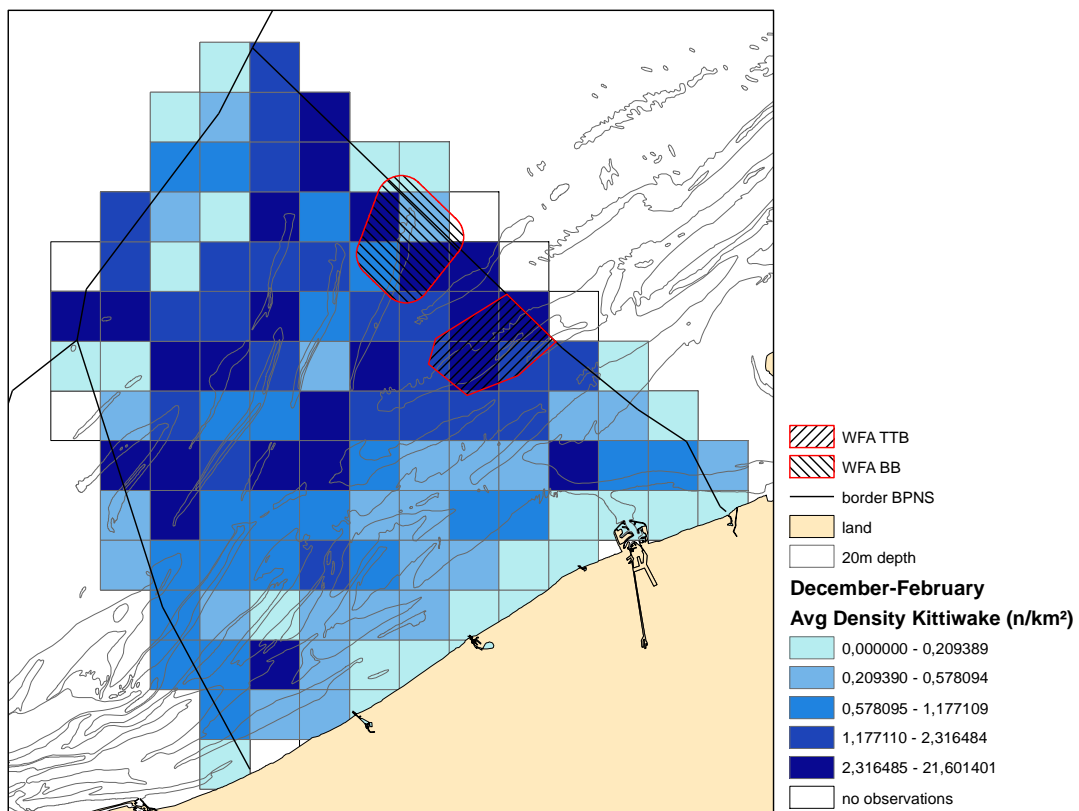
Figure 48. Winter distribution of Black-legged kittiwake on the BPNS.

December-February
Avg Density Kittiwake (n/km²)
- 0,000000 - 0,209389
- 0,209390 - 0,578094
- 0,578095 - 1,177109
- 1,177110 - 2,316484
- 2,316485 - 21,601401
- no observations

WFA TTB
WFA BB
border BPNS
land
20m depth

62

Common guillemot (*Uria aalge*)

With a mean density of 3.26 individuals per km², the Common guillemot is the most common seabird at the BPNS during winter. The species is almost equally common at the WFA-BB, with a mean winter density of 3.10 Common guillemots per km².

Apart from the near shore zone east of Ostend, Common guillemots occur homogenously spread throughout the BPNS in moderately high to high densities. Based on the observed densities and the distribution pattern displayed in Figure 50, the WFA-BB cannot be assigned as being of particular importance to this species. Its high winter densities do make Common guillemot a suitable monitoring species.

Figure 49. Seasonal densities of Common guillemot on the BPNS and the WFA-BB (+ std. error).

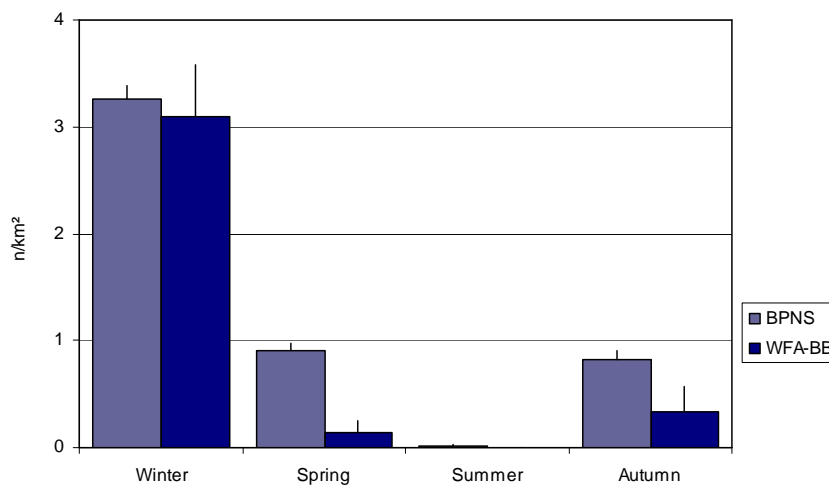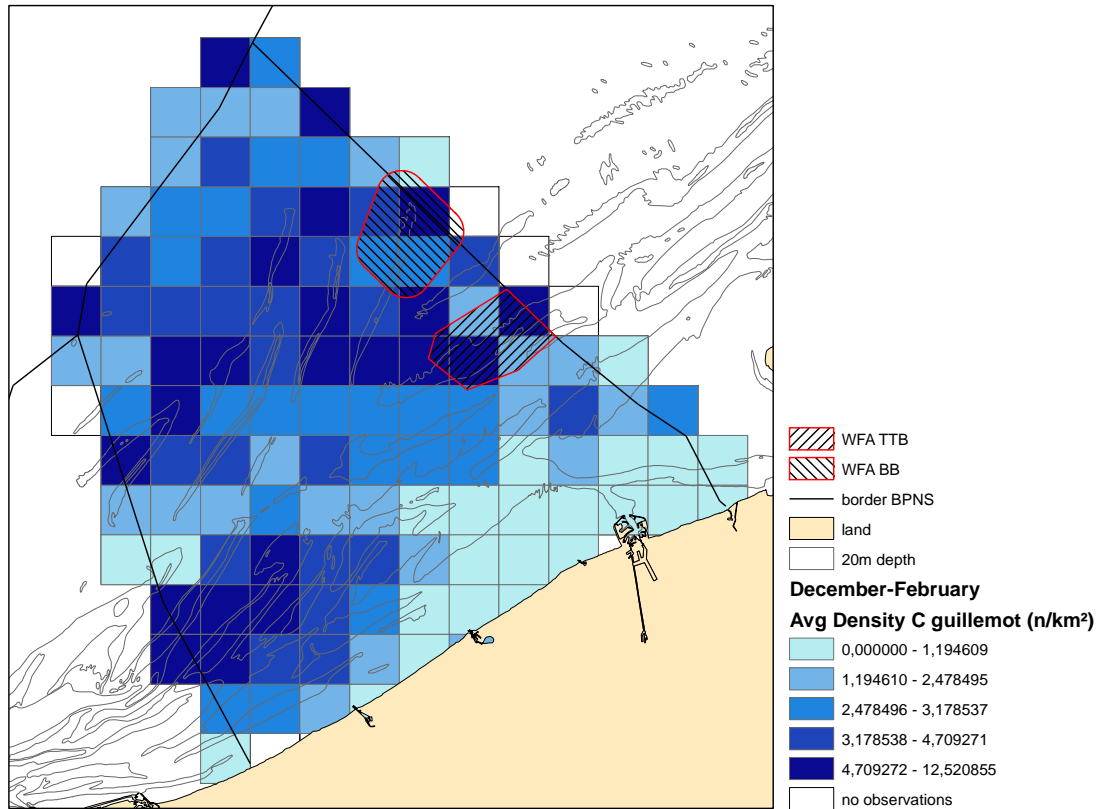**Figure 50. Winter distribution of Common guillemot on the BPNS.**

Legend:

- WFA TTB
- WFA BB
- border BPNS
- land
- 20m depth

December-February
Avg Density C guillemot (n/km²)

- 0,000000 - 1,194609
- 1,194610 - 2,478495
- 2,478496 - 3,178537
- 3,178538 - 4,709271
- 4,709272 - 12,520855
- no observations

5.2.3   Conclusions

Based on the previous discussion we conclude that:

- The WFA-BB is of no particular value to Red-throated diver, Great crested grebe, Northern fulmar, Common scoter, Common gull, Herring gull, Great black-backed gull, Sandwich tern, Common tern and Razorbill

- The WFA-BB is not particularly valuable to the following species, although increased or high densities may occur: Northern gannet, Lesser black-backed gull, Black-legged kittiwake, Common guillemot

  → *Considering their high densities in the reference period, these species are well suitable for monitoring regarding displacement effects by the future wind farm*

- The WFA-BB is probably of particular value to Great skua and Little gull

  → *Future monitoring is needed to assess the actual value of the WFA-BB to these species. To accurately assess possible effects of the future wind farm, migration behaviour and occurrence of these birds in the WFA-BB needs to be investigated in detail. Research should also focus on displacement through avoidance behaviour, as well as migration flux and collision risk.*

6 Control area Blighbank

6.1 Introduction

To accurately assess the impact of human structures at sea, it is not sufficient to perform a before-after comparison. Ideally, the changes in the impact area are put in perspective by comparing these with possible changes in a control area. Naturally, changes in bird community and densities are not necessarily induced by local changes in the marine environment, and might as well be induced by larger scale processes. Such large scale events include temporary influxes of seabirds due to specific weather conditions or food availability elsewhere, as well as changes in population level.

In this chapter we will delineate a suitable control area (CA-BB) for the future wind farm at the Blighbank (WFA-BB). Analogous to earlier analyses performed for the Thorntonbank (Vanermen *et al.* 2006), we took in account a buffer area of 3km surrounding the future turbines. Extensive radar and visual observation studies in Denmark and Sweden showed that migrating birds may already show avoidance behaviour from up to 3km (Christensen *et al.* 2004, Kahlert *et al.* 2005, Pettersson *et al.* 2005). Hence, a buffer zone of 3km ensures that potential impacts are largely restricted to this zone. During all seasons, the bird densities in the CA-BB have to correspond as much as possible to those in the WFA-BB. In Vanermen *et al.* (2006), a control area (CA-TTB) for the wind farm area at the Thorntonbank (WFA-TTB) was already delineated. To this end, avian occurrence at the Thorntonbank was compared with 13 areas of equal depth, by visually interpreting graphs displaying seasonal bird densities and bird community, supported by several statistical analysis (cluster analysis, correspondence analysis and TWINSPAN). Based on the results obtained during this study, and taking in consideration several logistical and practical aspects, we are now able to simplify this process. Hence, two possible areas are proposed. Naturally, it would be very practical if the current CA-TTB could serve as a control area for the WFA-BB as well. On the other hand, when we compare the results of the reference situation of the marine avifauna in the WFA-BB (see Chapter 5) with the results in Vanermen *et al.* (2006), we expect the bird community to be more closely related to that of the far shore community of the Hinderbanken. Therefore, an area adjacent to the CA-TTB was delineated including the remaining part of the Blighbank itself and the nearby sandbank Oosthinder (Figure 51).
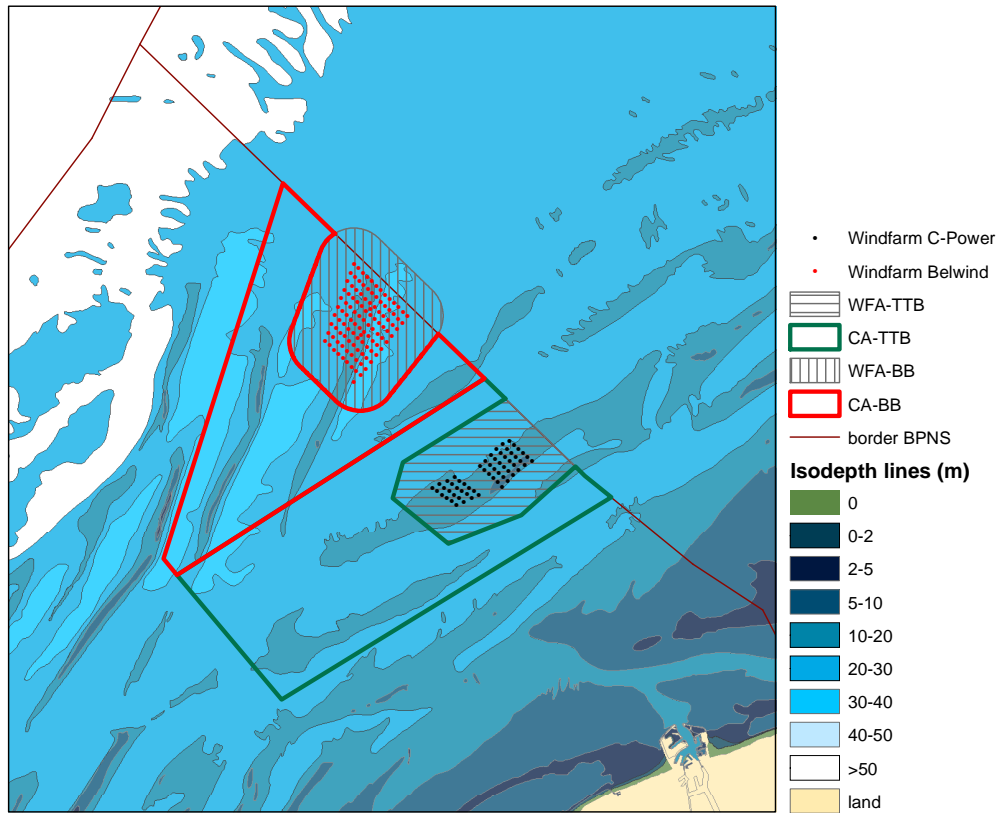
Figure 51. Proposed control areas for the future wind farm area at the Blighbank (WFA-BB).

6.2   Results

6.2.1   Seabird community

Since seabird densities in the WFA-BB are generally very low during spring and summer (see §5.2.1), this section will mainly focus on winter and autumn densities.

During winter, seabird composition in the WFA-BB is most comparable to the near CA-BB (Figure 52). These areas hold corresponding numbers of Northern gannets, Northern fulmars, Black-legged kittiwakes and auks. Densities in the CA-TTB are twice those observed in the WFA-BB. This is mainly due to a higher abundance of gulls (Black-legged kittiwake, Great black-backed gull, Common gull).
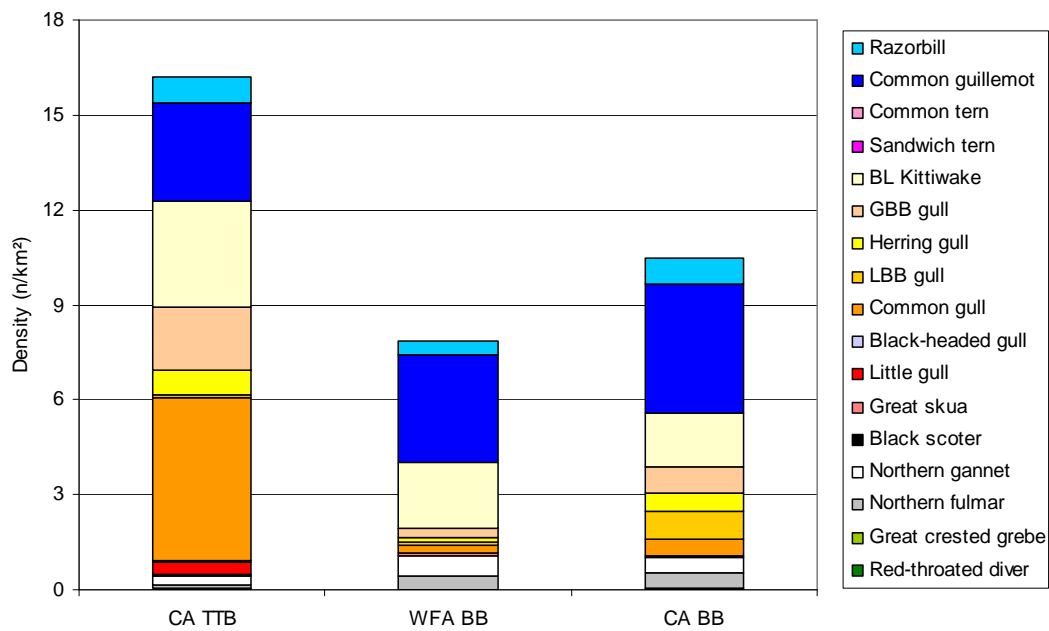

Figure 52. Winter densities of seabirds in the future wind farm area at the Blighbank (WFA-BB) and two proposed control areas CA-TTB and CA-BB.

During autumn, the seabird community in the WFA-BB is dominated by Northern gannets, Great black-backed gulls and Black-legged kittiwakes. Unfortunately, there is poor correspondence with both proposed control areas.
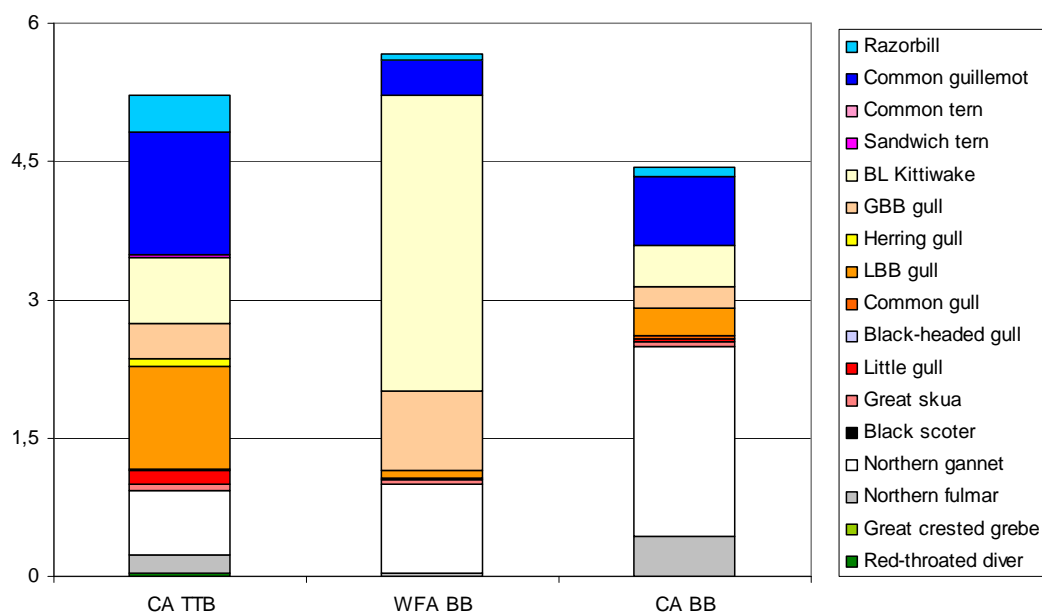

Figure 53. Autumn densities of seabirds in the future wind farm area at the Blighbank (WFA-BB) and two proposed control areas CA-TTB and CA-BB.

6.2.2 Species discussion

Northern gannet (*Morus bassanus*)

There is poor agreement in densities between the WFA-BB and both proposed control areas. In general, the species is most common during autumn, when densities in the WFA-BB correspond most to those in the CA-TTB. Regarding winter densities however, the WFA-BB shows more agreement with the CA-BB.
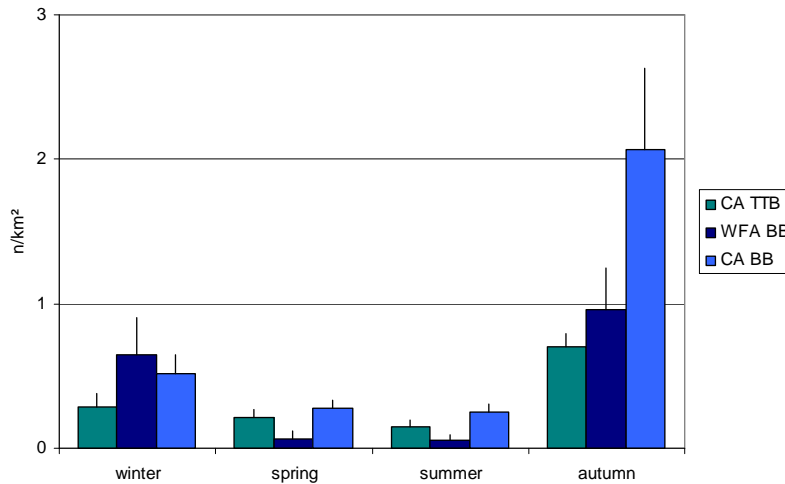

Figure 54. Seasonal densities of Northern gannet in the WFA-BB, CA-TTB & CA-BB (+ std. error).

Great skua (*Stercorarius skua*)

In winter, the WFA-BB holds a high density of Great skuas, which is almost six times higher than in the proposed control areas. Rare species are difficult to monitor, since encounters are more coincidental compared with common species, often resulting in skewed results. During summer and autumn however, almost equal densities of Great skua occur in the WFA-BB and the CA-BB. Based on these well corresponding numbers, the CA-BB seems most suitable as a control area for the WFA-BB.
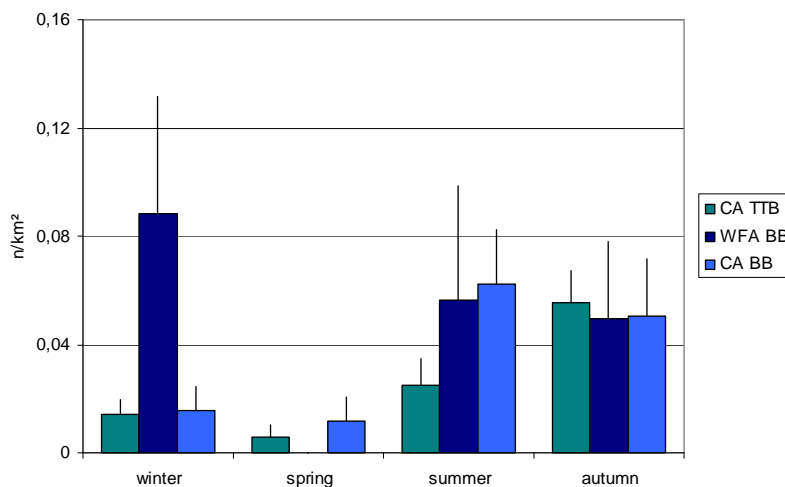

Figure 55. Seasonal densities of Great skua in WFA-BB, CA-TTB & CA-BB (+ std. error).

Little gull (*Larus minutus*)

As can be deducted from Figure 7 to Figure 9, Little gulls are mainly confined to a 40km wide band along the coast. Both the WFA-BB and CA-BB are located just outside this distribution range, and resulting, Little gulls are much more common in the CA-TTB (Figure 56). Hence, the CA-BB is most suitable as a control area for the WFA-BB.
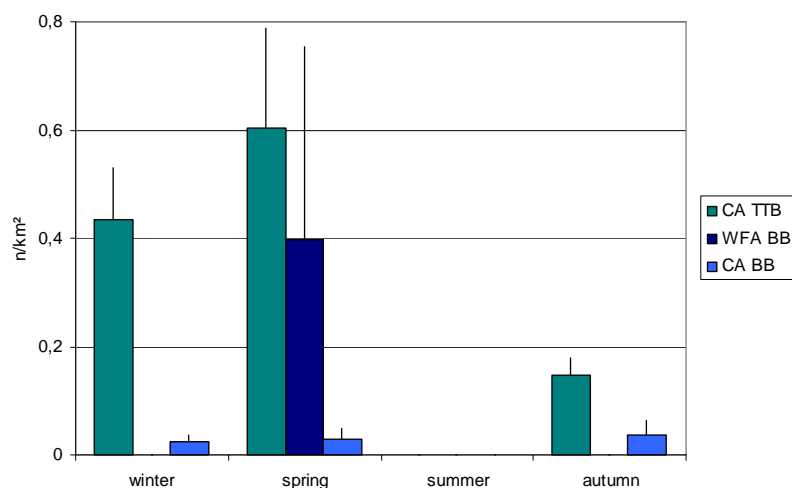
Figure 56. Seasonal densities of Little gull in the WFA-BB, CA-TTB & CA-BB (+ std. error).

Lesser black-backed gull (*Larus fuscus*)

Except for winter, the CA-TTB holds much higher densities of Lesser black-backed gull compared to the WFA-BB and CA-BB. To this species also, the CA-BB is most suitable as a control area.
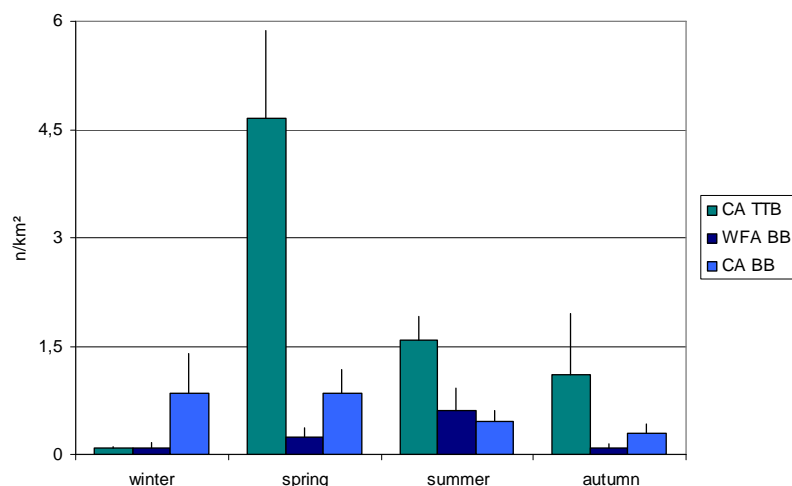

Figure 57. Seasonal densities of Lesser black-backed gull in the WFA-BB, CA-TTB & CA-BB (+ std. error).

Black-legged kittiwake (*Rissa tridactyla*)

During winter, the WFA-BB and CA-BB hold well corresponding densities of Black-legged kittiwake. Meanwhile the species is almost twice as common in the CA-TTB. In autumn, a highly increased density of kittiwakes occurs in the WFA-BB, which is due to one observation of a very a large number of birds in the transect, associated with a fishing vessel. Aggregated occurrence may result in strongly skewed data, as is the case here. Based on the winter occurrence however, the CA-BB seems of slightly higher suitability than the CA-TTB.
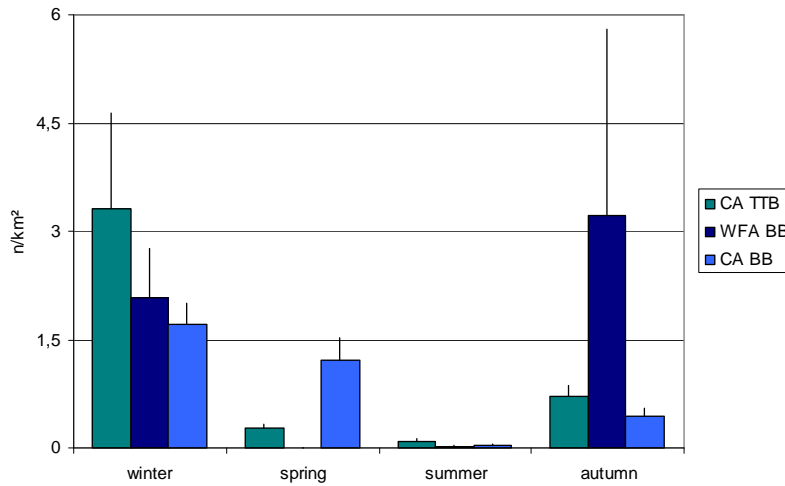
Figure 58. Seasonal densities of Black-legged kittiwake in the WFA-BB, CA-TTB & CA-BB (+ std. error).

Common guillemot (*Uria aalge*)

The winter density of Common guillemot in the WFA-BB corresponds well to those in proposed control areas. During spring and autumn, observed densities in the WFA-BB were clearly lower than in the CA-TTB and CA-BB. Based on these results both areas seem suited.

Figure 59. Seasonal densities of Common guillemot in the WFA-BB, CA-TTB & CA-BB (+ std. error).

6.2.3 Conclusion

In Chapter 5 it was concluded that six species of seabird occur in high or increased densities in the WFA-BB. In this chapter these spec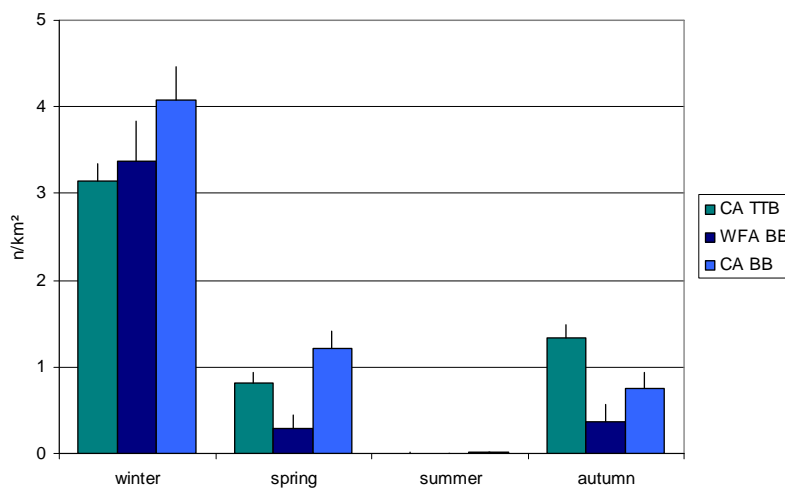ies' seasonal densities in the WFA-BB were compared to those in two proposed control areas. Based on a visual interpretation of the graphs displayed in the above paragraphs, the CA-BB seems slightly more suitable than the CA-TTB. To provide a more objective measure for equality, the differences in seasonal bird densities between the WFA-BB and both proposed control areas were summed (Table 7).

The numbers in the first 2 columns in Table 7 represent the sum of the absolute differences in (relevant) seasonal densities in the WFA-BB on the one hand and both control areas on the other hand. The last two columns provide a standardised measure, which equals the weighted mean of the proportional differences in seasonal densities. Either way, absolute as well as standardized differences in bird densities are in favour of the control area CA-BB including the 'Oosthinderbank' and the 'Blighbank'.

Table 7. Differences in seabird densities between the WFA-BB on one hand and CA-TTB and CA-BB on the other hand.

Species	Seasons	CA-TTB	CA-BB	CA-TTB	CA-BB
		Sum absolute differcence		Standardised difference	
Nothern gannet	Autumn / Winter	0.62	1.24	0.38	0.77
Great skua	Winter / Summer / Autumn	0.11	0.08	0.57	0.41
Little gull	Autumn / Winter / Spring	0.79	0.43	0.51	0.92
Lesser black-backed gull	Spring / Summer	5.39	0.75	6.38	0.88
Black-legged kittiwake	Spring / Summer	3.73	3.15	0.70	0.59
Common guillemot	Autumn / Winter	1.19	1.08	0.32	0.29
	Total	11.82	6.72	8.87	3.87

7   Collision risk migrating seabirds

In this chapter we will model the expected number of collision fatalities among seabirds at the Thorntonbank wind farm. First, we present the results of the flying height assessments. Clearly, the number of victims through collision depends on the proportion of birds flying at rotor height, which is strongly species-specific. Secondly, since the number of collisions is positively correlated to the number of flight movements we estimated the flux of birds through the wind farm area. And lastly, we modelled the chance that birds approaching the wind farm actually collide with the turbine blades. Integrating these results, we are able to make a preliminary estimation of the number of collision victims.

7.1   Flying height

7.1.1   Visual flying height assessment during transect counts

During the seabird counts along fixed monitoring routes, the flying height of all birds was visually estimated and scored as follows:

- 0= beneath the rotor sweep area <31m
- 1= in the rotor sweep area 31-157m
- 2= above the rotor sweep area

Table 8 includes all data collected on flying height during 2005 and 2008. The conclusion is more or less equal to the one presented in Vanermen *et al.* (2006). Some species were never observed flying above 31m, like Northern fulmar, Common guillemot and Razorbill. In contrast, more than 15% of the large gull species Lesser black-backed, Herring and Great black-backed gulls were observed flying at rotor height.

There seems to be considerable day to day variation in the number of birds flying at rotor height, illustrated by the boxplots in Figure 60. Some observation days more than 60% of the Lesser black-backed and Herring gulls flew higher than 31m, which was mainly observed in calm and sunny weather. Collision risk will vary accordingly, in which the weather conditions play a key role.

Table 8. Proportion of birds flying at rotor height, sorted from low to high proportions.

| Species	N	% flying at rotor sweep heights
Great crested grebe	78	0,0%
Northern fulmar	1251	0,0%
Common scoter	801	0,0%
Common guillemot	280	0,0%
Razorbill	59	0,0%
Common tern	3166	0,4%
Sandwich tern	1318	1,1%
Little gull	973	1,3%
Red-throated diver	239	2,5%
Black-legged kittiwake	2682	4,5%
Black-headed gull	1314	5,0%
Northern gannet	2064	5,7%
Great skua	133	7,5%
Common gull	2135	7,9%
Herring gull	1903	14,5%
Lesser black-backed gull	8044	16,7%
Great black-backed gull	1482	17,1%
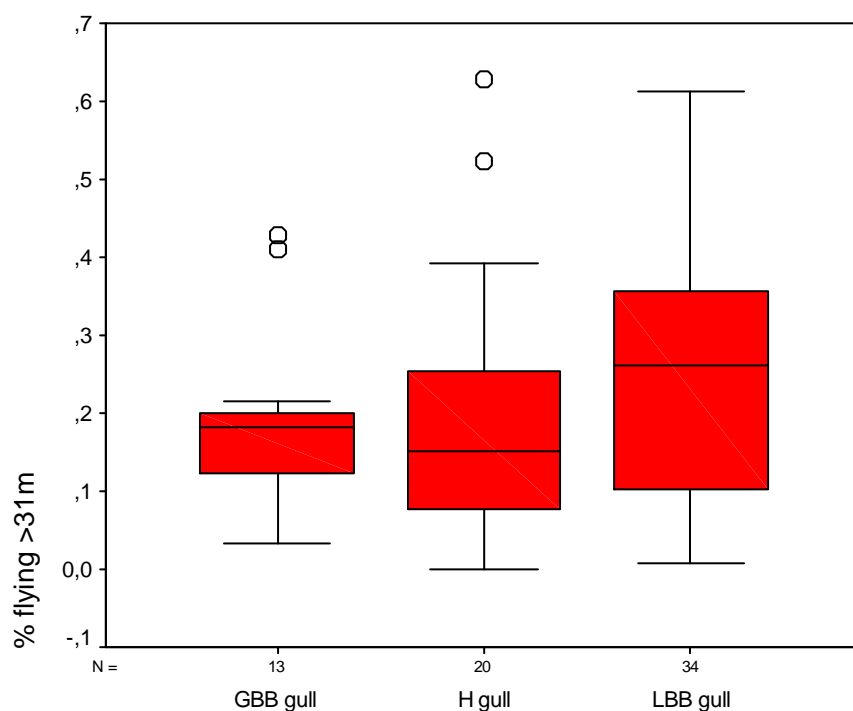
Figure 60. Boxplot of percentages of birds flying at rotor height (only days with more than 10 observations were included in the analysis).

7.1.2   Flying height assessment during flux counts

By means of calibrating our visual height estimations, we used an alternative method to assess flying height during flux counts on 2 observation days in September and October 2008 (see also §7.2). We did so by determining the flight angle and estimating the horizontal distance.

7.1.2.1   Methodology

For this type of assessment, only birds within 200 metres away from the boat were withheld. As in the transect counts, it was visually estimated whether the birds were flying at rotor sweep height or not. Meanwhile, their flight angle was measured using a clinometer, and the distance at which they were flying was estimated (categories: A1=0-25m / A2=25-50m / B=50-100m / C=100-200m).

The flying height is then obtained by multiplying the distance with the tangent of the flight angle. Since distances were estimated in categories, a range of flying heights is obtained (h1-h2, see Example). Nevertheless, in the presented results, the mean of h1 and h2 was used.

Example:

For a bird flying at a distance of 50-100m (B) and in an angle Θ of 30°, the bird's flying height will range between h1 and h2.

h1= (tg 30°) * (50m) = 28.9m
h2= (tg 30°) * (100m) = 57.7m
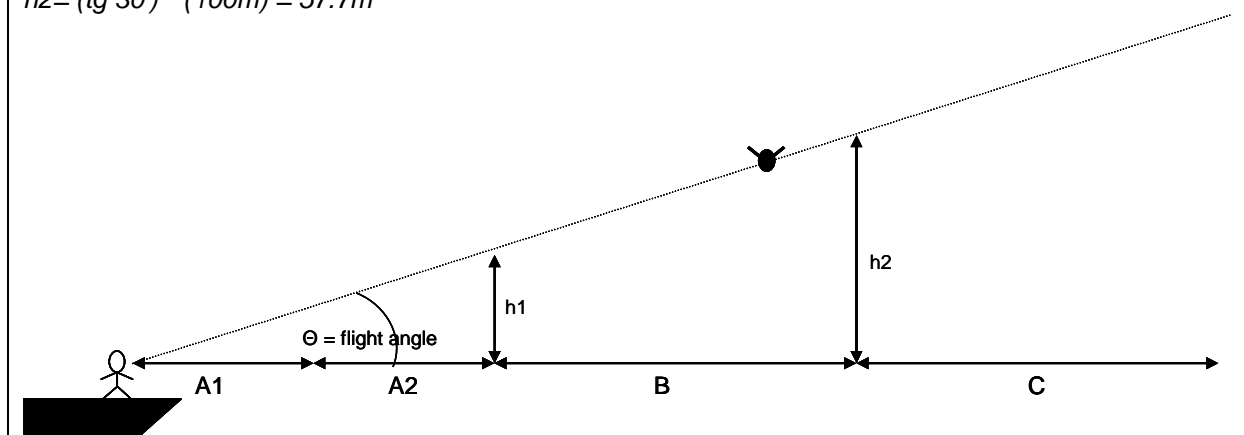
7.1.2.2   Results

Based on the results of the clinometer method (Table 9), proportionally more birds seemed to fly at rotor sweep heights compared to the results in Table 8. More than 50% of the Lesser black-backed and Herring gulls were estimated to fly between 31 and 157 m of height.

This does not necessarily mean that flying heights were underestimated during visual assessments. Based on Figure 60, we already pointed out that there was a large day-to-day variation in observed flying heights. Therefore these results should only be compared with the results of the simultaneously performed visual assessments (§7.1.2.3).

Table 9. Estimated percentage of birds flying at rotor sweep height according to clinometer method (excl. birds of which less than 10 observations are available).

Species	Number	% flying at rotor sweep height
Northern gannet	66	12%
Common gull	15	20%
Lesser black-backed gull	278	56%
Herring gull	28	54%
Great black-backed gull	22	18%
Black-legged kittiwake	31	16%

With this type of analysis it was also possible to make frequency distributions of observed flying heights as shown in Figure 61 to Figure 66.
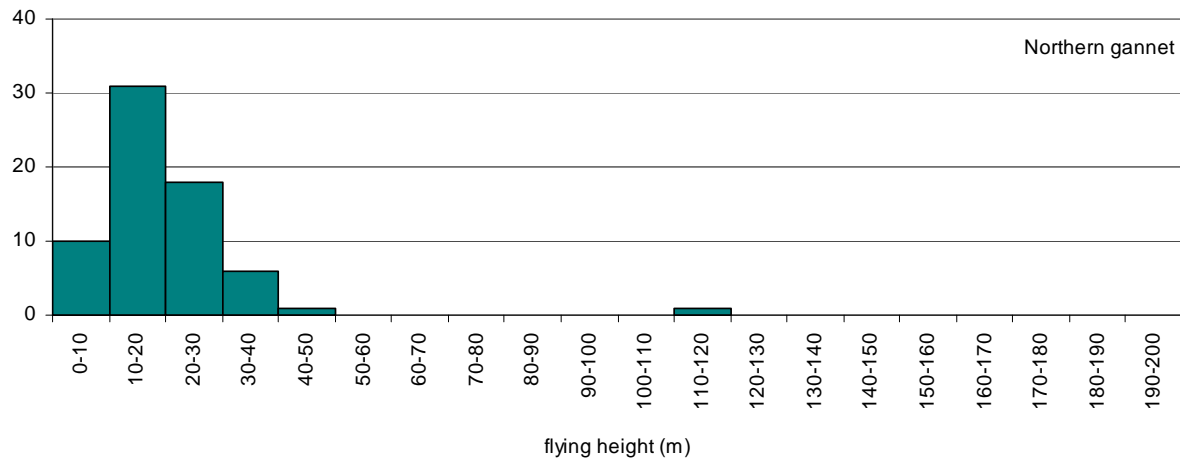
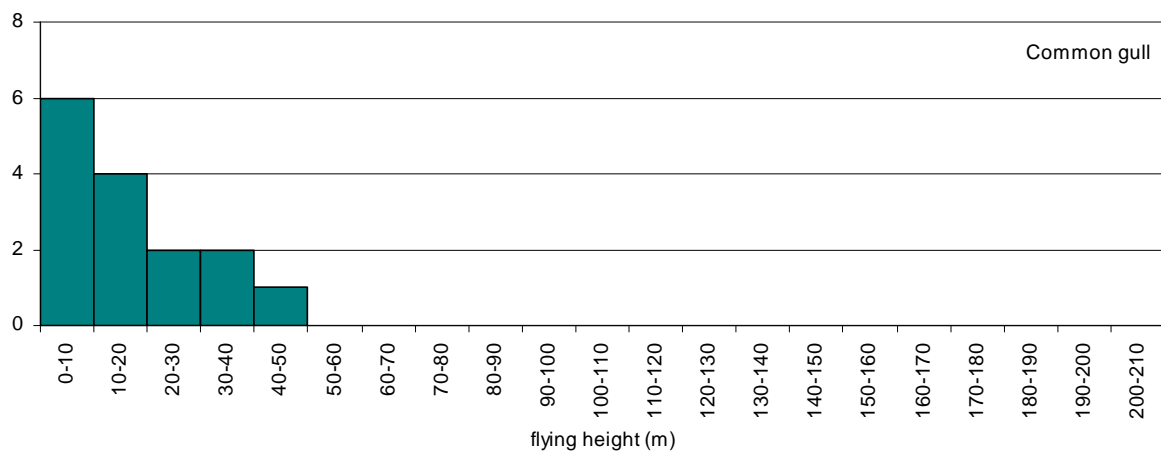**Figure 61. Frequency distribution of flying heights of Northern gannet.**

Figure 62. Frequency distribution of flying heights of Common gull.
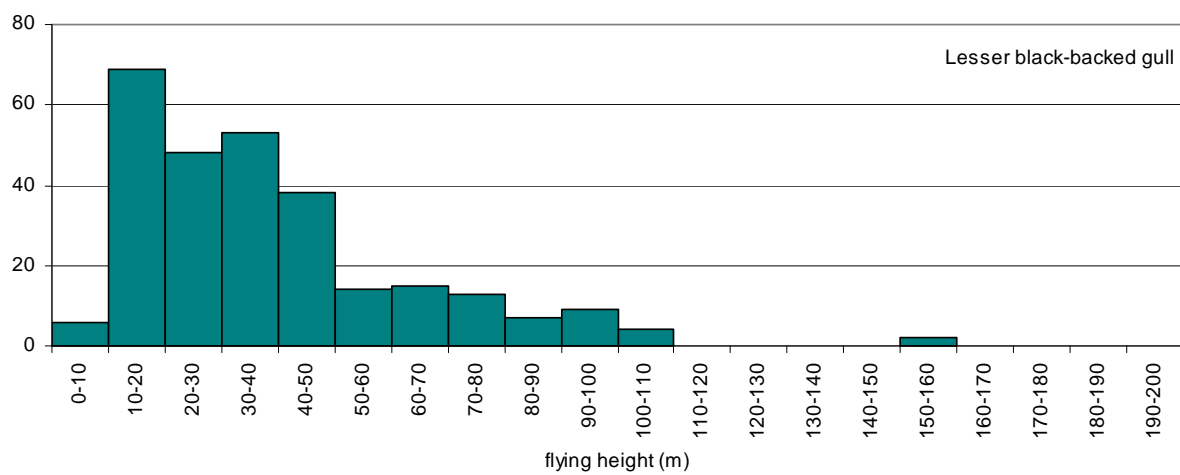
Figure 63. Frequency distribution of flying heights of Lesser black-backed gull.

Figure 66. Frequency distribution of flying heights of Black-legged kittiwake.

Black-legged kittiwake

flying height (m)

Figure 65. Frequency distribution of flying heights of Great black-backed gull.

Great black-backed gull

flying height (m)

Figure 64. Frequency distribution of flying heights of Herring gull.

Herring gull

flying height (m)

7.1.2.3   Comparison results of visual assessment and assessment using a clinometer

Simultaneously with the clinometer assessments, it was visually estimated whether the birds flew beneath (<31m) or through the rotor sweep area (31-157m). This allows us to compare our visual assessment of flying height (higher or lower than 31m) with the flying heights obtained through measurements with the clinometer.

Only 3% of the visual height assessments did not correspond to the assessment using a clinometer, which is a very low percentage. However, there is a large 'grey' zone due to the categorical distance estimation. The grey zone comprises of no less than 28% of all observations.

Table 10. Comparison of the results of visual flying height assessment with assessment using clinometer.

Visual	Clinometer		
	<31m	31-157m	????
< 31 m	199	2	59
31-157 m	12	81	58

7.2 Bird flux in the Thorntonbank wind farm area

7.2.1 Methodology

During the migration periods April-May and September-October we performed so-called 'flux counts' to estimate the number of flight movements occurring in the WFA-TTB (Table 11). In contrast to the standardized seabird counts, these counts were made from a stationed ship. At each of 4 fixed locations (Figure 67), all birds passing an imaginary transect line oriented NW-SE (perpendicular to the supposed migration direction) were counted during one hour. The birds' flight direction was determined making use of a compass. Meanwhile we assessed flying heights as explained in the previous paragraph §7.1.2.

Table 11. Overview of flux counts.

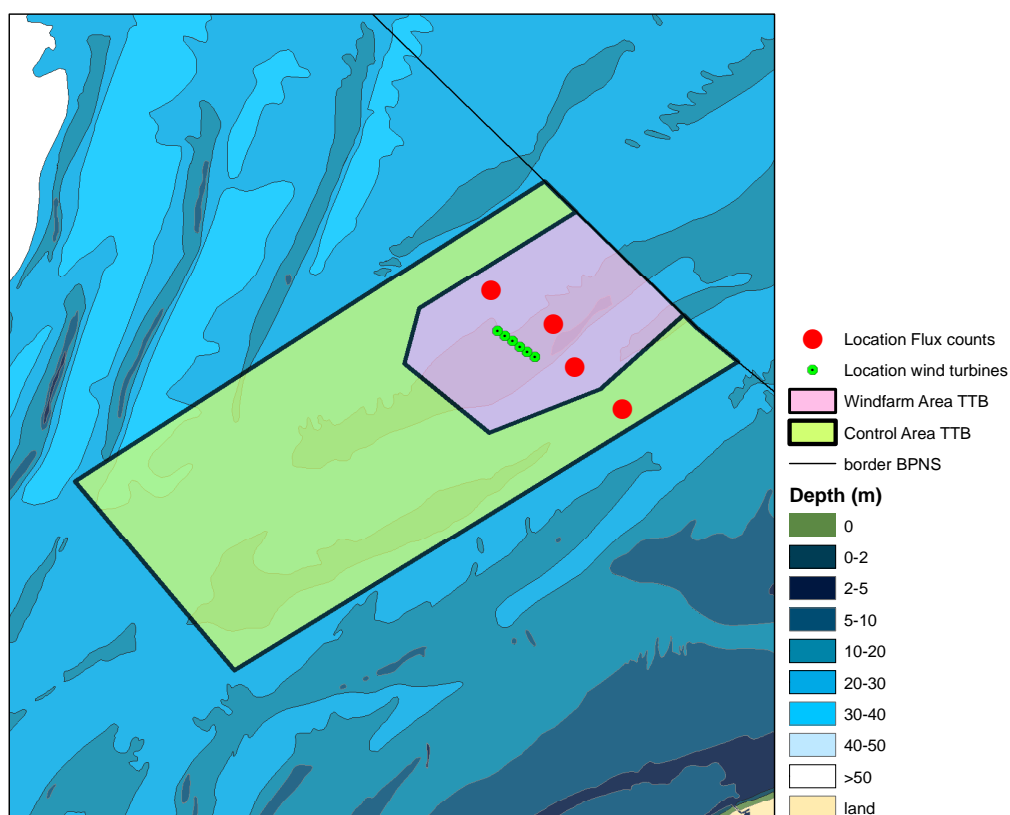| Season	Date	Number of locations	Time counted
Spring	21/04/2008	4	3h53'
	27/05/2008	2	2h00'
	28/05/2008	2	2h00'
Autumn	18/09/2008	4	3h55'
	30/10/2008	4	3h46'

Figure 67. Locations of flux counts.

7.2.2 Results: Flight directions

During autumn and spring, respectively 997 and 1507 flying birds were counted. As expected there was a clear north-eastern component in the flight directions observed during spring, and a clear south-western component in flight directions during autumn (Figure 68). According to the output of the Bolker-model (Figure 82), these are the most unfavourable flight directions with regard to collision risk.
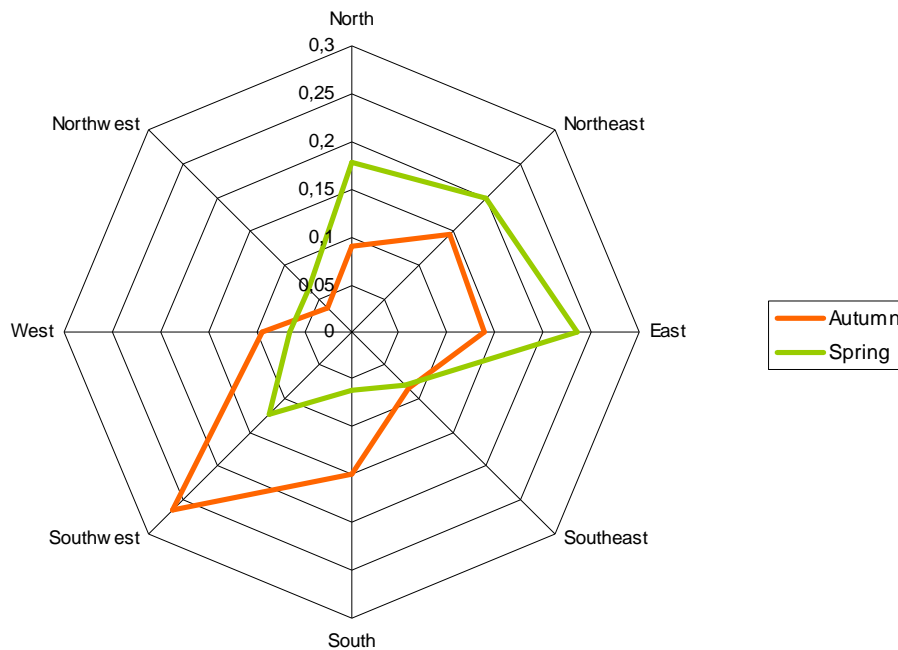

Figure 68. Proportional flight directions observed during flux counts in spring and autumn of the year 2008.

7.2.3 Results: Flux

All birds flying closer than 100m (spring) or 200m (autumn) were withheld for flux calculation. Hence, for each flight direction, the observed numbers could be converted into a flux, expressed in number of birds flying through the smallest 'containing circle' of the future wind farm per hour (diameter = 8.7km) (see Figure 69 & Figure 70).

During autumn, up to 1,800 flight movements cross the wind farm area each daylight hour, mostly oriented east (21%) and south (18%). In contrast to what we see in Figure 68, the south-western component in flight directions is no longer apparent in Figure 69. This is probably due to the fact that the most observed species are gulls, which mainly reside in the area rather than migrating through.

During April and May, the WFA-TTB is crossed by an estimated number of 1,820 flight movements each daylight hour. 29% of this flux has a north-eastern orientation.
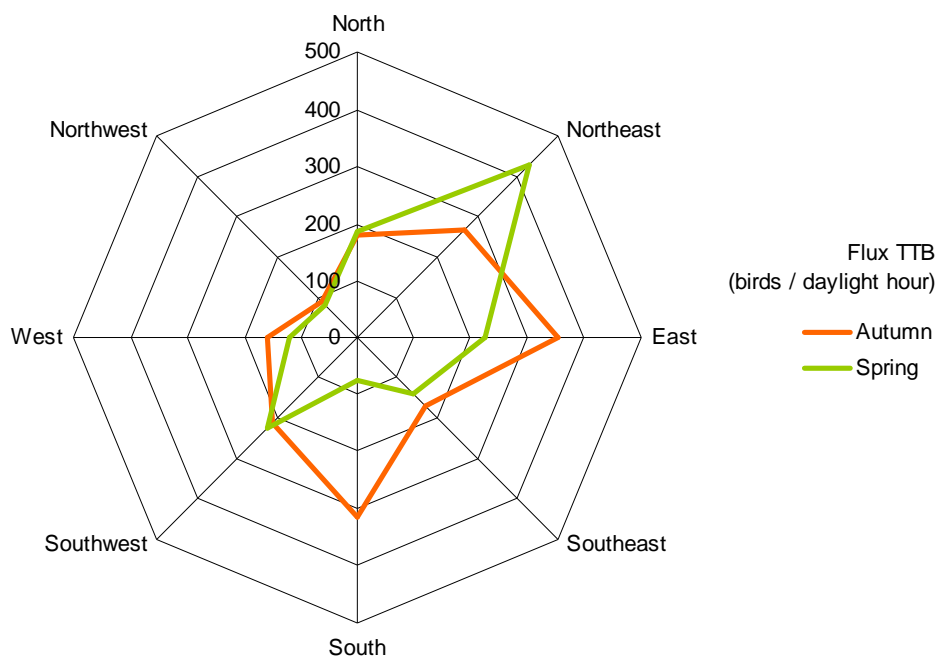
Figure 69. Flux of birds (ind./ hour) flying through the smallest containing circle (diameter = 8.7km), based on flux counts in spring and autumn 2008.
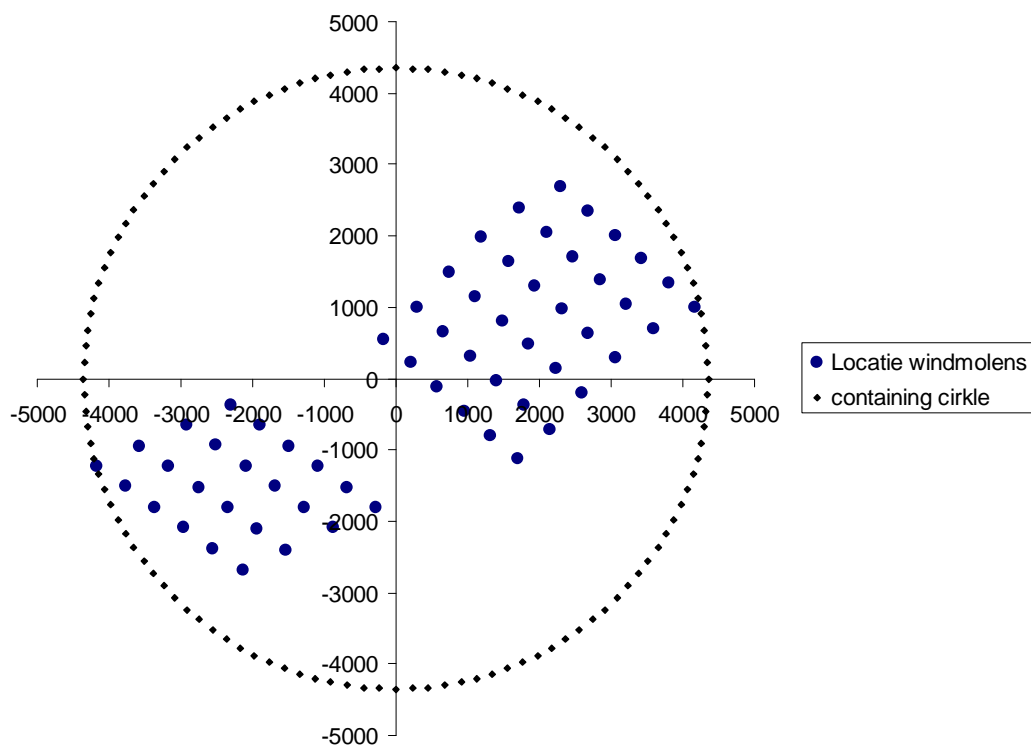
Figure 70. Position of the turbines in the Thorntonbank wind farm with indication of the smallest 'containing circle' with radius 4,352m.

7.2.4   Results: species composition

In spring, the most common species were Lesser black-backed gull (58%) and Northern fulmar (28%). We counted only low numbers of Annex I species Little gull (1.5%), Common tern (1.8%) and Sandwich tern (1.8%).
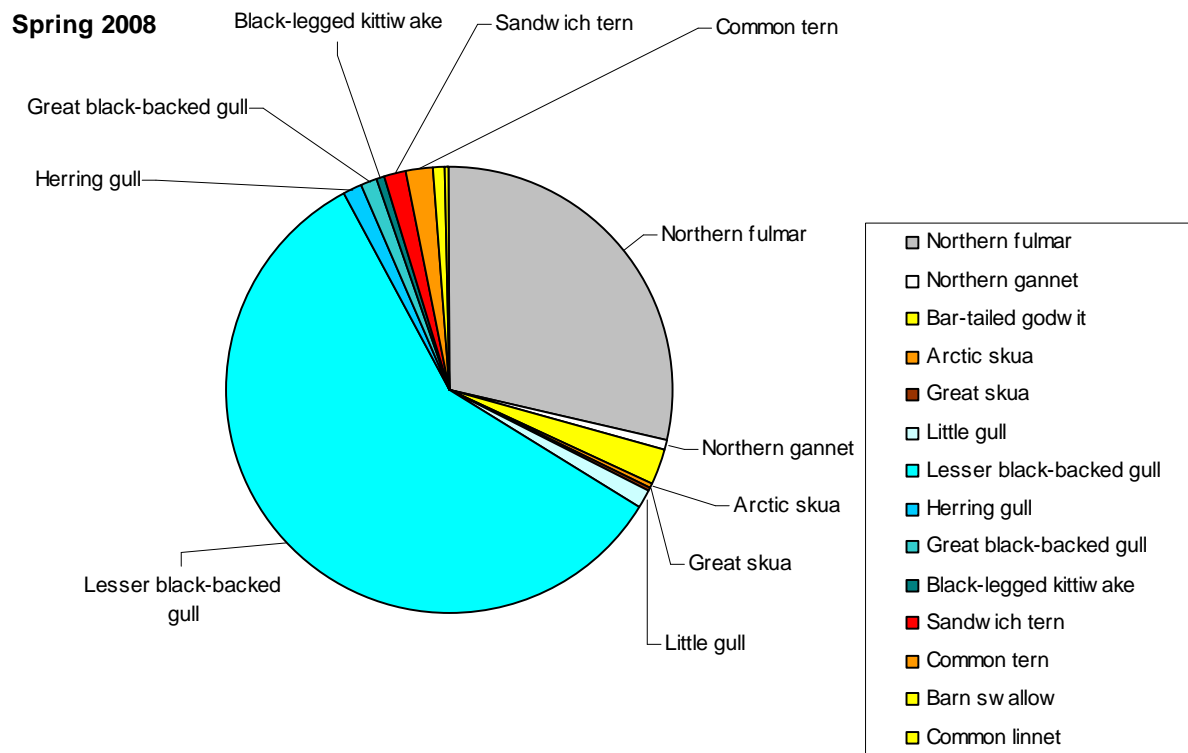
Figure 71. Proportion of bird species observed during spring flux counts (birds flying within 100m).

Species composition in autumn was made up of gulls (70%), Northern gannets (10%) and passerines migrating over sea (20%). As in spring, Lesser black-backed gull was the most observed species (44%). An unexpected result was the migration of Black-headed gulls this far at sea (7.7%). Annex I species Little gull and Sandwich tern were observed in very low numbers (<1%).
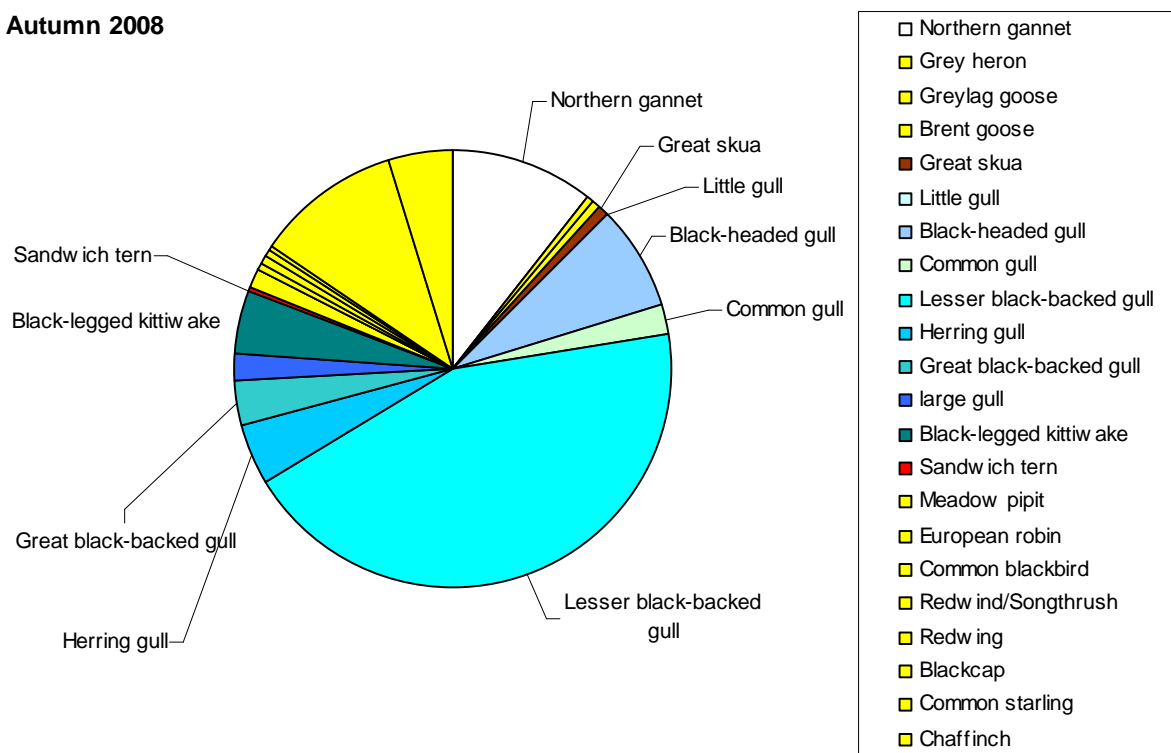

Figure 72. Proportion of bird species observed during autumn flux counts (birds flying within 200m).

Table 12 shows the measured bird fluxes for all observed species. For each species, the observed numbers were extrapolated to a transect of 8.7km long, equalling the diameter of the smallest containing circle of the WFA-TTB (Figure 70). Fluxes of more than 100 birds/h were observed for Northern fulmar, Northern gannet, Black-headed gull and Lesser black-backed gull. Lower numbers were noted for the Annex I species Little gull, Sandwich tern and Common tern, who still showed moderately high fluxes of around 30 birds/h. During one of the observation days in autumn, there was massive migration of passerines, which is translated in high fluxes of Common starling and Chaffinch. All of these species (marked bold in Table 12) will be discussed in detail in §7.2.5.

Table 12. Summary of measured bird fluxes through the WFA-TTB (number of birds per daylight hour).

Species	Spring	Autumn
Northern Fulmar	**518.9**	**0.0**
Northern Gannet	**16.6**	**188.9**
Grey Heron	0.0	2.8
Greylag Goose	0.0	5.6
Brent Goose	0.0	11.3
Bar-tailed Godwit	44.2	0.0
Arctic Skua	5.5	0.0
Great Skua	5.5	14.1
Little Gull	**27.6**	**2.8**
Black-headed Gull	**0.0**	**138.2**
Common Gull	0.0	42.3
Lesser Black-backed Gull	**1059.9**	**786.7**
Herring Gull	27.6	79.0
Great Black-backed Gull	22.1	62.0
large gull	0.0	31.0
Black-legged Kittiwake	5.5	87.4
Sandwich Tern	**33.1**	**5.6**
Common Tern	**33.1**	**0.0**
Barn Swallow	16.6	0.0
Meadow Pipit	0.0	22.6
European Robin	0.0	2.8
Common Blackbird	0.0	8.5
T. philomelos / iliacus	0.0	11.3
Redwing	0.0	11.3
Blackcap	0.0	2.8
Common Starling	**0.0**	**194.6**
Chaffinch	**0.0**	**84.6**
Common Linnet	5.5	0.0

7.2.5 Species discussion

Northern fulmar (*Fulmaris glacialis*)

During spring large numbers of Northern fulmar were observed during the flux counts, resulting in a calculated flux of more than 500 individuals per daylight hour, most birds heading northeast. In contrast, not one single Northern fulmar was observed during autumn. At the BPNS, an influx of Northern fulmars took place in the spring of 2008, which is quite unusual, since highest densities are normally observed during November-January. However, there is no need for concern regarding this species since it was never observed flying at rotor height.
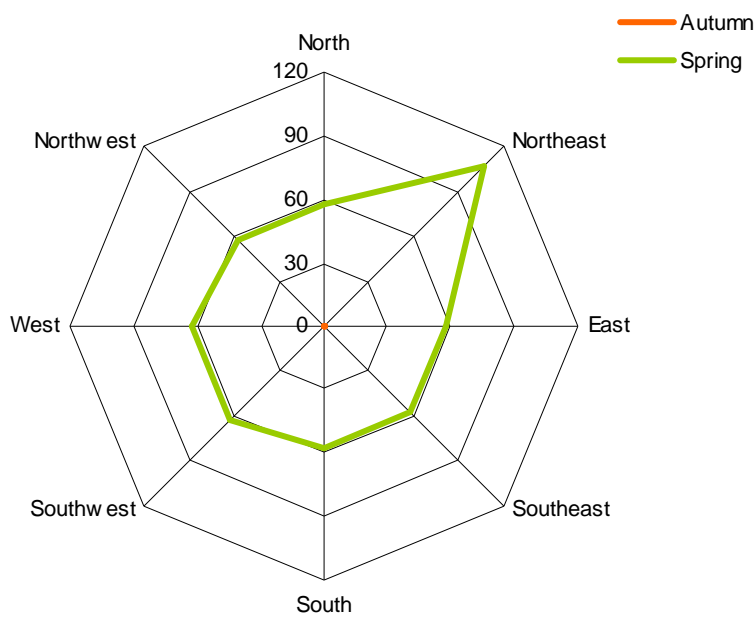

Figure 73. Flux of Northern fulmar through the Thorntonbank wind farm area (n birds / daylight hour).

Northern gannet (*Morus bassanus*)

As expected, the number of flight movements of Northern gannet was highest during autumn (190 birds per daylight hour), when large numbers are present at the BPNS. Flight orientation had a clear southern to western component (resp. 42 and 44 birds per daylight hour). During spring most birds flew in a north and north-easterly direction (resp. 6 and 11 birds per daylight hour). Considering this high flux, combined with the relatively high collision risk (Table 13), there is strong reason to believe there will be many collision fatalities among Northern gannets.

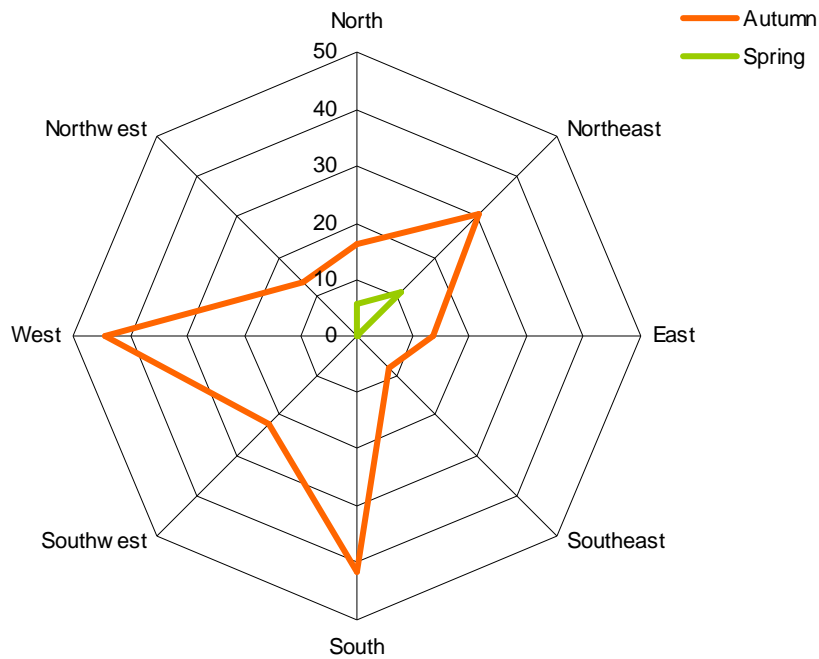

Figure 74. Flux of Northern gannet through the Thorntonbank wind farm area (n birds / daylight hour).

Little gull (*Larus minutus*)

Little gulls were observed solely during spring, with a total flux of 28 birds per daylight hour, mainly heading north (17 birds per daylight hour).
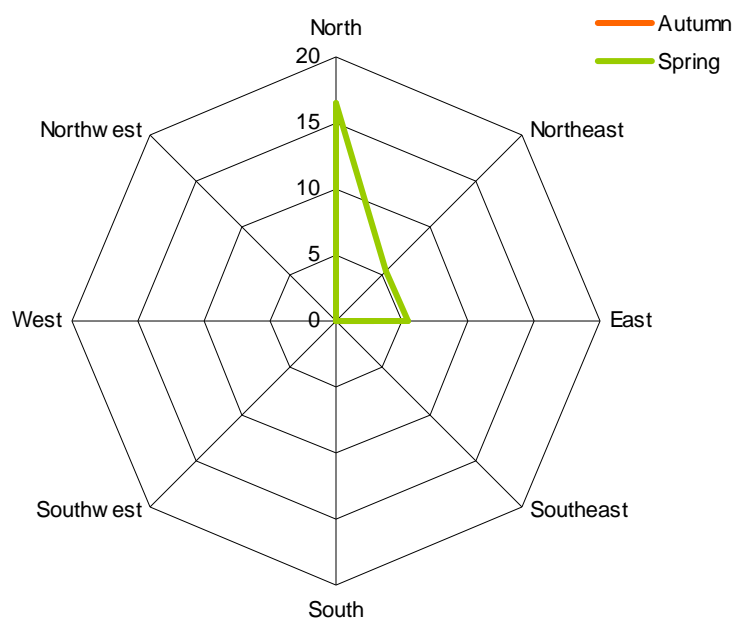
Figure 75. Flux of Little gull through the Thorntonbank wind farm area (n birds / daylight hour).

Black-headed gull (*Larus ridibundus*)

In general, this is a coastal bound species, but during autumn several groups of Black-headed gulls were observed migrating through the WFA-TTB. This resulted in a high flux of 138 birds per daylight hour, flying south and southeast.
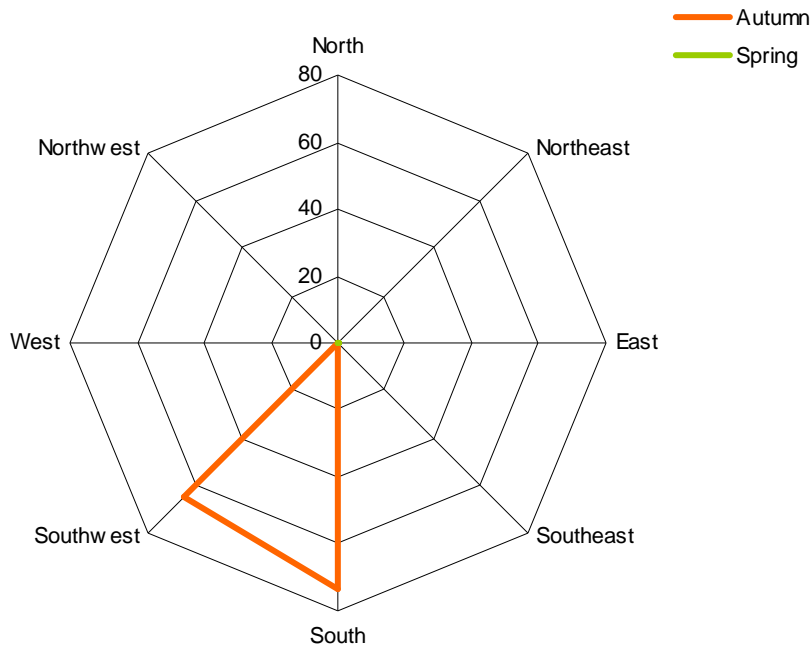
Figure 76. Flux of Black-headed gull through the Thorntonbank wind farm area (n birds / daylight hour).

Lesser black-backed gull (*Larus fuscus*)

This was the most commonly observed species during spring and autumn (resp. 1,060 and 790 birds per daylight hour). Movements occurred scattered over all directions, but with a clear north-eastern aspect during both migration seasons. Probably most gulls reside in the area for foraging, rather than migrating through. These high fluxes combined with the high species-specific collision risk will inevitably result in high numbers of collision victims.
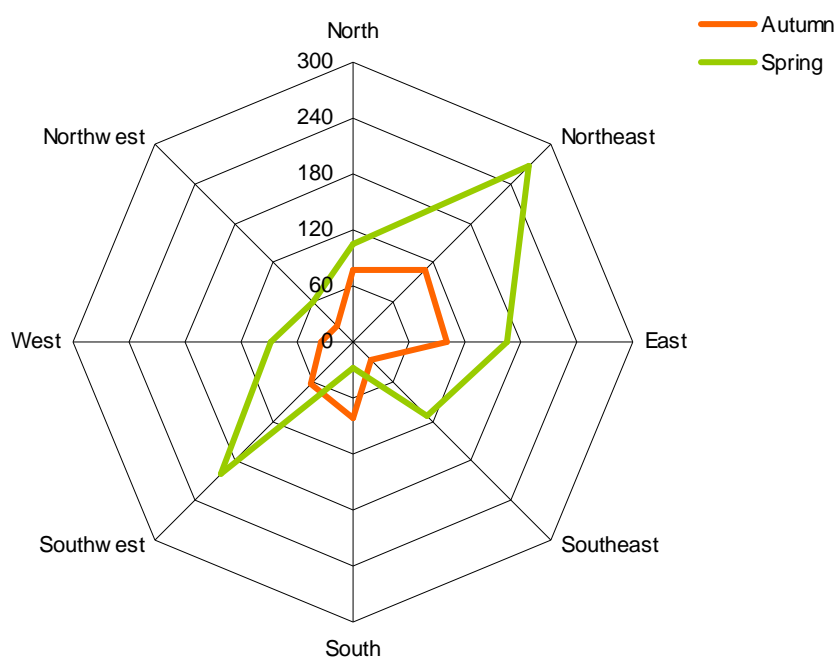
Figure 77. Flux of Lesser black-backed gull through the Thorntonbank wind farm area (n birds / daylight hour).

Sandwich tern (*Sterna sandviscensis*)

Most Sandwich terns were observed in spring with a resulting flux of 33 birds per daylight hour. This flux had a clear eastern component. Autumn saw far less Sandwich terns, with 2 observed individuals and a flux of 6 birds per daylight hour.
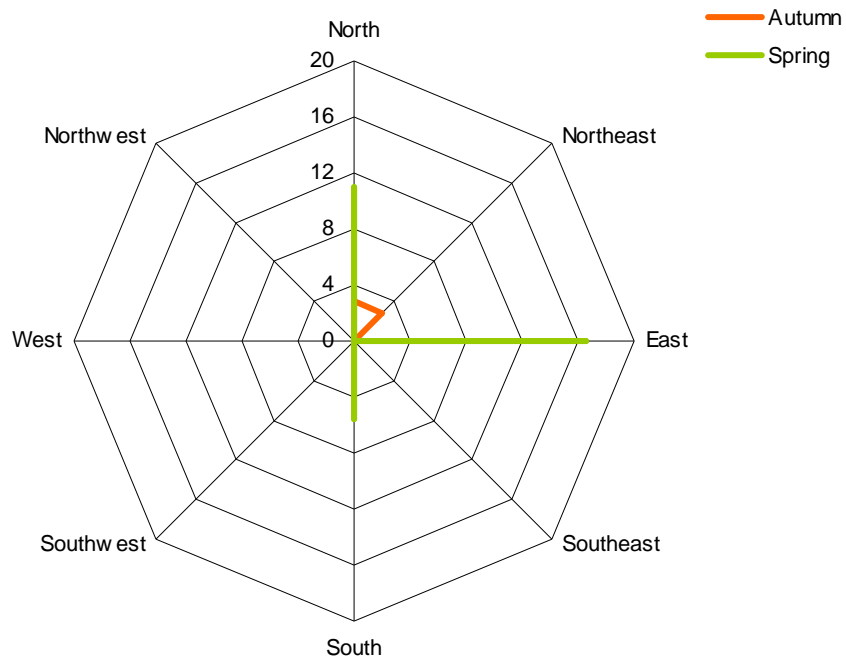
Figure 78. Flux of Sandwich tern through the Thorntonbank wind farm area (n birds / daylight hour).

Common tern (*Sterna hirundo*)

Common terns were exclusively observed in spring with a total flux of 33 birds per daylight hour. Most birds headed northeast (17 birds per daylight hour).
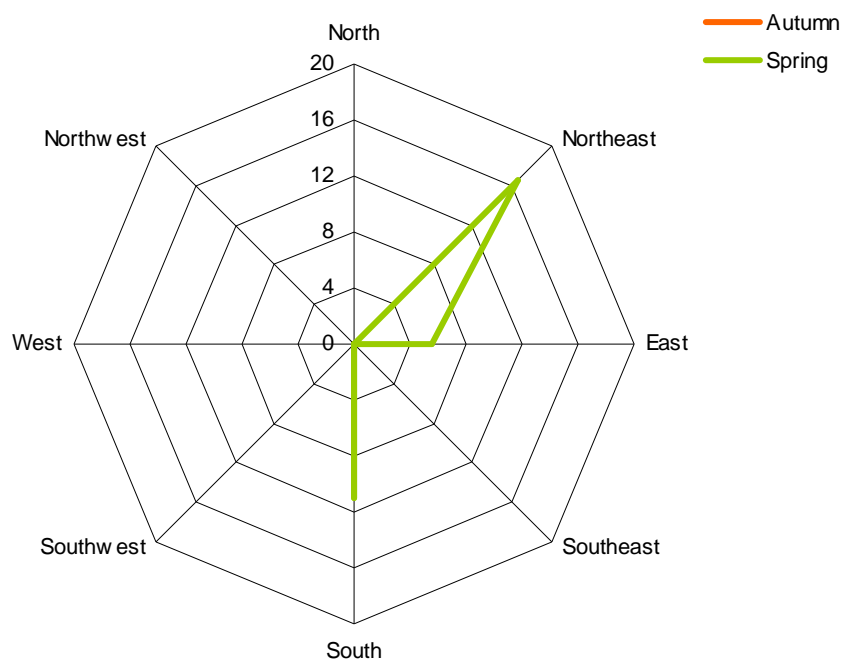
Figure 79. Flux of Common tern through the Thorntonbank wind farm area (n birds / daylight hour).

Chaffinch / Starling (Fringilla coelebs / Sturnus vulgaris)

On 30 October 2008, there was massive migration of passerines above the Belgian part of the North Sea. Strikingly, the migrating passerines mainly flew in east to south-eastern directions, straight towards land. Except for small numbers of thrushes, most passerines however were flying below rotor height.
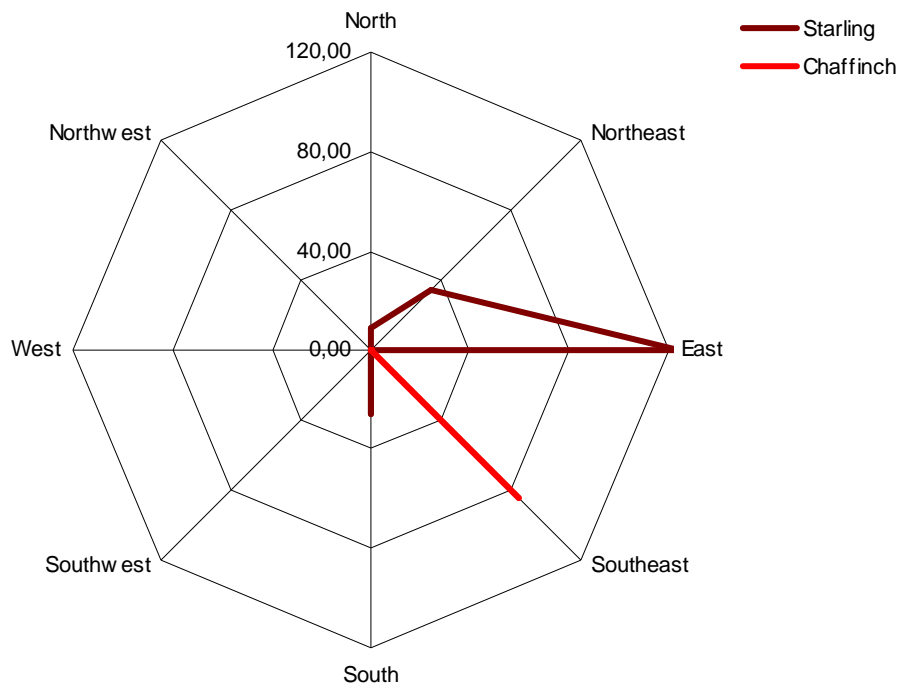
Figure 80. Autumn migration flux of passerines through the Thorntonbank wind farm area (n birds / daylight hour).

7.3 Collision risk assessment

In this chapter we make a preliminary estimation of the expected collision risk of migrating seabirds. Based on the results discussed in Chapters 2 & 5, the estimation is done for nine species or species groups: Northern gannet, Great skua, Little gull, Common gull, large gulls, Black-legged kittiwake, Sandwich tern, Common tern and auks.

7.3.1 Collision risk assessment: methodology

Step 1: assessment of the number of bird movements through the wind farm (1)

In a first step we need to assess how many birds will fly through the wind farm at rotor height, for which three input parameters are needed:

- Flux **F**: Number of bird movements per time unit;

- Correction for flying height **Cfh** (%): Percentage of birds flying at rotor height (§7.1);

- Correction for macro-avoidance **Cma** (%): Birds flying towards the wind farm may deflect their flight path to fly around the wind farm. This value represents the fraction of birds avoiding the wind farm as a whole.

$\rightarrow$ **(1)** = **F** x **Cfh** x **Cma**

Step 2: assessment of the collision risk for birds flying through the wind farm (2)

In a second step we assess the collision risk for birds flying through the wind farm at rotor height. This value is deducted from two mathematical models. Again, three input parameters are needed:

- Average number of turbines encountered **Nt**: This value can be calculated using the geometrical Bolker-model (Bolker *et al.* 2006). In this mathematical model it is assumed that birds fly in straight lines through the wind farm, without taking any avoidance action. Moreover, it assumed that the rotor plain is oriented perpendicular to the flight direction. Input parameters include height of turbine centre, rotor length and turbine positions;
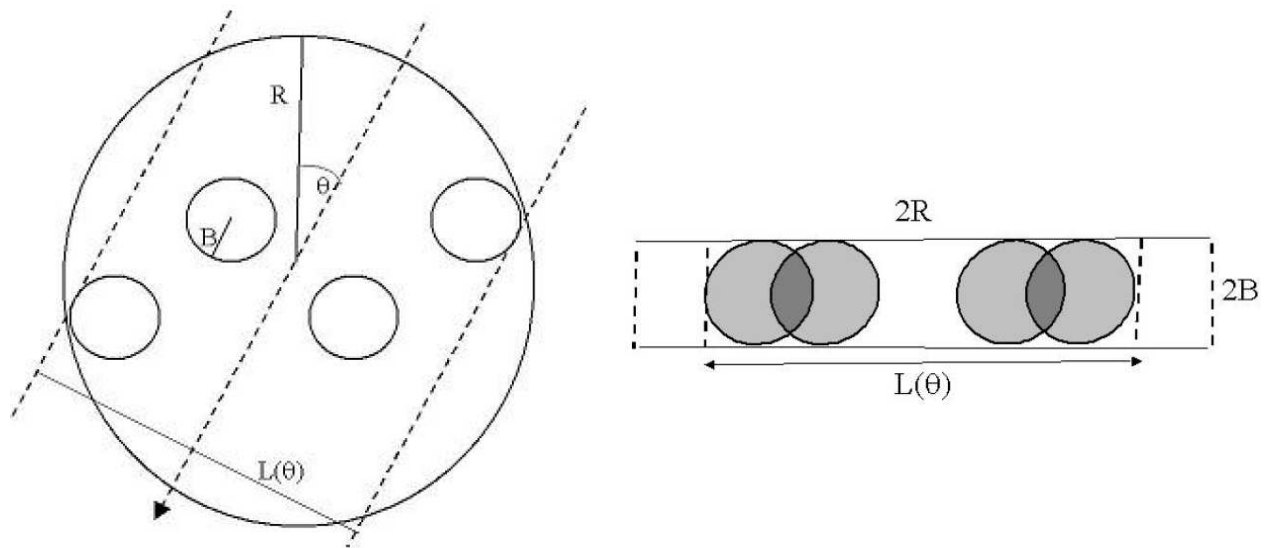
Figure 81. The Bolker model: top view of an imaginary wind farm, and side view for birds arriving from an angle Θ, with the rotor plane perpendicular to the birds' flight direction (Bolker *et al.* 2006).

Example:
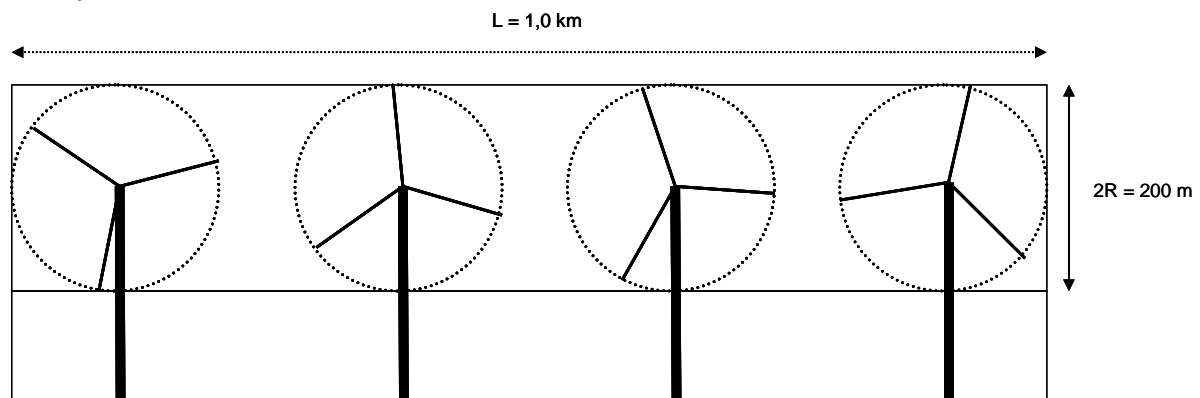
Imagine a wind farm of 4 turbines with rotor blade length R placed in one line as in the figure above. Assuming that all birds fly perpendicular to the turbine alignment, then the Bolker model calculates the 'average amount of turbines' these birds will encounter. We already corrected for flying height in step (1), so this equals the ratio of the total rotor surface area to the vertical area available at rotor height ($[4 \sqcap R^2] / [2RL] = 0.63$). Hence, birds flying at rotor height perpendicular to the turbine alignment will encounter less than one turbine on average. Alternatively, birds flying in line with the turbines will encounter more than 3 turbines on average ($[4 \sqcap R^2] / [2R]^2 = 3.14$). Obviously, in case of a two-dimensional configurated wind farm these calculations are much more complicated, but the results are easily obtained using the Bolker Excell-spreadsheet.

- No-avoidance collision risk **Cr**: This parameter is the probability of a bird being hit by a rotor blade when it flies through the rotor sweep zone, in the assumption that the bird takes no avoidance action at all. Therefore the mathematical Band-model and the accompanying Excell-spreadsheet is used. The collision probability depends on the size of the bird, chord width and pitch angle of the turbine blade, rotation speed of the turbine and flight speed of the bird (Band *et al.* 2007);

- Correction for micro-avoidance **Cmi** (%): When birds fly into a wind farm they may choose to fly through the corridors to stay away from the rotating blades. Also, they may perform last-minute actions to avoid a collision. This behavioural aspect is compensated for through the micro-avoidance factor.

$\rightarrow$ **(2)** = **Nt** x **Cr** x **Cmi**

Step 3: collision risk

$\rightarrow$ **Collision Risk** = **(1)** x **(2)**

7.3.2 Collision risk assessment: results

7.3.2.1 Input parameters

All input parameters for collision risk calculation were chosen based on the worst case scenario principle. This means that we made the following assumptions:

- Number of bird movements per time unit (Flux) **F**: this value is set to 100 birds/year and hence the modelled number of victims value may be considered as a collision risk, expressed in percent (%);

- Correction for flying height **Cfh** (%): This value is species-specific. Based on our ship-based seabird observations we are able to deduct a percentage of birds flying at rotor height;

- Correction for macro-avoidance **Cma** (%): This parameter is species and site specific. Up until now, there are few publications reporting on the macro-avoidance of seabirds towards offshore wind farms, and long term in situ research is needed for reliable determination. Compared to the pre-construction of the Nysted wind farm, a reduction of 46 - 78% of migrating waterfowl entering the wind farm area was found. Based on that research, we set this value is set to 0.5 (worst case scenario) (Kahlert *et al.* 2005, Desholm & Kahlert 2005);

- Average number of turbines encountered **Nt**: The Bolker-model shows that the least favourable flight directions are 60° and 240°, at which birds should encounter 1.88 turbines per crossing. Calculations are based on the assumption that all birds fly in these directions;
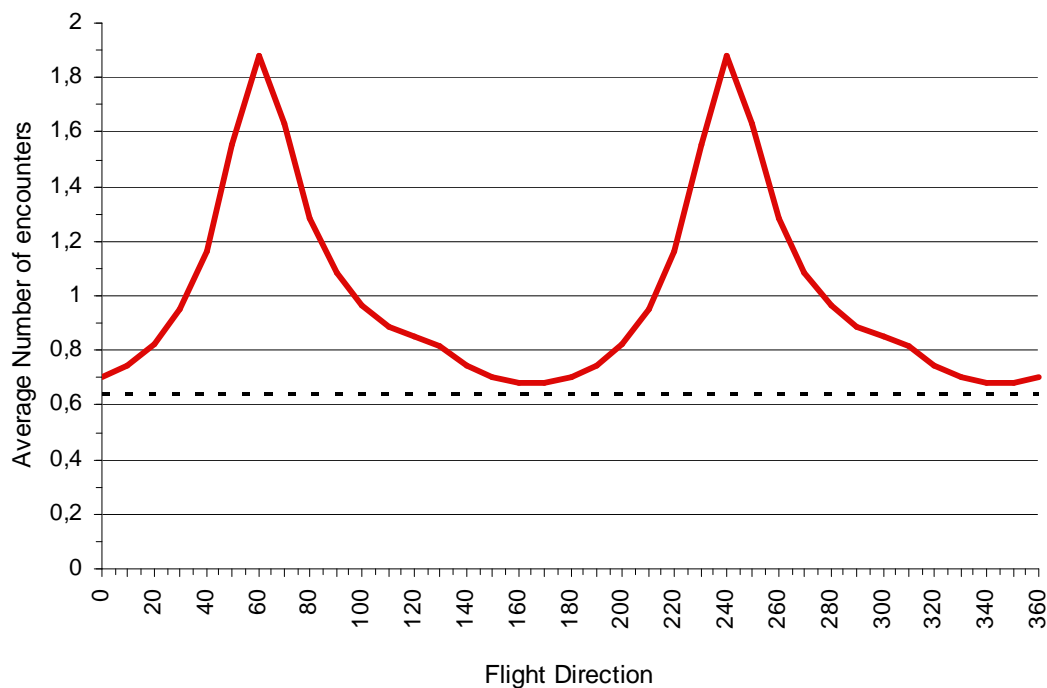

Figure 82. Average Number of Turbines Encountered per flight direction.

- No-avoidance collision risk **Cr**: For the calculation of this parameter, maximum rotation speed, maximum bird length and maximum wingspan were used (Jonsson, 1997), as well as minimum flight speeds (Spear & Ainley, 1997). The turbine paramaters 'maximum chord width' and 'pitch angle' were estimated to be 8m and 30°r espectively;

- Correction for micro-avoidance **Cmi** (%): This value is extremely difficult to determine reliably. Moreover, Chamberlain *et al.* (2006) showed that only slight variations in this avoidance factor lead to large changes in mortality estimations. For most species this value is set to 0.95, which according to literature is likely to be a minimum value (Band *et al.* 2007, Chamberlain *et al.* 2006). For Sandwich and Common tern however, we followed a different path. We estimated this value by comparing modelled collision risk with actual collision risk, based on in situ data on bird flux and corpse searches by Everaert (2008) (analogous to Hatch & Brault, 2007). This resulted in a micro-avoidance of 0.992 and 0.985 for Sandwich and Common tern respectively.

7.3.2.2   Results

Table 13 shows the calculated collision risks, sorted from low to high. Auks were never observed at rotor height and show a collision risk of zero. Collision risk for Annex I species Sandwich terns and Common tern is very small, due to their small size, generally low flying height and high micro-avoidance. In contrast, the risk for Little gull is much higher, with 1 victim each 7,000 flight movements. Black-legged kittiwake, Northern gannet, Great skua and Common gull all show intermediate collision risks of 1 to 10 victims per 10,000 flight movements. Large gulls appear to be most sensitive, with more than 2 collisions per 1,000 flight movements.

Table 13. Estimated collision risks for nine species or species groups at the Thorntonbank wind farm according to a worst case scenario (species marked with (*) are on the Annex I of the Birds Directive).

Species	Collisison risk (%)	Collision risk
auk sp.	0.0000	-
Sandwich tern*	0.0010	1 / 100,000
Common tern*	0.0010	1 / 100,000
Little gull*	0.0141	1 / 7,000
Black-legged kittiwake	0.0511	1 / 2,000
Northern Gannet	0.0668	1 / 1,500
Great skua	0.0717	1 / 1,400
Common gull	0.0883	1 / 1,100
large gull sp.	0.2153	1 / 500

7.4 Conclusion

Integrating above information we are able to calculate the expected number of collision victims. Be aware of the fact that these are preliminary results based on fairly limited research and according to a worst case scenario principle. Nevertheless, it makes clear that there will be relatively few victims among the protected Annex I species. In contrast, it appears that high numbers of collisions could occur among gulls and gannets.

It could well be possible that fluxes of gulls were overestimated due to attraction to the ship. In the future, radar research should give true and reliable insight in the bird flux through the wind farm area. These data should be supported by visual flux counts from the transformator platform, or even better, the wind turbines themselves. Also, we are largely ignorant regarding avoidance by birds, which remains one of the most crucial parameters to reliably estimate numbers of collision victims.

Table 14. Estimated number of collision victims in the future wind farm area at the Thorntonbank.

Species	Collision risk (%)	Spring flux (n ind. / (apr-may)	Autumn flux (n ind. / (sept-oct)	Number of victims (spring)	Number of victims (autumn)
auk sp.	0.0000	0	0	**0.0**	**0.0**
Sandwich tern	0.0010	23 760	0	**0.2**	**0.0**
Common tern	0.0010	23 760	4 320	**0.2**	**0.0**
Little gull	0.0141	19 440	0	**2.7**	**0.0**
Great skua	0.0717	4 320	10 080	**3.1**	**7.2**
Common gull	0.0883	0	30 240	**0.0**	**26.7**
Black-legged kittiwake	0.0511	4 320	62 640	**2.2**	**32.0**
Northern Gannet	0.0668	12 240	136 080	**8.2**	**90.9**
large gull sp.	0.2153	799 200	691 200	**1 720.5**	**1 488.0**

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