Update of KEC bird collision calculations in line with the 2030 Roadmap

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Foreword

The 2030 Offshore Wind Energy Roadmap was published in March 2018. In response, Bureau Waardenburg was asked to calculate the estimated number of bird victims due to collisions for all existing and planned wind farms in the Roadmap. The reader is referred to the approach adopted in the report *Voorziene effecten van Vervolgroutekaart windenergie op zee (2024 – 2030) op enkele vogelsoorten* (Gyimesi *et al.* 2018b).

The following persons were involved in the production of this report:

Abel Gyimesi	calculations, reporting, project management;
Job de Jong	calculations, GIS processing;
Astrid Potiek	calculations;
Elisa Bravo Rebolledo	reporting;
Ruben Fijn	quality control.

On the basis of their training, work experience and self-study, these persons were qualified for the work they have carried out. The project was completed in accordance with Bureau Waardenburg's quality manual. The quality management system of Bureau Waardenburg is ISO-certified.

This assignment was supervised by Martine Graafland of Rijkswaterstaat. Suzanne Lubbe and Maarten Platteeuw (both Rijkswaterstaat employees) provided substantive support for the project. Densities of seabirds and corresponding population sizes (virtual and otherwise) in the North Sea were supplied by Jan-Tjalling van der Wal (WMR). We thank them all for the pleasant cooperation.

Contents

1 Introduction

In the context of the Site Decision for the roll-out of the SER agreement, numbers of collision victims were calculated for all future wind farms in the southern North Sea (Rijkswaterstaat 2015) for the purposes of the Framework for Assessing Ecological and Cumulative Effects (hereinafter "KEC[1] 1.1; 2015"). At the time, in order to make those calculations, all the wind farms were then 'filled' with standard 3MW turbines rather than the turbines that were actually planned. These numbers of collision victims were then assessed using the Potential Biological Removal (PBR) for the relevant population of the species in the southern North Sea. The calculated numbers of victims exceeded the PBR for the three large gull species: the Lesser Black-backed Gull, Herring Gull and Great Black-backed Gull. When the calculations were updated with more realistic types of wind turbine for the existing and planned wind farms in the southern North Sea, the number of victims was still above the PBR standard for the Lesser Black-backed Gull (Gyimesi & Fijn 2015b). Moreover, it has become clear on the basis of a range of EIAs that the cumulative numbers of victims stay below the Dutch PBR standard for all gull species in the Dutch wind energy areas only (Gyimesi *et al*. 2018a).

However, since the completion of the KEC 1.1 study (Rijkswaterstaat 2015), the proposed developments in the Offshore Wind programme in the Dutch areas of the North Sea in the period leading up to 2030 have also been elaborated. For example, new wind energy areas have been defined in the Netherlands, namely IJmuiden Ver, Holland Coast West and North of the Wadden Islands, which also have to be included in the cumulative calculations of bird victims. Since the KEC 1.1 (Rijkswaterstaat 2015) was drawn up, the international plans for wind farm developments have also become more concrete and new knowledge has become available about bird behaviour in wind farms and flight routes across the North Sea.

The main objective of this report is to provide a description of the changes in the number of collision victims after the updating of the KEC 1.1 in line with the current KEC 3.0 scenario: that is to say in line with the most recent plans for wind farm locations and types of wind turbine in the central and southern North Sea in the period leading up to 2030. The present study looked at those species for which victim numbers in the KEC 1.1 reached the highest fraction of the PBR: Northern Gannet, Great Skua, Great Black-backed Gull, Lesser Black-backed Gull, Herring Gull, Black-legged Kittiwake, Bewick's Swan, Brent Goose, Common Shelduck, Curlew and Black Tern (Rijkswaterstaat 2015). Both the most recent distribution data (prior to 2017) and new knowledge about bird flight behaviour and flight routes in offshore areas were used in the calculations. On the basis of the results, it was possible to determine whether the PBR for the species concerned will be exceeded on the basis of the latest turbine specifications in the planned farms.

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[1] Dutch abbreviation for 'Framework for Ecology and Cumulative effects'.

2 Materials and methods

2.1 Distribution data and fluxes

The main purpose of this study was to use the Band model to calculate collision victims for the Northern Gannet, Great Skua, Great Black-backed Gull, Lesser Black-backed Gull, Herring Gull, Black-legged Kittiwake, Bewick's Swan, Brent Goose, Common Shelduck, Curlew and Black Tern. The basic input parameter for the Band model is the wind farm-specific flux of birds flying through a given rotor swept area. This flux can:

- be measured, for example with radar systems, cameras or visual observations;
- be calculated on the basis of densities of local birds; or
- be estimated on the basis of flyway population sizes, as has been done for a number of migratory birds in the present study.

In the case of *seabird species*, fluxes are usually calculated on the basis of the local density of a species as determined on the basis of data from ship and/or aircraft surveys. In the case of seabirds, these bird densities are based on distribution data acquired in the large-scale ESAS and MWTL monitoring programmes (see details below). In the present study, fluxes were used that were determined more recently than those in the KEC 1.1 (2015) calculations. The migration routes of the *migratory bird species* Bewick's Swan and Brent Goose across the North Sea are based on GPS tracking data previously published by Gyimesi *et al.* (2017b) that are set out in §2.1.2 of this report. Specific migration routes for the other migratory bird species (Common Shelduck, Curlew and Black Tern) were not available. For these species, the fluxes were determined on the basis of the estimates of the flyway population size (see §2.3).

2.1.1 Seabirds

The collision victim calculations were made in the present study for five seabird species:

1. Great Black-backed Gull
2. Lesser Black-backed Gull
3. Herring Gull
4. Black-legged Kittiwake
5. Great Skua

The KEC 1.1 study (Rijkswaterstaat 2015) worked with bird distribution data collected from 1991 through to 2014 during the international ESAS monitoring programme (European Seabirds At Sea) and the Dutch MWTL programme (Monitoring Waterstaatkundige Toestand des Lands, *Survey of National Water Management Status*). Since these calculations were made in KEC 1.1, new survey data have been collected and they have been included in the present study to update the density data for seabird species.

Wageningen Marine Research (WMR) used the ESAS and MWTL data from the period 1991-2014 as a basis for KEC 1.1. Bureau Waardenburg manages the most recent data on numbers of seabirds in the North Sea in the period 2014-2017 (MWTL surveys). In the context of the current KEC update, these two databases were merged by WMR into a single joint database in order to determine the densities of seabirds in the same way.

In KEC 1.1, different datasets were used for different species (Rijkswaterstaat 2015) because the first calculations with a combined ESAS/MWTL dataset for all species were followed by two iterative stages. The first iteration (Leopold *et al.* 2015) was based on the same dataset but it spread high concentrations of Northern Gannets, Northern Fulmars, Black-legged Kittiwakes, Herring Gulls, Great Black-backed Gulls and Lesser Black-backed Gulls behind fishing vessels through space. The reliability of the analyses was improved further in the second iteration (van der Wal *et al.* 2015) by basing the density calculations for large gulls in the Netherlands exclusively on MWTL aircraft surveys. This is because ships, including the survey vessels used to make the surveys, can attract gulls and therefore affect the density surveys.

During a workshop organised for staff from Rijkswaterstaat, Wageningen Marine Research and Bureau Waardenburg, it was decided, due to major differences in the offshore habitat use between the species, to use the various iteration methods from the KEC 1.1 study again to determine the densities of the seabird species in KEC 3.0 rather than to adopt a single specific method for all species (Bravo Rebolledo & Gyimesi 2018). However, the most recent survey data for seabirds (2014-2017) were added to the dataset and both an international and a national scenario were calculated. The aim of the two scenarios was to consider the effect of the number of victims on different sub-populations. In the international scenario, the number of victims in all international wind farms is determined on the basis of the density maps and this number of victims is compared with a given population size calculated on the basis of the same density maps for the southern and central North Sea. In the national scenario, the number of victims in Dutch wind farms is compared with a population determined on the basis of the density maps for the Dutch Continental Shelf (DCS). In both the international and national scenarios, the population sizes are based on the merging of bimonthly density maps (see §2.3). This approach to calculating population size therefore assumes that different individuals are counted during the bimonthly surveys. In reality, this leads to an overestimation of the population size because individuals of seabird species may be present in a given area for more than two months. The population sizes presented are therefore virtual and they are not estimates of the actual population. The purpose of determining these population sizes was solely to assess the effect of the number of victims calculated using the density maps by reference to the population sizes calculated using the same density maps (see §2.3).

International scenario

The international ESAS and Dutch MWTL survey data for the southern and central parts of the North Sea over the period 1991-2017 were used for density calculations in the international scenario. This period was selected because ESAS surveys for 2000 were made more frequently than in the period after that. The longer time period therefore introduced greater reliability into the calculated average densities. In the international scenario, densities for large gulls in the Netherlands were calculated on the basis of the second iteration (which was limited to the use of the Dutch MWTL data) (van der Wal *et al.* 2015) and densities outside the Netherlands were calculated on the basis of the first iteration (Leopold *et al.* 2015). Calculations were made using the first iteration (Leopold *et al.* 2015) for the Black-legged Kittiwake and using the original KEC 1.1 approach (see Table 2.1) for the Great Skua. The resulting density maps for the central and southern North Sea have been included in Annex A for each seabird species.

National scenario

The national scenario is limited to the Dutch section of the North Sea. In this scenario, all iterations are based on surveys (both ESAS and MWTL) made in the period 2000-2017 (see Table 2.1) because the MWTL surveys were extended starting in 2000 and so the counting activities were more intensive than in previous years, remaining fairly constant thereafter. Moreover, this more recent data series provides a better picture of the current distribution of seabirds. The resulting density maps for each seabird species for the Dutch North Sea can be found in Annex B.

Table 2.1 Summary table of the different datasets, data periods and data iterations for each seabird species for the international and national scenarios (cf. Van der Wal et al. *2018). Density maps were drawn up by WMR in line with the structure below.*

	International scenario			National scenario		
	Data	Period	Iteration	Data	Period	Iteration
Great Skua	ESAS+MWTL	1991-2017	Basis	ESAS+MWTL	2000-2017	Basis
Northern Gannet	ESAS+MWTL	1991-2017	1st	MWTL	2000-2017	2nd
Black-legged Kittiwake	ESAS+MWTL	1991-2017	1st	MWTL	2000-2017	2nd
Great Black-backed Gull	ESAS+MWTL	1991-2017	1st	MWTL	2000-2017	2nd
Lesser Black-backed Gull	ESAS+MWTL	1991-2017	1st	MWTL	2000-2017	2nd
Herring Gull	ESAS+MWTL	1991-2017	1st	MWTL	2000-2017	2nd

Flux determination

On the basis of the scenarios above, WMR (van der Wal *et al.* 2018) determined bimonthly interpolated densities in a grid of 5 x 5 km. A long-term average (for the years covered by the two scenarios; see Table 2.1) was calculated for each bimonthly period and for each grid cell. The layouts of the wind farms (supplied by Rijkswaterstaat) were laid over these density maps with average densities per species. The average density per wind farm was calculated for each grid cell overlapping with the wind farm layout.

Fluxes for flying birds were used in the Band model calculations. However, due to a number of agreements included in the ESAS method, the numbers of flying birds were underestimated in these surveys. The total density of birds in each wind farm (both sitting and flying) was therefore used and multiplied by a correction factor. This factor is the fraction of the total time budget during which the bird is in the air. The correction factors as determined by Bradbury *et al.* (2014) were used for the Northern Gannet, Great Skua, Great Black-backed Gull and Black-legged Kittiwake; the factors determined by Gyimesi *et al.* (2017a) were used for the Lesser Black-backed Gull and the Herring Gull.

These densities are stated as fluxes at rotor height on the basis of species-specific flight height distributions and turbine specifications. The flight height data come from Johnston *et al.* (2014), who published a modelled flight height distribution based on all available data relating to the flight heights of different species of seabirds. Flight height distributions were used for the Lesser Black-backed Gull and the Herring Gull, based on the monitoring results for birds with GPS loggers in the Netherlands, Belgium and England (Gyimesi *et al.* 2017a).

2.1.2 Migratory birds

In addition to seabird species, knowledge is also needed about collision victims in offshore wind farms for a number of migratory bird species. In contrast to seabird species, offshore areas are not the natural habitat of these species. However, during seasonal migration, they cross the central and southern North Sea and may collide there with wind turbines in offshore wind farms. The following five species have been identified as priority species for which the present study will update the KEC 1.1:

- Bewick's Swan
- Brent Goose
- Common Shelduck
- Curlew
- Black Tern

There is no systematic monitoring of migratory birds at sea and no location-specific offshore densities or fluxes are therefore available. For these species, KEC 1.1 estimated the number of victims on the basis of a global flux across the southern North Sea that was used for each wind farm (Rijkswaterstaat 2015). These fluxes are corrected for the present KEC 3.0 study, based on the percentage changes in population estimates by BirdLife International (2004; 2015; see also §2.3). For Bewick's Swan and the Brent Goose, specific migration routes were recently determined on the basis of GPS logger data (Gyimesi *et al.* 2017b), allowing wind farm-specific fluxes to be applied. No such detailed measurements were available for the other species and global fluxes that were used in all wind farms were therefore adopted again (Table 2.2).

Table 2.2 Fluxes used during the Band model calculations in the KEC 1.1 study (Rijkswaterstaat 2015) and in the present study.

species	flux in KEC 1.1 (2015)	update of flux for KEC 3.0
Common Shelduck	576	644
Curlew	742	645
Black Tern	674	608

2.2 Victim calculations

In the KEC 1.1, the number of collision victims for wind farms built in the period leading up to 2023 was determined using the theoretical extended Band model (Band 2012). The present study also includes the plans for offshore wind farms in the period leading up to 2030 on the basis of the 2030 Offshore Wind Energy Roadmap.

For most species, a species-specific flight height distribution was available that allowed for the application of the extended Band model (Band 2012). No species-specific height distributions were available for the Common Shelduck, Curlew and Black Tern. The Basic Band model was therefore used for the latter species (Band *et al.* 2007) in line with the KEC 1.1 study (Rijkswaterstaat 2015).

2.2.1 Bird-related data

On the basis of species-specific fluxes, the numbers of collision victims per wind energy area and per bird species for the entire central and southern North Sea were calculated every two months and then totalled. New figures on flight behaviour were available for the Lesser Black-backed Gull, Herring Gull, Bewick's Swan and Brent Goose (Gyimesi *et al.* 2017a, b) which were also applied in the current calculations. New GPS logger data also became available recently for Great Black-backed Gulls and they were worked up for breeding birds in a Swedish colony and a Danish colony (Gyimesi *et al.* 2017b). However, the data for the two colonies led to very different results. The application of these ambiguous data from the breeding season to wintering animals in the Dutch North Sea was therefore not considered justified. Accordingly, the same parameters were used for this species as in the KEC 1.1 calculations (Rijkswaterstaat 2015). Figures relating to flight behaviour also remained unchanged by comparison with the KEC 1.1 study (Rijkswaterstaat 2015) for the other species.

Table 2.3 provides a summary of all bird-related figures used in the calculations. **Bird data** such as length (m) and wingspan (m) are based on Snow & Perrins (1998), with the centre being taken for range values. For most species, **flight speeds** (m/s) are based on the publication of Alerstam *et al.* (2007). In the case of the Herring Gull, Lesser Black-backed Gull , Bewick's Swan and Brent Goose, they are based on the work of Gyimesi *et al.* (2017a, b). In the case of the Herring Gull and Lesser Black-backed Gull, **nocturnal activity** and **fraction time in flight** are also based on these studies (Gyimesi *et al.* 2017a, b), while the assumptions of Garthe & Hüppop (2004) are adopted for the other seabird species.

For the *seabird species* Northern Gannet, Great Skua, Great Black-backed Gull and Black-legged Kittiwake, **flight heights** as determined by Johnston *et al.* (2014) were used in the calculations. The modelled flight height distribution in metre classes by Johnston *et al.* (2014) is based on the working up of visual and radar surveys of flight heights of different species of seabirds collected in 32 potential offshore wind farm locations. For the Lesser Black-backed Gull and Herring Gull, new values were determined explicitly for use in collision models for flight height, flight speed, fraction of time in flight and nocturnal activity on the basis of data from GPS loggers on birds in Dutch, Belgian and English colonies around the Dutch North Sea (Gyimesi *et al.* 2017a).

Table 2.3 Parameters used in the Band model calculations for the current study. Nocturnal activity and flight height distribution were not available for Common Shelduck, Black Tern and Curlew. The basic Band model was used for these species with a given fraction of birds at rotor height. For Bewick's Swan and Brent Goose, the extended Band model used concrete fluxes at rotor height and these were not therefore corrected for nocturnal activity and fraction time in flight. Densities of seabird species were corrected with these parameters. Data sources for the various parameters are stated as numbers in the table and shown below it. Data updated since the KEC 1.1 study are shown in bold type.

English name	length (m)[1]	wing span (m)[1]	speed (m/s)	nocturnal activity[5]	avoidance (%)[6]	fraction at rotor height[7]	fraction time in flight[6]
Black-legged Kittiwake	0.39	1.075	13.1[2]	0.5	99.5		0.6
Herring Gull	0.595	1.44	**11.34**[3]	**0.0125**	99.5		**0.3**
Great Black-backed Gull	0.71	1.575	13.7[2]	0.5	99.5		0.4
Great Skua	0.555	1.36	14.9[2]	0	99.5		0.8
Lesser Black-backed Gull	0.58	1.425	**9.41**[3]	**0.4275**	99.5		**0.4**
Northern Gannet	0.935	1.725	14.9[2]	0.25	99.5		0.6
Bewick's Swan	0.121	1.955	**16.16**[4]		98		
Brent Goose	0.585	1.15	**17.06**[4]		98		
Common Shelduck	0.625	1.215	15.4[2]		98	0.5	
Black Tern	0.23	0.66	12[2]		98	0.07	
Curlew	0.55	0.9	17,69[2]		98	0.75	

[1] Snow & Perrins 1998

[2] Alerstam *et al.* 2007

[3] Gyimesi *et al.* 2017a

[4] Gyimesi et al. 2017b

[5] Garthe & Hüppop 2004

[6] Maclean *et al.* 2009

[7] Rijkswaterstaat 2015

GPS transmitter data have also become available for the *migratory bird species* Bewick's Swan and Brent Goose (Gyimesi *et al.* 2017b) that made it possible to correct the flight height and flight speed. These data were collected in offshore areas and contain real-life measurement data, unlike figures used previously that were partly based on assumptions (such as nocturnal activity and fraction time in flight). For the migratory bird species Common Shelduck, Black Tern and Curlew, such detailed measurements were not available and a general fraction at rotor height was used, as proposed by Wright *et al.* (2012) and used in the KEC 1.1 calculations (Rijkswaterstaat 2015).

The total numbers of collision victims per species were then calculated using species-specific values for avoidance (totalled macro- and micro-avoidance). These avoidance figures were taken from Maclean *et al.* (2009) and this approach is also in line with the KEC 1.1 study (Rijkswaterstaat 2015). They concluded that avoidance rates of 99.5% should be used for Northern Gannets, Great Skuas and gulls until better information becomes available. An avoidance rate of 98% was used for migratory bird species (cf. Rijkswaterstaat 2015). In the present study, calculations were also made using avoidance percentages established in the recently completed ORJIP project (see § 2.2.2 below). The results of these calculations will be covered in a separate chapter.

2.2.2 Avoidance rates based on the ORJIP study

Since KEC 1.1 was drafted, important studies have also been completed internationally. For example, the results of the ORJIP study were presented recently (Skov *et al.* 2018). It emerged from those results that the avoidance of offshore wind farms by seabirds is more significant than previously thought. To show the impact of a change in avoidance percentages, additional calculations were made using the ORJIP avoidance percentages. Except for the Great Skua, all other species covered by the present KEC 3.0 study were also looked at in the ORJIP study and a general avoidance percentage was established (Table 2.4). However, these results have not yet been widely accepted internationally.

Table 2.4 Avoidance percentages used during the Band model calculations in line with the KEC 1.1 study (Rijkswaterstaat 2015) and the ORJIP study (Skov et al. *2018).*

species	**Avoidance (%) KEC 1.1**	**Avoidance (%) ORJIP**
Black-legged Kittiwake	99.5	99.8
Great Black-backed Gull	99.5	99.6
Northern Gannet	99.5	99.9
Lesser Black-backed Gull	99.5	99.8
Herring Gull	99.5	99.9

2.2.3 Wind farm-related data

In the KEC 1.1, the numbers of collision victims were determined for wind farms that will be built in the period leading up to 2023 (Rijkswaterstaat 2015). The present report includes the wind farms that will in all probability be built in the period leading up to 2030 on the basis of the most realistic possible size of the turbines to be installed. The location and specifications of the wind farms were supplied by the principal and are summarised in Annex C.

The Band model also uses wind turbine characteristics. These are based on data provided by Rijkswaterstaat for KEC 1.1 and for a range of EIA studies for offshore wind farms and the present project (Rijkswaterstaat 2015; Gyimesi *et al.* 2018a). Some power ratings of wind turbines are still under development and exact data are therefore not yet available. For these turbines, the specifications are calculated on the basis of the extrapolation of the values for known, smaller, turbines (Table 2.5).

Table 2.5 Parameters used for the different turbine power ratings. All calculations are based on triple-blade turbines.

Turbine power (MW)	Speed (rpm)	Rotor diameter (m)	Tower height (m)	Blade width (m)	Pitch (°)
2	19.11	80	40	3.5	6.1
2.3	16.03	93	46.5	3.3	6.1
3	15.31	100	50	3.5	6
3.3	14.85	112	56	3.6	6.0
3.6	13.06	120	60	3.7	5.9
4	13.94	116	58	3.8	5.9
5	12.96	129	64.5	4.0	5.7
6	12.22	142	71	4.3	5.6
7	11.62	153	76.5	4.6	5.4
8	12.12	164	82	4.9	5.3
8.4	10.95	164	111.5	5.0	5.2
9	10.70	174	87	5.1	5.1
9.5	10.52	164	105	5.3	5.1
10	10.00	221	110.5	5.4	5.0
12	9.75	220	145	5.9	4.7
15	9.06	232	142	6.8	4.3

2.3 Potential Biological Removal (PBR) calculation

The calculated collision victim numbers have been compared with Potential Biological Removal (PBR) for a given species. The KEC 1.1 report (Rijkswaterstaat 2015) compares only the cumulative victims in the southern North Sea with the PBR for the population of the southern North Sea. The present document also compares the cumulative victims in the Dutch North Sea with the PBR for the Dutch population.

Furthermore, independent literature sources for population sizes were consulted for the PBR calculations in KEC 1.1. In order to use the same underlying assumptions for both exposure (number of collision victims) and effect determination (PBR limit values) in the present KEC 3.0, the population sizes of seabirds in the PBR calculations are based on the same density maps as those used for the flux calculations in the extended Band model (cf. van der Wal *et al.* 2018). For example, the victim calculations are based on the bimonthly survey data. The annual mortality is then obtained by totalling the mortality figures from the six bimonthly periods. Here, the Band model does not allow for a correction for the fact that a bird can only die once. This annual mortality was therefore also compared with a PBR standard in which the population size used was the total of six population sizes, each of which was determined on the basis of the bimonthly density maps. **The population sizes used are therefore emphatically not estimates of the actual population and they have been used only to assess the relative effect of the number of collision victims on the population.**

For migratory birds, the population estimates in KEC 1.1 are based on detailed population figures published by BirdLife International (2004); the estimates for

Bewick's Swans are based on figures from Rees & Beekman (2010). In the KEC 1.1 calculations, specific sub-populations that may be found in the central and southern North Sea were totalled to establish a specific flyway population.

Since the publication of the KEC 1.1, published population estimates have become available only on the European scale and not for each sub-population (BirdLife International 2015). In order to make it possible to use a population estimate in the present KEC 3.0 that is more recent than the data from 2004 (BirdLife International), a correction has been made. Here, on the basis of the ratio between the total sub-populations used in KEC 1.1 and the total European population in 2004 (cf. BirdLife International), the European population sizes from 2015 (cf. BirdLife International) were corrected to produce a flyway population for the central and southern North Sea (Table 2.6).

Table 2.6 Population sizes used in KEC 1.1 (BirdLife International 2004) and in the present document for the calculation of PBR limit values

species	population size in KEC 1.1	population size update KEC 3.0
Bewick's Swan	18,000	9,986
Brent Goose	148,073	199,879
Common Shelduck	65,054	72,775
Curlew	61,888	53,779
Black Tern	5,263	4,751

Since the KEC 1.1 study, the conservation status of some seabird species has been modified by the IUCN (2018). On the basis of the new IUCN criteria and the current population trends, the values for the recovery factor in the PBR calculations were adjusted. This factor was used for the recovery capacity of a population. For example, the status of the Razorbill has been changed from 'Least concern' to 'Near Threatened' (IUCN 2018) and that of the Black-legged Kittiwake from 'Least concern' to 'Vulnerable'. Accordingly, the recovery factor for these species has been adjusted from 0.5 to 0.1 in line with the criteria in the KEC 1.1 document (Rijkswaterstaat 2015). On the other hand, sustained population growth has been seen for the Northern Gannet, which has 'Least concern' status, as a result of which the recovery factor has been adjusted from 0.5 to 1.0, once again in line with the criteria in the KEC 1.1 document (Rijkswaterstaat 2015). For the other species, the recovery factors used are the same as those in the KEC 1.1 study (see Table 3.5 for the factors used).

2.4 Differences with the KEC 1.1

In summary, the approach differs from the KEC 1.1 study as follows:

- Wind farm plans have been updated in line with the latest knowledge;
- Wind turbine sizes in these calculations are wind farm-specific rather than a worst-case scenario of 3MW in each wind farm;
- Count data for the period 2014-2017 have been added to the densities of seabirds;

- Densities of seabirds for the national scenario were determined over the period 2000-2017 instead of 1991-2014 to improve reliability;
- Data on the flight behaviour of the Lesser Black-backed Gull and Herring Gull have been updated on the basis of the study by Gyimesi *et al.* (2017a) in the WOZEP research programme;
- Data on flight behaviour and migration routes of the Bewick's Swan and Brent Goose have been updated on the basis of the study by Gyimesi *et al.* (2017b) in the WOZEP research programme;
- Fluxes for the Common Shelduck, Curlew and Black Tern have been updated on the basis of population developments since the KEC 1.1 study (cf. BirdLife International 2004, 2015);
- Victim calculations were also made with avoidance percentages determined during the recent ORJIP study (Skov *et al.* 2018);
- In PBR calculations, seabird population sizes were determined using the same density maps as the input for the victim calculations;
- In PBR calculations, values for recovery capacity were adjusted in line with the latest conservation status classification by IUCN (IUCN 2018);
- In PBR calculations, population sizes or migratory birds were updated on the basis of population developments since the KEC 1.1 study (cf. BirdLife International 2004, 2015).

3 Results for collision victims

3.1 Seabirds

The estimates of the number of victims among Northern Gannets, Great Skuas, Black-legged Kittiwakes, Lesser Black-backed Gulls, Great Black-backed Gulls and Herring Gulls were updated in the present victim calculations on the basis of the new density calculations and wind farm scenarios by comparison with the KEC 1.1 document, which assumes as a worst-case scenario that all wind farms in the southern North Sea consist of 3MW turbines (Rijkswaterstaat 2015). In the case of Lesser Black-backed Gulls and Herring Gulls, new values for variables relating to flight behaviour were also used in the present calculations (Gyimesi *et al.* 2017a).

By comparison with the calculations for the KEC 1.1 document, realistic turbine power ratings (up to 12MW) were used in these calculations. In fact, of all the wind farms, only seven consist of 3MW turbines and there is one with 2MW turbines. Larger turbines will be installed in all other wind farms. Upgrading to larger wind turbine types generally results in a lower risk of collision for birds. For example, scaling up from 3MW to 5MW results in a 25%-31% decrease in the number of victims among large gulls (Gyimesi & Fijn 2015b). In sites I and II of the Borssele wind farm also, the use of 3MW turbines rather than 10MW turbines would result in four times as many victims among large gulls (Gyimesi & Fijn 2015a). In addition, the use of larger turbines also reduces the total number of turbines with which birds can collide in the central and southern North Sea. Furthermore, the new densities in KEC 3.0 have proven to be significantly lower for a number of species than those used in the KEC 1.1 calculations. This could be the result in part of the different time periods adopted but an important difference in the density determinations (the approach to IDW interpolation calculations) certainly led to significantly lower densities in KEC 3.0 (see Annex 5 in van der Wal *et al.* 2018).

3.1.1 International scenario

As a result of the new input values listed above, the new calculations show a significant decrease in the expected number of collision victims for the six seabird species studied. In all wind farms in the central and southern North Sea, the number of collision victims will exceed 1,000 for Lesser Black-backed Gulls only (i.e. 2,026) and the number will be far lower for the other species (Table 3.1). For all species, this means a decrease of more than 60% by comparison with the original KEC 1.1 calculations (Rijkswaterstaat 2015) and a decrease of more than 80% by comparison with the second iteration for the three large gull species (van der Wal *et al.* 2015). The expected number of collision victims per wind farm according to the international scenario has been included in Annex D.

Table 3.1 Estimated annual number of victims in existing and future wind farms in the ***central and southern North Sea*** *for a number of* ***seabird species****, as determined with the extended Band model (Band 2012). Results were compared with calculations from*

KEC 1.1 (Rijkswaterstaat 2015), with the lowest victim figures from the second iteration being shown for the three large gull species (van der Wal et al. *2015).*

Species	victims in KEC 1.1 (2015)	victims in KEC 3.0 in all wind farms (incl. NL)	% decrease
Great Skua	12	4	66
Northern Gannet	2,631	211	92
Black-legged Kittiwake	5,930	347	94
Great Black-backed Gull	4,082	781	81
Lesser Black-backed Gull	11,918	1,991	83
Herring Gull	4,274	743	83

3.1.2 National scenario

Calculations were also made for the national scenario in the Netherlands. This includes the existing wind farms Luchterduinen and Gemini, as well as the planned Borssele, Holland Coast, IJmuiden Ver and North of the Wadden Islands farms. The existing OWEZ and Prinses Amalia wind farms have not been included in the present calculations since they are expected to be decommissioned between 2023 and 2030; they have been discussed in a separate report (Gyimesi & Leemans 2018). By comparison with previous calculations for the 2030 Roadmap (Gyimesi *et al.* 2018b), the calculations for the wind farms were made with new bird densities for the period 2000-2017 in line with the agreements for the present study (Bravo Rebolledo & Gyimesi 2018). In addition, specific capacities (8, 9.5 or 10 MW) were used for the future wind farms instead of ranges. The number of collision victims for a number of seabird species in the existing and future Dutch offshore wind farms is shown in Table 3.2.

It is not expected that there will be any Great Skua victims in the Netherlands. There will also be fewer than 100 victims annually in the Dutch farms among Northern Gannets and Black-legged Kittiwakes. In the case of the Lesser Black-backed Gull, it is expected that there will be 547 victims annually. The number of victims is less than half of that figure for the Herring Gull and less than one third for the Great Black-backed Gull (Table 3.2).

Table 3.2 Estimated annual number of victims in existing and future wind farms in the ***central and southern North Sea*** *for a number of* ***seabird species***, as determined with the extended Band model (Band 2012).

Dutch wind farms	**Great Skua**	**Northern Gannet**	**Black-legged Kittiwake**	**Great Black-backed Gull**	**Lesser Black-backed Gull**	**Herring Gull**
Gemini	0	6	10	18	42	7
Holland Coast (West) N	0	1	3	8	28	15
Holland Coast (West) S	0	1	2	7	26	12
IJmuiden Ver NE	0	1	4	7	44	9
IJmuiden Ver NW	0	1	3	8	52	7
IJmuiden Ver SE	0	1	3	9	39	8
IJmuiden Ver SW	0	1	3	11	39	7
Luchterduinen	0	2	2	9	22	10
North of Wadden Islands	0	1	2	11	23	3
Borssele I and II	0	5	6	12	40	21
Borssele III and IV	0	3	7	10	28	13
Holland Coast South I and II	0	2	4	16	55	26
Holland Coast South III and IV	0	2	5	15	56	28
Holland Coast North I and II	0	3	5	22	53	45
Total	**0**	**30**	**58**	**164**	**547**	**209**

3.1.3 ORJIP avoidance

One of the most important parameters with a major impact on the outcome of the Band model is avoidance. A difference of a few tenths in avoidance percentages can lead to a difference in the number of collision victims amounting to percentages in multiples of ten (Cook *et al.* 2018). Despite the importance of this consideration, this is also one of the most difficult parameters in terms of collecting reliable measurements. Recently, general avoidance rates have been published for a number of seabird species on the basis of radar measurements and linked camera recordings, and supported by visual observations made in the context of the ORJIP research programme (Skov *et al.* 2018). With the exception of the Great Skua, the species covered by the ORJIP study are the same as in the present study. According to the authors, the published avoidance percentages can be used directly in the Band model. Despite the fact that there is still no broad international acceptance of the avoidance percentages determined during the ORJIP study, the current KEC 3.0 calculations were also made with these recent data to illustrate the effect of uncertainty in avoidance figures. However, given the lack of broad scientific acceptance, the current KEC 3.0 is based on the avoidance percentages used in KEC 1.1 (Rijkswaterstaat 2015).

In the case of the current study, applying the ORJIP avoidance percentages would result in a reduction of between 20% and 80%. The smallest decrease in the number of victims would be seen in Great Black-backed Gulls, for which the avoidance percentage only changes by one tenth (from 99.5% to 99.6%). An increase of 0.3% in the avoidance percentages for Black-legged Kittiwakes and Lesser Black-backed Gulls resulted in 60% fewer collision victims. For Northern Gannets and Herring Gulls, the reduction in the number of collision victims is even larger (80%) as a result of an increase in the avoidance percentages of 0.4%.

Table 3.3 Estimated annual number of victims in existing and future wind farms in the international and national scenarios for a number of seabird species assuming the use of the avoidance percentages from the ORJIP study (Skov et al. *2018) in the extended Band model (Band 2012) and the fall in percentages relative to the number of victims presented in Tables 3.2 and 3.3.*

species	ORJIP international scenario	ORJIP national scenario	decrease (%)
Black-legged Kittiwake	139	24	-58
Great Black-backed Gull	625	125	-24
Northern Gannet	42	6	-80
Lesser Black-backed Gull	797	221	-60
Herring Gull	149	48	-77

3.2 Migratory birds

On the basis of the new wind farm scenarios, new estimates were calculated for the number of collision victims in the migratory bird species Bewick's Swan, Brent Goose, Common Shelduck, Curlew and Black Tern. The new flight speed and flight height figures based on the GPS data for **Bewick's Swan** and **Brent Goose** were lower than previously estimated (Gyimesi *et al.* 2017b). Because the collision risk near the nacelle is highest, which is higher in the case of larger turbines, the collision risk falls significantly with increasing turbine sizes. All this led to a significant decrease in the estimated number of collision victims among Bewick's Swans and Brent Geese in comparison to the KEC 1.1 study (Table 3.4). In fact, there would be annual victims among Bewick's Swans only in the future IJmuiden Ver wind farms; the remaining victims are the totalled collision probabilities (Annex E). Due to the important migration routes of Bewick's Swans and Brent Geese in the Dutch section of the North Sea, 41% and 40% respectively of the victims in these species will be in Dutch offshore wind farms (Table 3.4).

*Table 3.4 Estimated annual number of victims in existing and future wind farms in **the central and southern North Sea** for a number of **migratory bird species**. The numbers were determined for Bewick's Swan and the Brent Goose with the extended Band Model (Band 2012) and for the other species with the basic Band model (Band* et al. *2007). Results were compared with calculations from KEC 1.1 (Rijkswaterstaat 2015).*

species	victims in KEC 1.1 (2015)	victims in international wind farms (incl. NL)	victims in Dutch wind farms	% change
Bewick's Swan	58	6	2	-90
Brent Goose	155	110	42	-28
Common Shelduck	158	367	63	+134
Curlew	543	496	86	-8
Black Tern	23	38	7	+66

Flight height profiles were not available for the **Common Shelduck**, **Curlew** and **Black Tern** and the birds in the model were distributed evenly over the air column. An increase in the rotor swept area for larger turbines results in a higher bird flux at rotor height. This contrasts with the species in which available GPS logger measurements show higher fluxes at lower heights. As a result of the adjusted fluxes in comparison to KEC 1.1 (relative to population size trends), the calculated numbers of collision victims in KEC 3.0 varied. The numbers for Common Shelduck and Black Tern victims were a lot higher (Table 3.4) than in the KEC 1.1 document. In the case of the Curlew, the decline in the population resulted in fewer collision victims than in the KEC 1.1 study (Table 3.4). In the absence of information about the exact migration routes for these species, the victims were distributed evenly across all the wind turbines in offshore wind farms in the central and southern North Sea. Accordingly, the share of Dutch offshore wind farms in the total number of victims is as high as the share in the total number of turbines for these species (17%; Table 3.4). The numbers of victims per wind farm can be found in Annex E.

3.3 Comparison with PBR

3.3.1 Seabirds

The assessment of the cumulative effects of all wind farm developments in the southern North Sea in the KEC 1.1 study made it clear that there would be more victims among Lesser Black-backed Gulls and Herring Gulls than the individual species can cope with according to the Potential Biological Removal (PBR) principle (van der Wal *et al.* 2015). The original calculations were made as a worst-case scenario with the smallest 3 MW variant and upgraded later to 4 MW and 5 MW. The current calculations show a fall in the number of collision victims if turbine capacity in the farms is estimated more realistically (by using larger turbines).

The updated number of collision victims is compared below with newly defined PBR values. In the current KEC 3.0 PBR calculations, the population sizes of seabirds are based on the same density maps (cf. van der Wal *et al.* 2018) as those used to calculate the number of collision victims. Accordingly, annual mortality is determined by adding up mortality figures from the six bimonthly periods but the PBR standard is also based on the sum of six population sizes, each determined using the bimonthly density maps. The population sizes used are therefore emphatically not estimates of the actual population and they have been used only to assess the relative effect of the number of collision victims on the population.

Table 3.5 does this for the international scenario and Table 3.6 focuses on the Dutch scenario. The calculations show that the numbers of collision victims for all seabird species remain safely below the PBR standard in both the international and the national scenario (Tables 3.5 and 3.6) due to the sharp fall in the number of collision victims (see §3.1), but also because the PBR values used for most species are higher than in the KEC 1.1 calculations (see Rijkswaterstaat 2015).

Table 3.5 Number of seabird victims as a result of collisions with wind turbines in existing and future wind farms in the central and southern North Sea, also stated as a fraction of the ***central and southern North Sea PBR population****. The population sizes presented were determined for the PBR calculations on the basis of density maps from the period 1991-2017 and they do not represent estimates of the actual population. Recovery factors (rf) indicate the recovery capacity of a species determined on the basis of IUCN conservation status and current population trends (IUCN 2018).*

Species	international PBR population	victims in international wind farms (incl. NL)	rf	PBR	victims as a fraction of PBR
Great Skua	86,392	4	0.5	1,464	0.003
Northern Gannet	507,215	211	1.0	22,354	0.01
Black-legged Kittiwake	830,413	347	0.1	2,373	0.15
Great Black-backed Gull	434,508	781	0.5	11,799	0.07
Lesser Black-backed Gull	367,543	1,991	0.5	9,481	0.21
Herring Gull	473,144	743	0.1	2,235	0.33

N.B: the number of victims and PBR populations should not be used separately.

Table 3.6 Number of seabird victims as a result of collisions with wind turbines in existing and planned wind farms on the Dutch Continental Shelf, also stated as a fraction of the ***Dutch PBR population****. The population sizes presented were determined for the PBR calculations on the basis of density maps from the period 2000-2017 and they do not represent estimates of the actual population. Recovery factors (rf) indicate the recovery capacity of a species determined on the basis of IUCN conservation status and current population trends (IUCN 2018).*

species	Dutch PBR population	victims in Dutch wind farms	rf	PBR	victims as a fraction of PBR
Great Skua	1,633	0.2	0.5	28	0.006
Northern Gannet	76,338	30	1.0	3,364	0.01
Black-legged Kittiwake	124,176	58	0.1	581	0.10
Great Black-backed Gull	84,326	164	0.5	2,290	0.07
Lesser Black-backed Gull	96,588	547	0.5	2,492	0.22
Herring Gull	91,493	209	0.1	432	0.48

N.B: the number of victims and PBR populations should not be used separately.

3.3.2 Migratory birds

The results of the calculations of the number of collision victims in migratory bird species show a decrease in comparison to the KEC 1.1 results in the two species (Bewick's Swan, Brent Goose) with a flight height distribution because the collision probability and the proportion of birds at rotor height falls when turbines are larger. On the other hand, the numbers for Common Shelduck and Black Tern actually increased when real (and larger) turbines were used in comparison to KEC 1.1.

As a result, the calculated number of collision victims among Bewick's Swans and Brent Geese has fallen far below the PBR standard (Table 3.7) and no longer reaches

10% of the PBR level. On the other hand, given the increased number of victims, the Black Tern is almost at the level of the PBR. At the same time, in the case of the Curlew (despite a decrease in the number of victims), the prediction is that 64% of the PBR standard will collide with wind turbines in the central and southern North Sea (Table 3.7). According to the current calculations, the increased number of victims reaches 10% of the PBR level in the Common Shelduck by comparison with 4.8% in KEC 1.1 (Table 3.7).

Table 3.7 Number of seabird victims as a result of collisions with wind turbines in existing and future wind farms in the central and southern North Sea, also stated as a fraction of the PBR for the ***flyway population****. Population sizes were determined using population estimates (BirdLife International 2004 and 2015) and current population trends (IUCN 2018).*

Species	PBR international	Victims as a fraction of PBR
Bewick's Swan	73	0.08
Brent Goose	8175	0.01
Common Shelduck	3856	0.10
Curlew	783	0.64
Black Tern	39	0.98

4 Discussion

The current KEC 3.0 study contains the best available data for the species studied about distribution, bird densities, flight speed, flight height, percentage of flying birds and nocturnal activity. The results of the calculations for collision victims are therefore an improvement on the estimates in the KEC 1.1 study. The largest knowledge gap in terms of predicting the number of victims relates to migratory birds: the Black Tern, Curlew and Common Shelduck. Knowledge relating to these species is lacking with regard to both migration routes and offshore flight behaviour. It was therefore possible to make broad assumptions only in the Band model calculations: for example that these species can be found in any wind farm in the central and southern North Sea and assumptions about the percentage of birds at rotor height. New information relating to these knowledge gaps could lead to an improvement in the calculated numbers of victims.

The number of collision victims among seabirds was assessed in the present KEC 3.0 on the basis of population sizes determined using the same density maps as those for the flux calculations in order to apply the same underlying principles for both exposure (number of collision victims) and effect determination (PBR limit values). According to the Band model, the annual mortality is the total mortality in all months (in the present study, the total for the bimonthly periods), which does not correct for the fact that a bird can die only once. These victim numbers can therefore be seen as an overestimation and this complies with the precautionary principle. In a similar way, the population sizes in this document cannot be interpreted as actual population estimates: they are the sum of six population sizes, each determined on the basis of the bimonthly density maps. These population sizes can be used only in conjunction with the calculated summed number of victims and it is crucial to realize that they are not estimates of the actual population. For these reasons, the calculated number of victims should not be used to assess the conservation objectives for Natura 2000 areas because the numbers of victims based on the density maps for seabird surveys would then be assessed on the basis of a population that would not be based on the same density maps.

Finally, it should be stressed that the Band model also uses monthly bird densities to calculate monthly victim numbers which are then added together to produce annual victim numbers. This therefore assumes that different individuals have been counted during the bird surveys that can become victims in the wind farm. It is likely that this results in an overestimation of the total number of victims because the successive monthly densities have not been corrected for the victims in the preceding months. In the future, validation of the model results with the actual number of seabird victims will have to provide a clear indication of the margin of error in the calculated number of victims.

5 Conclusions and recommendations

5.1 Conclusions

When determining the total number of collision victims, we drew on the most recent plans for wind farm developments and associated wind turbines in the southern and central North Sea for this KEC 3.0 (2018) report. Recent knowledge about the flight behaviour of Herring Gulls and Lesser Black-backed Gulls in offshore areas was also used. The calculations also include comparable data and migration routes based on GPS data for Bewick's Swans and Brent Geese.

Collision victim numbers have been calculated for the entire central and southern North Sea area and separately for the Dutch section. Despite the scaling up of wind farms, a fall in the number of victims is expected in both the international and national scenarios. In the international scenario, the number of victims is between 67 and 94% lower than found on the basis of the KEC 1.1 calculations (Rijkswaterstaat 2015).

No new data were available for the other migratory bird species Common Shelduck, Curlew and Black Tern. Without known migration routes and flight height distributions for these species, the larger rotor diameters of larger turbines result in more Common Shelduck and Black Tern victims: more than twice the number of Common Shelduck victims and one and a half times as many Black Terns as in the KEC 1.1 document. New information relating to these knowledge gaps in migration routes and flight heights of these migratory bird species may lead to an improvement of the accuracy of the calculated victim numbers.

The numbers of victims were also compared with a PBR level that was updated on the basis of population sizes determined using the density maps used to make the victim calculations. The PBR calculations show that, for all seabird species, the numbers of collision victims remain safely below the PBR standard in both the international and national scenarios due to the sharp decrease in the number of collision victims and a higher PBR value for most species in comparison to the KEC 1.1 study (Rijkswaterstaat 2015). In fact, the numbers of victims in the current KEC 3.0 are more than 10% of the PBR level (34%, 21% and 15% respectively) only for the Herring Gull, Lesser Black-backed Gull and Black-legged Kittiwake. Nevertheless, it should be emphasised that, when new population estimates become available, the calculations should be made again. The most up-to-date calculations should always be used in future EIA and AA studies.

Of the migratory bird species, the number of victims is also far below the PBR standard (8% and 1% respectively) in Bewick's Swans and Brent Geese. On the other hand, given the increased number of victims, the Black Tern is almost at the level of the PBR, while, in the case of the Curlew and the Common Shelduck, the prediction is that 10% of the PBR standard will collide with wind turbines in the central and southern North Sea.

5.2 Recommendations

Of the eleven species studied, new types of data about flight behaviour produced specific knowledge, relating to four species, that was very useful in terms of enhancing the reliability of calculations of the number of collision victims in offshore wind farms in the central and southern North Sea. On the basis of the enhanced knowledge, it can be concluded that, if larger turbines are used, the number of collision victims in offshore wind farms among seabird species, Bewick's Swans and Brent Geese will remain below the PBR standard. However, some of these species also use terrestrial habitats or fly over land during seasonal migration, where more individuals of these species die as a result of wind farms, high-voltage lines and hunting. Ideally, a cumulative assessment should also take this additional mortality into account, in order to determine the actual population impact.

In migratory bird species for which no wind farm-specific fluxes and flight height distributions are available, the number of collision victims increases because of the larger rotor swept areas. GPS logger data for the migratory bird species Bewick's Swan and Brent Goose helped to determine fluxes along the migration routes and determine flight heights. As a result, it was possible to calculate new collision probabilities for all turbine capacity variants and apply them to each wind farm. In any event in the case of the Curlew and Common Shelduck, it was possible to collect data of this kind in order to obtain more reliable estimates of the number of collision victims using GPS loggers for these species. The Black Tern is too light for the GPS loggers currently available. Nevertheless, it could be possible to investigate how far the migration routes can be determined more specifically than the generic fluxes used in the present KEC 3.0 study.

The current calculations of collision victims are based on the best available estimates of flight speed, flight height, percentage of flying birds, nocturnal activity, etc. However, there is a margin of uncertainty in all input parameters and therefore in the results. Band (2012) stresses the importance of identifying uncertainties in the Band model but acknowledges that, at present, the approach to uncertainties is largely based on expert judgment. Recently, Marine Scotland published a stochastic Collision Risk Model that includes uncertainty as a structural part of the calculations. This model can be used not only to estimate the central tendency but also to estimate variation in the final results.

Finally, it was intended to use the same principles for both exposure (number of collision victims) and effect determination (PBR limit values) in the present KEC 3.0. The seabird population sizes in the PBR calculations are therefore based on the same bimonthly density maps as those used for the flux calculations. The annual mortality in the Band model is the sum of mortality for the different periods and does not take into account the fact that a bird can die only once. This problem can be addressed by using population models which can also be used to determine the effect of the number of victims on the population. Ideally, a realistic population estimate should be used here rather than totalled population sizes determined in different periods.

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Annex A Seabird density maps, international scenario

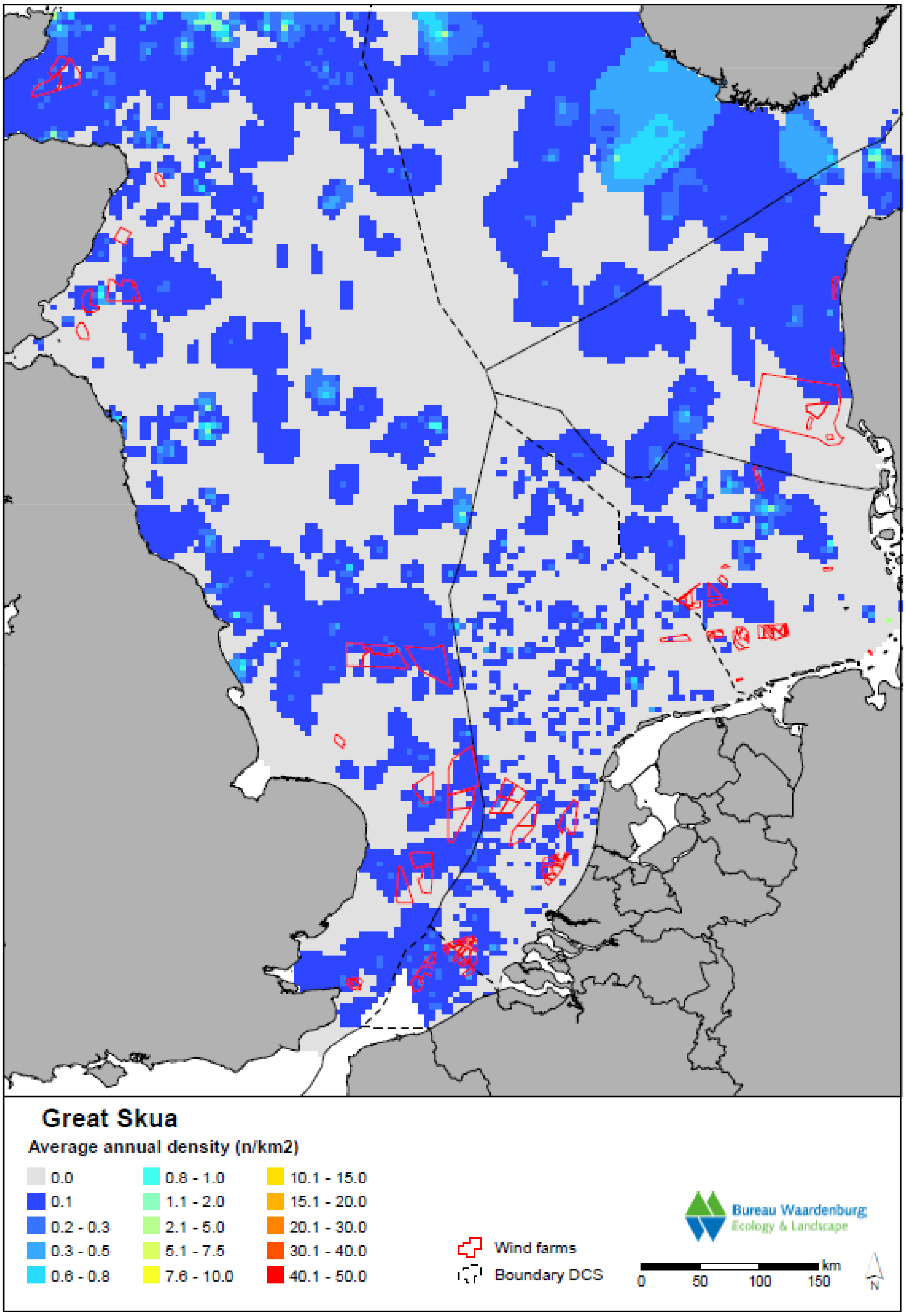

Figure A.1 Multi-year (period 1991-2017) seasonal average densities of Great Skuas in the central and southern North Sea in and around offshore wind farm areas (red line). Blue lines are international boundaries.

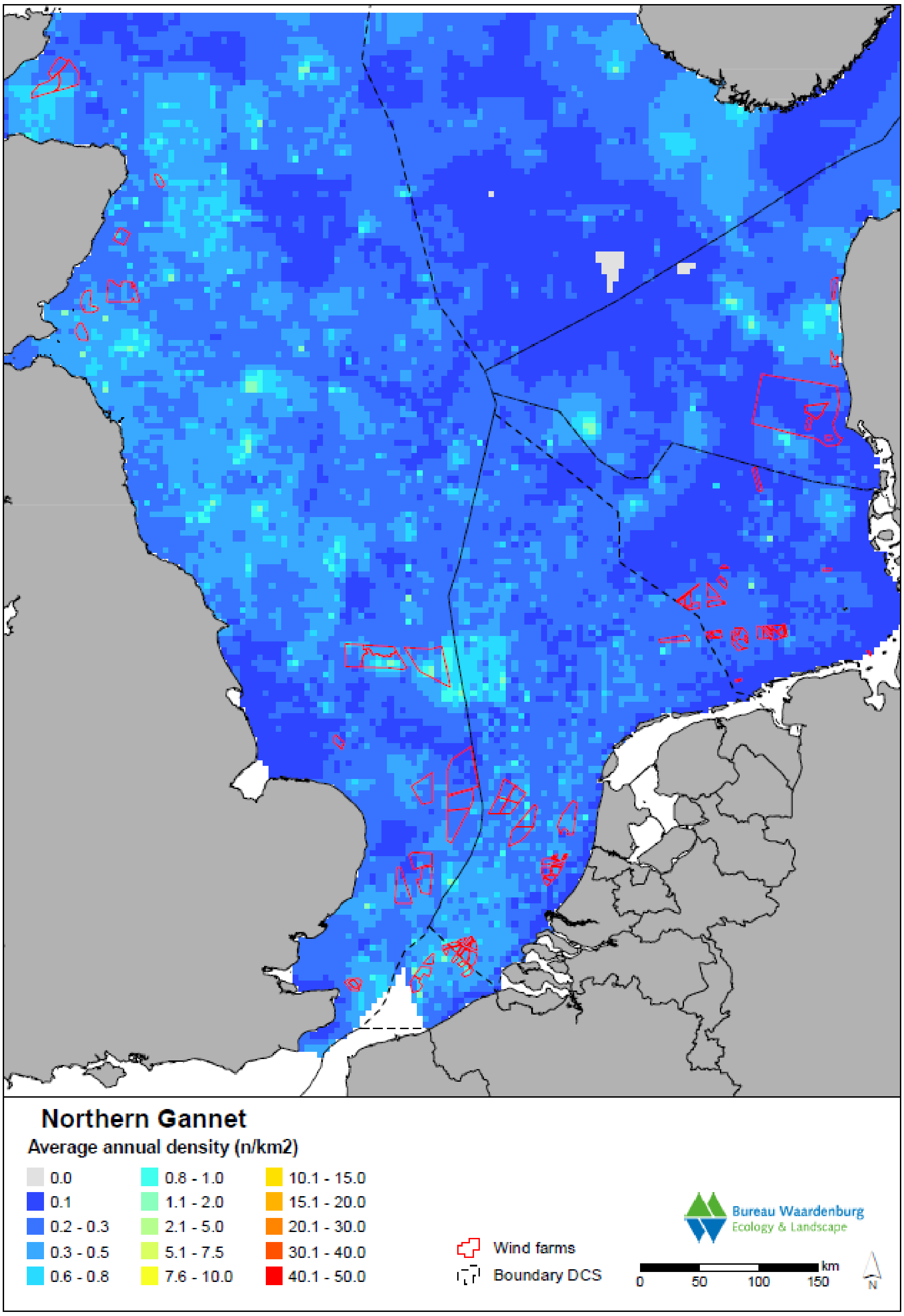

Figure A.2 Multi-year (period 1991-2017) seasonal average densities of Northern Gannets in the central and southern North Sea in and around offshore wind farm areas (red line). Blue lines are international boundaries.

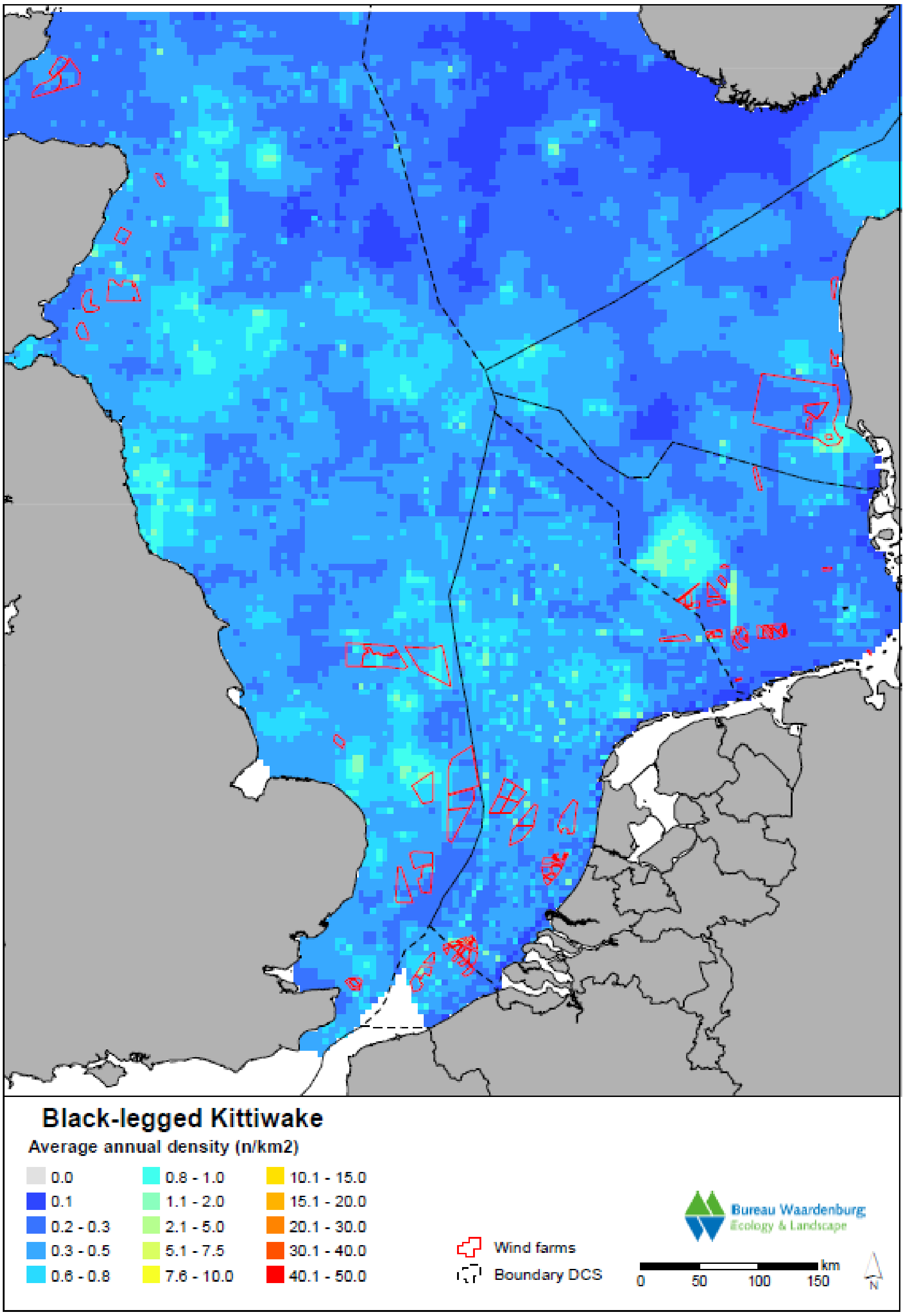

Figure A.3 Multi-year (period 1991-2017) seasonal average densities of Black-legged Kittiwakes in the central and southern North Sea in and around offshore wind farm areas (red line). Blue lines are international boundaries.

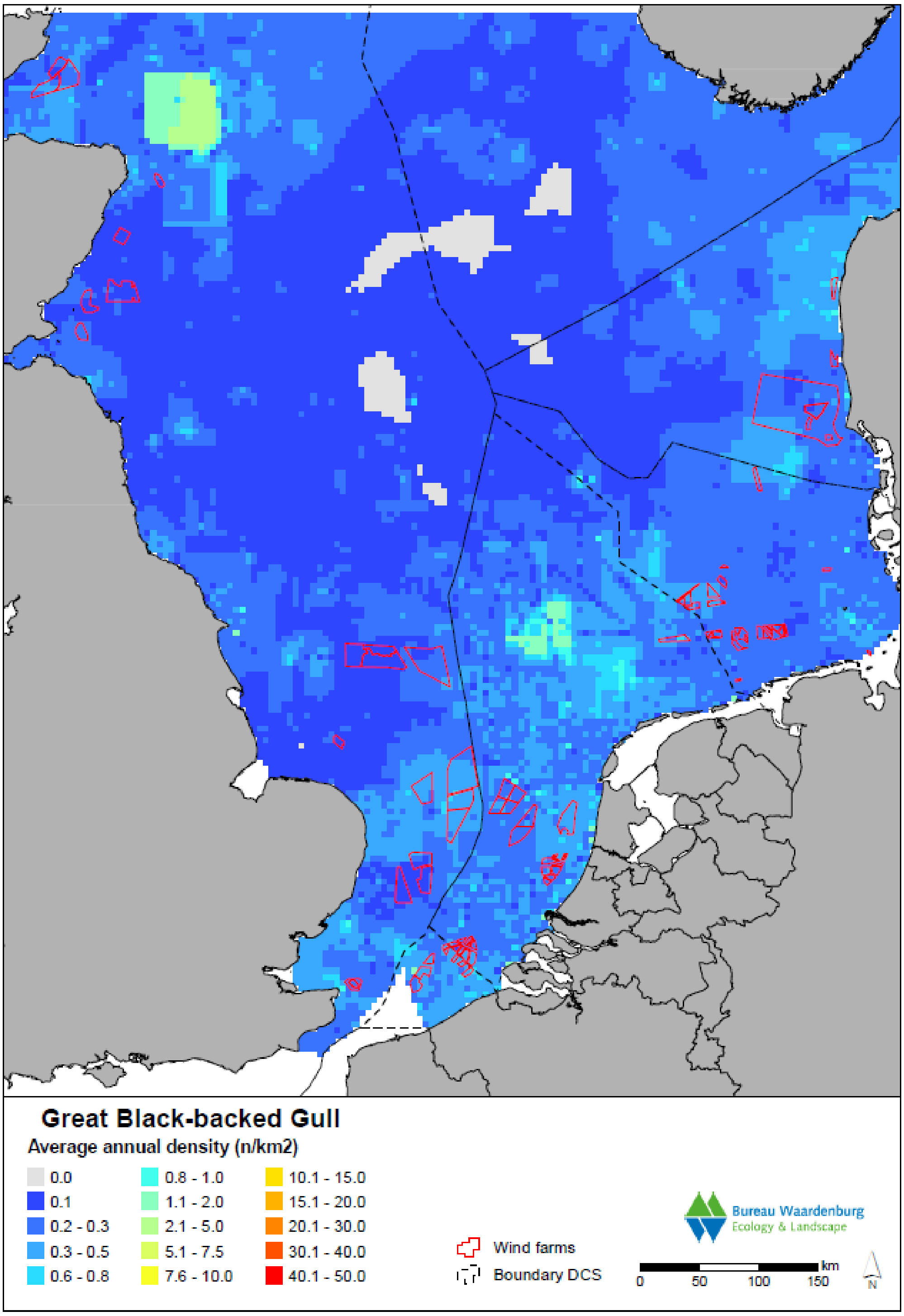

Figure A.4 Multi-year (period 1991-2017) seasonal average densities of Great Black-backed Gulls in the central and southern North Sea in and around offshore wind farm areas (red line). Blue lines are international boundaries.

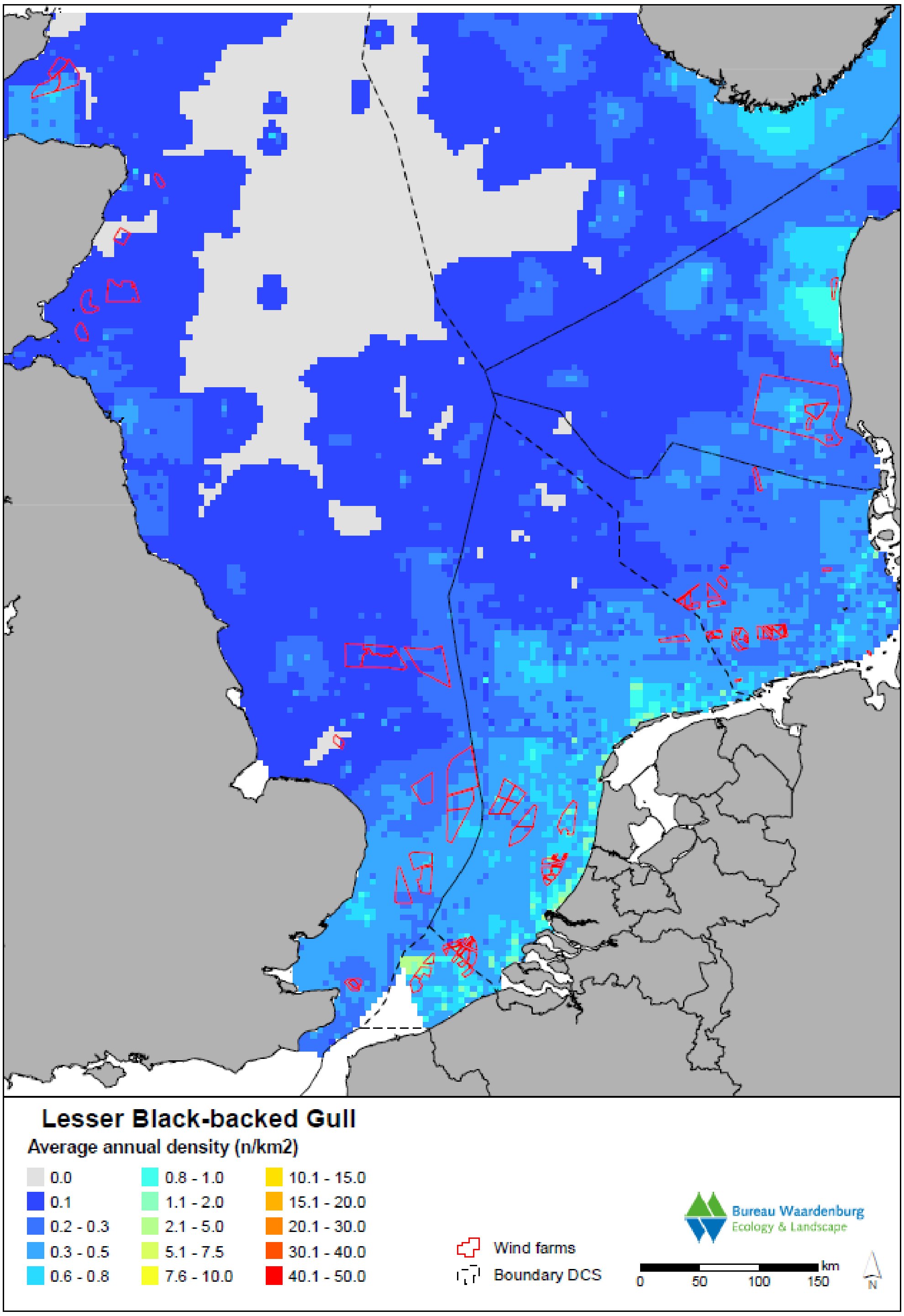

Figure A.5 Multi-year (period 1991-2017) seasonal average densities of Lesser Black-backed Gulls in the central and southern North Sea in and around offshore wind farm areas (red line). Blue lines are international boundaries.

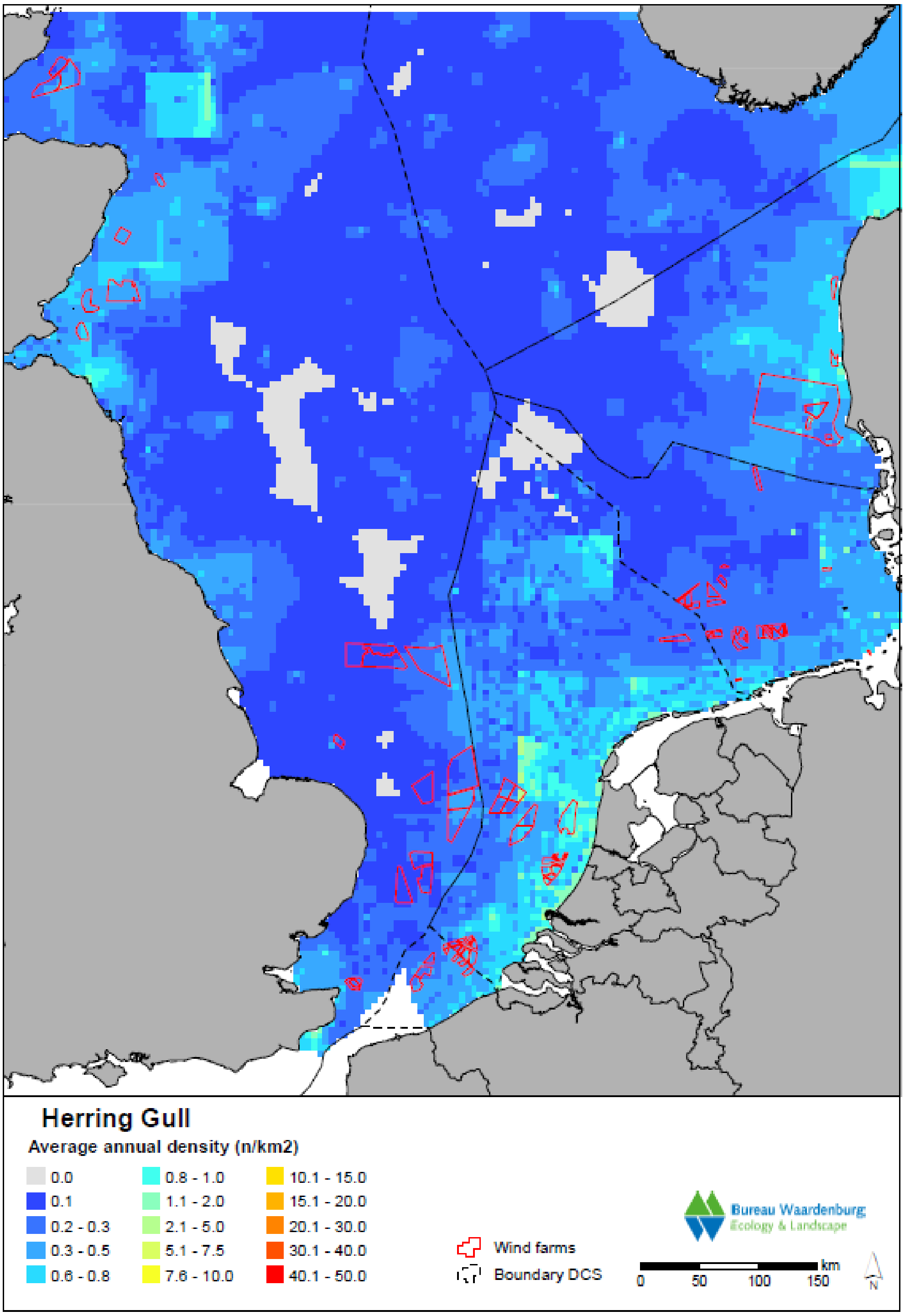

Figure A.6 *Multi-year (period 1991-2017) seasonal average densities of Herring Gulls in the central and southern North Sea in and around offshore wind farm areas (red line). Blue lines are international boundaries.*

Annex B Seabird density maps, national scenario

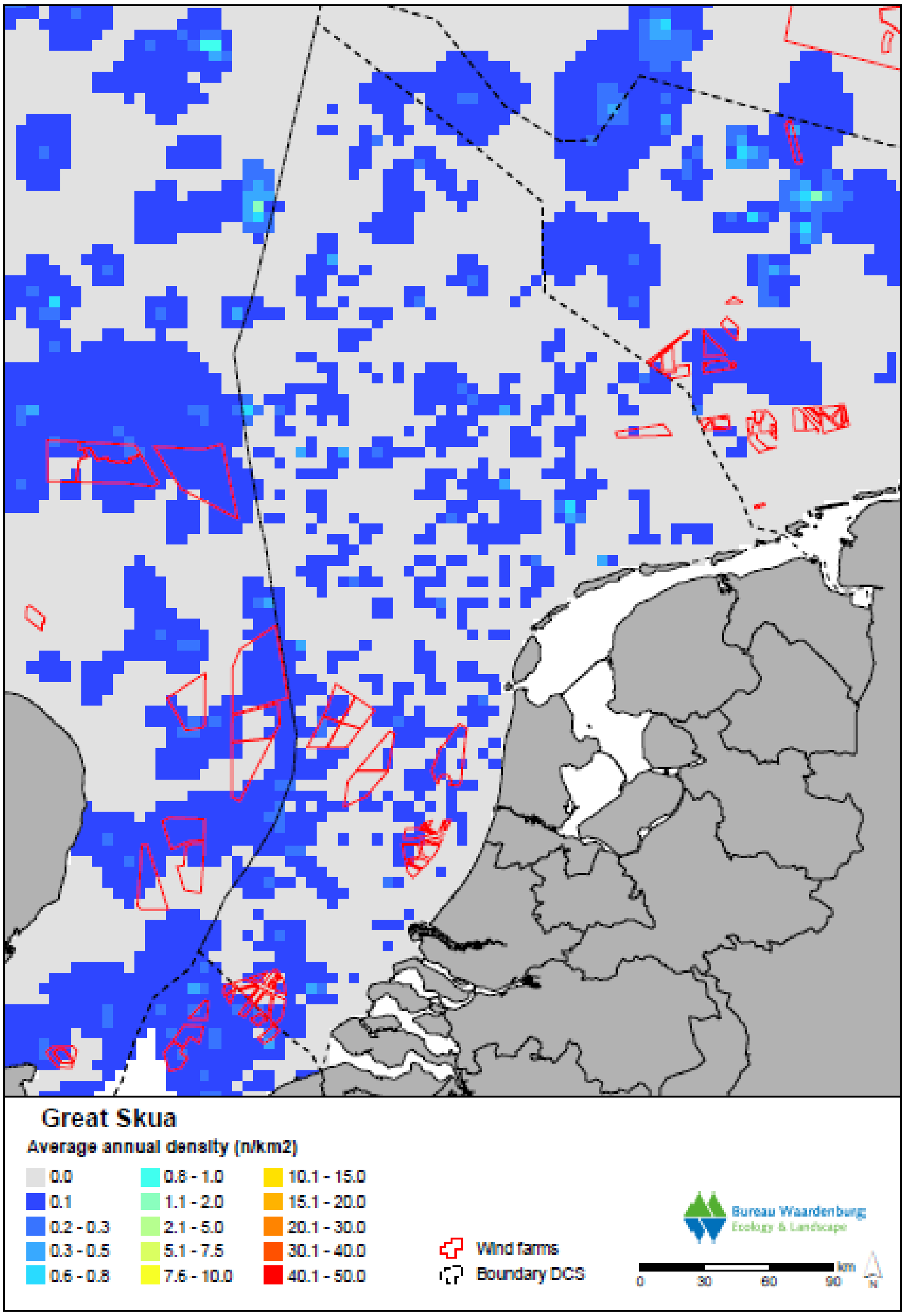

Figure B.1 Multi-year (period 2000-2017) seasonal average densities of Great Skuas in the central and southern North Sea in and around offshore wind farm areas

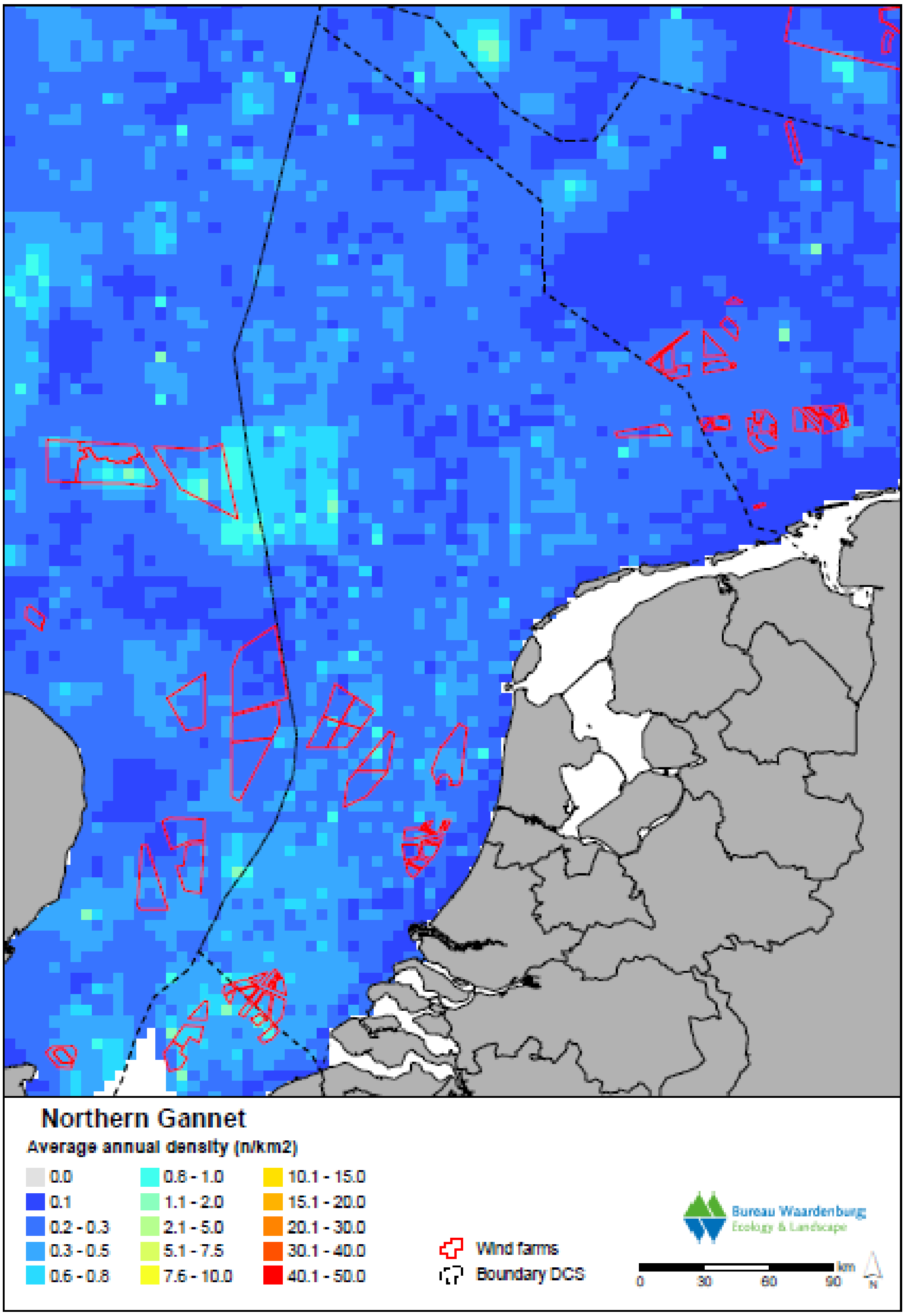

Figure B.2 *Multi-year (period 2000-2017) seasonal average densities of Northern Gannets in the central and southern North Sea in and around offshore wind farm areas*

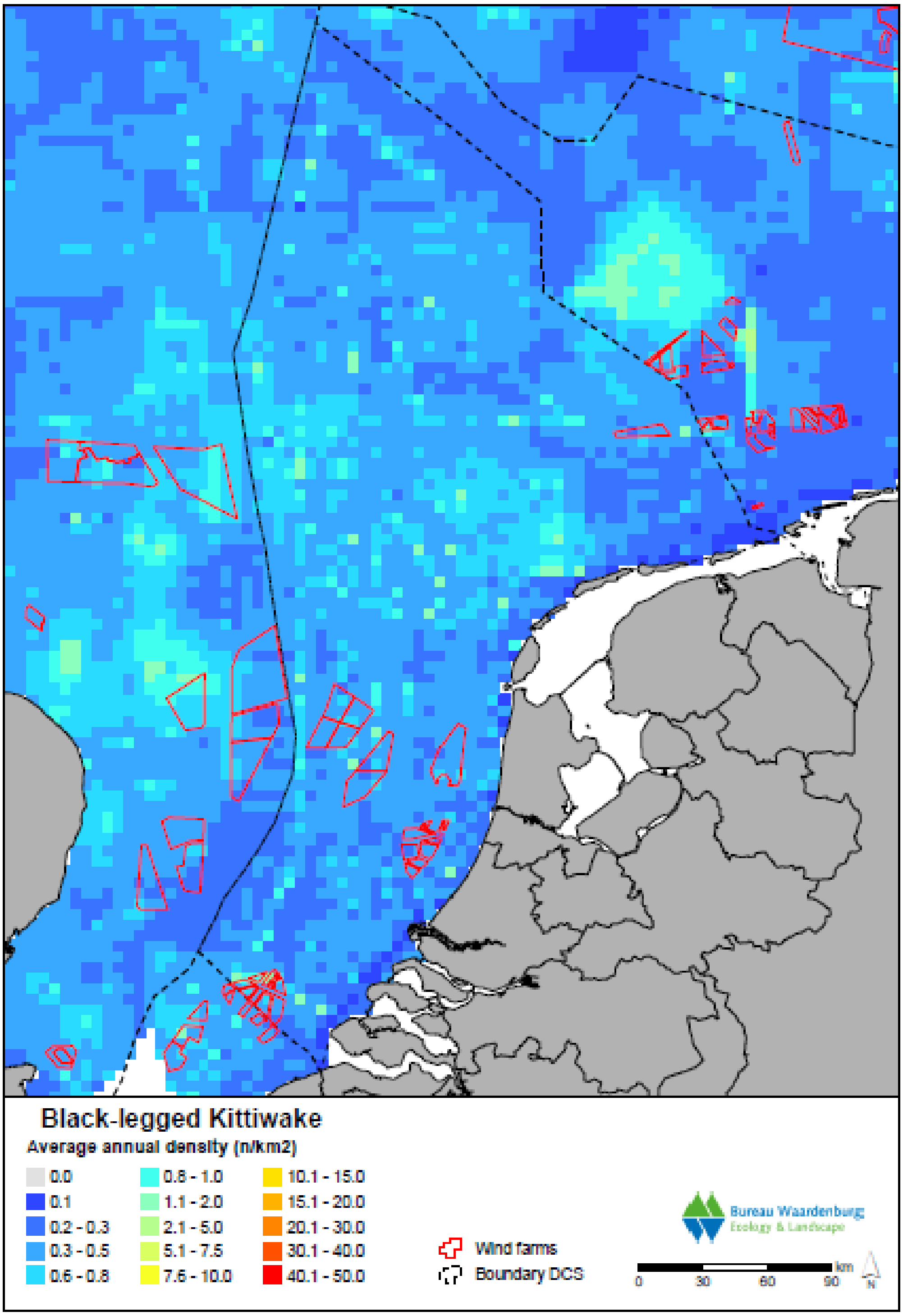

Figure B.3 Multi-year (period 2000-2017) seasonal average densities of Black-legged Kittiwakes in the central and southern North Sea in and around offshore wind farm areas

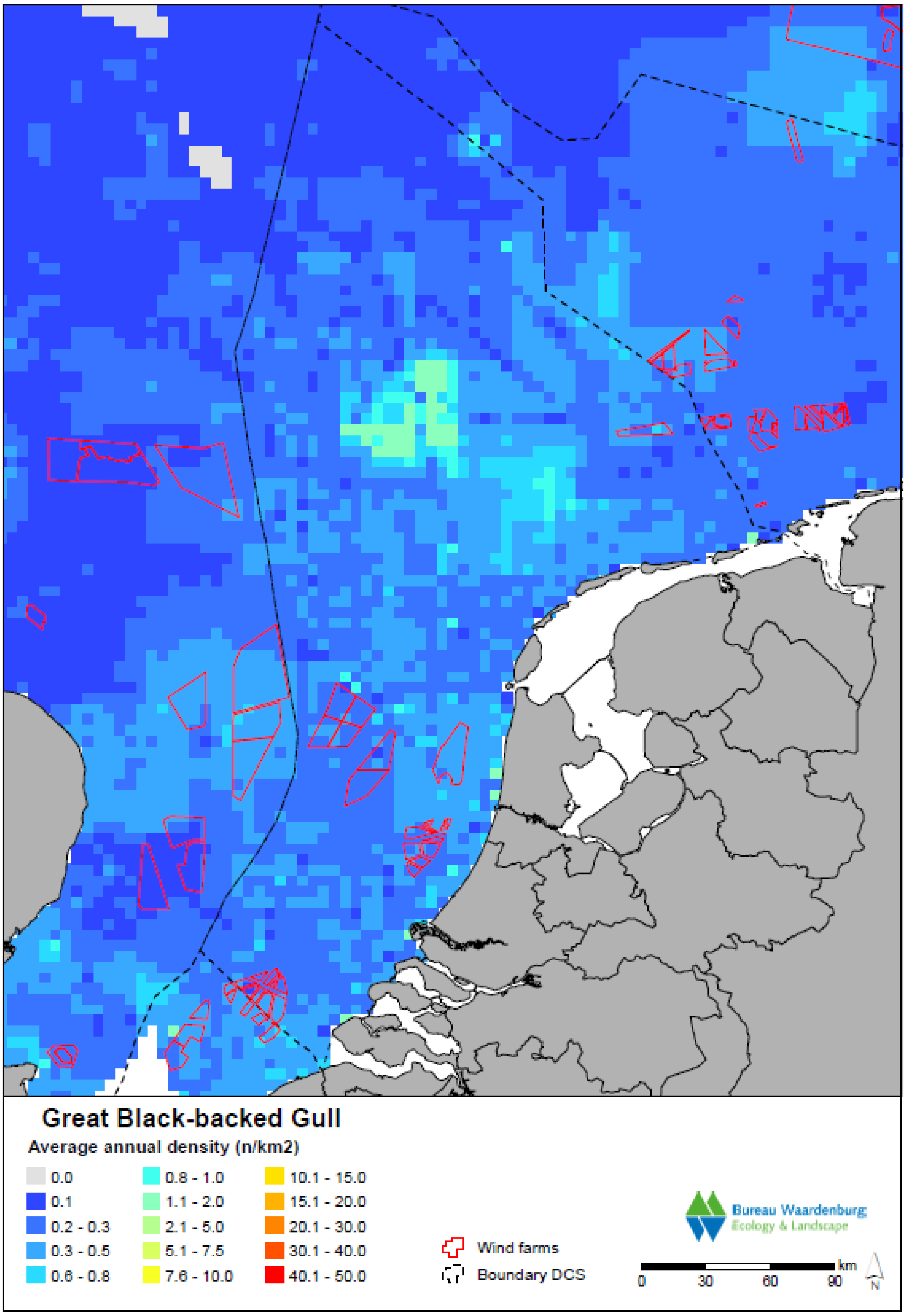

Figure B.4 Multi-year (period 2000-2017) seasonal average densities of Great Black-backed Gulls in the central and southern North Sea in and around offshore wind farm areas

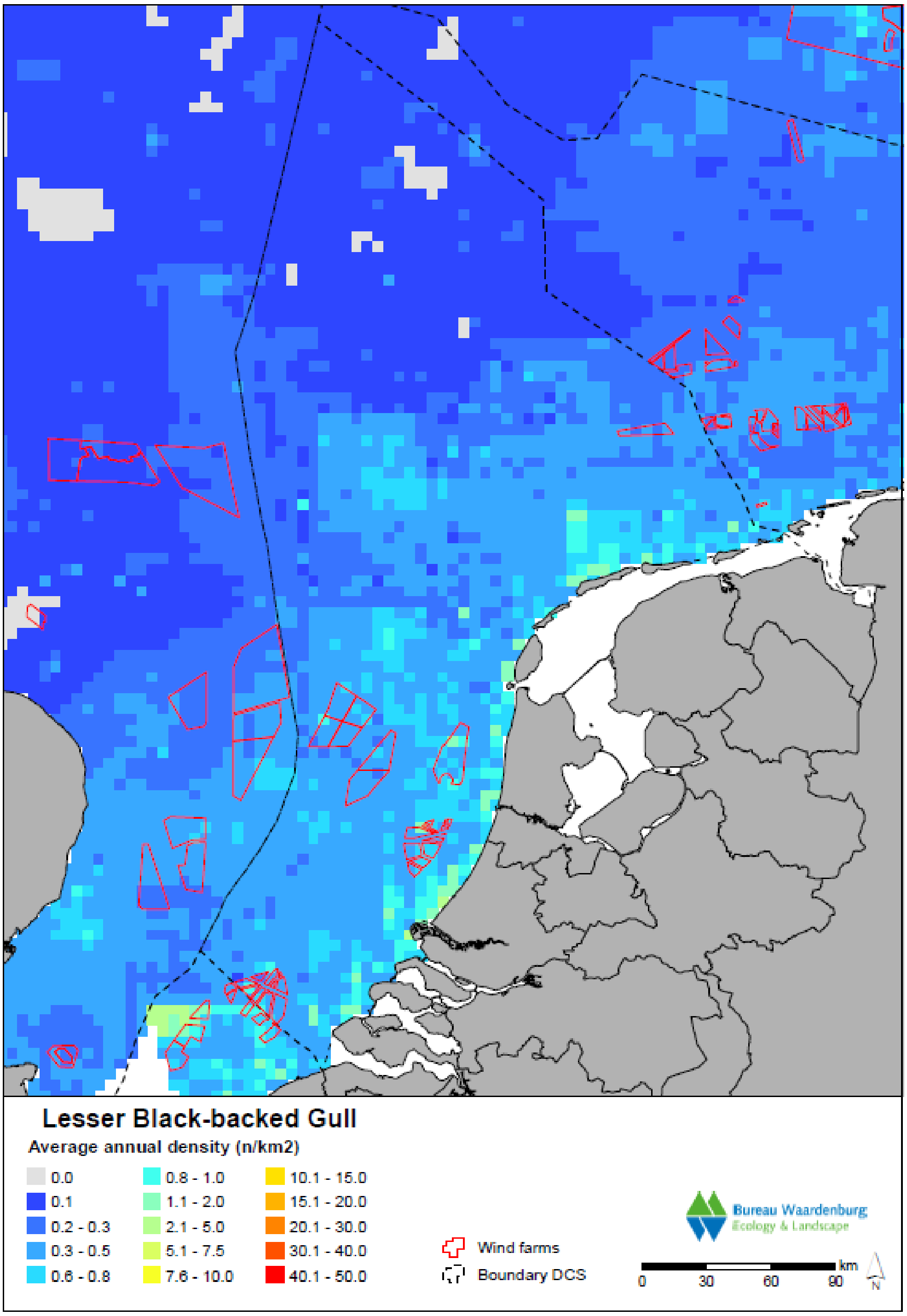

Figure B.5 Multi-year (period 2000-2017) seasonal average densities of Lesser Black-backed Gulls in the central and southern North Sea in and around offshore wind farm areas

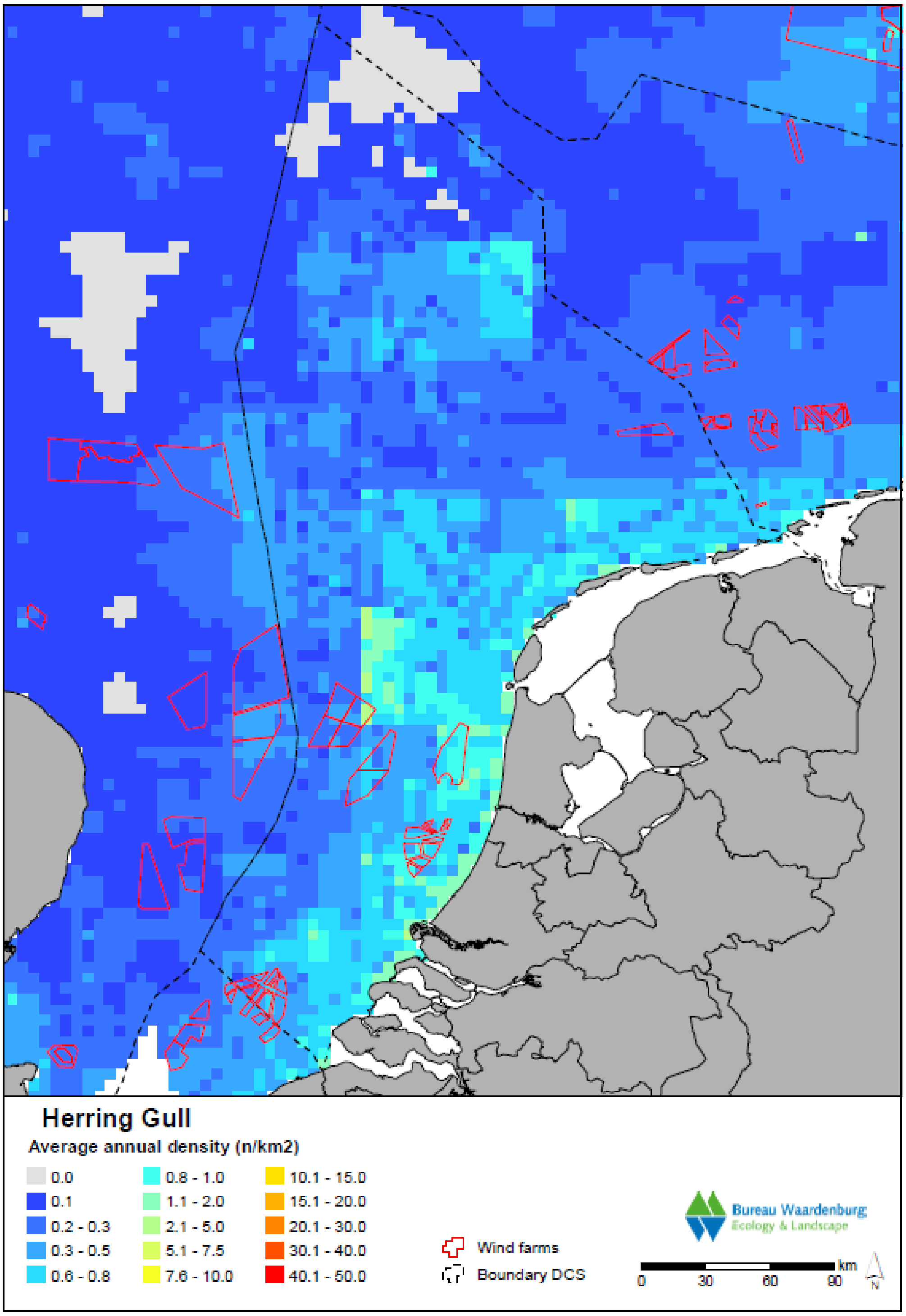

Figure B.6 Multi-year (period 2000-2017) seasonal average densities of Herring Gulls in the central and southern North Sea in and around offshore wind farm areas

Annex C Wind farm data

Name	Country	Estimated number of turbines	MW turbines
Belwind	Belgium	55	3
Fairy Bank 1	Belgium	70	10
Fairy Bank 2	Belgium	58	12
Fairy Bank 3, N2000	Belgium	47	15
Mermaid	Belgium	31	8
Mermaid Same area as above	Belgium	150	10
Nobelwind	Belgium	50	3.3
Norther	Belgium	29	8
Northwester	Belgium	24	9.5
Northwind	Belgium	72	3
Rentel	Belgium	44	7
Seastar	Belgium	31	8
Thorton Bank	Belgium	54	6
Horns Rev 3	Denmark	49	8
Tender 2019	Denmark	80	10
Vesterhavet Nord/Syd	Denmark	41	8
Albatros (ID N-8.3)	Germany	16	7
Amrumbank West (ID N-4.3)	Germany	80	3.6
BARD Offshore 1	Germany	80	5
Borkum Riffgrund 1 (ID N-2.4)	Germany	78	4
Borkum Riffgrund II (ID N-2.5)	Germany	56	8
Borkum Riffgrund West I (ID N-1.3)	Germany	24	10
Borkum Riffgrund West II (ID N-1.2)	Germany	24	10
Butendiek (ID N-5.2)	Germany	80	3.6
DanTysk (ID N-5.1)	Germany	80	3.6
Deutsche Bucht (ID N-6.3)	Germany	31	8.4
Deutsche Bucht Pilot (ID N-6.3-P)	Germany	2	8.4
EnBW He dreiht (ID N-7.1)	Germany	90	10
EnBW Hohe See (ID N-8.2)	Germany	71	7
GlobalTech I (ID N-8.1)	Germany	80	5
Gode Wind 01 (ID N-3.1)	Germany	55	6
Gode Wind 02 (ID N-3.2)	Germany	42	6
Gode Wind 04 (ID N-3.7)	Germany	13	10
Gode Wind III (ID N-3.4)	Germany	11	10
KASKASI II (ID N-4.4)	Germany	33	10
Meerwind Süd/Ost (ID N-4.1)	Germany	80	3.6
Merkur Offshore (ID N-2.6)	Germany	66	6
N-3.5	Germany	25	12
N-3.6	Germany	63	12
N-3.7 (except Gode Wind 04)	Germany	19	12
N-3.8	Germany	29	12
N-6.6	Germany	45	15
N-6.7	Germany	23	12
N-7.2	Germany	90	10
NOR 0-1 Riffgat	Germany	30	3.6
NOR 0-2 Nordergründe	Germany	19	6
NOR 2-1 Alpha ventus	Germany	12	5
Nordsee One (ID N-3.3)	Germany	55	6
Nordsee Ost (ID N-4.2)	Germany	49	6
OWF West (ID N-1.1)	Germany	24	10
Sandbank (ID N-5.3)	Germany	72	4
Trianel Borkum Wind Farm (ID N-2.2)	Germany	40	5
Trianel Wind Farm Borkum Bauphase 2 (ID N-2.3)	Germany	33	6
Veja Mate (ID N-6.2)	Germany	67	6
Gemini	Netherlands	150	4
Holland Coast (West) N	Netherlands	76	10
Holland Coast (West) S	Netherlands	76	10
IJmuiden Ver 1	Netherlands	100	10
IJmuiden Ver 2	Netherlands	100	10
IJmuiden Ver 3	Netherlands	100	10
IJmuiden Ver 4	Netherlands	100	10
Luchterduinen	Netherlands	43	3
North of Wadden Islands	Netherlands	76	10

Name	Country	Estimated number of turbines	MW turbines
Tender 2015 (1)- Borssele I and II	Netherlands	94	8
Tender 2016 (3) - Borssele III and IV	Netherlands	77	9.5
Tender 2017 (5) - Holland Coast South Holland I and II	Netherlands	94	8
Tender 2018 (7)- Holland Coast South Holland III and IV	Netherlands	94	8
Tender 2019 (9) - Holland Coast North Holland I and II	Netherlands	95	8
Beatrice BOWL	United Kingdom	84	7
Dudgeon	United Kingdom	67	6
East Anglia 1	United Kingdom	102	7
East Anglia 1 North	United Kingdom	80	10
East Anglia 2	United Kingdom	80	10
East Anglia 3	United Kingdom	150	8
Galloper	United Kingdom	59	6
Greater Gabbard	United Kingdom	140	3.6
Gunfleet Sands Demonstration Project	United Kingdom	2	6
Gunfleet Sands I + II	United Kingdom	48	4
Hornsea Project One	United Kingdom	174	7
Hornsea Project Three	United Kingdom	300	8
Hornsea Project Two	United Kingdom	173	8
Humber Gateway	United Kingdom	73	3
Hywind Scotland Pilot Farm	United Kingdom	5	6
Inch Cape	United Kingdom	131	7
Inner D, Racebank, Lincs, S. Shoal	United Kingdom	349	3.6
Kentish Flats 1	United Kingdom	30	3
Kentish Flats 2	United Kingdom	15	3
Kincardine	United Kingdom	6	8.4
London Array	United Kingdom	175	3.6
Lynn	United Kingdom	27	4
MORAY West	United Kingdom	75	10
MORL - Stevenson, Telford, Macoll (Moray)	United Kingdom	110	10
Neart na Gaoithe	United Kingdom	54	8
Norfolk Boreas	United Kingdom	180	10
Norfolk Vanguard	United Kingdom	180	10
Repsol - Inchcape	United Kingdom	79	10
Scroby Sands	United Kingdom	30	2
Seagreen - Alpha and Bravo	United Kingdom	105	10
Thanet	United Kingdom	100	3
Thanet extension	United Kingdom	34	10
Triton Knoll	United Kingdom	143	6
Westermost Rough	United Kingdom	35	6

Annex D Seabird victims per wind farm, international scenario

Wind farm	Black-legged Kittiwake	Great Skua	Great Black-backed gull	Northern Gannet	Lesser Black-backed Gull	Herring Gull
Albatros (ID N-8.3)	1	0	1	0	2	1
Amrumbank West (ID N-4.3)	2	0	8	2	16	20
BARD Offshore 1	6	0	18	2	15	6
Beatrice BOWL	4	0	6	3	9	6
Belwind	3	0	11	5	28	7
Borkum Riffgrund 1 (ID N-2.4)	2	0	7	2	18	4
Borkum Riffgrund II (ID N-2.5)	2	0	5	1	13	4
Borkum Riffgrund West I (ID N-1.3)	1	0	2	0	7	1
Borkum Riffgrund West II (ID N-1.2)	1	0	2	0	7	1
Butendiek (ID N-5.2)	6	0	7	6	23	7
DanTysk (ID N-5.1)	5	0	18	1	21	5
Deutsche Bucht (ID N-6.3)	1	0	4	1	6	2
Deutsche Bucht Pilot (ID N-6.3-P)	0	0	0	0	0	0
Dudgeon	4	0	3	2	0	2
East Anglia 1	5	0	5	4	35	3
East Anglia 1 North	2	0	5	1	30	3
East Anglia 2	2	0	2	1	20	2
East Anglia 3	8	0	32	3	60	16
EnBW He dreiht (ID N-7.1)	2	0	13	1	14	6
EnBW Hohe See (ID N-8.2)	4	0	7	2	11	3
Fairy Bank 1	2	0	8	2	30	8
Fairy Bank 2	2	0	8	4	46	6
Fairy Bank 3, N2000	3	0	8	3	61	5
Galloper	3	0	7	2	20	3
Gemini	12	0	18	5	41	8
GlobalTech I (ID N-8.1)	3	0	7	1	10	3
Gode Wind 01 (ID N-3.1)	2	0	4	1	16	6
Gode Wind 02 (ID N-3.2)	1	0	3	1	12	4
Gode Wind 04 (ID N-3.7)	0	0	1	0	4	1
Gode Wind III (ID N-3.4)	0	0	1	0	3	1
Greater Gabbard	6	0	14	7	52	7
Gunfleet Sands Demonstration Project	0	0	0	0	1	0
Gunfleet Sands I + II	3	0	9	1	15	5
Holland Coast (West) N	3	0	8	1	26	14
Holland Coast (West) S	2	0	6	1	25	12
Horns Rev 3	2	0	4	1	14	9
Hornsea Project One	12	0	7	14	12	4
Hornsea Project Three	27	0	32	15	47	25
Hornsea Project Two	11	0	6	5	13	2
Humber Gateway	5	0	2	1	5	1
Hywind Scotland Pilot Farm	0	0	0	0	0	1
IJmuiden Ver 1	4	0	7	1	42	30
IJmuiden Ver 2	3	0	8	1	48	8
IJmuiden Ver 3	4	0	9	1	35	9
IJmuiden Ver 4	3	0	9	1	37	8
Inch Cape	6	0	8	8	3	24
Inner D, Racebank, Lincs, S. Shoal	21	0	10	5	13	6
KASKASI II (ID N-4.4)	1	0	2	0	6	8
Kentish Flats 1	1	0	8	0	9	5
Kentish Flats 2	1	0	4	0	5	3
Kincardine	0	0	0	0	0	1
London Array	13	0	22	6	48	17
Luchterduinen	6	0	24	5	59	27
Lynn	2	0	1	0	1	0
Meerwind Süd/Ost (ID N-4.1)	3	0	11	4	17	15
Merkur Offshore (ID N-2.6)	2	0	5	1	18	4
Mermaid	2	0	5	2	11	4

Wind farm	Black-legged Kittiwake	Great Skua	Great Black-backed gull	Northern Gannet	Lesser Black-backed gull	Herring Gull
MORAY West	2	0	7	2	21	7
MORL - Stevenson, Telford, Macoll (Moray)	2	0	10	2	23	13
N-3.5	0	0	1	0	6	3
N-3.6	1	0	3	1	16	5
N-3.7 (except Gode Wind 04)	0	0	1	0	5	2
N-3.8	0	0	1	0	7	3
N-6.6	2	0	6	1	12	3
N-6.7	1	0	2	1	4	2
N-7.2	2	0	10	1	20	6
Neart na Gaoithe	3	0	4	2	4	11
Nobelwind	3	0	10	6	29	7
NOR 0-1 Riffgat	1	0	3	0	14	6
NOR 0-2 Nordergründe	0	0	2	0	6	5
NOR 2-1 Alpha ventus	0	0	1	0	3	1
Nordsee One (ID N-3.3)	2	0	5	1	14	7
Nordsee Ost (ID N-4.2)	2	0	5	2	13	11
Norfolk Boreas	5	0	24	1	51	11
Norfolk Vanguard	8	0	28	2	48	11
North of Wadden Islands	2	0	9	1	20	4
Norther	1	0	8	2	20	6
Northwester	1	0	4	1	9	4
Northwind	4	0	18	8	47	14
OWF West (ID N-1.1)	1	0	2	0	6	1
Rentel	2	0	9	4	29	10
Sandbank (ID N-5.3)	4	0	13	1	9	5
Scroby Sands	3	0	7	1	7	1
Seagreen - Alpha and Bravo	3	0	4	2	2	18
Seastar	2	0	7	2	22	6
Tender 2015 (1)- Borssele I and II	7	0	12	4	41	19
Tender 2016 (3) - Borssele III and IV	5	0	15	3	37	22
Tender 2017 (5) - Holland Coast South Holland I and II	4	0	15	2	57	24
Tender 2018 (7)- Holland Coast South Holland III and IV	4	0	12	2	61	32
Tender 2019	2	0	5	0	21	11
Tender 2019 (9) - Holland Coast North Holland I and II	6	0	19	3	62	37
Thanet	7	0	15	5	22	7
Thanet extension	1	0	3	1	7	3
Thorton Bank	3	0	11	4	43	7
Trianel Wind Farm Borkum Bauphase 2 (ID N-2.3)	2	0	3	1	10	2
Triton Knoll	12	0	7	3	6	1
Veja Mate (ID N-6.2)	5	0	13	2	14	5
Vesterhavet Nord/Syd	2	0	13	1	37	10
Westermost Rough	2	1	4	1	2	2

Annex E Victims among migratory birds per wind farm

wind farm	Bewick's Swan	Brent Goose	Common Shelduck	Curlew	Black Tern
Albatros (ID N-8.3)	0.00	0.1	0.77	1.05	0.08
Amrumbank West (ID N-4.3)	0.09	0.5	3.25	4.37	0.33
BARD Offshore 1	0.02	0.0	3.51	4.74	0.36
Beatrice BOWL	0.00	0.0	4.05	5.49	0.42
Belwind	0.01	1.4	2.16	2.90	0.22
Borkum Riffgrund 1 (ID N-2.4)	0.05	0.5	3.26	4.38	0.33
Borkum Riffgrund II (ID N-2.5)	0.05	0.4	2.91	3.93	0.30
Borkum Riffgrund West I (ID N-1.3)	0.03	0.2	1.38	1.87	0.14
Borkum Riffgrund West II (ID N-1.2)	0.03	0.2	1.38	1.87	0.14
Butendiek (ID N-5.2)	0.05	0.0	3.25	4.37	0.33
DanTysk (ID N-5.1)	0.05	0.0	3.25	4.37	0.33
Deutsche Bucht (ID N-6.3)	0.01	0.0	1.57	2.14	0.17
Deutsche Bucht Pilot (ID N-6.3-P)	0.00	0.0	0.10	0.14	0.01
Dudgeon	0.00	0.4	3.09	4.18	0.32
East Anglia 1	0.06	3.8	4.92	6.67	0.51
East Anglia 1 North	0.07	3.2	4.59	6.22	0.48
East Anglia 2	0.07	3.2	4.59	6.22	0.48
East Anglia 3	0.37	1.0	7.79	10.53	0.81
EnBW He dreiht (ID N-7.1)	0.11	0,6	5.17	7.00	0.54
EnBW Hohe See (ID N-8.2)	0.06	0.5	3.43	4.64	0.36
Fairy Bank 1	0.03	2.3	4.02	5.44	0.42
Fairy Bank 2	0.03	1.9	3.51	4.79	0.37
Fairy Bank 3, N2000	0.02	2.0	3.03	4.16	0.33
Galloper	0.02	2.1	2.72	3.67	0.28
Gemini	0.03	0.9	6.26	8.42	0.64
GlobalTech I (ID N-8.1)	0.06	0.5	3.51	4.74	0.36
Gode Wind 01 (ID N-3.1)	0.04	0.4	2.54	3.43	0.26
Gode Wind 02 (ID N-3.2)	0.03	0.3	1.94	2.62	0.20
Gode Wind 04 (ID N-3.7)	0.02	0.1	0.76	1.03	0.08
Gode Wind III (ID N-3.4)	0.01	0.1	0.63	0.85	0.07
Greater Gabbard	0.03	4.4	5.69	7.64	0.58
Gunfleet Sands Demonstration Project	0.00	0.1	0.09	0.12	0.01
Gunfleet Sands I + II	0.01	1.5	1.95	2.62	0.20
Holland Coast (West)	0.51	6.0	8.73	11.81	0.90
Horns Rev 3	0.04	0.0	2.54	3.44	0.26
Hornsea Project One	0.00	0.0	8.40	11.38	0.88
Hornsea Project Three	0.00	2.0	15.57	21.06	1.61
Hornsea Project Two	0.00	0.0	8.99	12.16	0.93
Humber Gateway	0.00	0.0	2.87	3.85	0.29
Hywind Scotland Pilot Farm	0.00	0.0	0.23	0.31	0.02
Ijmuiden Ver	1.34	15.9	22.96	31.09	2.38
Inch Cape	0.00	0.0	6.32	8.57	0.66
Inner D, Racebank, Lincs, S. Shoal	0.00	0.0	14.17	19.04	1.45
KASKASI II (ID N-4.4)	0.07	0.2	1.87	2.53	0.19
Kentish Flats 1	0.01	0.9	1.18	1.58	0.12
Kentish Flats 2	0.00	0.5	0.61	0.82	0.06
Kincardine	0.00	0.0	0.30	0.41	0.03
London Array	0.04	5.5	7.11	9.55	0.73
Luchterduinen	0.02	1.8	4.72	6.32	0.48
Lynn	0.00	0.0	1.10	1.47	0.11
Meerwind Süd/Ost (ID N-4.1)	0.09	0.5	3.25	4.37	0.33
Merkur Offshore (ID N-2.6)	0.05	0.4	3.05	4.12	0.32
Mermaid	0.01	1.0	1.60	2.16	0.17
Mermaid Same area as above	0.07	5.0	8.61	11.66	0.89
MORAY West	0.00	0.0	4.31	5.83	0.45
MORL - Stevenson, Telford, Macoll (Moray)	0.00	0.0	6.31	8.55	0.65
N-3.5	0.03	0.2	1.50	2.05	0.16
N-3.6	0.07	0.4	3.76	5.13	0.40

N-3.7 (except Gode Wind 04)	0.02	0.1	1.15	1.57	0.12
N-3.8	0.03	0.2	1.75	2.39	0.19
N-6.6	0.02	0.0	2.90	3.99	0.31
N-6.7	0.01	0.0	1.40	1.92	0.15
N-7.2	0.11	0.6	5.17	7.00	0.54
Neart na Gaoithe	0.00	0.0	2.80	3.79	0.29
Nobelwind	0.01	1.3	2.05	2.74	0.21
NOR 0-1 Riffgat	0.03	1.1	1.22	1.64	0.12
NOR 0-2 Nordergründe	0.02	0.0	0.85	1.15	0.09
NOR 2-1 Alpha ventus	0.01	0.1	0.54	0.73	0.06
Nordsee One (ID N-3.3)	0.04	0.4	2.56	3.45	0.26
Nordsee Ost (ID N-4.2)	0.06	0.3	2.27	3.07	0.24
Norfolk Boreas	0.08	1.2	10.33	13.99	1.07
Norfolk Vanguard	0.60	1.2	10.33	13.99	1.07
North of Wadden Islands	0.03	0.5	4.36	5.91	0.45
Norther	0.01	1.0	1.49	2.02	0.15
Northwester	0.01	0.8	1.23	1.68	0.13
Northwind	0.01	1.8	2.83	3.79	0.29
OWF West (ID N-1.1)	0.03	0.0	1.38	1.87	0.14
Rentel	0.01	1.4	2.13	2.89	0.22
Repsol - Inchcape	0.00	0.0	4.54	6.14	0.47
Sandbank (ID N-5.3)	0.05	0.0	3.01	4.04	0.31
Scroby Sands	0.04	0.2	1.18	1.59	0.12
Seagreen - Alpha and Bravo	0.00	0.0	6.03	8.16	0.62
Seastar	0.01	1.0	1.60	2.16	0.17
Tender 2015 (1)- Borssele I and II	0.03	3.2	4.88	6.60	0.50
Tender 2016 (3) - Borssele III and IV	0.03	2.7	4.01	5.49	0.43
Tender 2017 (5) - Holland Coast South Holland I and II	0.06	3.8	4.88	6.60	0.50
Tender 2018 (7)- Holland Coast South Holland III and IV	0.06	3.8	4.88	6.60	0.50
Tender 2019	0.10	0.0	4.59	6.22	0.48
Tender 2019 (9) - Holland Coast North Holland I and II	0.24	3.8	4.93	6.67	0.51
Thanet	0.02	3.1	3.93	5.27	0.40
Thanet extension	0.02	1.4	1.95	2.64	0.20
Thorton Bank	0.02	1.6	2.49	3.37	0.26
Trianel Borkum Wind Farm (ID N-2.2)	0.03	0.2	1.76	2.37	0.18
Trianel Wind Farm Borkum Bauphase 2 (ID N-2.3)	0.03	0.2	1.54	2.08	0.16
Triton Knoll	0.00	0.0	6.62	8.95	0.69
Veja Mate (ID N-6.2)	0.01	0.0	3.09	4.18	0.32
Vesterhavet Nord/Syd	0.00	0.0	2.13	2.88	0.22
Westermost Rough	0.00	0.0	1.62	2.18	0.17