SEANSE

Seabird cumulative collision risk

Prepared for Bundesamt für Seeschiffahrt und Hydrographie

Represented by Ms Marie Dahmen, Advisor

Co-funded by the
European Maritime and
Fisheries Fund of the
European Union

20 January 2020

This proposal has been prepared under the DHI Business Management System
certified by Bureau Veritas to comply with ISO 9001 (Quality Management)

ISO 9001
Management System Certification
BUREAU VERITAS
Certification Denmark A/S

SEANSE

Cumulative collision risk for seabirds

Authors	Florence Cuttat, Henrik Skov

Approval date	20/01/2020
Revision	02
Classification	Public

CONTENTS

1 Introduction ... 3

2 Methods ... 3
2.1 Input parameters ... 5

3 Results ... 7

4 Discussion ... 10

5 References ... 10

Appendices ... 12

Appendix A – Collision risk calculations by wind farm ... 13

FIGURES

Figure 1 Overview of main processes in the Band CRM ... 3
Figure 2 Comparison of the estimated number of collisions per country by each of the three sets of collision simulation ... 9

TABLES

Table 1 Flight/track speeds commonly applied to Band CRM and those recorded empirically in the ORJIP project ... 4
Table 2 Overview of avoidance rates commonly applied to Band CRM and those recorded empirically in the ORJIP project ... 5
Table 3. Comparison of the estimated number of collisions per country by each of the three sets of collision simulation ... 8

1 Introduction

As part of the feasibility study on methods and models for the assessment of cumulative impacts from offshore wind farm development under the SEANSE project, cumulative collision impacts have been assessed for the two-target species: lesser black-backed gull (Larus fuscus) and black-legged kittiwake (Rissa tridactyla). The calculations were conducted with the stochastic collision risk model (McGregor et al 2018) using the KEC-2018 seabird density data on the bird species and information on planned wind farms in the North Sea until 2030 (SEANSE Scenario 2). The focus was put on the late summer season for the lesser black-backed gull (August-September) and on the winter season for the black-legged kittiwake (December-January), as densities are highest in these seasons.

In order to evaluate the robustness of the Band CRM the collision calculations for both species were undertaken with the stochastic CRM using the Band Model Option 2 (Basic Model) and Option 3 (Extended Model) with different input parameters and mean densities extracted from the perimeter of the wind farms.

2 Methods

The first version of the Band CRM was developed in 2000 (Band 2000) and is often referred to as the Basic model. An extended version of the model describing the flight height distribution more accurately in relation to the rotor-swept area was finalised in 2012, the so-called Extended model (Band 2012). Neither the Basic nor the Extended model explicitly included stochasticity, and a first attempt to transfer the CRM to a fully stochastic model within R was undertaken by Masden (2015). The stochastic model was finalised by McGregor et al. (2018) which included both a framework in R as well as a web-based tool. We used the stochastic model in R to simulate the different collision scenarios.

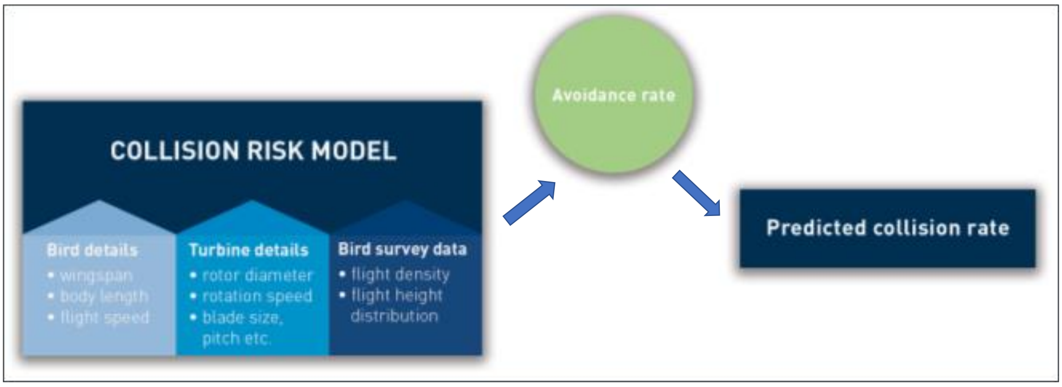


Figure 1 Overview of main processes in the Band CRM

The main processes of the Band CRM are illustrated in Figure 1. Calculating a collision mortality rate involves the following stages (Band 2012):
Stage A: Assemble data on the number of flights which, in the absence of birds being displaced, taking other avoiding action or being attracted to the wind farm, are potentially at risk from wind farm turbines;
Stage B: Use that flight activity data to estimate the potential number of birds flying through the rotor-swept zone throughout a given time unit (bird flux rate);
Stage C: Calculate the probability of a bird being hit by the wind farm rotor blades given that it passes through the rotor-swept zone. This is based on the technical specifications of the turbines and the morphology of the bird, speed and flight behaviour (flapping or soaring of the bird).

Stage D: Multiply these to yield the potential collision mortality rate for the bird species in question, allowing for the proportion of time that turbines are not operational, assuming current bird use of the site and that no avoiding action is taken;
Stage E: Allow for the proportion of birds likely to avoid the wind farm or its turbines, either because they have been displaced from the site or because they take evasive action, multiplying the potential collision mortality rate by an avoidance rate.

Several parameters regarding the behaviour of seabirds have proven critical to the estimated collision mortality rates. The flight height distribution is especially important when applying the Extended model. In the absence of detailed empirical data from a site, the modelled generic height distributions by Johnston et al. (2014) are frequently used, and have also been applied here. It should be noted that the input data used by Johnston et al. were dominated by estimates made by observers during boat-based surveys and no results from GPS-tracking studies were included.

Flight speed of the bird constitutes an important parameter, and although it is applied by the user as one value, the Band CRM actually uses the value in two different ways. The flight speed is used both for estimating the probability of collision (P Coll) as the bird crosses the rotor-swept area (Band CRM simplifies the flights through the rotor-swept area as always being perpendicular to the rotor plane) and for estimating the flux of birds through the wind farm. These two processes have reverse effects on the collision risk, albeit the flux rate has the largest effect, and hence higher flight speeds result in higher collision risk. Due to a lack of empirical data on seabird flight speeds measurements from studies on birds on long-distance migration (Pennycuick 1997, Alerstam et al. 2007) are typically applied. These values however reflect flight speeds, which are significantly higher than flight speeds recorded empirically in offshore wind farms (Table 1, Skov et al. 2018). To test the feasibility of the Band CRM we applied both types of flight speeds.

Avoidance rates obviously have a large effect on the estimated mortality rates. In the past, generic rates have typically been applied based on back-calculations to collision and passage rates obtained from mainly land-based wind farms (Cook et al. 2014). As a result, these generic avoidance rates only apply with a fixed set of flight speed and height parameters (those used for the back-calculations), assume identical flight behavior in land-based and offshore wind farms and include model errors. The first empirical avoidance rates for seabirds integrating macro, meso and micro avoidance were collected during the ORJIP study (Skov et al. 2018). The empirical avoidance rates were significantly higher than the generic rates used in the past (Table 2). To test the feasibility of the Band CRM we applied both generic and empirical avoidance rates.

Table 1 Flight/track speeds commonly applied to Band CRM and those recorded empirically in the ORJIP project

Species	Commonly used flight speed (Alerstam et al. 2007)	ORJIP Flight speed	ORJIP Track speed
Lesser Black-backed Gull	13.1	10.13 (±3.93)	8.10 (±3.11)
Black-legged Kittiwake	13.1	8.71 (±3.16)	6.22 (±3.40)

Table 2 Overview of avoidance rates commonly applied to Band CRM and those recorded empirically in the ORJIP project

Species	Current Basic model	Current Extended model	ORJIP Basic/Extended model
Lesser Black-backed Gull	0.995 (± 0.001)	0.989 (± 0.002)	0.998 (± 0.006)
Black-legged Kittiwake	0.989 (± 0.002)	0.989 (± 0.002)	0.998 (± 0.006)

Collision calculations of the two target species were made by automating the stochastic collision risk model (McGregor et al. 2018) https://github.com/dmpstats/stochCRM using scripts in Python 3.7.0 with Spyder 3.3.6 and RStudio (version 1.1.456). Python was mainly used for the pre and post- processing of the data when the collision estimates were handled in R Studio. The cumulative number of birds colliding was estimated by combining flux rates and Pcoll values to estimate the total number of expected collisions without avoidance behaviour and subsequently the total number of collisions using the avoidance rates of 0.998 (both species) from the ORJIP project (Skov et al. 2018). The proportion of birds flying at collision risk height was calculated with generic species-specific flight heights from Johnston et al. (2014). The speed of the two species was taken from the species-specific track speeds recorded during the ORJIP project (Skov et al. 2018).

The KEC-2018 seabird density data which consist of interpolated survey data from European Seabirds At Sea database (ESAS) and aerial survey data from the Dutch sector 1991-2017 at 5 km^2 resolution formed the basis for extracting the densities of the two target species. The seabird density grid contained bird densities for 10 different bird categories (Euring) and six bimonthly seasons. North Sea densities for Lesser Black-backed Gull (Euring 5910) were extracted for season 1 (Aug-Sep) and for Black-legged Kittiwake (Euring 6020) for season 3 (Dec-Jan) and processed separately as GeoDataFrames (GDF).

2.1 Input parameters

The automated stochCRM model calculated the collision risk in each OWF using the following parameters and settings:

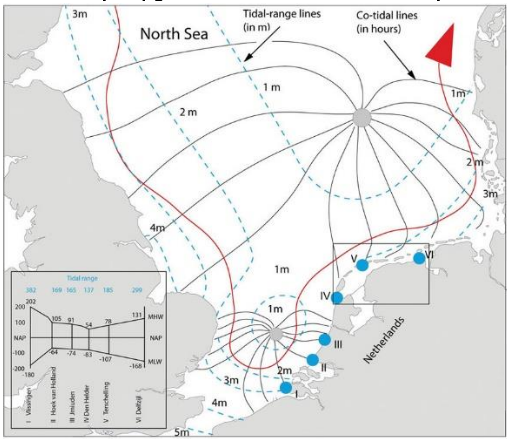
1) BirdDataFile

Contains data on each species of bird analysed

Species	Black Legged Kittiwake	Lesser Black Backed Gull
AvoidanceBasic	0.998	0.998
AvoidanceBasicSD	0.006	0.006
AvoidanceExtended	0.998	0.998
AvoidanceExtendedSD	0.006	0.006
Body_Length	0.39	0.58
Body_LengthSD	0.005	0.03
Wingspan	1.08	1.43
WingspanSD	0.0625	0.0375
Flight_Speed	6.22	8.01
Flight_SpeedSD	3.4	3.11

Nocturnal_Activity	0.12	0.25
Nocturnal_ActivitySD	0.012	0.025
Flight	Flapping	Flapping
Proportion_Flight	0.6	0.4

2) TurbineDataFile
   Specific to each windfarms model
3) CountDataFile
   Contains bird densities and SD for each months of the year. This file has been made for each windfarm by extracting these densities and their SD at the location of the windfarm for August and September. All other months are set to 0.
4) FlightDataFile
   Generic file contain the probabilities of the birds flying at a specific height.
5) Iter
   The number of iteration for the stochastic model was set to 100
6) CRSpecies
   Name of species analysed: Lesser Black Back gull and Black legged Kittiwake
7) TPower
   Total power generated by the windfarm (estimated)
8) WFWidth
   Parameter extracted from the polygons of each windfarm by searching for the distance between the two most far apart vertices defining the windfarm.
9) Prop_Upwind
   0.5
10) Latitude
    Extracted from the centroid of the polygon defined in the windfarm shapefile
11) TideOff
    The tide offset or tidal range was estimated from the following map. It was roughly reproduced in QGIS as polygons, extracted as a shapefile and averaged for the location of the windfarm in Python.



Nieuwhof, Annet & Vos, Peter. (2018). New data from terp excavations on sea-level index points and salt marsh sedimentation rates in the eastern part of the Dutch Wadden Sea. Geologie en Mijnbouw. 97. 31-43. 10.1017/njg.2018.2.

12) windSpeedMean
    Estimated to be 10 m/s
13) windSpeedSD
    Estimated to be 3 m/s
14) DensityOpt
    Truncated Norm

3 Results

The results of the collision risk scenarios are summarised per country in Table 3 and Figure 2. Detailed results for each wind farm are found in Appendix A. The results clearly show significantly different estimates depending on the parameter setting with the empirical avoidance and speed parameters resulting in estimated collision risks at a level of 3-10 times the collisions risks estimated with generic avoidance and speed parameters. Using generic avoidance rates and empirical speed parameters resulted in estimated collision risks 2-3 times the collisions risks estimated with both generic avoidance and speed parameters.

As expected the estimated collision rates with the extended model were significantly lower than the rates estimated with the basic version of the model, as the two selected species typically fly at altitudes representing the lower part of the turbine rotor. The relative effect of the different behaviour parameters on the estimates from the two models, however were at the same level.

Table 3. Comparison of the estimated number of collisions per country by each of the three sets of collision simulation

Black-legged Kittiwake - Basic CRM						
Simulation/Country	**BE**	**DE**	**DK**	**NL**	**UK**	**Total**
ORJIP	4.0	20.9	0.9	4.2	17.4	**47.4**
Generic AR, ORJIP speed	29.0	121.5	6.6	30.4	118.2	**305.7**
Generic AR + speed	38.9	162.1	8.2	433.0	158.4	**800.6**

Black-legged Kittiwake - Extended CRM						
Simulation/Country	**BE**	**DE**	**DK**	**NL**	**UK**	**Total**
ORJIP	1.1	4.7	0.1	1.1	4.5	**11.5**
Generic AR, ORJIP speed	1.2	4.8	0.3	1.3	5.5	**13.1**
Generic AR + speed	1.8	6.7	0.4	17.7	6.0	**32.6**

Lesser Black-backed Gull - Basic CRM						
Simulation/Country	**BE**	**DE**	**DK**	**NL**	**UK**	**Total**
ORJIP	23.1	46.9	4.0	74.6	50.9	199.5
Generic AR, ORJIP speed	66.7	130.3	10.2	208.3	147.3	562.8
Generic AR + speed	79.6	231.4	12.9	999.8	226.6	1550.3

Lesser Black-backed Gull - Extended CRM						
Simulation/Country	**BE**	**DE**	**DK**	**NL**	**UK**	**Total**
ORJIP	8.8	18.4	1.5	33.0	20.8	82.5
Generic AR, ORJIP speed	12.6	20.9	1.6	37.0	25.5	97.6
Generic AR + speed	24.1	95.6	4.9	24.1	96.5	245.2

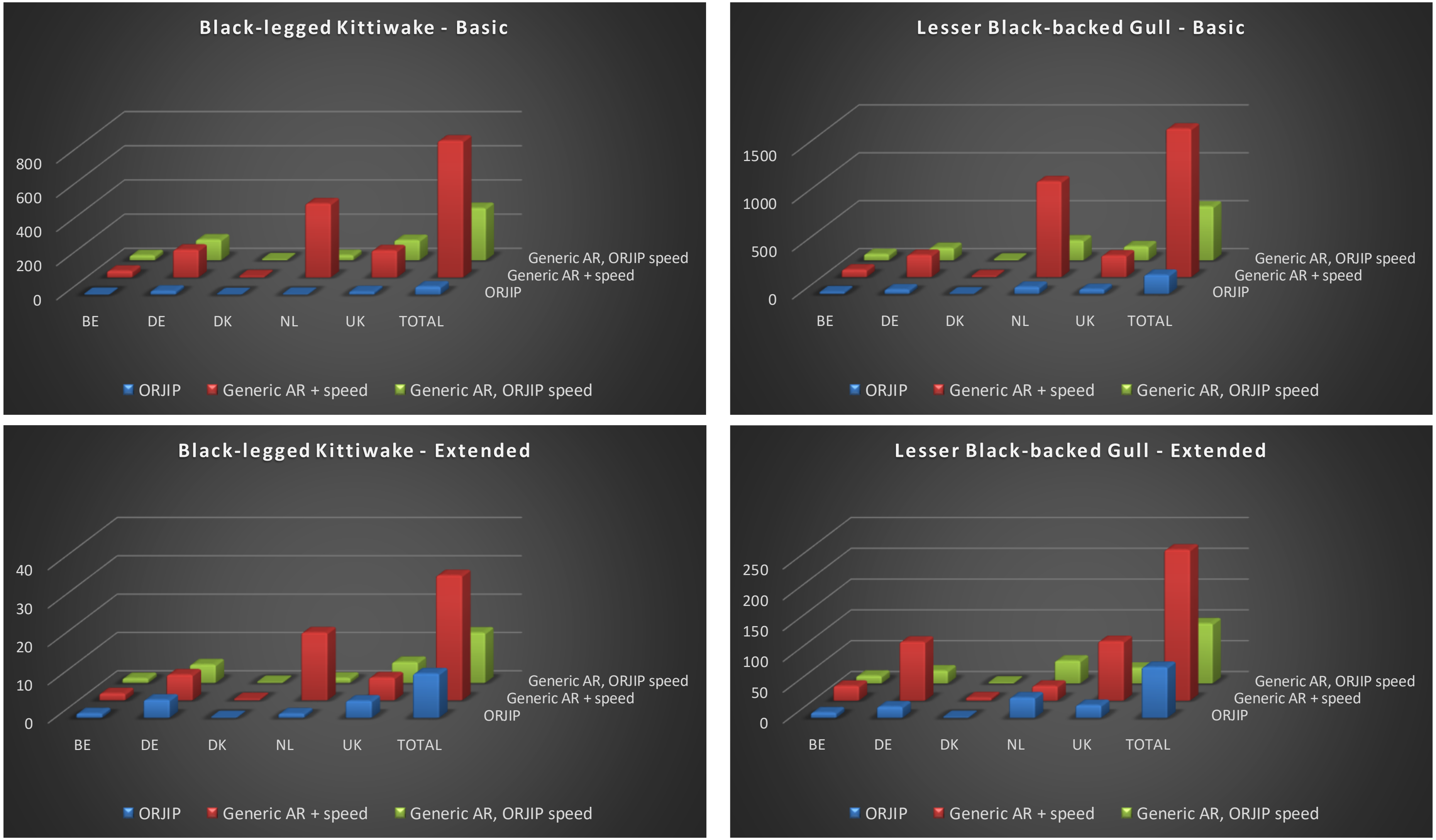


Figure 2 Comparison of the estimated number of collisions per country by each of the three sets of collision simulation

4 Discussion

The comparative simulations of the cumulative collision risks using the stochastic Band CRM underlined that the model is highly sensitive to behavior parameters and lacks flexibility to apply empirical data. The model is especially sensitive to applied avoidance rates and in fact the empirical avoidance rates collected during post-construction monitoring in offshore wind farms are not comparable to the generic ones inferred from carcass surveys at land-based wind farms. In addition, The Band CRM is sensitive to applied flight speed data, and as for the avoidance rates the model is inflexible to using other flight speeds than those applied for model back-calculations and estimation of generic avoidance rates. As generic avoidance rates also integrate model uncertainty and error the use of empirical avoidance and speed parameters cannot be recommended (Bowgen & Cook 2018). Accordingly, the use of the Band CRM with future monitoring data to estimate cumulative collision risks from offshore wind farms should be limited to qualitative assessments comparing outcomes between different OWF scenarios.

It is therefore recommended to develop a new generation CRM which allows for estimation of realistic fluxes based on measured bird behaviour by various tracking methods involving radar, rangefinder and GPS-tagging. An improved CRM should also allow for estimation of realistic collision probability based on recorded bird responses to rotor blades. For cumulative assessments of collision risk it would further be useful to include the possibility to run scenarios, “what if cases” and data displaying the inherent individual variability in flight behaviour of seabirds. Further, useful capabilities of a new generation would include the possibility to integrate area-specific habitat displacements and use high-resolution empirical tracking data.

5 References

Alerstam, T., Rosen, M., Backman, J., Ericson, P.G.P. and Hellgren, O. 2007. Flight speeds among bird species: allometric and phylogenetic effects. PLoS Biology 5(8): e197. doi: 10.1371/journal.pbio.0050197 (open source).

Band, W. 2000. Windfarms and Birds: calculating a theoretical collision risk assuming no avoiding action. Scottish Natural Heritage Guidance Note. http://www.snh.gov.uk/planning-and-development/renewableenergy/onshore-wind/assessing-bird-collision-risks/.

Band, W. 2012. Using a collision risk model to assess bird collision risks for offshore windfarms. The Crown Estate.

Bowgen, K. & Cook, A. 2018. Bird Collision Avoidance: Empirical evidence and impact assessments, JNCC Report No. 614, JNCC, Peterborough, ISSN 0963-8091.

Cook, A.S.C.P., Humphreys, E.M., Masden, E.A. and Burton, N.H.K. 2014. The avoidance rates of collision between birds and offshore turbines. BTO Research Report No. 656. British Trust for Ornithology, Thetford, 273pp.

Johnston, A., Cook, A.S.C.P., Wright, L.J., Humphreys, E.M. and Burton, N.H.K. 2014. Modelling flight heights of marine birds to more accurately assess collision risk with offshore wind turbines. Journal of Applied Ecology, 51: 31-41.

Masden, E. 2015. Developing an avian collision risk model to incorporate variability and uncertainty. Marine Scotland.

McGregor et al. 2018. A Stochastic Collision Risk Model for Seabirds in Flight. Marine Scotland.

Pennycuick, C.J. 1997. Actual and “optimum” flight speeds: field data reassessed. Journal of Experimental Biology, 200, 2355-2361.

Skov, H., Heinänen, S., Norman, T., Ward, R.M., Méndez-Roldán, S. & Ellis, I. 2018. ORJIP Bird Collision and Avoidance Study. Final report – April 2018. The Carbon Trust. United Kingdom. 247 pp.

Appendices

Appendix A – Collision risk calculations by wind farm

Number of birds colliding per bi-monthly period

Application with empirical avoidance and speed parameters

OWF project	Black-legged Kittiwake Dec-Jan		Lesser Black-backed Gull Aug-Sep	
	Basic model	Extended model	Basic model	Extended model
Amrumbank West	0.2	0.1	0.4	0.3
BARD Offshore 1	0.4	0.1	0.9	0.3
Beatrice	0.2	0.0	0.0	0.0
Belwind	0.1	0.1	1.4	0.4
Belwind Alstom Haliade Demonstration	0.1	0.1	0.5	0.3
Borkum Riffgrund I	0.1	0.0	2.1	1.3
Borkum Riffgrund II	0.1	0.0	0.8	0.8
Borkum Riffgrund West 1	0.1	0.0	0.8	0.2
Borkum Riffgrund West 2	0.1	0.0	0.6	0.3
Borkum West II Phase 1	5.0	1.5	4.3	2.5
Butendiek	0.1	0.0	0.4	0.3
DanTysk	0.1	0.0	2.4	2.0
Deutsche Bucht	0.4	0.1	0.3	0.1
Dudgeon	0.2	0.1	0.0	0.0
East Anglia One	0.6	0.1	1.9	1.2
East Anglia ONE North	0.4	0.1	1.6	0.5
East Anglia TWO	0.4	0.1	1.3	0.7
East Anglia Three	0.4	0.1	1.9	0.7
EnBW He Dreiht	0.2	0.1	1.3	0.3
EnBW Hohe See	2.7	0.4	0.8	0.5
Eneco Luchterduinen	0.0	0.0	1.6	1.4
Vesterhav Nord	0.1	0.0	0.6	0.2
Fairy Bank 1	0.1	0.0	1.5	0.2
Fairy Bank 2	0.1	0.0	1.9	0.3
Fairy Bank 3	0.1	0.0	1.6	0.6
Galloper	0.2	0.0	1.1	0.5
Gemini East	0.6	0.3	2.4	1.3
Gemini West	0.6	0.2	1.5	0.7
Global Tech 1	0.4	0.1	0.8	0.7
Gode Wind 1 and 2	1.0	0.2	0.7	0.2
Gode Wind 04	0.1	0.0	0.3	0.1
Gode Wind 03	0.1	0.0	0.1	0.1
Greater Gabbard	0.4	0.1	1.4	0.7

OWF project	Black-legged Kittiwake Dec-Jan		Lesser Black-backed Gull Aug-Sep	
	Basic model	Extended model	Basic model	Extended model
Hollandse Kust (west)	0.2	0.0	1.5	0.6
Horns Rev 3	0.2	0.0	0.7	0.3
Hornsea Project One	1.9	0.7	1.9	0.6
Hornsea Project Three	2.7	0.3	3.5	2.2
Hornsea Project Two	2.0	0.5	3.1	0.7
Hywind 2 Demonstration	0.0	0.0	0.0	0.0
IJmuiden Ver	0.6	0.1	2.7	1.9
Inch Cape	0.5	0.1	0.4	0.1
Inner Dowsing	0.1	0.1	1.3	0.4
Kaskasi II	0.1	0.0	0.7	0.1
Kincardine Offshore Windfarm Project	0.0	0.0	0.0	0.0
Lincs	0.3	0.1	1.4	0.3
London Array 1	0.2	0.1	0.6	1.3
Lynn	0.5	0.1	1.3	0.8
Meerwind SÃƒÂƒÃ‚Â¼d/Ost	0.3	0.1	0.7	0.7
Merkur Offshore	0.5	0.2	2.8	1.0
THV Mermaid	0.1	0.0	0.4	0.1
Moray Firth Western Development Area	0.3	0.1	0.0	0.0
Moray Firth Eastern Development Area	0.3	0.1	0.0	0.0
N-3.5 DE-tender 2025	1.0	0.1	0.6	0.1
N-3.6 DE-tender 2024	0.7	0.1	1.6	0.4
N-3.7 DE-tender 2026	0.3	0.0	0.3	0.1
N-3.8 DE-tender 2022	0.8	0.1	1.1	0.2
N-6.6 DE-tender 2026	0.2	0.2	1.8	0.4
N-6.7 DE-tender 2029	0.1	0.0	0.3	0.1
N-7.2 DE-tender 2027	0.4	0.1	3.4	0.7
Neart na Gaoithe	0.5	0.1	0.2	0.1
Nobelwind	0.1	0.1	0.6	0.5
Riffgat	0.0	0.0	0.1	0.1
NordergrÃƒÂƒÃ‚Â¼nde	0.1	0.0	0.7	0.1
Alpha Ventus SÃƒÂƒÃ‚Â¼d	0.0	0.0	1.1	0.3
Alpha Ventus Nord	0.0	0.0	1.1	0.3
Nordsee One	0.3	0.0	2.4	0.5
Nordsee Ost	0.4	0.0	2.0	0.8
Norfolk Boreas	1.0	0.2	8.3	2.0
Norfolk Vanguard	0.9	0.3	5.2	1.4
Norther	0.4	0.0	2.5	1.3
Northwester 2	0.1	0.0	0.7	0.5
Northwind	0.1	0.1	1.1	1.0
OWEZ	0.0	0.0	6.2	4.5

OWF project	Black-legged Kittiwake Dec-Jan		Lesser Black-backed Gull Aug-Sep	
	Basic model	**Extended model**	**Basic model**	**Extended model**
OWP West	0.1	0.0	1.7	0.3
Prinses Amaliawindpark	0.0	0.0	15.9	4.4
Race Bank	1.0	0.4	7.5	3.9
RENTEL	0.3	0.1	1.5	0.9
Sandbank 24	1.2	0.3	1.6	0.5
SeaGreen Bravo	0.9	0.3	1.5	0.4
SeaGreen Alpha	0.5	0.3	0.8	0.3
Seastar	0.2	0.0	0.8	0.6
Ten Noorden van de Waddeneilanden (2)	0.5	0.1	1.7	0.6
Borssele 1	0.1	0.0	1.0	0.9
Borssele 2	0.3	0.1	6.7	2.7
Borssele III	0.4	0.1	3.3	0.6
Borssele IV	0.5	0.1	1.1	0.9
Hollandse Kust Zuid Kavel 1	0.0	0.0	3.7	1.7
Hollandse Kust Zuid Kavel 2	0.1	0.0	3.7	1.9
Hollandse Kust Zuid Kavel 3	0.1	0.0	4.6	2.8
Hollandse Kust Zuid Kavel 4	0.0	0.0	7.1	2.4
Hollandse Kust Noord (zoekgebied)	0.1	0.0	9.9	3.5
Horns Rev Reserved Area	0.4	0.1	2.5	1.0
Thanet	0.2	0.0	1.1	0.7
Thanet Extension	0.1	0.0	0.3	0.2
Thornton Bank I	0.7	0.3	3.6	1.2
Thornton Bank II	0.7	0.1	2.4	0.7
Thornton Bank III	0.7	0.2	2.6	0.4
Borkum West II Phase 2	2.5	0.4	4.3	1.0
Triton Knoll	0.6	0.2	3.0	1.0
Veja Mate	0.8	0.1	1.8	0.6
Vesterhav Syd	0.3	0.0	0.2	0.1
Total	**47.3**	**11.5**	**199.5**	**82.4**