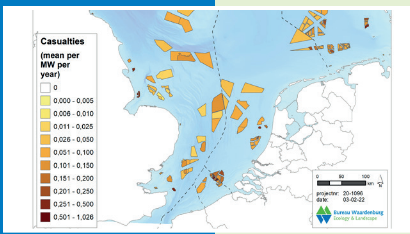
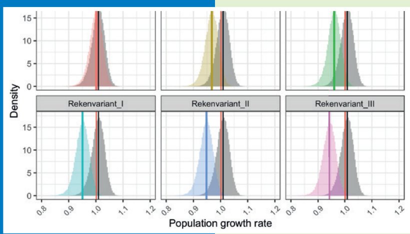
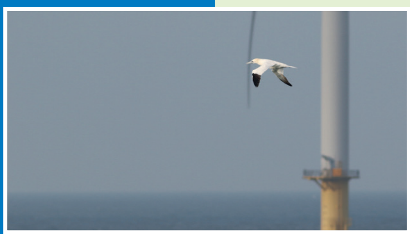
Cumulative impact assessment of collisions with existing and planned offshore wind turbines in the southern North Sea

Analysis of additional mortality using collision rate modelling and impact assessment based on population modelling for the KEC 4.0







A. Potiek
J.J. Leemans
R.P. Middelveld
A. Gyimesi

Bureau Waardenburg
Ecology & Landscape

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Commissioned by: Rijkswaterstaat Water, Verkeer en Leefomgeving

07 March 2022
report nr 21-205

Cumulative impact assessment of collisions with existing and planned offshore wind turbines in the southern North Sea

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dr. A. Potiek, J.J. Leemans *MSc*., R.P. Middelveld *MSc*., dr. A. Gyimesi

Status: final report

Report nr:	21-205
Project nr:	20-1096
Date of publication:	07 March 2022
Project manager:	dr. Abel Gyimesi
Quality control:	Ruben Fijn, *MSc.,* Mark Collier, *MSc*.
Name & address client:	Rijkswaterstaat Water, Verkeer en Leefomgeving Griffioenlaan 2 3526 LA UTRECHT
Reference client:	zaak 31167080
Signed for publication:	Team Manager Bureau Waardenburg bv R.C. Fijn, *MSc*.
Signature:	

Please cite as: Potiek, A., J.J. Leemans, R.P. Middelveld & A. Gyimesi, 2022. Cumulative impact assessment of collisions with existing and planned offshore wind turbines in the southern North Sea. Analysis of additional mortality using collision rate modelling and impact assessment based on population modelling for the KEC 4.0. Report 21-205. Bureau Waardenburg, Culemborg.

Keywords: offshore wind, wind turbine, collision, seabird, acceptable level of impact, southern North Sea

The Quality Management System of Bureau Waardenburg bv has been certified by EIK Certification according to ISO 9001:2015.

Bureau Waardenburg
Ecology & Landscape

Bureau Waardenburg, Varkensmarkt 9, 4101 CK Culemborg, the Netherlands
0031 (0) 345 512 710, info@buwa.nl, www.buwa.nl

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1 Introduction

1.1 Background

The intended developments of offshore wind energy in the Dutch North Sea up to 2030 including an additional 10 GW (North Sea Programme 2022-2027) may lead to cumulative effects on seabird and/or migratory bird species, in terms of estimated numbers of collision victims. In the Framework for Assessing Ecological and Cumulative Effects (in short KEC; cf. the Dutch abbreviation), the cumulative effects of all existing and planned Dutch and foreign wind farms in the southern North Sea are predicted and evaluated. This was done in 2015 in KEC 1.1 for offshore wind developments until 2023, covering a large number of bird species with a protected status (Rijkswaterstaat 2015). In 2019, this exercise was updated for the Roadmap for Offshore Wind Energy 2030 (Rijkswaterstaat 2019), to also include plans for offshore wind farms up to 2030 in the calculations.

In the 'North Sea Programme 2022-2027', zones for new offshore wind energy areas are designated. For now, 10 GW is needed before 2030 to achieve the aims set in the Energy Agenda. In order to be able to realize this further development of offshore wind energy in accordance with the Energy Agenda, the KEC needed to be actualised with the most recent knowledge. This includes, among other things, the application of new insights into the occurrence and flight behaviour of birds in the North Sea, carrying out calculations with the most recent models and evaluate the effects against the species-specific Acceptable Levels of Impact (ALI), as assigned by the ministry of Agriculture, Nature and Food quality (LNV). The methodology for coming to these species-specific thresholds is described in Potiek *et al.* (2021). Moreover, new wind energy zones, hereafter 'search areas', were defined for options for accelerated development up to 2030. The effects of these search areas in terms of numbers of bird victims need to be calculated in combination with existing and planned wind farms up to 2030, according to the most realistic possible assumptions.

1.2 Objective

The aim of the report at hand is to calculate the population level effects of bird collisions in offshore wind farms included in the 'North Sea Programme' 2022-2027 for a number of relevant bird species. The calculations have been actualised based on the most recent knowledge. Subsequently, the calculated numbers of casualties have been projected against acceptable standards, providing insight into whether the development of offshore wind farms remains within the ecological constraints.

2 Materials and methods

2.1 Wind farm scenarios

We performed impact assessments for different wind farm scenarios, provided by Rijkswaterstaat (Table 2.1). These consist of a null model representing the unimpacted scenario, four scenarios with combinations of wind farms on the Dutch Continental Shelf encompassing existing and 'realistic' wind farms until 2030 (part of Roadmap 2030; Table 2.2), the new search areas of the North Sea Programme (Table 2.2), and one scenario including international wind farms. All currently simulated scenarios are based on the roadmap up to 2030.
A list and some basic characteristics of the wind farms currently taken into account in the calculations are reported in Appendix I.

Table 2.1 Wind farm scenarios used in this study, as provided by Rijkswaterstaat.

Scenario name	Bird densities	Description
null	-	scenario without wind farms
Basic nat 30	national	basic: existing and realistic wind farms up to 2030
Rekenvariant I	national	basic + 10.7 GW
Rekenvariant II	national	basic + 12.7 GW
Rekenvariant III	national	basic + 16.7 GW
Int 30	international	basic nat 30 + Rekenvariant III + all international wind farms planned with starting date until end 2030

Table 2.2 Wind farms being part of the Roadmap 2030, forming the basic scenario and taken up in each future scenario.

Wind farm
Borssele I-V
Egmond aan Zee
Prinses Amaliawindpark
Eneco Luchterduinen
Gemini
Hollandse Kust Zuid I-IV
Hollandse Kust Noord
Ten Noorden v. d. Waddeneilanden
Hollandse Kust West
IJmuiden Ver

Table 2.3 Wind farm search areas taken up in the North Sea Programme. Combinations of these search areas form the different future scenarios.

Wind farm	Basic nat 30	Rekenvariant I	Rekenvariant II	Rekenvariant III
Hollandse Kust West zuidelijke punt	-	X	X	X
Zoekgebied 1 Noord	-	-	-	X
IJmuiden Ver Noord	-	X	X	X
Zoekgebied 1 Zuid	-	-	X	X
Zoekgebied 2 Noord	-	X	X	X
Zoekgebied 5 Oost	-	X	X	X

2.2 Estimating number of victims using collision rate modelling

Numbers of victims were first estimated for each wind farm, and then summed over the wind farms according to the different scenarios. The approach of estimating the numbers of victims differed between seabirds and migratory birds. All collision victim calculations were carried out using the stochastic Collision Risk Model (hereafter the 'sCRM').

2.2.1 Seabirds

Collision mortality was calculated for ten seabird species:

- Great black-backed gull *Larus marinus*
- Lesser black-backed gull *Larus fuscus*
- Herring gull *Larus argentatus*
- Little gull *Hydrocoloeus minutus*
- Black-legged kittiwake *Rissa tridactyla*
- Northern gannet *Morus bassanus*
- Great skua *Stercorarius skua*
- Arctic skua *Stercorarius parasiticus*
- Common tern *Sterna hirundo*
- Sandwich tern *Thalasseus sandvicensis*

International versus national densities

The basic input parameter for the sCRM is the flux of birds flying through a given rotor surface. This flux can be measured (e.g. with radar, camera or visual), but in the KEC calculations the species- and wind farm-specific fluxes are based on the local density of a species, as determined with data from ship and/or aircraft counts.

The recently updated ESAS (European Seabirds At Sea) database provides data on international seabird counts that can be used for these purposes. However, in some North

Sea countries no systematic counting programmes are carried out, surveys have not been conducted in recent years or the performed counts are not publicly available. Hence, the counting effort is not homogeneous over the entire North Sea. In the Netherlands, the MWTL (Monitoring Waterstaatkundige Toestand des Lands) aerial monitoring is carried at relatively small intervals (2 months) and covers the entire Dutch part of the North Sea in detail. Consequently, the density estimates from these surveys are considered more reliable for the Netherlands than those from the international ESAS data. In order to account for this disparity in the available international and Dutch seabird count data, in the KEC methodology densities of seabirds are calculated for two scales: international and national densities.

For the international densities, ESAS data from 1991 to 2020 were used as input. This relatively long period was chosen due to the strong variation between counts, as well as due to the limited data availability. Such a longer period offers more data and therefore more reliability. For the calculations of national densities, only MWTL aerial survey data have been used. In order to have surveys conducted according to the same methodology and to avoid using surveys from the far past in the calculations of mean densities, for the national scale a shorter period of data collection (1999-2020) was selected.

In order to generate the density maps, different datasets were used for different species (cf. Rijkswaterstaat 2015). Namely, high concentrations of northern gannets, black-legged kittiwakes, herring gulls, great black-backed gulls and lesser black-backed gulls behind fishing vessels were spread out in space in the first iteration of the KEC 1.1 (Leopold *et al.* 2015). The reliability of the analyses was improved further in a second iteration (van der Wal *et al.* 2015) by basing the density calculations for large gulls in the Netherlands exclusively on MWTL aerial surveys.

Flux determination

Based on the two scales described above, Wageningen Marine Research (WMR) determined bimonthly species densities in a grid of 5 x 5 km by interpolating the count data. A long-term average over the whole study period (*i.e.,* 1991-2020 for the international scenario and 1999-2020 for the national scenarios) was calculated for each bimonthly period and for each grid cell to create density maps per species. Subsequently, the wind farm layouts were projected over these bird density maps. The average species-specific bimonthly density per wind farm was calculated over all grid cells overlapping with the wind farm layout.

The basic input parameter for the collision rate calculations is the wind farm- and species-specific flux flying through the rotor swept area of a particular wind farm. For seabirds, this flux of flying birds was based on the local density of each species in each wind farm. However, the ESAS methodology that was used to collect the density data uses two different methods to estimate birds on the water and flying birds. For this exercise, the total density (*i.e.,* swimming and flying birds together) in each wind farm in each bimonthly period was multiplied by a species-specific correction factor, accounting for the mean fraction of the time budget that particular bird species tends to spend in the air. For most species, this mean fraction of time flying (Table 2.4) was based on the publication of Garthe and Hüppop

(2004). The correction factor as determined by Collins *et al.* (2016) was used for black-legged kittiwake and the factors as determined by Gyimesi *et al.* (2017b) were used for the lesser black-backed gull and herring gull. A study with GPS-loggers in the United Kingdom provided the fraction of time flying for the northern gannet (Cleasby *et al.* 2015), while another GPS-study in Canada is the source of the value for the great black-backed gull (Maynard 2018).

Subsequently, the collision rate model transforms densities of flying birds into fluxes at rotor height, based on species-specific flight height distributions relative to the turbine specifications (*i.e.,* hub height and rotor diameter). Bird-related data like flight height distributions are specified in §2.3.1, while turbine specifications are discussed in §2.3.2.

2.2.2 Migratory birds

In addition to seabird species, collision victims in offshore wind farms were also calculated for several (other) 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 hence may collide with wind turbines in offshore wind farms. The following eight species have been identified in KEC 1.1 (Rijkswaterstaat 2015) as priority species for which collision victims were calculated in the present study:

- Bewick's swan *Cygnus (columbianus) bewickii*
- Brent goose *Branta bernicla*
- Common shelduck *Tadorna tadorna*
- Curlew *Numenius arquata*
- Red knot *Calidris canutus*
- Bar-tailed godwit *Limosa lapponica*
- Black tern *Chlidonias niger*
- Common starling *Sturnus vulgaris*

Flux determination

There is no systematic monitoring of migratory birds at sea and therefore no location-specific offshore densities or fluxes are available. As the above-mentioned migratory bird species are not expected to use the sea for resting or feeding, their occurrence can generally be expressed as a straight flight across the North Sea during their seasonal migration in spring and autumn. In order to calculate the total number of collisions offshore on a yearly basis for the purposes of the KEC, the number of migrating non-seabirds crossing the North Sea twice a year was estimated in KEC 1.1 (Rijkswaterstaat 2015). Firstly, the total catchment population was determined for all species. Secondly, it was determined which part crosses the North Sea, either to travel to or from the British Isles or more southerly wintering areas. These two steps largely relied on a review on the number of migrants over the North Sea (Lensink & van der Winden 1997), that was based on published population estimates in different parts of the breeding range, in combination with information on the number of birds in the wintering area. Thirdly, a species-specific assumption was made with respect to which part of the birds crossing the North Sea will fly at rotor height (see further details in Rijkswaterstaat 2015).

The calculation of species-specific fluxes is described in the KEC 1.1 (Rijkswaterstaat 2015) as follows: "The available information suggests that around 85 million birds cross the North Sea in autumn. In spring roughly 60% makes the return journey as well. These figures can be recalculated into a flux (mean traffic rate of birds, MTR as n/km). The distance between the southern tip of Norway and the border between Belgium and France, as the starting point of the Channel, is 750 km. If 85 million birds pass over a length of 750 km length, the MTR in autumn is around 114,000 birds/km." Following the same assumption on the width of the migration corridor and based on estimated population sizes, there was an estimated flux (number of birds per km) of migrants crossing the North Sea provided for each regular migrant species, which was fed into the Band model used in the in KEC 1.1 (Rijkswaterstaat 2015).

In the present actualisation of the KEC, in accordance with the KEC 3.0 study, the species-specific fluxes were corrected based on the percentual change in population size estimates (BirdLife International 2004, 2015). Furthermore, for Bewick's swan and brent goose species-specific migration routes were earlier determined based on GPS logger data, and hence the species-specific fluxes could also be further refined to distinguish different migration intensities in the different wind farms, based on the geographical location of these relative to the migration routes (Gyimesi *et al.* 2017a). For black tern no such GPS-data exist, but an indication of the offshore migration routes could be derived from the offshore observations of this species available in the ESAS database (Potiek *et al.* 2019b). Based on these defined migration routes for these three species, also the total length of the migration corridors could be adjusted, allowing the correction of the KEC 1.1 fluxes into wind farm-specific fluxes. No such detailed measurements were available for the other species (*i.e.* common shelduck, curlew, red knot, bar-tailed godwit and common starling), and hence the generic fluxes for all wind farms defined in the KEC 1.1 study were used for these species (Table 2.3).

Table 2.3 Mean fluxes (number of birds/km/year) used in the collision rate calculations in the KEC 1.1 and KEC 3.0 studies (Rijkswaterstaat 2015, 2019) and in the present study. Note that three species were not actualised in KEC 3.0 (-).

species	flux in KEC 1.1 (2015)	flux in KEC 3.0 (2019)	flux in present study
Bewick's swan	43	43	37
brent goose	432	432	589
common shelduck	576	644	644
curlew	742	645	645
red knot	1,349	-	1,434
bar-tailed godwit	742	-	742
black tern	674	608	681
common starling	38,400	-	39,469

2.3 Collision calculations

The numbers of collision victims were calculated using the stochastic Collision Risk Model (sCRM). This model is based on the SOSS Band model (Band 2012) but allows more detailed input data to be used, specifically in relation to modelling variability around certain parameters (Marine Scotland 2018). This translates into a range of estimates being produced, as opposed to single figures. Therefore, the model has the ability to calculate standard deviations around the mean monthly numbers of expected collisions. This gives an indication of the uncertainty around the estimated collision rate. For each species, 1,000 iterations have been run.

The sCRM requires several input parameters related to the characteristics of the bird species and the wind turbines to calculate the theoretical collision risk of each species per type of wind turbine. The calculated species-specific collision risk is then multiplied by the species-specific bird flux through the total rotor-swept area of each wind farm and adjusted for the species-specific avoidance behaviour. The estimated number of collision victims per wind farm and per bird species is subsequently calculated for each month.

For most species, a species-specific flight height distribution was available which allowed the application of the sCRM. No species-specific height distributions were available for the common shelduck, curlew, red knot, bar-tailed godwit, black tern and common starling. Therefore, for these latter species the basic Band model was used (Band *et al.* 2007) in line with the previous KEC studies (Rijkswaterstaat 2015, 2019). All sCRM simulations were performed in R (R Core Team 2019). The original code of the model was slightly adapted to allow calculations for migratory birds in addition to seabirds.

2.3.1 Bird data

As a part of the present study, a literature review was carried out for each species separately, to update the knowledge base of bird parameters used in the sCRM and the population models. In this chapter, we provide the species-specific figures used in the sCRM and describe whether these differ from the values used in KEC 3.0, as a result of the updated knowledge base. Table 2.4 provides a summary of all these bird-related figures used in the calculations, and Table 2.5 reports the difference in mean values with KEC 3.0 (Rijkswaterstaat 2019).

Body length and wingspan

As all values for body length and wingspan remained the same as in previous KEC reports, these parameters are not reported in Table 2.5. We did incorporate variability in the body length and wingspan of each species by adding standard deviations (Table 2.4). Based on these range of values (following a normal (zero-truncated) distribution with given mean and standard deviation), the model randomly sampled a value for these parameters for each iteration. Means and standard deviations of body length and wingspan of each species were calculated based on ranges given by Snow and Perrins (eds) (1998) and the assumptions that the middle of this range was the mean value and that all data fall within three standard deviations from the mean.

Flight speed

For **common tern** and **Sandwich tern** the same flight speeds were used as in KEC 3.0, extended with standard deviations (Wakeling & Hodgson 1992; Fijn & Gyimesi 2018 respectively). The means and standard deviations of flight speeds of **herring gull** and **lesser black-backed gull** were calculated based on data from GPS tags placed on birds in Dutch, Belgian, and British colonies around the southern North Sea (Gyimesi *et al.* 2017b), while we used flight speeds for **great black-backed gull**, **little gull** and **Arctic skua** as reported in Alerstam *et al.* (2007) and for **great skua** and **northern gannet** as reported in Pennycuick (1990). For **bar-tailed godwit** and **starling** we used flight speeds of Pennycuick *et al.* (2013).

Updated values

For **black-legged kittiwake**, based on the literature review, we used two different values of flight speed for flux and collision risk calculations respectively, as recommended by Skov *et al.* (2018). The knowledge update also resulted in updated flight speeds of **Bewick's swan** and **brent goose**, which were recalculated for this study based on data from Gyimesi *et al.* (2017b). Similarly, new flight speeds of **curlew** and **red knot** were calculated from raw GPS-data from studies of Schwemmer *et al.* (2016) and Duijns *et al.* (2017). Flight speed of **shelduck** was updated based on a recent study of Green *et al.* (2021), which reported GPS measurements of shelducks crossing the North Sea. For black tern, the flight speed was updated based on Blake and Chan (2006).

Nocturnal activity

Due to a lack of data, we did not incorporate standard deviations for nocturnal activity in the sCRM. For **most of the species**, the assumptions of Garthe and Hüppop (2004) were adopted. Nocturnal activity of **lesser black-backed gull** and **herring gull** was based on Gyimesi *et al.* (2017a), just as in KEC 3.0.

Updated values

In the case of **Sandwich tern**, nocturnal activity was updated based on unpublished data of Fijn & Collier (*i.e.* 5%), while the update resulted in a lower nocturnal activity for **northern gannet** compared with KEC 3.0 (8% during the breeding season and 3% outside the breeding season based on Furness *et al.* (2018) versus 25% used in KEC 3.0).

Fraction of time in flight

Fraction of time in flight was previously mainly based on the assumptions of Garthe and Hüppop (2004) for seabirds. In KEC 3.0, GPS data were used for the herring gull and lesser black-backed gull to determine fraction of time in flight (Rijkswaterstaat 2019).

Updated values

In the current report, new values were defined based on GPS-data for the northern gannet (Cleasby *et al.* 2015) and for the black-legged kittiwake (Collins *et al.* 2016). For the **northern gannet**, the resulting fraction time in flight was higher than the one used in KEC 3.0 (0.82 vs. 0.6) and for the **black-legged kittiwake** it changed only slightly (from 0.6 to 0.672). Moreover, the ability of the sCRM to randomly sample from different measurements was also utilised for the **great black-backed gull** (based on Gyimesi *et al.* 2017b), resulting in a marginally lower fraction time in flight for this species compared with the KEC 3.0 (0.34 versus 0.4). The same exercise was carried out for the herring gull and lesser black-backed gull (based on Gyimesi *et al.* 2017a), not changing the parameter value for **herring gull**, while leading to a slightly higher fraction time in flight for **lesser black-backed gull** relative to the KEC 3.0 values (*i.e.* 0.4 versus 0.43 in this version).

Flight height distribution

Updated values

The sCRM has the ability to randomly sample a flight height distribution in each iteration from a catalogue of different flight height distributions. Therefore, we incorporated more variability in the model in the current calculations by adding different flight height distributions for each species. Flight height distributions of **lesser black-backed gull** and **herring gull** were calculated based on data from GPS tags placed on birds in Dutch, Belgian, and British colonies around the southern North Sea (Gyimesi *et al.* 2017a). We used a separate distribution for each individual bird with more than 1,500 data points. The same method was applied to generate different flight height distributions for **great skua** and **northern gannet** based on GPS-data of Ross-Smith *et al.* (2016) and Cleasby *et al.* (2015), respectively. For **great black-backed gull**, we sampled from two different distributions from Swedish and Danish logger data (Gyimesi *et al.* 2017b), and one distribution as used in the previous KEC studies, which is based on Johnston *et al.* (2014). For all other seabird species, we generated 200 different flight height distributions by sampling from a zero-truncated normal distribution, with means and standard deviations based on 95% confidence intervals presented per height class in Johnston *et al.* (2014). Lastly, flight height distributions of **Bewick's swan** and **brent goose** were based on data from Gyimesi *et al.* (2017b).

Avoidance rates

Due to a lack of data, we did not incorporate standard deviations for avoidance rates in the sCRM. Avoidance rates for several seabird species were updated based on the most recently available review on offshore avoidance rates carried out by Cook *et al.* (2018). For all other seabird species not dealt with in the review of Cook *et al*. (2018) and all migratory species, we used avoidance rates based on (Maclean *et al.* 2009), which is in line with the previous KEC studies (Rijkswaterstaat 2015, 2019).

Updated values

Cook *et al.* (2018) considered in their review the currently available evidence to quantify avoidance behaviour for five key species, namely the northern gannet, lesser black-backed gull, herring gull, great black-backed gull and black-legged kittiwake, viewed as being at a high risk of collision with offshore wind farms due to their flight altitude. Cook *et al.* (2018) described for these species an overall avoidance rate, specifically suitable for use in CRMs. Compared with the KEC 3.0 study, this review resulted in different avoidance rate values for the **lesser black-backed gull** (an increase from 99.5% to 99.8%), **northern gannet** (a decrease from 99.5% to 98.9%) and **black-legged kittiwake** (a decrease from 99.5% to 99.2%). For the **herring gull** and **great black-backed gull** the review did not reveal a need of change in avoidance rates (*i.e.* remained at 99.5%).

Table 2.4 *Parameters used in the sCRM calculations in this study. Nocturnal activity and fraction of time in flight was only used for seabird species. The basic Band model was used for the species with a given fraction of birds at rotor height. * For Bewick's swan and brent goose, concrete fluxes at rotor height were used in the Band model, which therefore did not need to be corrected for fraction at rotor height. Note that for black-legged kittiwake two different values of flight speed were used for flux calculation and collision rate calculation. Data sources for the various parameters are stated as letters in the table and shown below it.*

	body length (m)[a]		wingspan (m)[a]		flight speed (m/s)		nocturnal activity	avoidance (%)	fraction at rotor height[r]	fraction time in flight
species	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**				
herring gull	0.60	0.015	1.44	0.020	11.34[b]	3.91[b]	0.01[b]	99.5[c]		0.3[b]
great black-backed gull	0.71	0.023	1.58	0.025	13.7[d]	1.20[d]	0.50[e]	99.5[c]		0.34[f]
lesser black-backed gull	0.58	0.020	1.43	0.025	9.41[b]	3.92[b]	0.43[b]	99.8[c]		0.43[b]
little gull	0.26	0.003	0.78	0.008	11.5[d]	0.10[d]	0.25[e]	99.5[g]		0.6[g]
northern gannet	0.94	0.022	1.73	0.025	14.9[h]	2.60[h]	0.08[i]	98.9[c]		0.82[j]
black-legged kittiwake	0.39	0.003	1.08	0.042	8.71 / 6.22[k]	3.16 / 3.40[k]	0.50[e]	99.2[c]		0.672[l]
Arctic skua	0.44	0.008	1.18	0.025	13.8[d]	2.20[d]	0[e]	99.5[g]		1[g]
common tern	0.33	0.007	0.88	0.035	9.2[m]	3.10[m]	0[e]	99.0[g]		1[g]
great skua	0.56	0.008	1.36	0.013	14.9[h]	3.80[h]	0[e]	99.5[g]		0.8[g]
Sandwich tern	0.39	0.008	1.00	0.017	10.3[n]	3.40[n]	0.05[o]	99.0[g]		1[g]
Bewick's swan	1.21	0.020	1.96	0.052	16.88[p]	0.62[p]		98.0[g]	*	
brent goose	0.59	0.008	1.15	0.017	17.25[p]	0.27[p]		98.0[g]	*	
shelduck	0.63	0.015	1.22	0.038	18.21[q]	4.32[q]		98.0[g]	0.5	
curlew	0.55	0.017	0.90	0.033	17.78[s]	3.30[s]		98.0[g]	0.75	
red knot	0.24	0.003	0.59	0.007	16.64[t]	0.56[t]		98.0[g]	0.75	
bar-tailed godwit	0.38	0.003	0.75	0.017	14.4[u]	1.97[u]		98.0[g]	0.75	
black tern	0.23	0.003	0.66	0.007	7.1[v]	0.64[v]		98.0[g]	0.07	
common starling	0.22	0	0.40	0.008	15.4[u]	1.71[u]		98.0[g]	0.5	

[a] Snow & Perrins 1998; [b] Gyimesi *et al.* 2017a; [c] Cook *et al.* 2018; [d] Alerstam *et al.* 2007; [e] Garthe & Hüppop 2004; [f] Maynard 2018; [g] Maclean *et al.* 2009; [h] Pennycuick 1990; [i] Furness *et al.* 2018; [j] Cleasby *et al.* 2015; [k] Skov *et al.* 2018; [l] Collins *et al.* 2016; [m] based on Wakeling & Hodgson 1992; [n] Fijn & Gyimesi 2018; [o] Collier, unpublished; [p] based on Gyimesi *et al.* 2017b; [q] Green *et al.* 2021; [r] Rijkswaterstaat 2015; [s] based on Schwemmer *et al.* 2016; [t] based on Duijns *et al.* 2017; [u] Pennycuick *et al.* 2013; [v] Blake & Chan 2006

Table 2.5 *Comparison of mean parameter values used in the calculations of collision victims in this study and in KEC 3.0. Estimates of body length and wingspan were the same as in KEC 3.0 and are therefore not shown. Nocturnal activity and fraction of time in flight was only used for seabird species. The basic Band model with a given fraction of birds at rotor height was used migratory species, except for Bewick's swan and brent goose, where concrete fluxes at rotor height were used in the Band model, which therefore did not need to be corrected for fraction of birds at rotor height. Note that for black-legged kittiwake two different values of flight speed were used for flux calculation and collision rate calculation. For data sources, see Table 2.4 and Rijkswaterstaat 2019. Values in grey represent estimates from new sources, and bold values indicate that the estimate changed based on new information. – indicates that the species was not part of KEC3.0. Empty cells indicate parameters not used for that species due to different approach for seabirds and migratory birds.*

	flight speed (m/s)		nocturnal activity		avoidance (%)		fraction at rotor height		fraction time in flight	
species	KEC4.0	KEC3.0	KEC4.0	KEC3.0	KEC4.0	KEC3.0	KEC4.0	KEC3.0	KEC4.0	KEC3.0
herring gull	11.34	11.34	0.01	0.01	99.5	99.5			0.3	0.3
great black-backed gull	13.7	13.7	0.50	0.5	99.5	99.5			**0.34**	**0.4**
lesser black-backed gull	9.41	9.41	0.43	0.43	**99.8**	**99.5**			**0.43**	**0.4**
little gull	11.5	-	0.25	-	99.5	-			0.6	-
northern gannet	14.9	14.9	**0.08**	**0.25**	**98.9**	**99.5**			**0.82**	**0.6**
black-legged kittiwake	**8.71 / 6.22**	**13.1**	0.50	0.5	**99.2**	**99.5**			**0.672**	**0.6**
Arctic skua	13.8	-	0	-	99.5	-			1	-
common tern	9.2	-	0	-	99.0	-			1	-
great skua	14.9	14.9	0	0	99.5	99.5			0.8	0.8
Sandwich tern	10.3	-	0.05	-	99.0	-			1	-
Bewick's swan	**16.88**	**16.16**			98.0	98.0	*	*		
brent goose	**17.25**	**17.06**			98.0	98.0	*	*		
shelduck	**18.21**	**15.4**			98.0	98.0	0.5	0.5		
curlew	**17.78**	**17.69**			98.0	98.0	0.75	0.75		
red knot	16.64	-			98.0	-	0.75	-		
bar-tailed godwit	14.4	-			98.0	-	0.75	-		
black tern	**7.1**	**12**			98.0	98.0	0.07	0.07		
common starling	15.4	-			98.0	-	0.5	-		

2.3.2 Wind farm and wind turbine data

Most of the data on wind farm configurations and the wind turbine specifications were provided by RWS in an Excel file (‘scenario KEC 4.0 versie 8.xlsx’), with an accompanying note (‘Memo Scenario en varianten KEC 4 17-5 definitief.docx’). RWS derived the data for the international wind farms from the Global Offshore Renewable Map | 4C Offshore in March 2021. In Appendix I, the capacity and number of wind turbines are reported for each wind farm of interest. In case of lacking data at that moment, RWS made assumptions on, for example, size of turbines planned for specific wind farms. These assumptions were based on discussions with the Netherlands WindEnergy Association, wind farm owners, turbine manufacturers and the Ministry for Economic Affairs and Climate Policy (see Memo scenario en varianten). Choices on these assumptions were conservative and worst case. For the variables rotation speed, pitch and blade width one value per wind turbine capacity (i.e. MW) was used. Unknown values for these variables for specific wind turbine capacities were calculated based on the extrapolation of known figures. Based on information gained by RWS from wind farm owners regarding wind availability and maintenance of wind turbines, the assumption was made that wind farms are 90% of the time operational during daytime hours in spring and summer. Consequently, we have taken a weighted average over the entire day at 90% for 9 hours of the day and 100% for the remaining hours, leading to a figure of 96.25% operationality in the months of March to August and 100% operationality in the rest of the year. Furthermore, for future wind farms in the Netherlands, the lowest tip height was set at 25 m. The results provided in the report are calculated with this lowest tip height. In order to provide an insight in the impact of using a higher lowest tip height, in Appendix V the results are presented of collision victim calculations with a lowest tip height of 40 m in offshore wind farm Zoekgebied 5 Oost for a selected number of bird species as an example.

2.4 Impact assessment at population level

2.4.1 Population models

Impacts at population-level were assessed using matrix population models. For this project, population models from Potiek *et al.* (2019a) and van Kooten *et al.* (2019) have been adapted, resulting in the R package KEC4popmodels. Within this package, the population growth rate (lambda) for the null scenario without additional mortality due to wind farms is calculated based on demographic rates. Subsequently, the wind farm mortality for the different scenarios (Rekenvariant I to III) was simulated (see §2.1) by adjusting survival rates of the relevant life stages.

2.4.2 Assumptions

Parameter uncertainty

Similar to the previous models used in Potiek *et al.* (2019a) and van Kooten *et al.* (2019), input parameters varied between simulations, not between years within a simulation. This is a worst-case approach, which assumes that variation between estimates is due to parameter uncertainty. This assumption resulted in a wider variation in model outputs.

2.4.3 Calculation of mortality fraction

Seabirds

For seabirds, the numbers of collision victims were estimated for each month based on the bimonthly estimates of bird densities. In order to get to an annual estimated mortality fraction, we calculated the average percentage of victims per period (*i.e.,* number of victims in period i / number of individuals present in period i based on density maps * 100%), and extrapolated this average per bimonthly period to a year. Subsequently, this number of victims was divided by the 'population size'. As the number of victims making use of the area differs per bimonthly period, and part of the individuals present in one period will generally be present in the following as well, we defined the population as follows:

Population seabirds = maximum of average interpolated bimonthly counts

In other words, for each species, the highest bimonthly estimated number of individuals defined the population size. This maximum number of individuals present at any bimonthly period provides a minimum population estimate, as the actual population size can only be larger than the number of birds counted and not smaller. Therefore, this assumption provides a worst-case scenario for the calculation of the mortality fraction (*i.e.,* the smallest possible population size), and thus complies to the requirement of a precautionary approach.

For seabirds, the mortality fraction is calculated for each bimonthly period by dividing the estimated number of victims within a period by the number of individuals present during the same period. As the numbers of individuals present varied between periods, we decided to calculate the average mortality fraction based on the six bimonthly periods, and extrapolate this fraction to a year by the following equation:

$$\text{Mortality fraction seabirds} = \frac{1-(1-\text{average bimonthly mortality})^6}{Population}$$

Migratory birds

Instead of bimonthly counts, the numbers of collision victims for migratory birds were based on estimated fluxes in the autumn, which were based on the size of the flyway population, following the practices of the KEC 1.1 study (Rijkswaterstaat 2015). As described in chapter 2.2.2, the population sizes presented in KEC 1.1 were updated in the KEC 3.0 study based on percentual changes in population size estimates (BirdLife International 2004, 2015). In the present KEC, the same approach was followed and an actualisation was carried out if new population size estimates were available (BirdLife International 2015, 2021).

For migratory birds, the mortality fraction is calculated as the sum of the number of collision victims in autumn and spring, divided by the population size.

Mortality fraction migratory birds = $\frac{\text{Summed number of victims autumn+spring}}{Population}$

Apportioning mortality

The number of victims per (planned) wind farm is estimated using collision rate models (see §2.3). This estimate from the Band model only specifies the total estimated number of victims, without apportioning between age classes.

For the apportionment of victims among age classes, we assumed that the age distribution at sea gives an indication for the age distribution among victims. Estimates of offshore age distribution were available for black-legged kittiwake, little gull, northern gannet, great skua, Arctic skua, common tern and black tern (Potiek *et al.* 2019a).

2.4.4 Assessment of impact

The assessment of the impacts was carried out by comparing the outcome of the population models with the species-specific Acceptable Levels of Impact, as defined by the Ministry of Agriculture, Nature and Food Quality (

Table 2.6). The specifications per species were based on Potiek *et al.* (2021).
For each species, a threshold was defined for the maximally acceptable decline due to wind farms (X) as well as for the maximally acceptable level of causality (P_T) (Potiek *et al.* 2021). Depending on the IUCN status, the threshold value for X is either defined as a maximally 30% or 15% decline over three generations or 10 years (whichever is longer) as a result of the impact due to wind farms, compared to the population size over the same time span without additional mortality. Accepting maximally 15% decline gives a stricter threshold, which is violated at a lower impact than when accepting maximally 30% decline. This threshold of X may be violated due to uncertainty in the population model, instead of due to the impact of wind farms. The accepted level of causality (P_T) indicates the maximally acceptable probability of the violation being due to the impact, and not due to uncertainty in the population models. This value for P_T can either be 0.5, indicating that maximally 50% of the violations of the X threshold may be due to the impact of wind farms, or 0.1, indicating that maximally 10% of the violations of the X threshold may be caused by wind farms. This means that the threshold of 0.1 is stricter and is violated at a lower impact than the threshold of 0.5.

Table 2.6 *Decisions for Acceptable levels of impact, as defined by the Ministry of Agriculture, Nature and Food Quality (LNV) (email LNV 26-01-2022). IUCN status refers to the IUCN World status, based on BirdLife International (2021), with LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered.*

Species	IUCN_status	Threshold X after three generations or 10 years	P_T : accepted level of causality
Lesser black-backed gull	LC	30% decline	0.5
Herring gull	VU	15% decline	0.1
Great black-backed gull	LC	30% decline	0.5
Black-legged kittiwake	EN	15% decline	0.1
Little gull	LC	30% decline	0.5
Northern gannet	LC	30% decline	0.5
Arctic skua	EN	15% decline	0.1
Great skua	LC	30% decline	0.5
Common tern	LC	30% decline	0.5
Sandwich tern	LC	30% decline	0.5
Bewick's swan	EN	15% decline	0.1
Brent goose	LC	30% decline	0.5
Common shelduck	LC	30% decline	0.5
Eurasian curlew	VU	15% decline	0.1
Black tern	LC	30% decline	0.5
Common starling	LC	30% decline	0.5
Bar-tailed godwit	NT	15% decline	0.1
Red knot	LC	30% decline	0.5

3 Input parameters population models

3.1 General model description and demographic rates per species

Input for the population models consists of estimated stage-specific survival rates, fecundity and fraction non-breeding adults (floaters). Within this project, the knowledge base on demographic rates used within Potiek *et al.* (2019a) was updated to include recent relevant studies.

Within this chapter, the used demographic rates are reported, including data sources. The updated knowledge base is reported in Appendix II. Each data source within the updated knowledge base is scored for representativeness and data quality, using the same approach as in Horswill and Robinson (2015) and Potiek *et al.* (2019a).

This approach of Horswill and Robinson (2015) is based on the following criteria to assess data quality:

- Q1) the number of years (>10),
- Q2) the number of individuals and
- Q3) whether an indication of variation between years or areas (standard deviation), or a range of error (standard error) has been reported.

Each of these criteria is scored with 0, 1, or 2: 0 for ‘poor’, 1 for ‘intermediate/unknown’ and 2 for ‘good’.

In a similar way, we assess the representativeness of each data source. This representativeness is scored based on:

- R1) how recent the data are (score 2 for data of less than 10 years old; threshold between score 1 and 0 depends on the species and data availability),
- R2) how representative the area/site is for the Dutch part of the North Sea, and
- R3) how representative the data are for the current local trend in the Dutch part of the North Sea. In our study we used data on population trends since 1990 from Boele *et al.* (2021) to assess the current local trend of each species.

For each species, the defined stages are described using the following general structure:

- a first-year stage (stage J0),
- followed by one or more immature stages (stages starting with I, for example I1 to I4),
- and an adult stage (stage A).

Demographic rates are reported using the same stage indices, with for example SI1 being the survival of the I1 stage. Fecundity is presented as the number of fledglings per breeding pair. For most species, a fraction of floaters is assumed, if possible based on literature. This is depicted in the tables with demographic rates as prob. floater.

Lesser black-backed gull

The population model for lesser black-backed gull consists of a first-year stage (stage J0), four immature stages (I1 to I4), and an adult stage (A). Breeding only takes place in the adult stage. Demographic rates and references are reported in Table 3.1.

Based on the literature study, no new estimates were found for survival and fecundity of lesser black-backed gull. An overview of the data sources used for this species, including the scoring for data quality and representativeness, is reported in Appendix II.

Table 3.1 *Demographic rates of null model for lesser black-backed gull as used within this study, as well as in the previous version of the population models (Potiek et al. 2019a). Si indicates the survival rate of stage* i. *Fecundity is presented as the number of fledglings per breeding pair. Prob. floater indicates the probability of non-breeding for an adult. * several projects are currently being carried out to determine additional estimates of especially survival rates (colour-ring programmes in Europe) but also fecundity rates, so this overview is not a complete inventory and additional analyses might yield better estimates.*

	Parameters used in this study		**Mean Potiek et al. 2019a**	**Reference**
	Mean	**sd**		
SJ0	0.521	0.0375	0.521	[1]; [2]; [3]; [4]
SI1	0.856	0.052	0.856	[1]; [4]
SI2	0.856	0.052	0.856	[1]; [4]
SI3	0.856	0.052	0.856	[1]; [4]
SI4	0.856	0.052	0.856	[1]; [4]
SA	0.914	0.02	0.914	[3]; [4]; [5]; [6]
Fecundity	0.807	0.18	0.807	[5]; [7]; [8]; [9]; [10]; [11]; [12]
Prob. floater	0.435	0.1	0.435	[1]; [13]

Reference: [1] Camphuysen (2013); [2] Harris (1970); [3] Camphuysen and Gronert (2012); [4] Camphuysen (2011); [5] Wanless *et al*. (1996); [6] Horswill & Robinson (2015); [7] Gyimesi *et al*. (2011); [8] Camphuysen in Koffijberg *et al.* (2017); [9] Spaans *et al*. (1994); [10] (Sellers & Shackleton 2011); [11] (Perrins & Smith 2000); [12] Mavor *et al.* (2006); [13] Calladine and Harris (1997).

Herring gull

The population model for herring gull consists of a first-year stage (stage J0), three immature stages (I1 to I3), and an adult stage (A). Demographic rates and references are reported in
Table 3.2.

Based on the literature study, no new estimates were found for survival and fecundity of herring gull. An overview of the data sources used for this species, including the scoring for data quality and representativeness, is reported in Appendix II.

Table 3.2 *Demographic rates of null model for herring gull as used within this study, as well as in the previous version of the population models (Potiek et al. 2019a). Si indicates the survival rate of stage* i. *Fecundity is presented as the number of fledglings per breeding pair. Prob. floater indicates the probability of non-breeding for an adult.*

	Parameters used in this study		**Mean Potiek**	**Reference**
	Mean	**sd**	**et al. 2019a**	
SJ0	0.375	0.06	0.375	[1]; [2]; [3]
SI1	0.8	0.052	0.8	[1]; [4]
SI2	0.8	0.052	0.8	[1]; [4]
SI3	0.8	0.052	0.8	[1]; [4]
SA	0.8646	0.03	0.8646	[2]; [3]; [4]; [5]
Fecundity	0.8532	0.2	0.8532	[3]; [4]; [6]; [7]; [8]
Prob. floater	0.10	0.05	0.10	Estimate

References: [1] Camphuysen (2013); [2] Chabrzyk & Coulson (1976); [3] Wanless *et al.* (1996); [4] Camphuysen & Gronert (2012); [5] Glutz von Blotzheim *et al.* (1984); [6] Camphuysen in Koffijberg *et al.* (2017); [7] Koffijberg *et al.* (2017); [8] Sellers & Shackleton (2011).

Great black-backed gull

The population model for great black-backed gull consists of a first-year stage (stage J0), three immature stages (I1 to I3), and an adult stage (A). Demographic rates and references are reported in

Table 3.3.

Based on the literature study, data from a recent study by Collier *et al.* (2020) have been added to the knowledge base. From this study, new estimates were available for first-year and immature survival. This resulted in a change in the estimate of first-year survival, while the estimate for immature survival remained the same as used in Potiek *et al.* (2019a) (

Table 3.3). In addition, the probability of non-breeding is adjusted from 0.25 to 0.10, in order to better fit the observed population trend.

Although no new estimates were found for fecundity, the calculation of the weighted mean was now based on only estimates from Europe. This means that one estimate from the USA was excluded from the new weighted estimate. This resulted in a slight change in the parameter used for fecundity compared to Potiek *et al.* (2019a). An overview of the data sources used for this species, including the scoring for data quality and representativeness, is reported in Appendix II.

Table 3.3 *Demographic rates of null model for great black-backed gull as used within this study, as well as in the previous version of the population models (Potiek et al. 2019a). Cells in grey have changed based on new data sources. Si indicates the survival rate of stage* i. *Fecundity is presented as the number of fledglings per breeding pair. Prob. floater indicates the probability of non-breeding for an adult.*

	Parameters used in this study		**Mean Potiek et al. 2019a**	**Reference**
	Mean	**sd**		
SJ0	0.34	0.05	0.436	[1]; proxy herring gull
SI1	0.8	0.03	0.8	[1]
SI2	0.8	0.03	0.8	[1]
SI3	0.8	0.03	0.8	[1]
SA	0.86	0.02	0.86	[2]; [3]
Fecundity	0.98	0.4	0.968	[4]; [5]; [6]; [7]
Prob. floater	0.10	0.05	0.25	Estimate

References: [1] Collier *et al*. (2020); [2] Glutz von Blotzheim *et al*. (1984); [3] Barrett *et al.* (2015); [4] Mavor *et al*. (2008); [5] Verbeek (1979); [6] Schekkerman *et al.* (2017); [7] Butler & Trivelpiece (1981).

Little gull

The population model for little gull consists of a first-year stage (stage J0), one immature stages (I1), and an adult stage (A). Demographic rates and references are reported in Table 3.5.

Previously, no population model was made due to low data availability. Within the literature study, no new estimates on little were found. Hence, we included estimates for black-headed gull as a proxy. These new data sources are included in the overview of the data sources used for this species, including the scoring for data quality and representativeness (Appendix II).

Table 3.4 *Demographic rates of null model for little gull as used within this study, based on black-headed gull as a proxy. Si indicates the survival rate of stage* i. *Fecundity is presented as the number of fledglings per breeding pair. Prob. floater indicates the probability of non-breeding for an adult.*

	Parameters used in this study		**Reference**
	Mean	**Sd**	
SJ0	0.738	0.02	[1]
SI1	0.738	0.02	[1]
SA	0.827	0.01	[1]
Fecundity	0.75	0.2	Estimate, based on validation with observed trend
Prob. floater	0.10	0.05	estimate

References: [1] Majoor *et al.* (2005);

Black-legged kittiwake

The population model for black-legged kittiwake consists of a first-year stage (stage J0), three immature stages (I1 to I3), and an adult stage (A). Demographic rates and references are reported in Table 3.5.

Based on the literature study, new estimates were found for immature survival, adult survival and fecundity. These new data sources are included in the overview of the data sources used for this species, including the scoring for data quality and representativeness (Appendix II). Based on these new estimates, the immature survival declined, while adult survival and fecundity increased. In addition, the probability of non-breeding is adjusted from 0.25 to 0.10 in order to better fit the observed population trend.

Table 3.5 *Demographic rates of null model for black-legged kittiwake as used within this study, as well as in the previous version of the population models (Potiek et al. 2019a). Cells in grey have changed based on new data sources. Si indicates the survival rate of stage* i. *Fecundity is presented as the number of fledglings per breeding pair. Prob. floater indicates the probability of non-breeding for an adult.*

	Parameters used in this study		**Mean Potiek et al. 2019a**	**Reference**
	Mean	**sd**		
SJ0	0.79	0.05	0.79	[1]; [2]
SI1	0.7	0.04	0.9	[1]; [3]; [13]; [14]; [15]
SI2	0.7	0.04	0.9	[1]; [3]; [13]; [14]; [15]
SI3	0.7	0.04	0.9	[1]; [3]; [13]; [14]; [15]
SA	0.854	0.05	0.8487	[1] to [10]; [13] to [15]; [18] to [21]
Fecundity	0.66	0.2	0.558	[1]; [3]; [5]; [11]; [12]; [13] to [15]
Prob. floater	0.10	0.05	0.25	estimate

References: [1] Coulson & White (1959); [2] Horswill & Robinson (2015); [3] Thomas & Coulson (1988); [4] Harris *et al*. (2000); [5] Frederiksen *et al.* (2004); [6] Cam *et al.* (2002); [7] Sandvik *et al*. (2005); [8] Coulson & Wooller (1976); [9] Reiertsen *et al.* (2014); [10] del Hoyo *et al*. (1996); [11] Mavor *et al*. (2008); [12] JNCC Seabird Monitoring Programme Database, www.jncc.gov.uk/smp; [13] Searle *et al*. (2020); [14] Freeman *et al*. (2014); [15] Jitlal *et al*. (2017); [16] Christensen-Dalsgaard *et al*. (2019); [17] Christensen-Dalsgaard *et al*. (2018) [18] Horswill *et al.* (2021); [19] Rothery *et al*. (2002); [20] Oro & Furness (2002); [21] Coulson & Strowger (1999).

Northern gannet

The population model for northern gannet consists of a first-year stage (stage J0), three immature stages (I1 to I3), and two adult stages (A4 and AB). Although individuals in their fifth year (A4, age four) plumage-wise differ from adults (AB), these individuals experience the same survival rates as adults in the AB stage (Wanless *et al.* 2006). The difference with the AB stage is that individuals in stage A4 have adult survival, but do not reproduce yet, while AB are adults which can reproduce. Demographic rates and references are reported in Table 3.6.

This species was not part of the previous population models for collision victims. Hence, the data table below only presents currently used input parameters of the population model. For this species, WMR previously created a population model for habitat loss. The previously used parameters were updated based on the literature study (see Soudijn (2022)).

Table 3.6 *Demographic rates of null model for northern gannet. Si indicates the survival rate of stage* i. *Fecundity is presented as the number of fledglings per breeding pair. Prob. floater indicates the probability of non-breeding for an adult.*

	Mean	Sd	Reference
SJ0	0.481	0.0853	[1]
SI1	0.816	0.0393	[1]
SI2	0.884	0.0293	[1]
SI3	0.887	0.0301	[1]
SA	0.918	0.0199	[1] – [3]
Fecundity	0.7	0.082	[4]
Prob. floater	0.05	0.125	estimate

References: [1] Wanless *et al.* (2006); [2] Lane *et al.* (2020); [3] Deakin *et al.* (2019); [4] Horswill & Robinson (2015).

Arctic skua

The population model for Arctic skua consists of a first-year stage (stage J0), three immature stages (I1 to I3), and an adult stage (A). Demographic rates and references are reported in Table 3.7.

Table 3.7 *Demographic rates of null model for Arctic skua as used within this study, as well as in the previous version of the population models (Potiek et al. 2019a). Cells in grey have changed based on new data sources. Si indicates the survival rate of stage* i. *Fecundity is presented as the number of fledglings per breeding pair. Prob. floater indicates the probability of non-breeding for an adult.*

	Parameters used in this study		Mean Potiek et al. 2019a	Reference
	Mean	sd		
SJ0	0.57	0.05	0.74	[1]; [2]; [3]; [16]
SI1	0.77	0.05	0.77	[1]; [4]
SI2	0.77	0.05	0.77	[1]; [4]
SI3	0.77	0.05	0.77	[1]; [4]
SA	0.9	0.05	0.9	[1]; [2]; [5]; [15]; [16]
Fecundity	0.488	0.1	0.488	[3]; [5] to [14]; [15]
Prob. floater	0.25	0.05	0.25	estimate

References: [1] O'Donald (1983); [2] Robinson (2005); [3] Cook & Robinson (2010); [4] Horswill & Robinson (2015); [5] Phillips and Furness (1998); [6] O'Donald *et al*. (1974); [7] Phillips *et al.* (1996); [8] Dawson *et al.* (2011); [9] Perkins *et al*. (2018); [10] Mavor *et al*. (2008); [11] Jones (2003); [12] Baber (1989); [13] Baber (1990); [14] Furness & Aitken (1992); [15] van Bemmelen *et al*. (2021); [16] Snell (pers. comm.).

Based on the literature study, new data sources were available for first-year survival and adult survival (Snell, pers. comm; van Bemmelen *et al.* 2021). This resulted in a lower first-year survival. Including the new estimates for adult survival did not change the weighted estimate. An overview of the data sources used for this species, including the scoring for data quality and representativeness, is reported in Appendix II.

Great skua

The population model for great skua consists of a first-year stage (stage J0), six immature stages (I1 to I6), and an adult stage (A). Demographic rates and references are reported in Table 3.8.

Based on the literature study, new data sources were available for first-year survival, immature survival and adult survival. This resulted in a higher first-year survival, and lower immature and adult survival. An overview of the data sources used for this species, including the scoring for data quality and representativeness, is reported in Appendix II.

Table 3.8 *Demographic rates of null model for great skua as used within this study, as well as in the previous version of the population models (Potiek et al. 2019a). Cells in grey have changed based on new data sources. Si indicates the survival rate of stage* i. *Fecundity is presented as the number of fledglings per breeding pair. Prob. floater indicates the probability of non-breeding for an adult.*

	Parameters used in this study		**Mean Potiek et al. 2019a**	**Reference**
	Mean	**sd**		
SJ0	0.97	0.05	0.82	[1] to [3]
SI1	0.78	0.05	0.93	[4]
SI2	0.78	0.05	0.93	[4]
SI3	0.78	0.05	0.93	[4]
SI4	0.78	0.05	0.93	[4]
SI5	0.78	0.05	0.93	[4]
SI6	0.78	0.05	0.93	[4]
SA	0.882	0.055	0.89	[1] to [8]
Fecundity	0.536	0.3	0.536	[7]; [9] to [12]
Prob. floater	0.089	0.01	0.089	[7]

References: [1] Machado dos Santos (2018); [2]. Snell (pers. comm.); [3] Collier *et al.* (2020); [4]Furness (1978); [5] Balmer and Peach (1997); [6] Ratcliffe *et al.* (2002); [7] Catry *et al.* (1998); [8] del Hoyo *et al*. (1996); [9] JNCC Seabird Monitoring Programme Database, www.jncc.gov.uk/smp; Fair Isle; [10] Jones *et al.* (2008); [11] Phillips *et al.* (1999); [12] Mavor *et al*. (2008); [13] Robinson (2005); [14] Horswill & Robinson (2015).

Common tern

The population model for common tern consists of a first-year stage (stage J0), three immature stages (I1 to I3), and an adult stage (A). Demographic rates and references are reported in Table 3.9.

Based on the literature study, new input parameters were found for immature and adult survival (Schekkerman *et al.* 2021), and for fecundity (Koffijberg *et al.* 2017; van der Winden *et al.* 2019b). Incorporation of these new data sources resulted in a higher immature and adult survival, as well as a higher fecundity (Table 3.9). An overview of the data sources used for this species, including the scoring for data quality and representativeness, is reported in Appendix II.

Table 3.9 *Demographic rates of null model for common tern as used within this study, as well as in the previous version of the population models (Potiek et al. 2019a). Cells in grey have changed based on new data sources. Si indicates the survival rate of stage* i. *Fecundity is presented as the number of fledglings per breeding pair. Prob. floater indicates the probability of non-breeding for an adult.*

	Parameters used in this study		**Mean Potiek et al. 2019a**	**Reference**
	Mean	**sd**		
SJ0	0.685	0.05	0.685	[1]
SI1	0.72	0.05	0.646	[1] to [4]
SI2	0.72	0.05	0.646	[1] to [4]
SI3	0.72	0.05	0.646	[1] to [4]
SA	0.915	0.05	0.885	[1] to [4]
Fecundity	0.646	0.2	0.56	[1]; [3] to [16]
Prob. floater	0.1	0.03	0.1	estimate

References: [1] van der Jeugd *et al.* (2014); [2] Becker and Ludwigs (2004); [3] Becker *et al.* (2001); [4] Schekkerman *et al*. (2021); [5] Schekkerman *et al*. (2017); [6] Stienen *et al.* (2009), based on reports Griend study area; [7] Becker *et al.* (1994); [8] JNCC (2020); [9] Becker (1998); [10] van der Winden *et al.* (2018); [11] van der Winden *et al.* (2019b); [12] Thorup and Koffijberg (2015); [13] Walsh (1991); [14] Zintl (1998); [15] Koffijberg *et al*. (2017); [16] Van der Winden *et al.* (2019a).

Sandwich tern

The population model for Sandwich tern consists of a first-year stage (stage J0), an immature stage lasting two years (I1 and I2) and two adult stages (A3 and AB). Individuals in stage A3 can reproduce, but with lower fecundity than older adults (AB, from age 4 onwards). Survival in stage A3 is assumed to be the same as in stage AB (adult survival). Demographic rates and references are reported in This species was not part of the previous population models for collision victims. Hence, the data table below only presents currently used input parameters of the population model. For this species, WMR previously created a population model for habitat loss. The previously used parameters were updated based on the literature study (see Soudijn *et al.* 2022).

Table 3.10.

This species was not part of the previous population models for collision victims. Hence, the data table below only presents currently used input parameters of the population model. For this species, WMR previously created a population model for habitat loss. The previously used parameters were updated based on the literature study (see Soudijn *et al.* 2022).

Table 3.10 *Demographic rates of null model for Sandwich tern. Si indicates the survival rate of stage* i. *Fecundity is presented as the number of fledglings per breeding pair. *: fecundity during third calendar year is lower due to lack of experience. In order to get the fecundity for age 3, the fecundity is first calculated using the mean and standard deviation for the fecundity from age 4 onwards, after which the correction factor of 0.3 is applied. Prob. Floater indicates the probability of non-breeding for an adult.*

	Mean	**Sd**	**Reference**
SJ0	0.508	0.0917	[1]
SI1	0.777	0.0518	[1]; [2]
SA	0.942	0.108	[1]; [2]
Fecundity age 3	0.3 x 0.325	*	[1] – [7]
Fecundity from age 4 onwards	0.325	0.160	[1] – [7]
Prob. Floater	0.1	0.125	estimate

References: [1] van der Jeugd *et al.* (2014); [2] Schekkerman *et al.* (2021); [3] Derks and de Kraker (2005); [4] Koffijberg *et al.* (2017); [5] Beijersbergen (2001); [6] Veen (1977); [7] Stienen and Brenninkmeijer (1992).

Bewick's swan

The population model for Bewick's swan consists of a first-year stage (stage J0), one immature stage (I1) and an adult stage (A). Demographic rates and references are reported in Table 3.11. For this species, fecundity is based on relative numbers of first-year individuals and adults. Floaters are included in this estimate for fecundity and are therefore not separately taken into account in the population model.

Table 3.11 *Demographic rates of null model for* Bewick's swan *as used within this study, as well as in the previous version of the population models (Potiek et al. 2019a). Cells in grey have changed based on new data sources. Si indicates the survival rate of stage* i. *Fecundity is presented as the number of fledglings per adult, divided by two. For this species, fecundity is based on relative numbers of first-year individuals and adults. Floaters are included in this estimate for fecundity, and are therefore not separately taken into account in the population model.*

	Parameters used in this study		**Mean Potiek et al. 2019a**	**Reference**
	Mean	**sd**		
SJ0	0.908	0.05	0.78	[1]
SI1	0.936	0.05	0.83	[1]
SA	0.873	0.05	0.83	[1]
Fecundity	0.278	0.1	0.15	Based on [1], adjusted for first six months survival
Prob. floater	-	-		-

References: [1] Nuijten *et al.* (2020).

Based on the literature study, new data were available from Nuijten *et al.* (2020) and Beekman *et al.* (2019). Considering the high data quality from Nuijten *et al.* (2020), we decided to use estimates from this data source only. The use of these updated input parameters resulted in higher survival rates for each age class, and higher fecundity, compared to the estimates used in Potiek *et al.* (2019a). An overview of the data sources used for this species, including the scoring for data quality and representativeness, is reported in Appendix II.

Brent goose

The population model for brent goose consists of a first-year stage (stage J0), one immature stage (I1) and an adult stage (A). Demographic rates and references are reported in Table 3.12. For this species, fecundity is based on relative numbers of first-year individuals and adults. Floaters are included in this estimate for fecundity, and are therefore not separately taken into account in the population model.

Based on the literature study, new estimates were available for first-year survival and adult survival (Cleasby *et al.,* 2017). However, these estimates were based on light-bellied brent goose *Branta bernicla hrota* instead of dark-bellied brent goose *B. b. bernicla* and are therefore likely to be less relevant due to different wintering and breeding areas. Estimates of first-year survival and fecundity differed relatively strongly from the other available estimates from dark-bellied brent goose. For that reason, this data source is only included in the weighted estimate for adult survival. As a result, the parameter of adult survival was different from the one used in Potiek *et al.* (2019a), while other parameters remained the same. An overview of the data sources used for this species, including the scoring for data quality and representativeness, is reported in Appendix II.

Table 3.12 Demographic rates of null model for brent goose as used within this study, as well as in the previous version of the population models (Potiek et al. 2019a). Cells in grey have changed based on new data sources. Si indicates the survival rate of stage i. *Fecundity is presented as the number of fledglings per adult, divided by two. For this species, fecundity is based on relative numbers of first-year individuals and adults. Floaters are included in this estimate for fecundity, and are therefore not separately taken into account in the population model.*

	Parameters used in this study		**Mean Potiek et al. 2019a**	**Reference**
	Mean	**sd**		
SJ0	0.51	0.05	0.51	[1]
SI1	0.849	0.05	0.849	[1]; [3] to [5]
SA	0.868	0.03	0.859	[1] to [3]; [6] to [8]; [13]
Fecundity	0.588	0.1	0.588	[9]
Prob. floater	-	-	-	-

References: [1] Sedinger *et al*. (2007); [2] Robinson (2005); [3] Ebbinge *et al*. (2002); [4] Boyd (1962); [5] Balmer & Peach (1997); [6] Sedinger *et al*. (2002); [7] Cramp and Simmons (1983); [8] Desholm (2009); [9] Nolet *et al.* (2013); [10] Nicolai (2003), Chapter 2; [11] WWT monitoring programme; https://monitoring.wwt.org.uk/our-work/goose-swan-monitoring-programme/species-accounts/dark-bellied-brent-goose; [12] Sedinger *et al*. (2006); [13] Cleasby *et al*. (2017).

Common shelduck

The population model for shelduck consists of a first-year stage (stage J0), one immature stage (I1) and an adult stage (A). Demographic rates and references are reported in Table 3.13.

Based on the literature study, no relevant new estimates for demographic rates were available. The only change in the input parameters of the population models is the probability of floaters, which is adjusted based on validation with the observed population trend (Table 3.13). An overview of the data sources used for this species, including the scoring for data quality and representativeness, is reported in Appendix II.

Table 3.13 *Demographic rates of null model for common shelduck as used within this study, as well as in the previous version of the population models (Potiek et al. 2019). Cells in grey have changed based on new data sources. Si indicates the survival rate of stage* i. *Fecundity is presented as the number of fledglings per breeding pair. Prob. floater indicates the probability of non-breeding for an adult.*

	Parameters used in this study		**Mean Potiek et al. 2019**	**Reference**
	Mean	**sd**		
SJ0	0.25	0.05	0.25	[1]; [2]
SI1	0.67	0.05	0.67	[1]; [2]
SA	0.873	0.05	0.873	[1] to [3]
Fecundity	3.7	0.1	3.7	[4]
Prob. floater	0.35	0.05	0.1	estimate, based on [4] and validation with observed trend

References: [1] Patterson *et al*. (1983); [2] Robinson (2005); [3] Pienkowski and Evans (1982); [4] Lensink (2001).

Curlew

The population model for curlew consists of a first-year stage (stage J0), one immature stage (I1) and an adult stage (A). Demographic rates and references are reported in Table 3.14.

Table 3.14 *Demographic rates of null model for curlew as used within this study, as well as in the previous version of the population models (Potiek et al. 2019a). Cells in grey have changed based on new data sources. Si indicates the survival rate of stage* i. *Fecundity is presented as the number of fledglings per breeding pair. Prob. floater indicates the probability of non-breeding for an adult. *: validated with observed population trend*

	Parameters used in this study		**Mean Potiek et al. 2019a**	**Reference**
	Mean	**Sd**		
SJ0	0.5595	0.05	0.47	[1]; [2]
SI1	0.771	0.05	0.63	[1]; [2]
SA	0.912	0.05	0.84	[1]; [2]; [3]
Fecundity	0.34	0.1	0.34	[4]
Prob. floater	0.1	0.05	0.1	Estimate *

References: [1] Collier *et al*. (2020); [2] Gerritsen (2021); [3] Robinson (2005); [4] Roodbergen *et al.* (2012).

Based on the literature study, new estimates were available for first-year, immature and adult survival (Collier *et al.* 2020; Gerritsen 2021). This resulted in higher survival rates for each age class (Table 3.14). An overview of the data sources used for this species, including the scoring for data quality and representativeness, is reported in Appendix II.

Red knot

The population model for red knot consists of a first-year stage (stage J0), one immature stage (I1) and an adult stage (A). Demographic rates and references are reported in Table 3.15.

For red knot, several subspecies exist. Two of these subspecies may cross the North Sea: islandica which breeds in Greenland and Newfoundland and winters in the Wadden Sea, but also canutus which breeds in Siberia (e.g. Taymir peninsula) and winters in W Africa. Demographic rates are taken from literature on those two subspecies only; see Appendix II, table II.16.

This species was not part of the previous population models. Hence, the data table below only presents currently used input parameters of the population model. An overview of the data sources used for this species, including the scoring for data quality and representativeness, is reported in Appendix II.

Table 3.15 *Demographic rates of null model for red knot. Si indicates the survival rate of stage* i. *Fecundity is presented as the number of fledglings per breeding pair. Prob. floater indicates the probability of non-breeding for an adult. *: validated with observed population trend*

	Mean	**Sd**	**Reference**
SJ0	0.782	0.03	[1]; [2]
SI1	0.842	0.01	[2] to [4]
SA	0.842	0.01	[2] to [4]
Fecundity	0.284	0.03	[5]
Prob. floater	0.1	0.03	Estimate *

References: [1] Leyrer *et al*. (2013); [2] Spaans *et al*. (2011); [3] Brochard *et al*. (2002); [4] Rakhimberdiev *et al*. 2015; [5] Meltofte (2008).

Bar-tailed godwit

The population model for bar-tailed godwit consists of a first-year stage (stage J0), one immature stage (I1) and an adult stage (A). Demographic rates and references are reported in Table 3.16.

This species was not part of the previous population models. Hence, the data table below only presents currently used input parameters of the population model. An overview of the data sources used for this species, including the scoring for data quality and representativeness, is reported in Appendix II.

Table 3.16 *Demographic rates of null model for bar-tailed godwit. Si indicates the survival rate of stage* i. *Fecundity is presented as the number of fledglings per breeding pair. Prob. floater indicates the probability of non-breeding for an adult. *: validated with observed population trend*

	Mean	**Sd**	**Reference**
SJ0	0.57	0.05	[1]
SI1	0.8275	0.02	[1]; [2]
SA	0.8275	0.02	[1]; [2]
Fecundity	0.8	0.03	Estimate *
Prob. floater	0.1	0.05	Estimate *

References: [1] Spaans *et al*. (2011); [2] Piersma *et al*. (2016).

Black tern

The population model for black tern consists of a first-year stage (stage J0), two immature stage (I1 and I2) and an adult stage (A). Demographic rates and references are reported in Table 3.17. Reproduction occurs in stage I2 and the adult stage, with a higher probability of floaters in the I2 stage.

Based on the literature study, a new estimate for adult survival was available (van der Winden & van Horssen, unpublished data; based on Collier *et al.* 2020), which resulted in a slight change in the adult survival compared to Potiek *et al.* 2019a. For fecundity, the weighted estimate slightly changed due to a change in the assigned data quality (Table 3.17). An overview of the data sources used for this species, including the scoring for data quality and representativeness, is reported in Appendix II.

Table 3.17 *Demographic rates of null model for black tern as used within this study, as well as in the previous version of the population models (Potiek et al. 2019a). Cells in grey have changed based on new data sources. Si indicates the survival rate of stage* i. *Fecundity is presented as the number of fledglings per breeding pair. Prob. floater indicates the probability of non-breeding for an adult.*

	Parameters used in this study		**Mean Potiek et al. 2019a**	**Reference**
	Mean	**Sd**		
SJ0	0.595	0.05	0.595	[1]
SI1	0.595	0.05	0.595	[1]
SI2	0.595	0.05	0.595	[1]
SA	0.846	0.05	0.849	[1]; [5]
Fecundity	0.93	0.1	0.86	[1] to [4]
Prob. floater I2 stage	0.8	0.05	0.8	Estimate
Prob. floater adult stage	0.1	0.05	0.1	Estimate

References: [1] van der Winden & van Horssen (2008); [2] Tinbergen and Heemskerk (2016); [3] van der Winden (2008); [4] van der Winden (2005); [5] van der Winden & van Horssen, unpublished data (referred to in Collier *et al.* 2020).

Common starling

The population model for common starling consists of a first-year stage (stage J0) and an adult stage (A). Demographic rates and references are reported in Table 3.18. For this species, no floaters are assumed.

This species was not part of the previous population models. Hence, the data table below only presents currently used input parameters of the population model. An overview of the data sources used for this species, including the scoring for data quality and representativeness, is reported in Appendix II.

Table 3.18 *Demographic rates of null model for common starling. Si indicates the survival rate of stage* i. *Fecundity is presented as the number of fledglings per breeding pair. For this species, we assumed no floaters.*

	Mean	Sd	Reference
SJ0	0.102	0.034	[1]; [2]
SA	0.607	0.151	[1]; [2]
Fecundity	4.43	0.075	[1]; [2]
Prob. floater	-	-	-

References: [1] Versluijs *et al*. (2016); [2] Schippers *et al.* (2020).

3.2 Apportionment of victims among stages

Certain age classes could be more impacted than others. For the apportionment of victims among age classes, we assumed that the age distribution at sea is an indication for the age distribution among victims. In this chapter we provide the apportionments used in the calculations.

If certain age classes suffer higher collision risk due to more time spent offshore, the survival rates of these stages are adjusted more strongly than for other stages that do not spend much time offshore. If available, data from age distributions at sea are used as indicator for time spent offshore, for example based on the analysis within Potiek *et al.* (2019b). If based on Potiek *et al.* (2019b), the overall annual stage distribution in the entire southern North Sea is used, without taking into account spatial- and/or temporal variation.

For each species, we present a table with the following information for each life stage:

- *life stages:* survival rates can be applied to several stages, for example when several immature stages have the same survival rate.
- *stable stage distribution*: overall stage distribution in the population. If all age classes have the same vulnerability, the stage distribution among victims is assumed to be the same as the stable stage distribution.
- *vulnerability:* this represents the relative collision vulnerability of each age class. The vulnerability is 1 for the stage with the highest relative vulnerability. If no data are available for stage-specific differences in vulnerability, each stage has a vulnerability of 1, and the stage distribution among victims is assumed to follow the stable stage distribution. If a stage is not present in the southern North Sea, the vulnerability of this stage is 0, and if a species is present during six months, this is

0.5. If data are available on the age distribution at sea, for example based on ESAS/MWTL data, the vulnerability is assumed to follow this age distribution. If one survival rate applies to several stages, the vulnerability vector has several values as well, corresponding to each of the life stages.

- *scalar*: the scalar is the factor with which the survival is adjusted. As a result of multiplication with this stage-specific scalar, the stage distribution among victims is adjusted to follow the distribution as given in the vulnerability vector. Although the vulnerability vector can apply to several stages, the scalar is specific for each survival rate. This means that immature survival is adjusted with one specific scalar, even if several stages experience this survival rate.

Lesser black-backed gull

Victims were apportioned among age classes according to Camphuysen and Leopold (1994). The authors analysed the age distribution in the southern North Sea, and showed that 82.9% of all individuals were adults, 10.3% were first-year individuals, and the remaining 6.8% were immatures. We assumed the same age distribution among victims.

Table 3.19 Apportionment of victims among life stages for lesser black-backed gull. For each survival parameter, the relevant life stages are reported, and the stable stage distribution within the population. The vulnerability presents the relative vulnerability of individuals per age class (highest vulnerability is 1), which is presented for each life stage (hence several values). OWF scalar is used to adjust the mortality fraction for each survival rate, in order to match the relative stage structure among victims with OWF vulnerability.

Survival parameter	Life Stage	Stable stage distribution	Relative OWF vulnerability	OWF scalar
SJ0	J0	0.07011	0.12	0.18290
SI	I1,I2,I3,I4	0.26472	0.02,0.02,0.02,0.02	0.03019
SA	A	0.66517	1	1.47208

Herring gull

Individuals spending more time at sea are assumed to experience higher collision rate. Therefore, we used data from Camphuysen & Leopold (1994) to assess the distribution of age classes at sea. Based on this data source, we assumed 67% adults, 14% immatures, and 19% first-year individuals. This results in a stage-specific additional annual mortality.

Table 3.20 *Apportionment of victims among life stages for herring gull. For each survival parameter, the relevant life stages are reported, and the stable stage distribution within the population. The vulnerability presents the relative vulnerability of individuals per age class (highest vulnerability is 1), which is presented for each life stage (hence several values). OWF scalar is used to adjust the mortality fraction for each survival rate, in order to match the relative stage structure among victims with OWF vulnerability.*

Survival parameter	Life Stage	Stable stage distribution	Relative OWF vulnerability	OWF scalar
SJ0	J0	0.10844	0.28	0.41029
SI1	I1	0.09742	0.07	0.10078
SI2	I2	0.08200	0.07	0.10078
SI3	I3	0.06902	0.07	0.10078
SA	A	0.64312	1	1.44681

Little gull

For little gull, data from Potiek *et al.* (2019a) have been used. This analysis of ESAS data showed that 87% of all individuals with assigned age distribution during the ESAS surveys were adults. The summed relative vulnerability of other stages is the remaining 13%, which is divided among the J0 and immature stages based on the stable stage distribution.

Table 3.21 *Apportionment of victims among life stages for little gull. For each survival parameter, the relevant life stages are reported, and the stable stage distribution within the population. The vulnerability presents the relative vulnerability of individuals per age class (highest vulnerability is 1), which is presented for each life stage (hence several values). OWF scalar is used to adjust the mortality fraction for each survival rate, in order to match the relative stage structure among victims with OWF vulnerability.*

Survival parameter	Life Stage	Stable stage distribution	Relative OWF vulnerability	OWF scalar
SJ0	J0	0.10651	0.06	0.07777
SI	I1	0.17687	0.09	0.12443
SA	A	0.71661	1	1.35318

Great black-backed gull

For great black-backed gull, the stage distribution is based on ESAS data (analysed by Potiek *et al.* 2019a). This analysis of ESAS data showed that 58% of all individuals with assigned age distribution during the ESAS surveys were adults. The summed relative vulnerability of other stages is the remaining 42%, which is divided among the J0 and immature stages based on the stable stage distribution.

Table 3.22 Apportionment of victims among life stages for great black-backed gull. For each survival parameter, the relevant life stages are reported, and the stable stage distribution within the population. The vulnerability presents the relative vulnerability of individuals per age class (highest vulnerability is 1), which is presented for each life stage (hence several values). OWF scalar is used to adjust the mortality fraction for each survival rate, in order to match the relative stage structure among victims with OWF vulnerability.

Survival parameter	Life Stage	Stable stage distribution	Relative OWF vulnerability	OWF scalar
SJ0	J0	0.11958	1	1.57546
SI	I1,I2,I3	0.25287	1, 0.93, 0.95	1.51825
SA	A	0.62755	0.43	0.68152

Black-legged kittiwake

For black-legged kittiwake, the stage distribution is based on ESAS data (analysed by Potiek *et al.* 2019a). This analysis of ESAS data showed that 88% of all individuals with assigned age distribution during the ESAS surveys were adults. The summed relative vulnerability of other stages is the remaining 12%, which is divided among the J0 and immature stages based on the stable stage distribution.

Table 3.23 Apportionment of victims among life stages for black-legged kittiwake. For each survival parameter, the relevant life stages are reported, and the stable stage distribution within the population. The vulnerability presents the relative vulnerability of individuals per age class (highest vulnerability is 1), which is presented for each life stage (hence several values). OWF scalar is used to adjust the mortality fraction for each survival rate, in order to match the relative stage structure among victims with OWF vulnerability.

Survival parameter	Life Stage	Stable stage distribution	Relative OWF vulnerability	OWF scalar
SJ0	J0	0.07976	0.03	0.04907
SI	I1,I2,I3	0.33216	0.03,0.04,0.03	0.05835
SA	A	0.58808	1	1.66083

Northern gannet

For northern gannet, the stage distribution is based on ESAS data (analysed by Potiek *et al.* 2019a). This analysis of ESAS data showed that 73% of all individuals with assigned age distribution during the ESAS surveys were adults. Stages I1 to I3 are currently not used in the population models. The summed relative vulnerability of other stages is the remaining 27%, which is divided among the J0 and A4 stages based on the stable stage distribution.

Table 3.24 Apportionment of victims among life stages for northern gannet. For each survival parameter, the relevant life stages are reported, and the stable stage distribution within the population. The vulnerability presents the relative vulnerability of individuals per age class (highest vulnerability is 1), which is presented for each life stage (hence several values). OWF scalar is used to adjust the mortality fraction for each survival rate, in order to match the relative stage structure among victims with OWF vulnerability.

Survival parameter	Life Stage	Stable stage distribution	Relative OWF vulnerability	OWF scalar
SJ0	J0	0.09082	0.22	0.34470
S1	I1	0.09623	0	0.00000
S2	I2	0.07784	0	0.00000
S3	I3	0.06822	0	0.00000
SA	A4,AB	0.66690	0.15,1	1.45254

Arctic skua

For Arctic skua, the stage distribution is based on ESAS data (analysed by Potiek *et al.* 2019a). This analysis of ESAS data showed that 63% of all individuals with assigned age distribution during the ESAS surveys were adults. The summed relative vulnerability of other stages was the remaining 37%, divided among the subadult stages based on the stable stage distribution.

Table 3.25 Apportionment of victims among life stages for Arctic skua. For each survival parameter, the relevant life stages are reported, and the stable stage distribution within the population. The vulnerability presents the relative vulnerability of individuals per age class (highest vulnerability is 1), which is presented for each life stage (hence several values). OWF scalar is used to adjust the mortality fraction for each survival rate, in order to match the relative stage structure among victims with OWF vulnerability.

Survival parameter	Life Stage	Stable stage distribution	Relative OWF vulnerability	OWF scalar
SJ0	J0	0.06304	0.12	0.15332
SI	I1,I2,I3	0.19829	0.12,0.19,0.16	0.19664
SA	A	0.73867	1	1.28791

Great skua

For great skua, the stage distribution is based on ESAS data (analysed by Potiek *et al.* 2019a). This analysis of ESAS data showed that 82% of all individuals with assigned age distribution during the ESAS surveys were adults. The summed relative vulnerability of other stages was the remaining 18%, divided among the subadult stages based on the stable stage distribution.

Table 3.26 Apportionment of victims among life stages for great skua. For each survival parameter, the relevant life stages are reported, and the stable stage distribution within the population. The vulnerability presents the relative vulnerability of individuals per age class (highest vulnerability is 1), which is presented for each life stage (hence several values). OWF scalar is used to adjust the mortality fraction for each survival rate, in order to match the relative stage structure among victims with OWF vulnerability.

Survival parameter	Life Stage	Stable stage distribution	Relative OWF vulnerability	OWF scalar
SJ0	J0	0.05546	0.03	0.05615
SI	I1,I2,I3, I4,I5,I6	0.46190	0.03,0.05,0.04, 0.03,0.03,0.02	0.06643
SA	A	0.48264	1	2.00189

Common tern

For common tern, the stage distribution is based on ESAS data (analysed by Potiek *et al.* 2019a). This analysis of ESAS data showed that 89% of all individuals with assigned age distribution during the ESAS surveys were adults. The summed relative vulnerability of other stages was the remaining 11%, divided among the subadult stages based on the stable stage distribution.

Table 3.27 Apportionment of victims among life stages for common tern. For each survival parameter, the relevant life stages are reported, and the stable stage distribution within the population. The vulnerability presents the relative vulnerability of individuals per age class (highest vulnerability is 1), which is presented for each life stage (hence several values). OWF scalar is used to adjust the mortality fraction for each survival rate, in order to match the relative stage structure among victims with OWF vulnerability.

Survival parameter	Life Stage	Stable stage distribution	Relative OWF vulnerability	OWF scalar
SJ0	J0	0.08337	0.03	0.05433
SI	I1,I2,I3	0.28567	0,0.05,0.04	0.03952
SA	A	0.63096	1	1.55981

Sandwich tern

For Sandwich tern, victims were apportioned between life stages according to the stable stage structure based on the population models. This means that individuals from different age classes have the same collision probability. However, in case of Sandwich tern, the vast majority of juveniles and subadults do not return to the southern North Sea; hence, only adults are assumed to be vulnerable for collision. For that reason, the vulnerability of the J0 and I1 stage is 0.

Table 3.28 *Apportionment of victims among life stages for Sandwich tern. For each survival parameter, the relevant life stages are reported, and the stable stage distribution within the population. The vulnerability presents the relative vulnerability of individuals per age class (highest vulnerability is 1), which is presented for each life stage (hence several values). OWF scalar is used to adjust the mortality fraction for each survival rate, in order to match the relative stage structure among victims with OWF vulnerability.*

Survival parameter	Life Stage	Stable stage distribution	Relative OWF vulnerability	OWF scalar
SJ0	1	J0	0	0
SI	2	I1	0	0
SA	3	A3,AB	1, 1	1

Bewick's swan

For Bewick's swan, victims were apportioned between life stages according to a stable stage structure based on the population models. This means that individuals from different age classes have the same collision probability.

Table 3.29 *Apportionment of victims among life stages for Bewick's swan. For each survival parameter, the relevant life stages are reported, and the stable stage distribution within the population. The vulnerability presents the relative vulnerability of individuals per age class (highest vulnerability is 1), which is presented for each life stage (hence several values). OWF scalar is used to adjust the mortality fraction for each survival rate, in order to match the relative stage structure among victims with OWF vulnerability.*

Survival parameter	**Life Stage**	**Stable stage distribution**	**Relative OWF vulnerability**	**OWF scalar**
SJ0	J0	0.05491	1	1
SI	I1	0.10670	1	1
SA	A	0.83839	1	1

Brent goose

For brent goose, victims were apportioned between life stages according to a stable stage structure. This means that individuals from different age classes have the same collision probability.

Table 3.30 *Apportionment of victims among life stages for brent goose. For each survival parameter, the relevant life stages are reported, and the stable stage distribution within the population. The vulnerability presents the relative vulnerability of individuals per age class (highest vulnerability is 1), which is presented for each life stage (hence several values). OWF scalar is used to adjust the mortality fraction for each survival rate, in order to match the relative stage structure among victims with OWF vulnerability.*

Survival parameter	Life Stage	Stable stage distribution	Relative OWF vulnerability	OWF scalar
SJ0	J0	0.10177	1	1
SI	I1	0.11756	1	1
SA	A	0.78068	1	1

Common shelduck

Common shelducks migrate from their second calendar year onwards (Wernham *et al.* 2002). Individuals in stage J0 are therefore not vulnerable for collisions with wind farms on the North Sea. The vulnerability of immatures and adults is assumed to be equal.

Table 3.31 *Apportionment of victims among life stages for common shelduck. For each survival parameter, the relevant life stages are reported, and the stable stage distribution within the population. The vulnerability presents the relative vulnerability of individuals per age class (highest vulnerability is 1), which is presented for each life stage (hence several values). OWF scalar is used to adjust the mortality fraction for each survival rate, in order to match the relative stage structure among victims with OWF vulnerability.*

Survival parameter	Life Stage	Stable stage distribution	Relative OWF vulnerability	OWF scalar
SJ0	J0	0.24191	0	0.00000
SI	I1	0.16718	1	1.00000
SA	A	0.59091	1	1.00000

Eurasian curlew

For curlew, victims were apportioned between life stages according to a stable stage structure. This means that individuals from different age classes have the same collision probability.

Table 3.32 *Apportionment of victims among life stages for Eurasian curlew. For each survival parameter, the relevant life stages are reported, and the stable stage distribution within the population. The vulnerability presents the relative vulnerability of individuals per age class (highest vulnerability is 1), which is presented for each life stage (hence several values). OWF scalar is used to adjust the mortality fraction for each survival rate, in order to match the relative stage structure among victims with OWF vulnerability.*

Survival parameter	Life Stage	Stable stage distribution	Relative OWF vulnerability	OWF scalar
SJ0	J0	0.06167	1	1
SI	I1	0.07542	1	1
SA	A	0.86290	1	1

Black tern

For black tern, the stage distribution is based on ESAS data (analysed by Potiek *et al.* 2019a). This analysis of ESAS data showed that 82% of all individuals with assigned age distribution during the ESAS surveys were adults. The summed relative vulnerability of other stages was the remaining 18%. As only the stage J0 and I2 make use of the North Sea, this 18% is divided among these stages based on the stable stage distribution.

Table 3.33 *Apportionment of victims among life stages for black tern. For each survival parameter, the relevant life stages are reported, and the stable stage distribution within the population. The vulnerability presents the relative vulnerability of individuals per age class (highest vulnerability is 1), which is presented for each life stage (hence several values). OWF scalar is used to adjust the mortality fraction for each survival rate, in order to match the relative stage structure among victims with OWF vulnerability.*

Survival parameter	Life Stage	Stable stage distribution	Relative OWF vulnerability	OWF scalar
SJ0	J0	0.11564	0.23	0.34200
SI	I1,I2	0.27187	0,0.29	0.16508
SA	A	0.61249	1	1.49484

Common starling

For common starling, victims were apportioned between life stages according to a stable stage structure. This means that individuals from different age classes have the same collision probability.

Table 3.34 *Apportionment of victims among life stages for common starling. For each survival parameter, the relevant life stages are reported, and the stable stage distribution within the population. The vulnerability presents the relative vulnerability of individuals per age class (highest vulnerability is 1), which is presented for each life stage (hence several values). OWF scalar is used to adjust the mortality fraction for each survival rate, in order to match the relative stage structure among victims with OWF vulnerability.*

Survival parameter	Life Stage	Stable stage distribution	Relative OWF vulnerability	OWF scalar
SJ0	J0	0.3434	1	1
SA	A	0.6566	1	1

Bar-tailed godwit

Bar-tailed godwits generally spend the summer of their second calendar-year in wintering grounds. This means that individuals are vulnerable for collision during migration towards wintering grounds in their first autumn, and from the spring migration during their third calendar-year onwards. In addition, victims were apportioned according to a stable stage structure. This means that individuals making use of the North Sea have the same collision probability.

Table 3.35 *Apportionment of victims among life stages for bar-tailed godwit. For each survival parameter, the relevant life stages are reported, and the stable stage distribution within the population. The vulnerability presents the relative vulnerability of individuals per age class (highest vulnerability is 1), which is presented for each life stage (hence several values). OWF scalar is used to adjust the mortality fraction for each survival rate, in order to match the relative stage structure among victims with OWF vulnerability.*

Survival parameter	Life Stage	Stable stage distribution	Relative OWF vulnerability	OWF scalar
SJ0	J0	0.11497	0.5	0.57668
SI	I1	0.15098	0.5	0.57668
SA	A	0.73406	1	1.15336

Red knot

For red knot, victims were apportioned between life stages according to a stable stage structure. This means that individuals from different age classes have the same collision probability.

Table 3.36 Apportionment of victims among life stages for red knot. For each survival parameter, the relevant life stages are reported, and the stable stage distribution within the population. The vulnerability presents the relative vulnerability of individuals per age class (highest vulnerability is 1), which is presented for each life stage (hence several values). OWF scalar is used to adjust the mortality fraction for each survival rate, in order to match the relative stage structure among victims with OWF vulnerability.

Survival parameter	Life Stage	Stable stage distribution	Relative OWF vulnerability	OWF scalar
SJ0	J0	0.05174	1	1
SI	I1	0.09181	1	1
SA	A	0.85645	1	1

4 Numbers of victims and population-level impacts per wind farm scenario

In this chapter, we provide the results of the sCRM calculations and how these figures translate to mortality fractions relative to the used population sizes. The used approach differs for seabirds and migratory birds. Hence, these are discussed separately in §4.1 and §4.2.

For both groups of species, an overview of the number of casualties is provided per species per wind farm in Appendix IV. In addition, in Appendix V an example is provided on how the number of collision victims change by using a lowest tip height of 40 m. In the following chapter, the total numbers of victims per scenario are reported in Table 4.1 and Table 4.3. Furthermore, in these tables also the population size is reported, defined as referred to in § 2.4.3. Based on the population size and number of victims, the fraction mortality was calculated. This fraction mortality is reported for each scenario in Table 4.2 and Table 4.4.

For seabirds, the number of collision victims is highest for northern gannet, with an estimated average of 1,183 victims for the Basic national scenario up to 2030 (basic nat 30). The resulting mortality fraction is highest for northern gannet as well (0.04, i.e. 4%), followed by great black-backed gull (0.02, i.e. 2%).

For migratory birds, the highest number of collision victims were estimated for common starling (over 3,000 for the basic nat 30 scenario). However, due to the large population size, the fraction mortality was higher for other migratory species. The fraction mortality was highest among migratory birds for curlew, bar-tailed godwit and red knot (resp. 0.03%, 0.028% and 0.025%). Note that these mortality fractions for migratory bird species are clearly lower than for seabirds. This is likely caused by seabirds more intensively using the area for a prolonged time and hence suffering from higher mortality, whereas migratory birds are merely subjected to collision risk with offshore wind farms during their seasonal migration.

4.1 Numbers of victims: seabirds

Table 4.1 Numbers of estimated annual collision victims per scenario for seabirds. As reference, the maximum bimonthly number of individuals is shown for the national and international scenario. Within the population models, the fraction mortality is calculated as the number of victims divided by the maximum bimonthly number of individuals.

Species	Maximum bimonthly number of individuals		Number of victims per scenario				
	Dutch continental plate (national)	Southern North Sea (international)	Basic nat 30	Rekenvariant III	Rekenvariant II	Rekenvariant I	Int 30
Lesser black-backed gull	20,553	75,351	97 ± 5	153 ± 7	144 ± 7	139 ± 7	441 ± 10
Herring gull	21,138	124,964	180 ± 12	236 ± 13	223 ± 13	219 ± 13	655 ± 27
Little gull	57,833	55,817	91 ± 2	117 ± 2	112 ± 2	110 ± 2	143 ± 2
Great black-backed gull	16,264	92,417	338 ± 26	666 ± 48	578 ± 41	550 ± 41	2,174 ± 73
Black-legged kittiwake	78,921	444,163	229 ± 3	425 ± 5	381 ± 5	364 ± 5	1,268 ± 55
Northern gannet	31,858	162,867	1,183 ± 49	1,925 ± 66	1,771 ± 63	1,690 ± 62	7,001 ±126
Arctic skua	130	3,186	0.07 ± 0.01	0.09 ± 0.01	0.09 ± 0.01	0.09 ± 0.01	1.89 ± 0.03
Great skua	1,364	12,103	2 ± 0.2	6 ± 0.8	5 ± 0.8	5 ± 0.8	29 ± 1.7
Common tern	59,093	74,947	43 ± 2	58 ± 2	56 ± 2	55 ± 2	99 ± 2
Sandwich tern	22,602	25,881	32 ± 0.7	41 ± 0.8	40 ± 0.8	40 ±0.8	65 ± 0.9

Table 4.2 Mortality fraction due to collision with wind turbines per scenario for seabirds.

Species	Mortality fraction due to collisions = 1 – (1- mean bimonthly collision mortality) ^ 6 / (maximum bimonthly number of individuals)				
	Basic nat 30	Rekenvariant III	Rekenvariant II	Rekenvariant I	Int 30
Lesser black-backed gull	0.00470	0.00743	0.00701	0.00675	0.00584
Herring gull	0.00848	0.01109	0.01052	0.01031	0.00523
Little gull	0.00157	0.00202	0.00194	0.00191	0.00254
Great black-backed gull	0.02063	0.04028	0.03500	0.03337	0.02330
Black-legged kittiwake	0.00290	0.00537	0.00482	0.00460	0.00285
Northern gannet	0.03657	0.05893	0.05432	0.05189	0.04223
Arctic skua	0.00056	0.00068	0.00068	0.00066	0.00059
Great skua	0.00148	0.00425	0.00376	0.00345	0.00241
Common tern	0.00073	0.00098	0.00094	0.00093	0.00132
Sandwich tern	0.00142	0.00183	0.00176	0.00176	0.00249

4.2 Numbers of victims: migratory birds

Table 4.3 Numbers of estimated annual victims per scenario for migratory species.

Species	Autumn flux	Number of victims per scenario				
		Basic nat 30	Rekenvariant III	Rekenvariant II	Rekenvariant I	Int 30
Bewick's swan	17,450	3 ± 0.02	5 ± 0.03	5 ± 0.03	4 ± 0.03	10 ± 0.04
Brent goose	247,286	26 ± 0.06	51 ± 0.11	49 ± 0.11	44 ± 0.10	104 ± 0.13
Common shelduck	302,047	64 ± 2	128 ± 3	114 ± 3	106 ± 3	473 ± 5
Eurasian curlew	302,273	91 ± 2	182 ± 3	161 ± 3	151 ± 3	670 ± 5
Black tern	285,482	9 ± 0.1	18 ± 0.2	16 ± 0.1	15 ± 0.1	33 ± 0.2
Common starling	18,501,266	3,022 ± 15	6,154 ± 26	5,437 ± 24	5,078 ± 23	22,411 ± 41
Red knot	672,197	168 ± 0.3	341 ± 0.5	302 ± 0.4	282 ± 0.4	1245 ± 0.7
Bar-tailed godwit	347,670	98 ± 1	199 ± 2	176 ± 2	164 ± 2	729 ± 3

Table 4.4 Numbers of estimated annual victims per scenario for migratory species.

Species	Mortality Fraction (= myear / N)				
	Basic nat 30	Rekenvariant III	Rekenvariant II	Rekenvariant I	Int 30
Bewick's swan	0.00013	0.00026	0.00024	0.00022	0.00054
Brent goose	0.00010	0.00020	0.00020	0.00018	0.00042
Common shelduck	0.00021	0.00042	0.00038	0.00035	0.00157
Eurasian curlew	0.00030	0.00060	0.00053	0.00050	0.00221
Black tern	0.00003	0.00006	0.00006	0.00005	0.00012
Common starling	0.00016	0.00033	0.00029	0.00027	0.00121
Red knot	0.00025	0.00051	0.00045	0.00042	0.00185
Bar-tailed godwit	0.00028	0.00057	0.00051	0.00047	0.00210

4.3 Population-level impacts

The mortality estimates and the subsequent population model outcomes provided the basis for the evaluation of the population-level impacts. For these purposes the generated results were compared with the species-specific Acceptable Levels of Impact (ALI), as defined by the Ministry of Agriculture, Nature and Food Quality (email 26-01-2022).

The ALI consists of two parts:

1. Maximally acceptable population decline (X). A threshold population decline 30 years after the impact, as a percentage X of the projected population size without the impact, which is considered ‘acceptable’. This decline may already be violated in part of the unimpacted scenarios, as a result of the uncertainty in the population model. For that reason, the ALI consists also of a second part:
2. Maximally acceptable probability of the decline (Y), which is based on the chosen level of causality. With this level of causality, the probability of violating the X-threshold as result of the (OWF-induced) impact is calculated (i.e., not as the result of uncertainty in the population model).

Together, X and Y lead to an ALI, expressed as *‘The probability of a population decline of X% or more, 30 years after the onset of a continuous prolonged impact, cannot exceed Y’*.

In the following chapters, the outcome of this comparison is denoted by TRUE: the ALI threshold *is violated* or FALSE: the ALI threshold is *not violated*. In §5.1 the species-specific tables are presented and in §5.2 a summary of the assessments is provided in table 5.17.

In case of northern gannet and Sandwich tern, the mortality probability per scenario includes mortality due to collisions as well to habitat loss. Mortality probabilities due to habitat loss were taken from Soudijn *et al.* (2021).

For each species, this section consists of two tables and two or three figures (three for seabirds, two for migratory birds).

- *Figure presenting an overview of the number of victims per wind farm*: For each species, we show for each density scenario (national versus international densities for seabirds; one density map for migratory birds; see Chapter 2) a map in which the colour of each wind farm refers to the number of estimated collision victims. This gives insight in the spatial variation in collision mortality.
- *Two tables summarizing the results*: For each scenario, the bird abundance and the number of casualties result in a change in survival rates, as reported in the first table. In the second table, the median population growth rate is reported, as well as the 5th and 95th percentile, which gives an indication of the range of projected population growth rates. The last two columns present the results of the comparison with the ALI threshold. ‘P causality’ represents the probability that a violation of the X threshold results from an OWF induced impact. The last column shows whether P causality violates the ALI threshold.
- *Figure presenting distribution of projected population growth rates for each scenario*. Each panel presents a different scenario. Within each panel the

distribution of the unimpacted population growth rate (grey bars) is compared with the distribution of the impacted population growth rate (coloured bars). Black vertical lines indicate median population growth rates for the unimpacted scenario and red vertical lines indicate the threshold population growth rate (first part of the ALI, X% decline within 3 generations or 10 years). For each impacted scenario, different coloured vertical lines indicate the median. The larger the effect of the impact, the further the distribution of population growth rates moves towards the left. This shift results from a certain impact onwards in the median of the impacted scenario getting below the median of the threshold scenario. This can be observed in the figures as the coloured vertical line (median of impacted scenario) being below the red vertical line (median of threshold). As mentioned earlier in this chapter, the ALI threshold is violated when the causality of ending up below the red line (i.e., violating the X threshold) as result of the impact exceeds the probability Y. Note that the ALI thresholds are species-specific. As result of differences in acceptable causality between two species, these figures should not be compared between species, but only between scenarios for a certain species. A higher acceptable causality means that the threshold is only violated when relatively more simulations violate the X-threshold, i.e., when the population growth rate distributions of the impacted and null scenarios are further apart.

Lesser black-backed gull

The estimated number of collision victims per wind farm scenario, and the effect on the stage-specific survival rates are shown in Table 4.5. As adults are more strongly impacted than other stages (Table 3.19), the effect on adult survival is more pronounced than on other survival rates.

Figure 4.1 shows the variation in annual number of collision victims per wind farm and per MW based for the national scenario. The highest number of collision victims is estimated for IJmuiden Ver, with a mean estimate of 19 victims per year.
Within the international scenario, based on international bird densities, the number of estimated collision victims is relatively high on the Dutch continental shelf (Figure 4.2). The highest estimates are found for IJmuiden Ver (NL) and Northwind (UK).

This estimated level of additional mortality does not result in violation of the ALI threshold for this species.
Population growth rates change from 0.983 in the null scenario to 0.975-0.978 in the impacted scenarios. In Table 4.6, P causality gives the probability that the violation of the threshold population size (X, for this species 30% decline over 30 years compared to the null scenario) is caused by the impact and not by uncertainty in the population models. For this species, the probability that a population abundance is 30% lower than the null scenario as result of the impact is between 16.6% and 24%, depending on the scenario.

Table 4.5 Mortality estimates of lesser black-backed gull per scenario, and the resulting change in stage-specific survival per scenario. Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Mortality is the mortality probability due to collisions.

Scenario	Mean annual casualties	Mean bimonthly casualties	Max abundance	Additional mortality	survival S0	survival SJ	survival SA
Null					0.521	0.856	0.914
Basic_2030	97	17	20553	0.005	0.521	0.856	0.908
Rekenvariant_I	139	24	20553	0.007	0.520	0.856	0.905
Rekenvariant_II	144	25	20553	0.007	0.520	0.856	0.905
Rekenvariant_III	153	26	20553	0.007	0.520	0.856	0.904
International	441	74	75351	0.006	0.520	0.856	0.906

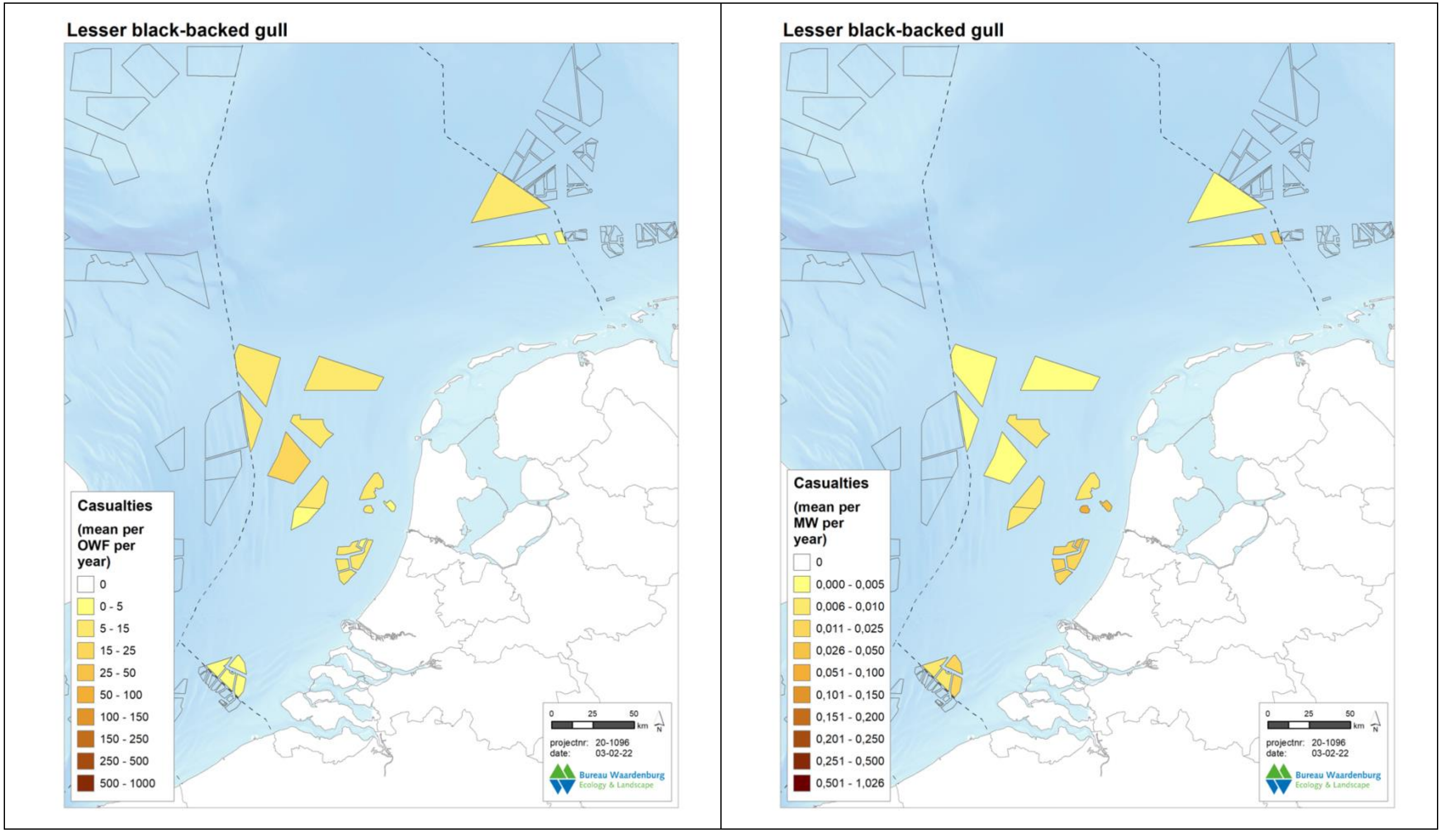

Figure 4.1 Mean estimated number of collision victims for lesser black-backed gull based on national bird densities per windfarm (left) and per MW (right).

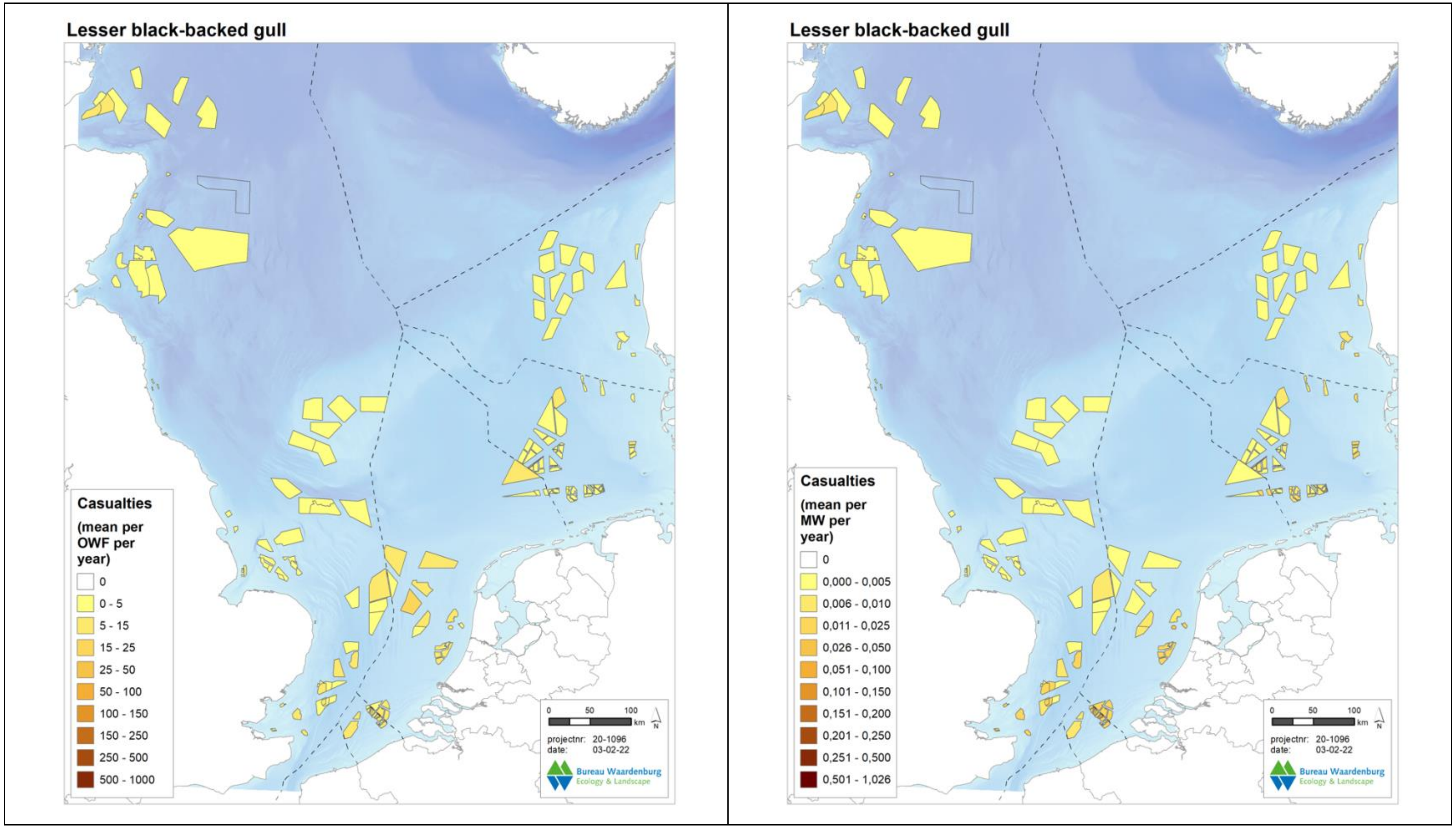

Figure 4.2 *Mean estimated number of collision victims for lesser black-backed gull based on international bird densities per windfarm (left) and per MW (right).*

Table 4.6 Summary lesser black-backed gull population level effects; The median, 5% and 95% percentiles of the population growth rates (lambda) are reported. P causality represents the probability that a violation of the X threshold results from an OWF induced impact. The last column shows whether P causality violates the ALI threshold.

Scenario	Lambda median	5%	95%	P causality X = 30%	ALI 0.5
Null	0.983	0.938	1.023	NA	NA
Basic_2030	0.978	0.933	1.019	0.166	FALSE
Rekenvariant_III	0.975	0.93	1.016	0.24	FALSE
Rekenvariant_II	0.976	0.931	1.017	0.223	FALSE
Rekenvariant_I	0.976	0.931	1.017	0.22	FALSE
International	0.977	0.932	1.018	0.2	FALSE

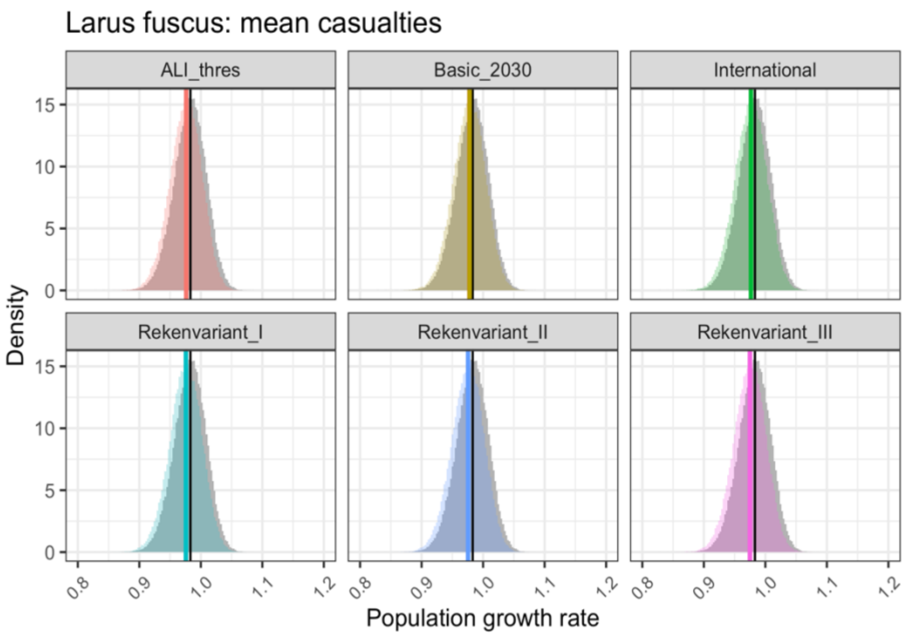

*Figure 4.3 Population growth rates per scenario for the lesser black-backed gull (*Larus fuscus*). Within each panel the distribution of the unimpacted population growth rate (grey bars) is compared with the distribution of the impacted population growth rate (coloured bars). Vertical lines indicate median population growth rates for unimpacted (black) and impacted (coloured) populations and the ALI threshold population growth rate (red).*

Herring gull

The estimated number of collision victims per wind farm scenario, and the effect on the stage-specific survival rates are shown in Table 4.7. As adults are more strongly impacted than other stages (Table 3.20), the effect on adult survival is more pronounced than on other survival rates.

Figure 4.4 shows the variation in annual number of collision victims per wind farm and per MW based for the national scenario. The highest number of collision victims is estimated for Hollandse Kust Noord, with a mean estimate of 26 victims per year.
Within the international scenario, based on international bird densities, the number of estimated collision victims are relatively high for Zoekgebied 2 Noord (39), IJmuiden Ver Noord (35) and IJmuiden Ver (32) (Figure 4.5).

The estimated level of additional mortality results in violation of the ALI threshold for all scenarios for this species. Population growth rates change from 0.951 in the null scenario to 0.940 in the impacted scenarios. In Table 4.8, P causality gives the probability that the violation of the threshold population size (X, for this species 15% decline over 30 years compared to the null scenario) is caused by the impact and not by uncertainty in the population models. For this species, the probability that a population abundance is 15% lower than the null scenario as result of the impact is between 13% and 25%, depending on the scenario. As the ALI threshold for this species is defined as maximally 10% probability of a 15% decline, the ALI threshold is violated for all scenarios.

Table 4.7 Mortality estimates of herring gull per scenario, and the resulting change in stage-specific survival per scenario. Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Additional mortality is the mortality probability due to collisions.

scenario	Mean annual casualties	Mean bimonthly casualties	Max abundance	Additional mortality	survival S0	survival SJ	survival SA
null				0	0.375	0.8	0.865
Basic_2030	180	30	21139	0.008	0.374	0.799	0.854
Rekenvariant_III	219	40	21139	0.011	0.373	0.799	0.851
Rekenvariant_II	223	38	21139	0.011	0.373	0.799	0.851
Rekenvariant_I	236	37	21139	0.01	0.373	0.799	0.852
International	655	110	124965	0.005	0.374	0.8	0.858

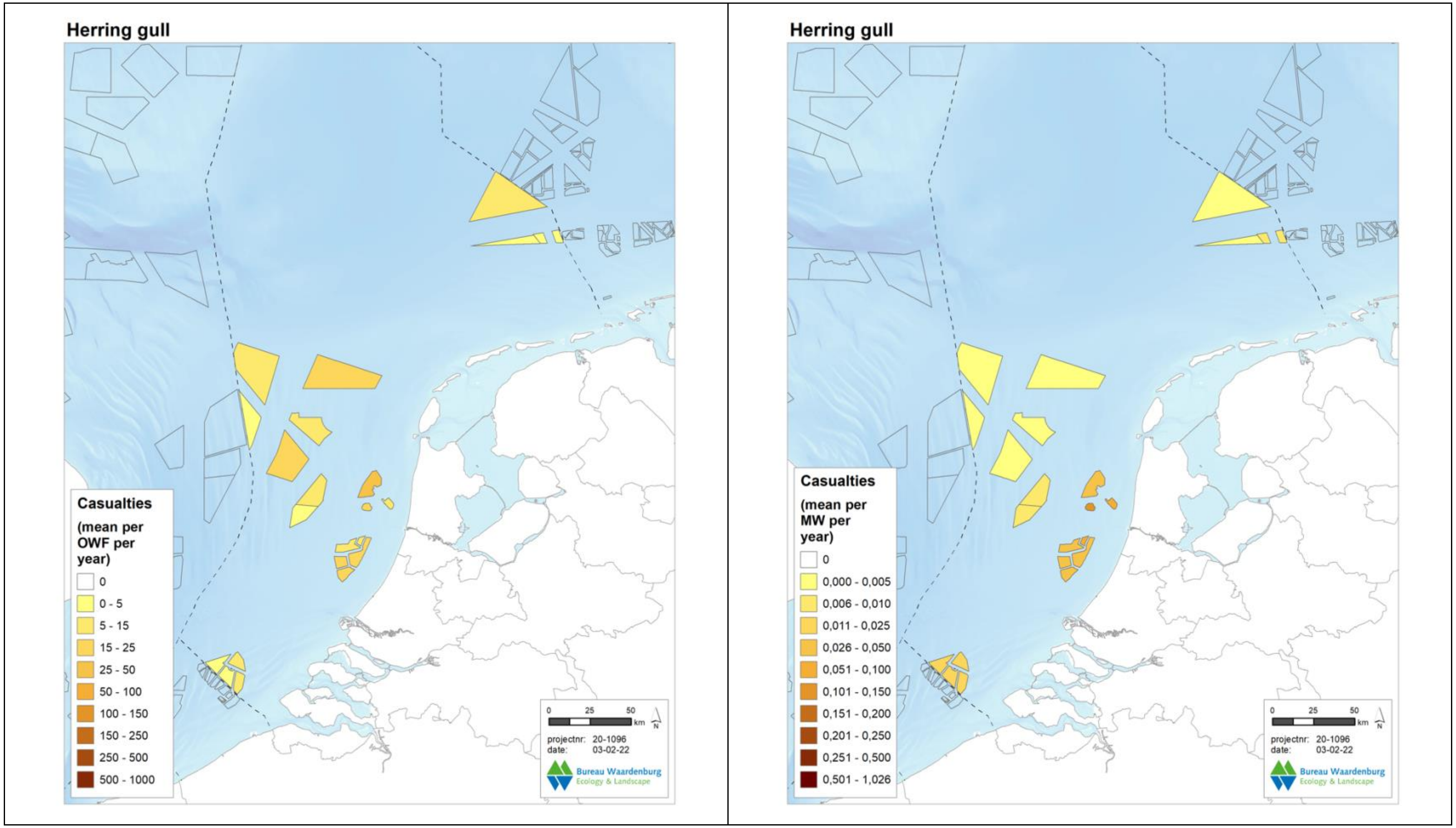

Figure 4.4 Mean estimated number of collision victims for herring gull based on national bird densities per windfarm (left) and per MW (right).

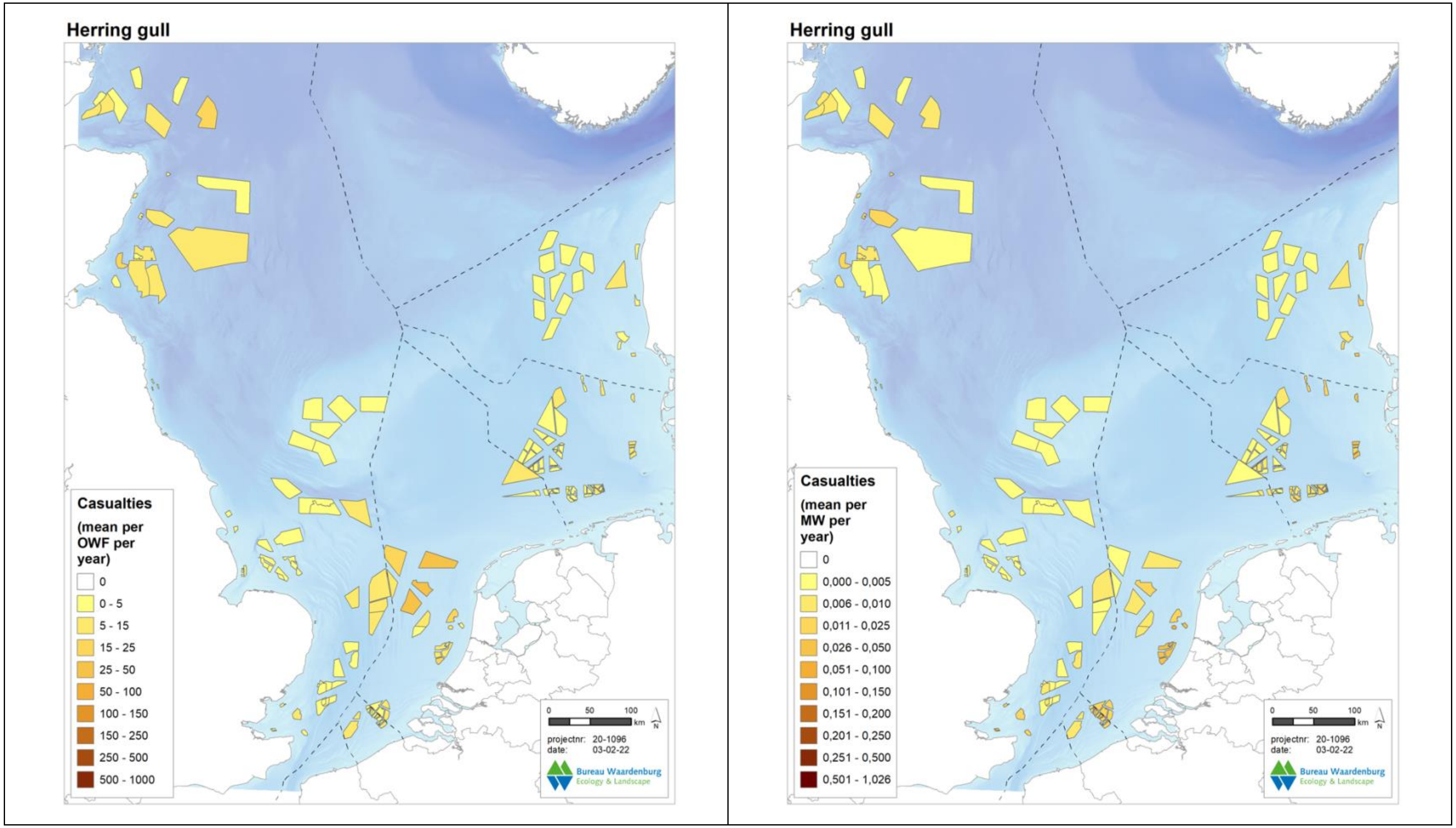

Figure 4.5 Mean estimated number of collision victims for herring gull based on international bird densities per windfarm (left) and per MW (right).

Table 4.8 *Summary herring gull population level effects; mortality is the mortality probability due to collisions. The median, 5% and 95% percentiles of the population growth rates (lambda) are also reported. P causality represents the probability that a violation of the X threshold results from an OWF induced impact. The last column shows whether P causality violates the ALI threshold.*

Scenario	Mortality	Lambda median	5%	95%	P causality X = 15%	ALI 0.1
Null	0	0.951	0.896	1	NA	NA
Basic_2030	0.008	0.942	0.887	0.992	0.203	TRUE
Rekenvariant_III	0.011	0.939	0.884	0.989	0.246	TRUE
Rekenvariant_II	0.011	0.939	0.885	0.99	0.238	TRUE
Rekenvariant_I	0.01	0.940	0.885	0.99	0.232	TRUE
International	0.005	0.945	0.891	0.994	0.134	TRUE

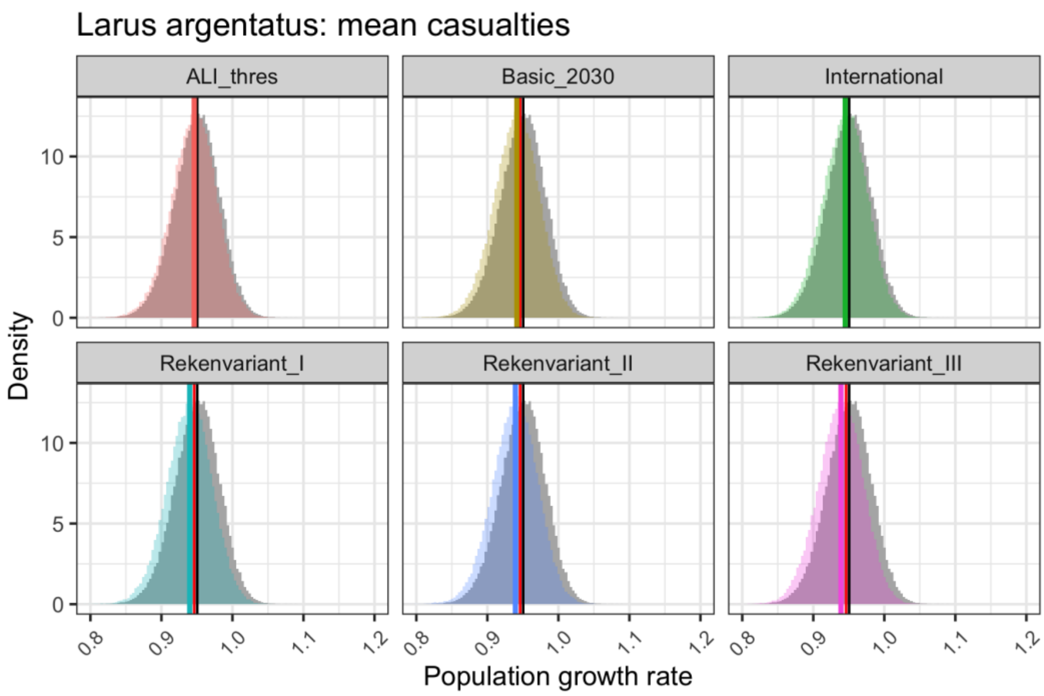

Figure 4.6 *Population growth rates per scenario for herring gull (*Larus argentatus*). Within each panel the distribution of the unimpacted population growth rate (grey bars) is compared with the distribution of the impacted population growth rate (coloured bars). Vertical lines indicate median population growth rates for unimpacted (black) and impacted (coloured) populations and the ALI threshold population growth rate (red).*

Little gull

The estimated number of collision victims per wind farm scenario, and the effect on the stage-specific survival rates are shown in Table 4.9. As adults are more strongly impacted than other stages (Table 3.21), the effect on adult survival is more pronounced than on other survival rates.

Figure 4.7 shows the variation in annual number of collision victims per wind farm and per MW based for the national scenario. The highest number of collision victims is estimated for IJmuiden Ver (14 victims per year), followed by Prinses Amaliawindpark (12), Hollandse Kust Zuid Holland IV and Egmond aan Zee (both 11).
Within the international scenario, based on international bird densities, the number of estimated collision victims is highest for IJmuiden Ver as well (14) (Figure 4.8).

The estimated level of additional mortality does not result in violation of the ALI threshold for this species. Population growth rates change from 1.009 in the null scenario to 1.006 in the impacted scenarios. In Table 4.10, P causality gives the probability that the violation of the threshold population size (X, for this species 30% decline over 30 years compared to the null scenario) is caused by the impact and not by uncertainty in the population models. For this species, the probability that a population abundance is 30% lower than the null scenario as result of the impact is between 3.5% and 4.8%, depending on the scenario.

Table 4.9 Mortality estimates of little gull per scenario, and the resulting change in stage-specific survival per scenario. Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Additional mortality is the mortality probability due to collisions.

scenario	Mean annual casualties	Mean bimonthly casualties	Max abundance	Additional mortality	survival S0	survival SJ	survival SA
null				0	0.738	0.738	0.827
Basic_2030	91	16	57833	0.002	0.738	0.738	0.825
Rekenvariant_III	117	20	57833	0.002	0.738	0.738	0.825
Rekenvariant_II	112	19	57833	0.002	0.738	0.738	0.825
Rekenvariant_I	110	19	57833	0.002	0.738	0.738	0.825
International	143	24	55817	0.003	0.738	0.738	0.824

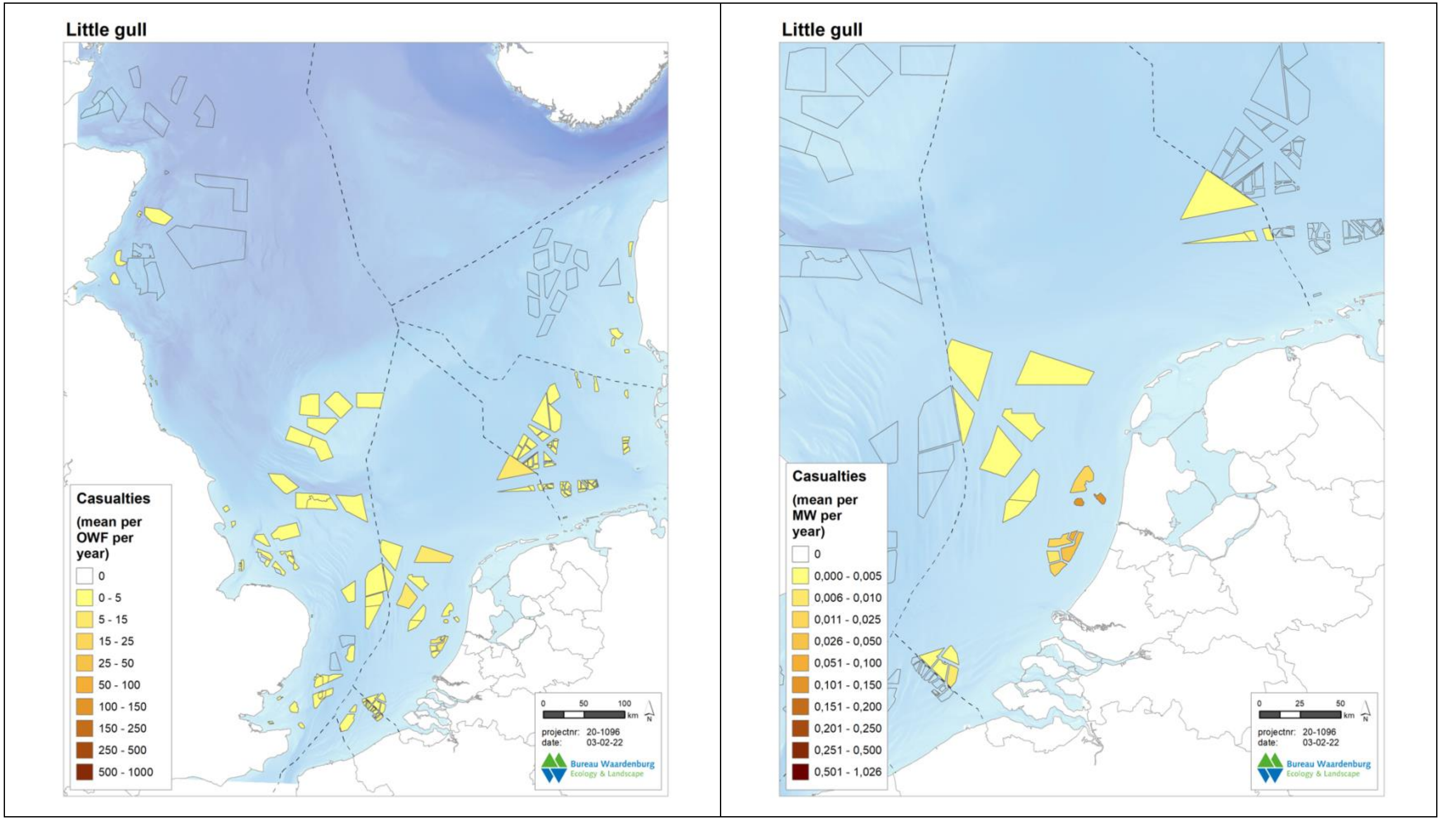

Figure 4.7 Mean estimated number of collision victims for little gull based on national bird densities per windfarm (left) and per MW (right).

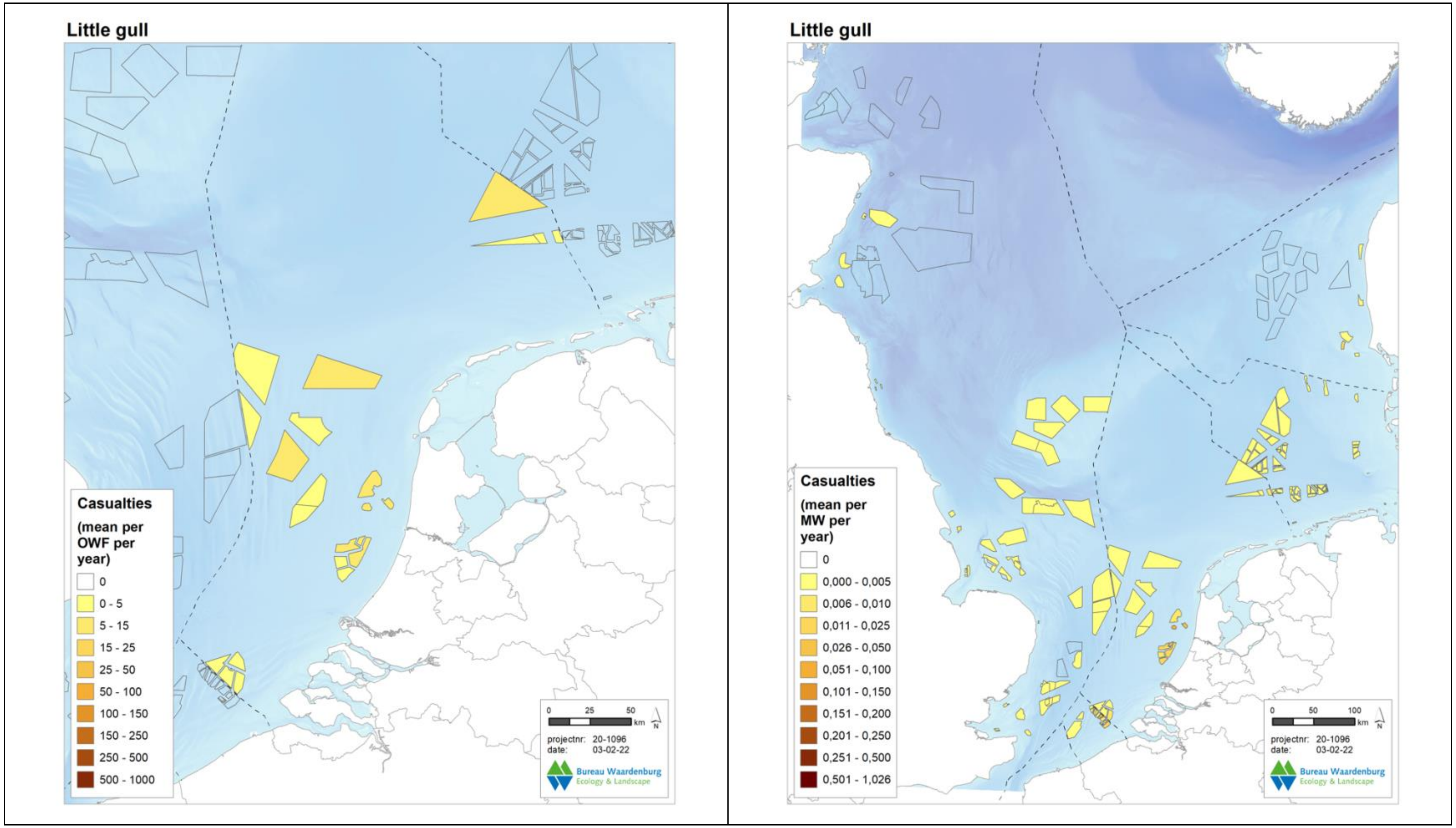

Figure 4.8 *Mean estimated number of collision victims for little gull based on international bird densities per windfarm (left) and per MW (right).*

Table 4.10 Summary little gull population level effects; casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Mortality is the mortality probability due to collisions. The median, 5% and 95% percentiles of the population growth rates (lambda) are also reported. P causality represents the probability that a violation of the X threshold results from an impact. The last column shows whether P causality violates the ALI threshold.

Scenario	Mortality	Lambda median	5%	95%	P causality X = 30%	ALI 0.5
Null	0	1.009	0.934	1.078	NA	NA
Basic_2030	0.002	1.007	0.932	1.076	0.035	FALSE
Rekenvariant_III	0.002	1.007	0.932	1.076	0.043	FALSE
Rekenvariant_II	0.002	1.006	0.932	1.076	0.047	FALSE
Rekenvariant_I	0.002	1.007	0.932	1.076	0.047	FALSE
International	0.003	1.006	0.932	1.075	0.048	FALSE

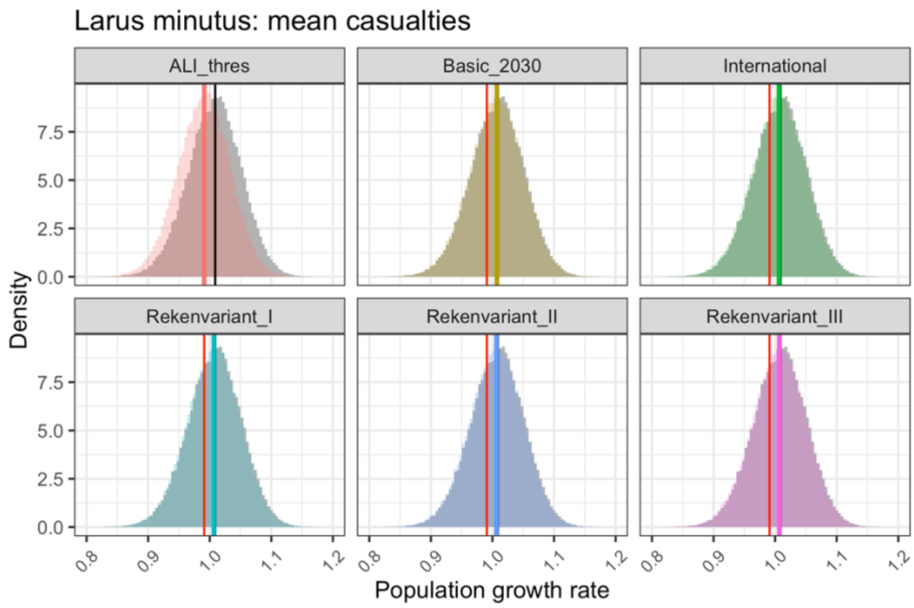

*Figure 4.9 Population growth rates per scenario for little gull (*Hydrocoloeus minutus*). Within each panel the distribution of the unimpacted population growth rate (grey bars) is compared with the distribution of the impacted population growth rate (coloured bars). Vertical lines indicate median population growth rates for unimpacted (black) and impacted (coloured) populations and the ALI threshold population growth rate (red).*

Great black-backed gull

The estimated number of collision victims per wind farm scenario, and the effect on the stage-specific survival rates are shown in Table 4.11.

Figure 4.10 shows the variation in annual number of collision victims per wind farm and per MW based for the national scenario. The highest number of collision victims is estimated for Zoekgebied 5 Oost, with a mean estimate of 100 victims per year.

Within the international scenario, based on international bird densities, the number of estimated collision victims are highest for Scottish Sectoral Marine Plan - NE7 (200), followed by Scottish Sectoral Marine Plan - NE6 (114) and Zoekgebied 5 Oost (105) (Figure 4.11).

The estimated level of additional mortality results in violation of the ALI threshold for this species for the scenario Rekenvariant III, while the threshold is not violated for the other scenarios.

Population growth rates change from 0.948 in the null scenario to 0.917 in the impacted scenarios. In Table 4.12, P causality gives the probability that the violation of the threshold population size (X, for this species 30% decline over 30 years compared to the null scenario) is caused by the impact and not by uncertainty in the population models. For this species, the probability that a population abundance is 30% lower than the null scenario as result of the impact is between 35% and 50.3%, depending on the scenario. For the scenario Rekenvariant III, the P causality of 50.3% exceeds the threshold value of 50%.

Table 4.11 Mortality estimates of great black-backed gull per scenario, and the resulting change in stage-specific survival per scenario. Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Additional mortality is the mortality probability due to collisions.

scenario	Mean annual casulaties	Mean bimonthly casualties	Max abundance	Additional mortality	survival S0	survival SJ	survival SA
null				0	0.34	0.8	0.86
Basic_2030	338	57	16264	0.021	0.329	0.775	0.848
Rekenvariant_III	666	112	16264	0.04	0.318	0.751	0.836
Rekenvariant_II	578	97	16264	0.035	0.321	0.757	0.839
Rekenvariant_I	550	92	16264	0.033	0.322	0.759	0.84
International	2,174	363	92417	0.023	0.328	0.772	0.846

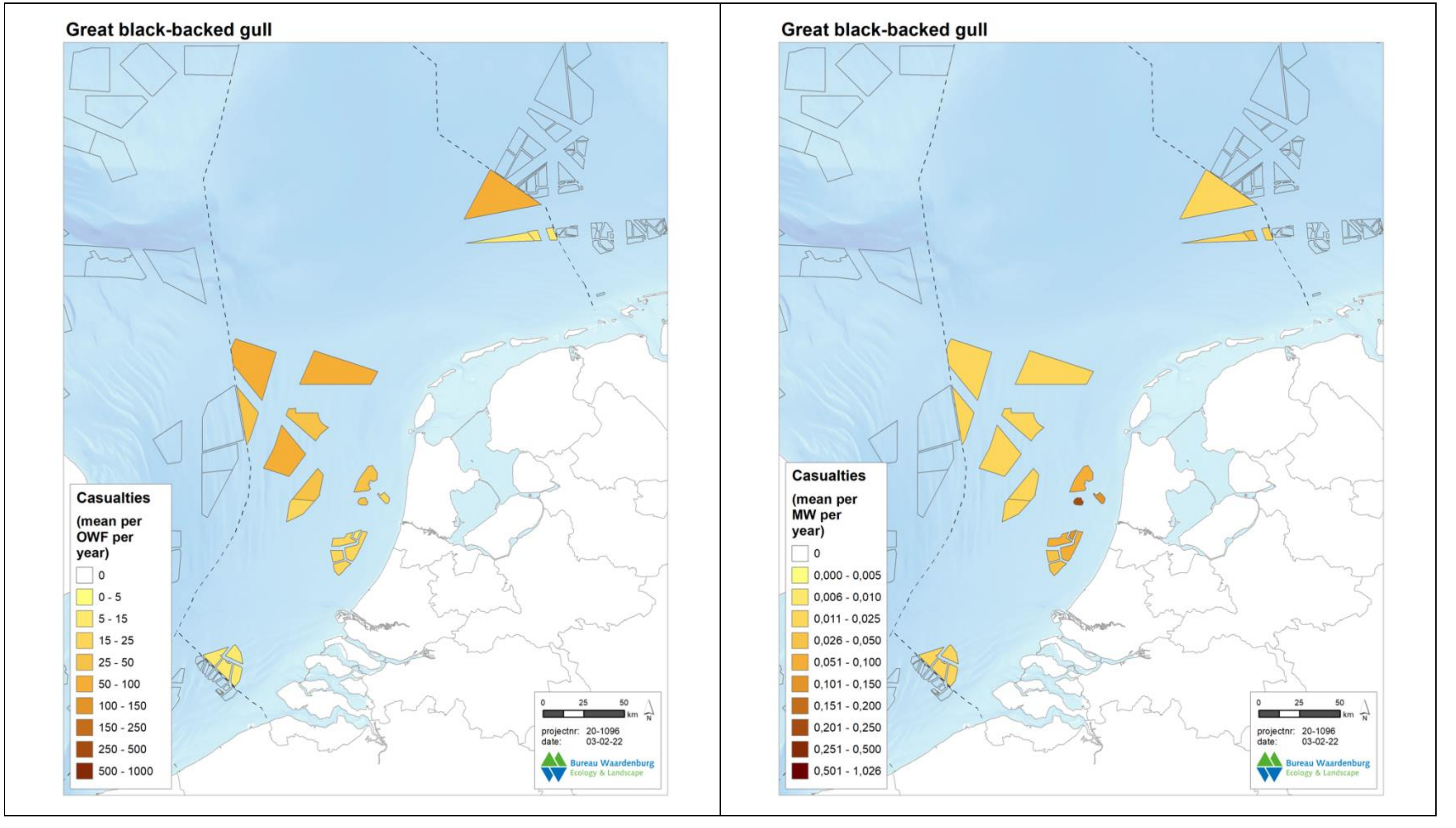

Figure 4.10 Mean estimated number of collision victims for great black-backed gull based on national bird densities per windfarm (left) and per MW (right).

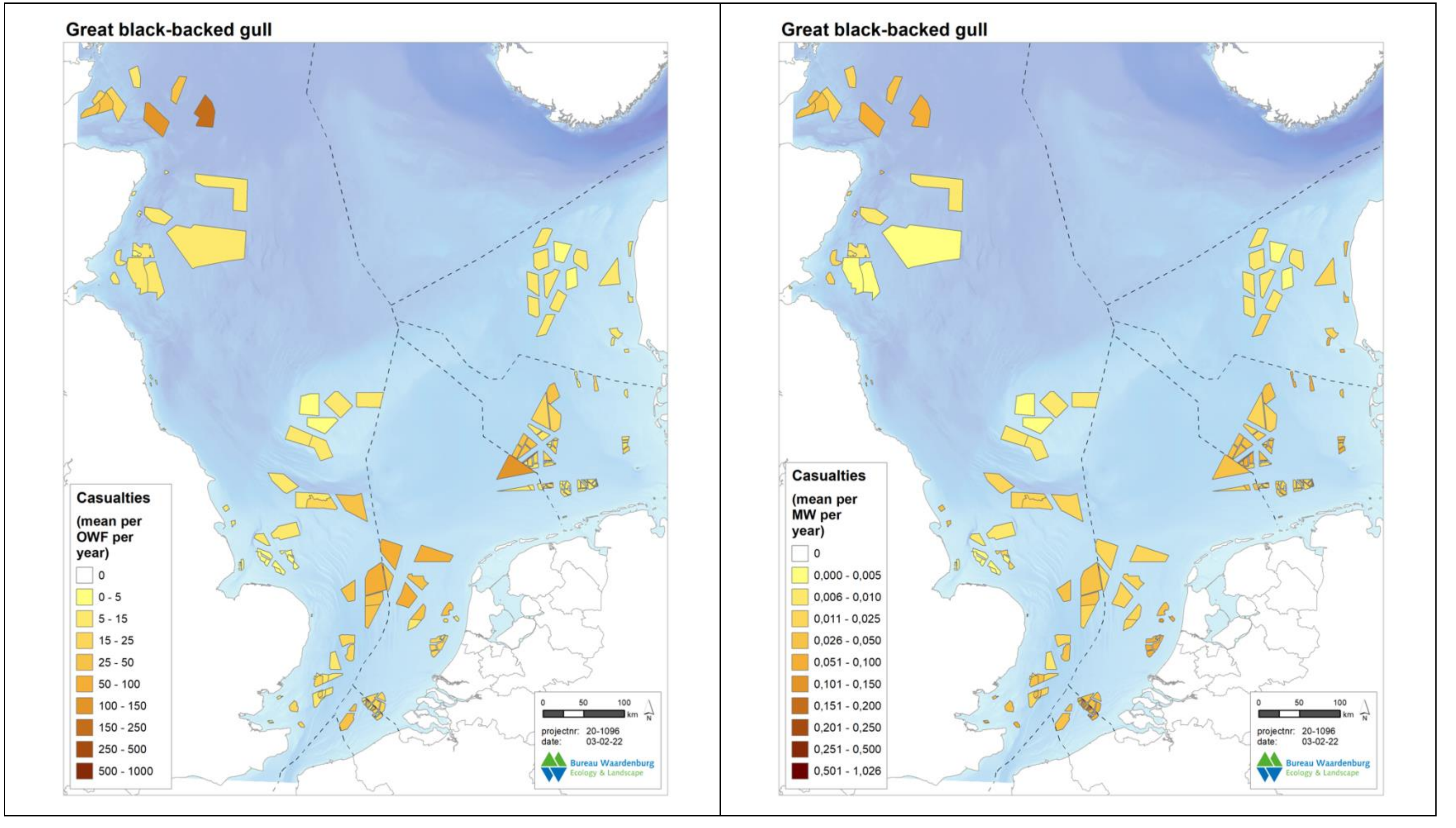

Figure 4.11 Mean estimated number of collision victims for great black-backed gull based on international bird densities per windfarm (left) and per MW (right).

Table 4.12 *Summary great black-backed gull population level effects; Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Mortality is the mortality probability due to collisions. The median, 5%and 95% percentiles of the population growth rates (lambda) are also reported. P causality represents the probability that a violation of the X threshold results from an OWF induced impact. The last column shows whether P causality violates the ALI threshold.*

Scenario	Mortality	Lambda median	5%	95%	P causality X = 30%	ALI 0.5
Null	0	0.948	0.887	1.005	NA	NA
Basic_2030	0.021	0.93	0.871	0.984	0.35	FALSE
Rekenvariant_III	0.04	0.913	0.857	0.965	0.503	TRUE
Rekenvariant_II	0.035	0.917	0.861	0.97	0.471	FALSE
Rekenvariant_I	0.033	0.919	0.862	0.972	0.461	FALSE
International	0.023	0.928	0.869	0.982	0.374	FALSE

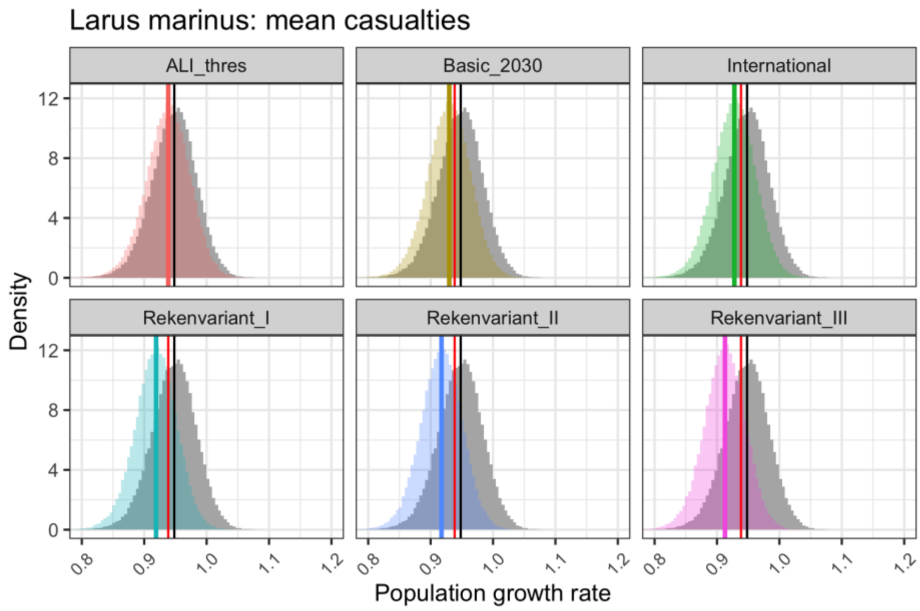

Figure 4.12 *Population growth rates per scenario for great black-backed gull (*Larus marinus*). Within each panel the distribution of the unimpacted population growth rate (grey bars) is compared with the distribution of the impacted population growth rate (coloured bars). Vertical lines indicate median population growth rates for unimpacted (black) and impacted (coloured) populations and the ALI threshold population growth rate (red).*

Black-legged kittiwake

The estimated number of collision victims per wind farm scenario, and the effect on the stage-specific survival rates are shown in Table 4.13. As adults are more strongly impacted than other stages (Table 3.23), the effect on adult survival is more pronounced than on other survival rates.

Figure 4.13 shows the variation in annual number of collision victims per wind farm and per MW based for the national scenario. The highest number of collision victims is estimated for Zoekgebied 5 Oost, with a mean estimate of 67 victims per year.
Within the international scenario, based on international bird densities, the number of estimated collision victims are highest for Norfolk Boreas (59), followed by Zoekgebied 5 Oost (48), Scottish Sectoral Marine Plan – E1 (39) and Zoekgebied 2 Noord (39) (Figure 4.14).

The estimated level of additional mortality results in violation of the ALI threshold for this species for Rekenvariant III, while the threshold is not violated for the other scenarios.
Population growth rates change from 0.951 in the null scenario to 0.945 in the impacted scenarios. In Table 4.14, P causality gives the probability that the violation of the threshold population size (X, for this species 15% decline over 30 years compared to the null scenario) is caused by the impact and not by uncertainty in the population models. For this species, the probability that a population abundance is 15% lower than the null scenario as result of the impact is between 4.8% and 10.0%, depending on the scenario. For the scenario Rekenvariant III, the P causality of 10.0% is equal to the threshold value of 10%. In other words, the level of estimated additional mortality results in reaching the ALI threshold for that scenario.

Table 4.13 Mortality estimates of kittiwake per scenario, and the resulting change in stage-specific survival per scenario. Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Additional mortality is the mortality probability due to collisions.

scenario	Mean annual casualties	Mean bimonthly casualties	Max abundance	Additional mortality	survival S0	survival SJ	survival SA
null				0	0.79	0.7	0.854
Basic_2030	229	39	78922	0.003	0.79	0.7	0.85
Rekenvariant_III	425	71	78922	0.005	0.79	0.7	0.846
Rekenvariant_II	381	64	78922	0.005	0.79	0.7	0.847
Rekenvariant_I	364	61	78922	0.005	0.79	0.7	0.847
International	1,268	212	444164	0.003	0.79	0.7	0.85

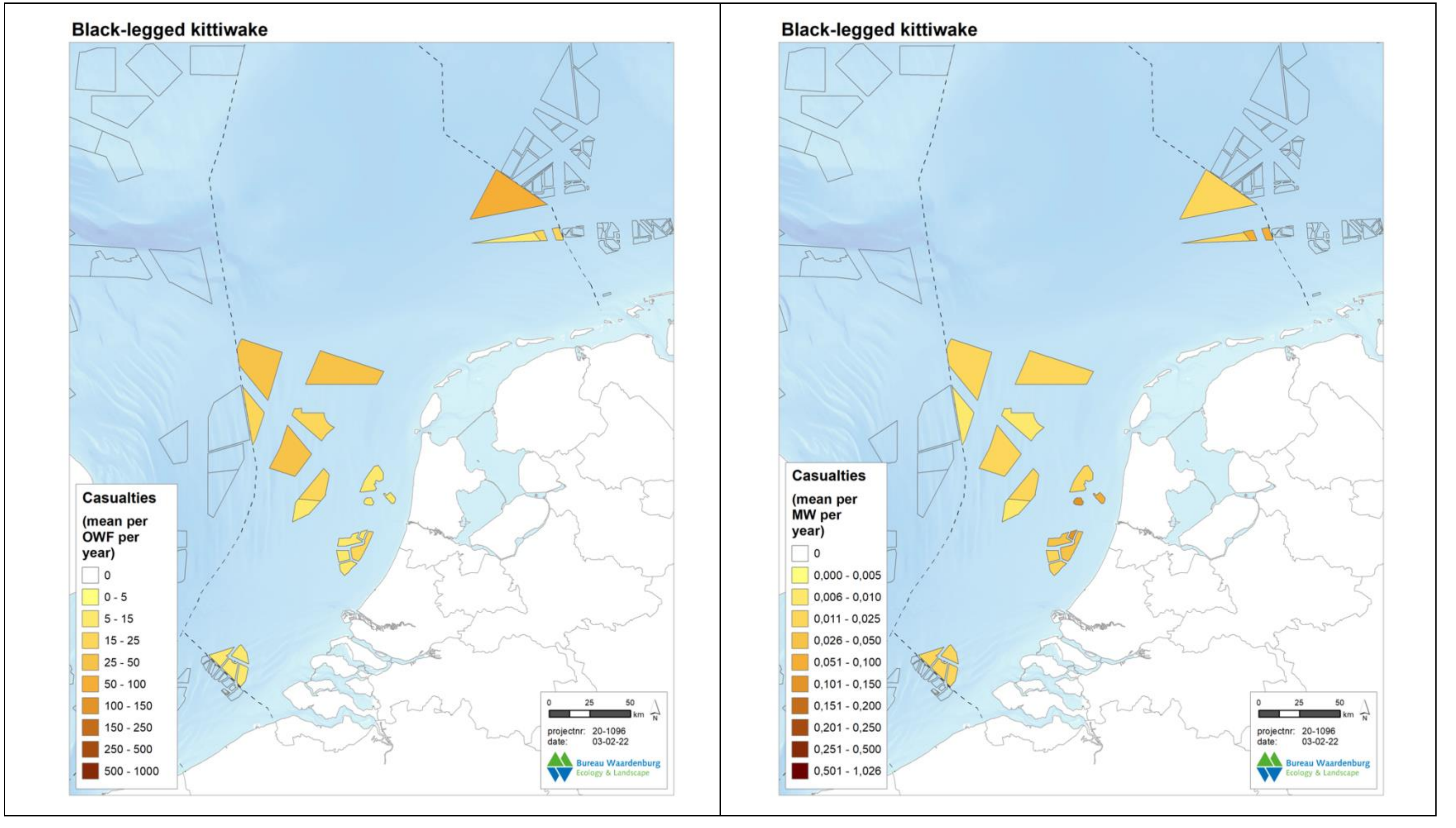

Figure 4.13 Mean estimated number of collision victims for black-legged kittiwake based on national bird densities per windfarm (left) and per MW (right).

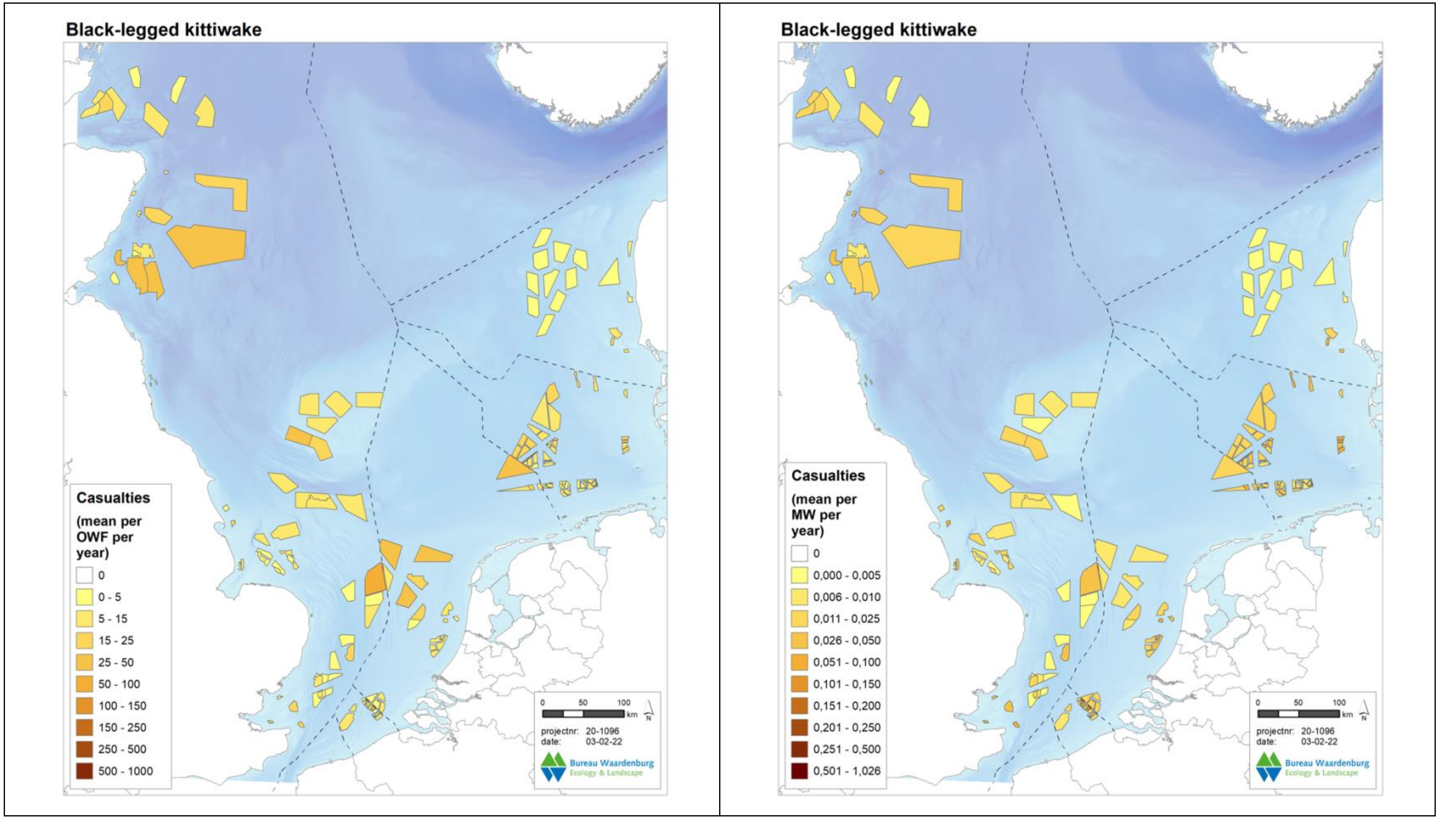

Figure 4.14 Mean estimated number of collision victims for black-legged kittiwake based on international bird densities per windfarm (left) and per MW (right).

Table 4.14 *Summary black-legged kittiwake population level effects; Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Mortality is the mortality probability due to collisions. The median, 5%and 95% percentiles of the population growth rates (lambda) are also reported. P causality represents the probability that a violation of the X threshold results from an OWF induced impact. The last column shows whether P causality violates the ALI threshold.*

Scenario	Mortality	Lambda median	5%	95%	P causality X = 15%	ALI 0.1
Null	0	0.951	0.866	1.018	NA	NA
Basic_2030	0.003	0.948	0.862	1.016	0.052	FALSE
Rekenvariant_III	0.005	0.945	0.859	1.013	0.010	TRUE
Rekenvariant_II	0.005	0.946	0.86	1.014	0.085	FALSE
Rekenvariant_I	0.005	0.946	0.86	1.014	0.08	FALSE
International	0.003	0.948	0.862	1.016	0.048	FALSE

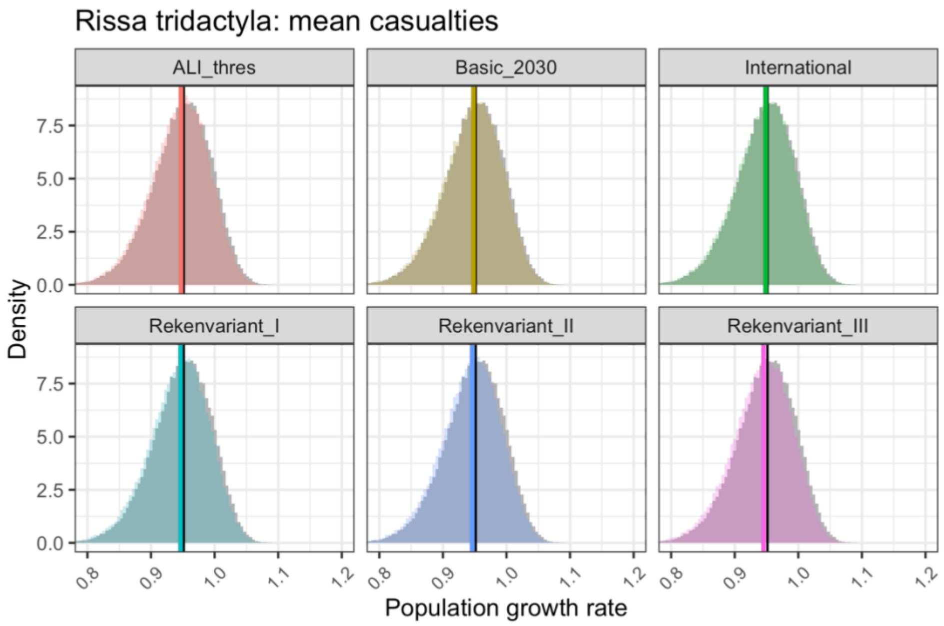

Figure 4.15 *Population growth rates per scenario for black-legged kittiwake (*Rissa tridactyla*). Within each panel the distribution of the unimpacted population growth rate (grey bars) is compared with the distribution of the impacted population growth rate (coloured bars). Vertical lines indicate median population growth rates for unimpacted (black) and impacted (coloured) populations and the ALI threshold population growth rate (red).*

Northern gannet

The estimated number of collision victims per wind farm scenario, and the effect on the stage-specific survival rates are shown in Table 4.15. As adults are more strongly impacted than other stages (Table 3.24), the effect on adult survival is more pronounced than on other survival rates.

Figure 4.16Figure 4.13 shows the variation in annual number of collision victims per wind farm and per MW based for the national scenario. The highest number of collision victims is estimated for IJmuiden Ver, Zoekgebied 2 Noord and Zoekgebied 5 Oost origineel, with mean estimates of 255, 190 and 176 victims per year. Within the international scenario, based on international bird densities, the number of estimated collision victims are highest for Northwind (301), followed by IJmuiden Ver (244) and Norfolk Boreas (219) (Figure 4.17). Note: the lower estimated numbers of victims for IJmuiden Ver within the international scenario compared to the national scenario are the result of using bird density data from an earlier period (1991 to 2020 in the international scenario, compared to 1999 to 2020 in the national scenarios), when densities of northern gannet were lower.

Table 4.15 Mortality estimates of northern gannet per scenario, and the resulting change in stage-specific survival per scenario. Based on Soudijn et al. (2021). Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Additional mortality is the mortality probability due to collisions.

scenario	Mortality source	Mean annual casualties	Mean bimonthly casualties	Max abundance	Additional mortality	survival S0	survival SJ	survival SA
null						0.48100	0.816	0.91800
Basic 2030	Collisions	1,183	198	31859	0.03657	0.46668	0.8395733	0.88230
Basic 2030	HabLoss	37	7	31859	0.00116	0.48054	0.86161	0.91686
Basic 2030	Total	1,220	204	31859	0.03770	0.46623	0.8388733	0.88120
Rekenvariant II	Collisions	1,771	296	31859	0.05432	0.45972	0.8285333	0.86498
Rekenvariant II	HabLoss	57	10	31859	0.00179	0.48030	0.86122	0.91625
Rekenvariant II	Total	1,828	305	31859	0.05603	0.45905	0.82747	0.86331
Rekenvariant III	Collisions	1,925	321	31859	0.05893	0.45792	0.8256667	0.86049
Rekenvariant III	HabLoss	63	11	31859	0.00197	0.48023	0.8611067	0.91607
Rekenvariant III	Total	1,988	332	31859	0.06080	0.45719	0.8245	0.85865
Rekenvariant I	Collisions	1,690	282	31859	0.05189	0.46067	0.8300433	0.86735
Rekenvariant I	HabLoss	54	9	31859	0.00169	0.48034	0.8612833	0.91635
Rekenvariant I	Total	1744	291	31859	0.05351	0.46004	0.8290367	0.86577
International	Collisions	7,001	1167	162868	0.04223	0.46446	0.83606	0.87679
International	HabLoss	251	42	162868	0.00154	0.48040	0.8613767	0.91650
International	Total	7,252	1209	162868	0.04371	0.46388	0.8351367	0.87534

For each of the scenarios, the estimated level of additional mortality results in violation of the ALI threshold for this species. Population growth rates change from 1.009 in the null scenario to 0.943-0.968 in the impacted scenarios. In Table 4.16, P causality gives the probability that the violation of the threshold population size (X, for this species 30% decline over 30 years compared to the null scenario) is caused by the impact and not by uncertainty in the population models. For this species, the probability that a population abundance is 30% lower than the null scenario as result of the impact is between 59.5% and 62.1%, depending on the scenario.

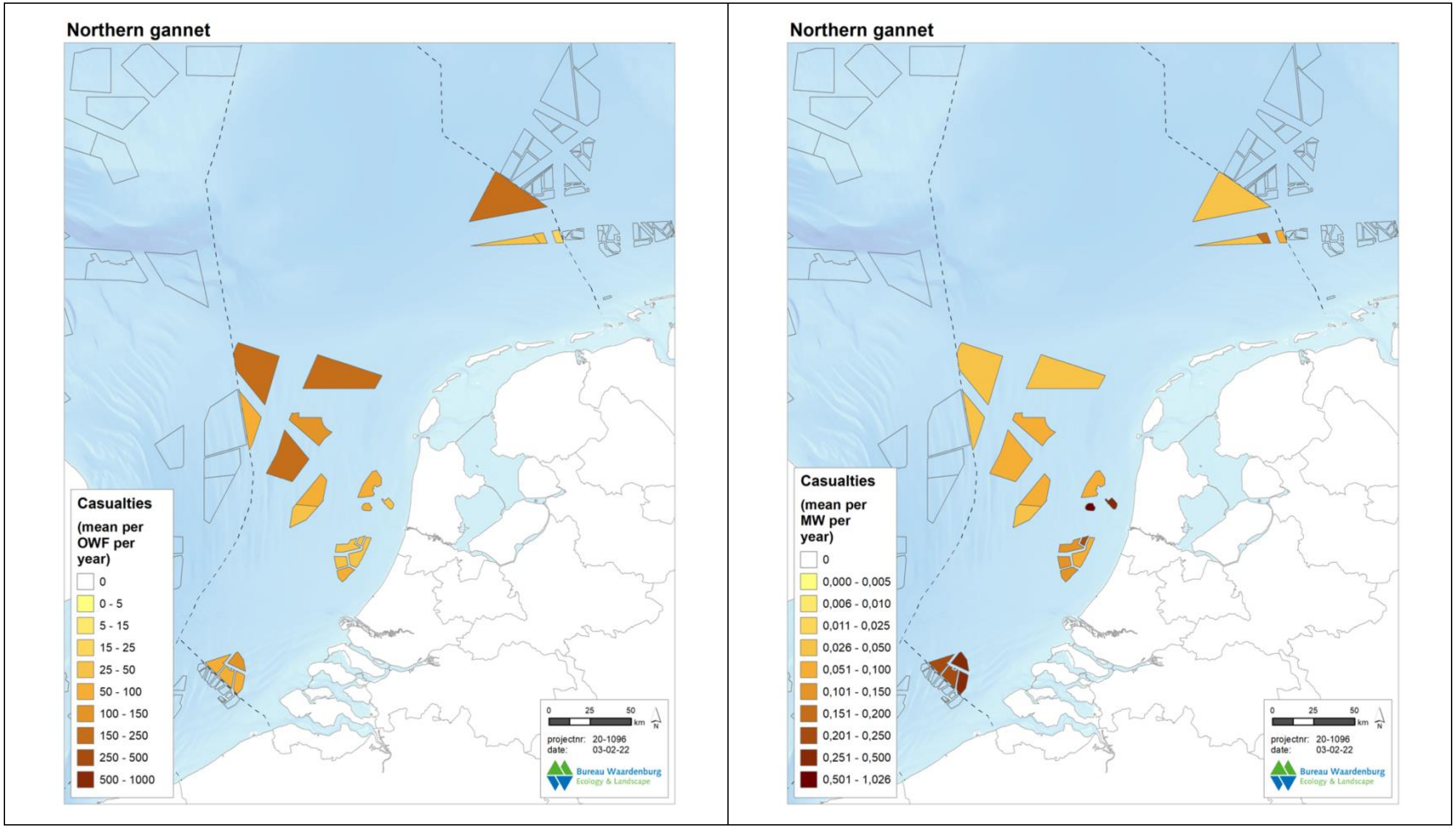

Figure 4.16 Mean estimated number of collision victims for northern gannet based on national bird densities per windfarm (left) and per MW (right).

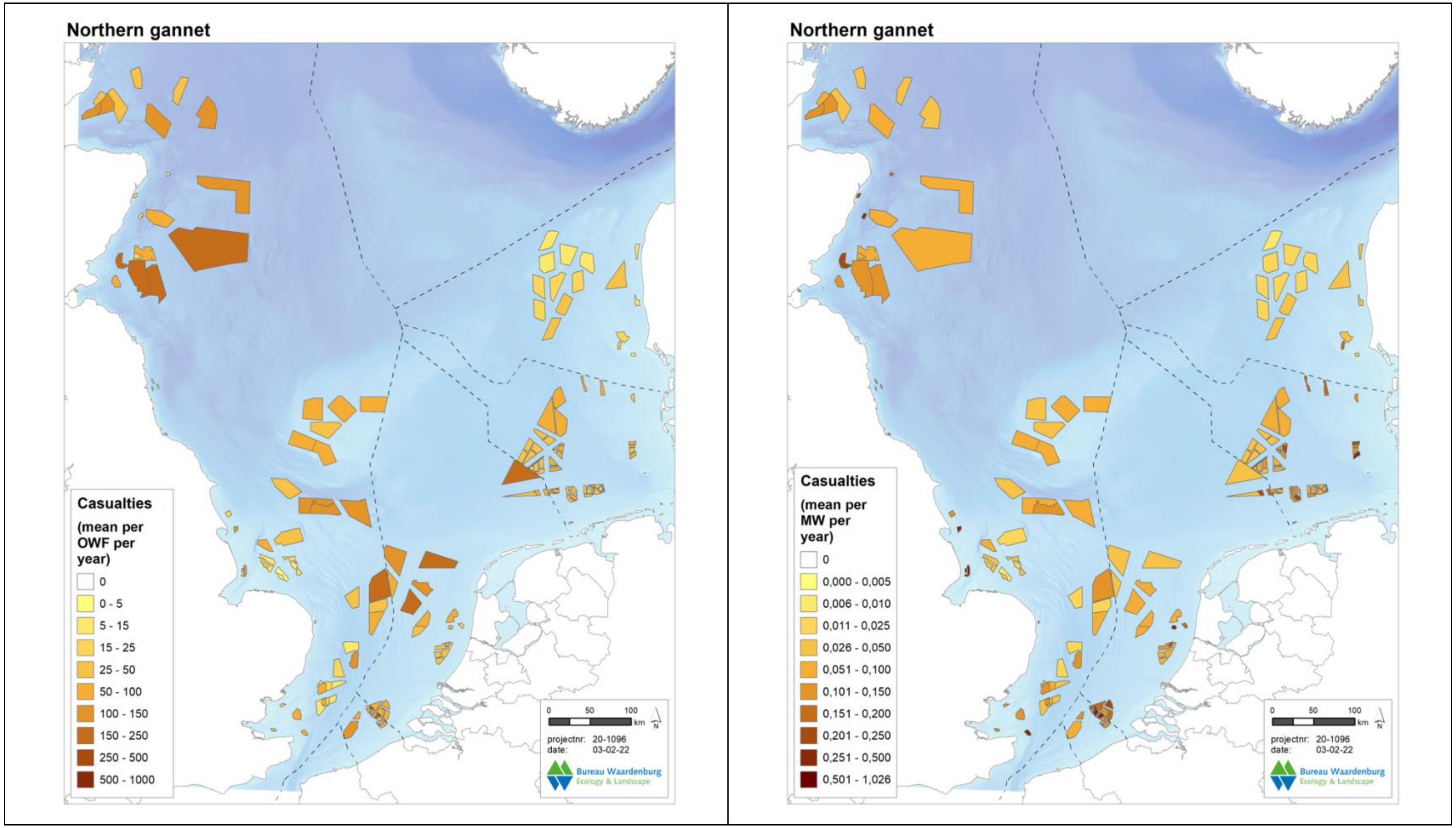

Figure 4.17 Mean estimated number of collision victims for northern gannet based on international bird densities per windfarm (left) and per MW (right).

Table 4.16 *Summary northern gannet population level effects; Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Mortality is the mortality probability due to collisions and habitat loss combined. The median, 5% and 95% percentiles of the population growth rates (lambda) are also reported. P causality represents the probability that a violation of the X threshold results from an OWF induced impact. The last column shows whether P causality violates the ALI threshold.*

Scenario	Mortality	Lambda median	5%	95%	P causality X = 30%	ALI 0.5
null	0	1.009	0.966	1.045	NA	NA
Basic_2030	0.038	0.968	0.924	1.005	0.595	TRUE
Rekenvariant_III	0.061	0.943	0.898	0.981	0.621	TRUE
Rekenvariant_II	0.056	0.948	0.904	0.986	0.62	TRUE
Rekenvariant_I	0.054	0.951	0.906	0.988	0.619	TRUE
International	0.044	0.961	0.917	0.999	0.608	TRUE

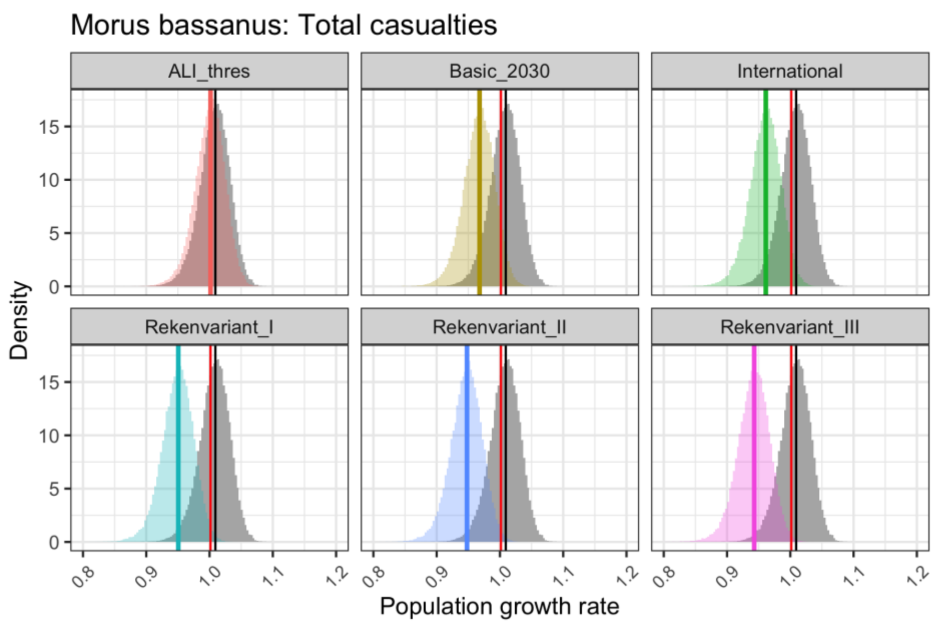

Figure 4.18 *Population growth rates per scenario for the northern gannet (*Morus bassanus*). Within each panel the distribution of the unimpacted population growth rate (grey bars) is compared with the distribution of the impacted population growth rate (coloured bars). Vertical lines indicate median population growth rates for unimpacted (black) and impacted (coloured) populations and the ALI threshold population growth rate (red).*

Arctic skua

The estimated number of collision victims per wind farm scenario, and the effect on the stage-specific survival rates are shown in Table 4.17. With only 1 estimated collision victim in each of the scenarios, the effect on survival rates is very small.

Figure 4.19 shows the variation in annual number of collision victims per wind farm and per MW based for the national scenario. The highest number of collision victims is estimated for IJmuiden Ver, with a mean estimate of 0.05 victims per year.
Within the international scenario, based on international bird densities, the number of estimated collision victims are highest for Moray East (0.3 victims per year) (Figure 4.20).

This estimated level of additional mortality does not result in violation of the ALI threshold for this species.
Population growth rates change from 0.961 in the null scenario to 0.960 in the impacted scenarios. In Table 4.18, P causality gives the probability that the violation of the threshold population size (X, for this species 15% decline over 30 years compared to the null scenario) is caused by the impact and not by uncertainty in the population models. For this species, the probability that a population abundance is 15% lower than the null scenario as result of the impact is between 0.4% and 1.2%, depending on the scenario.

Table 4.17 Mortality estimates of Arctic skua per scenario, and the resulting change in stage-specific survival per scenario. Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Additional mortality is the mortality probability due to collisions.

scenario	Mean annual casualties	Mean bimonthly casualties	Max abundance	Additional mortality	survival S0	survival SJ	survival SA
null				0	0.57	0.77	0.9
Basic_2030	1	1	131	0.001	0.57	0.77	0.899
Rekenvariant_III	1	1	131	0.001	0.57	0.77	0.899
Rekenvariant_II	1	1	131	0.001	0.57	0.77	0.899
Rekenvariant_I	1	1	131	0.001	0.57	0.77	0.899
International	2	1	3186	0.001	0.57	0.77	0.899

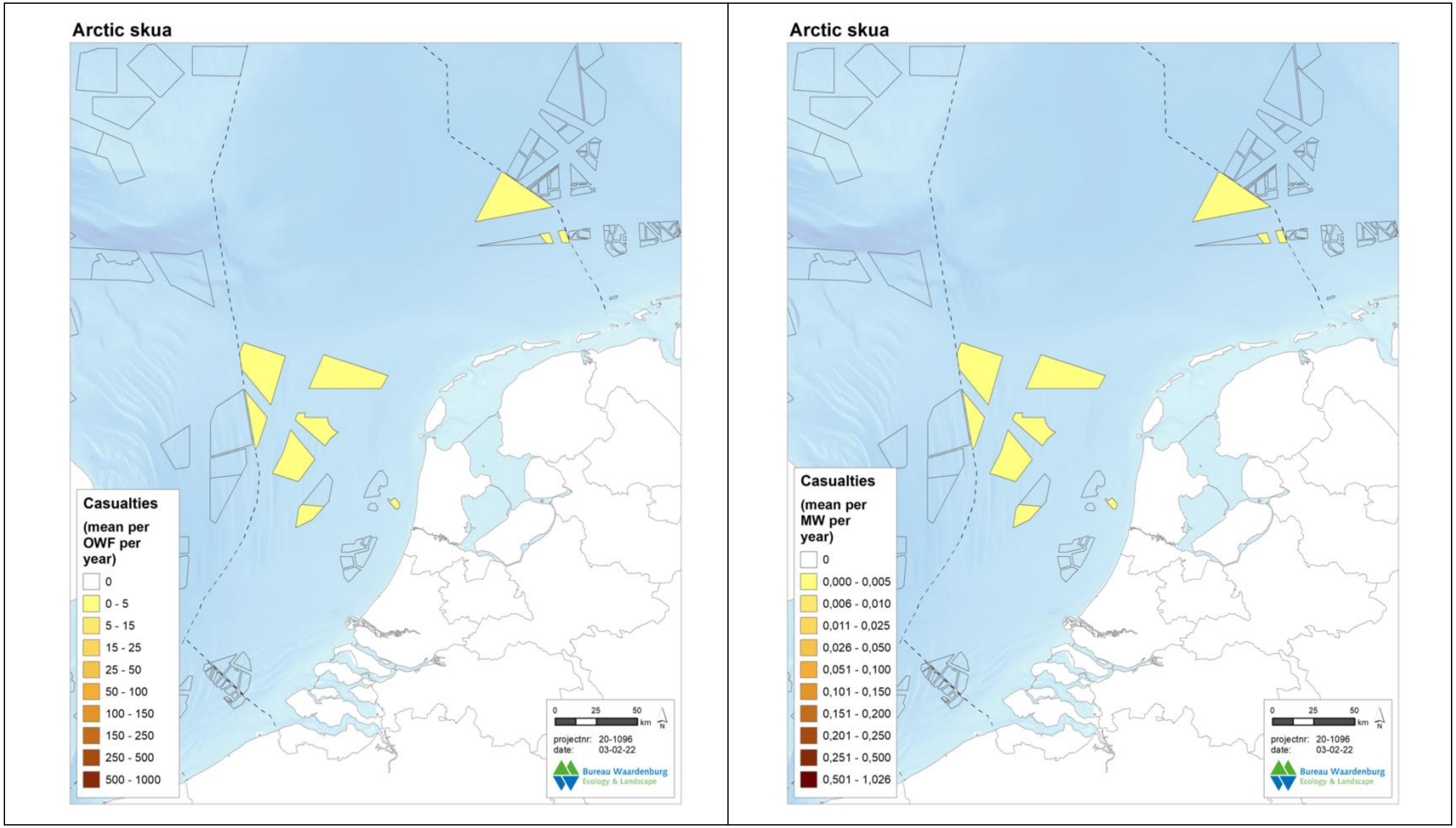

Figure 4.19 Mean estimated number of collision victims for Arctic skua based on national bird densities per windfarm (left) and per MW (right).

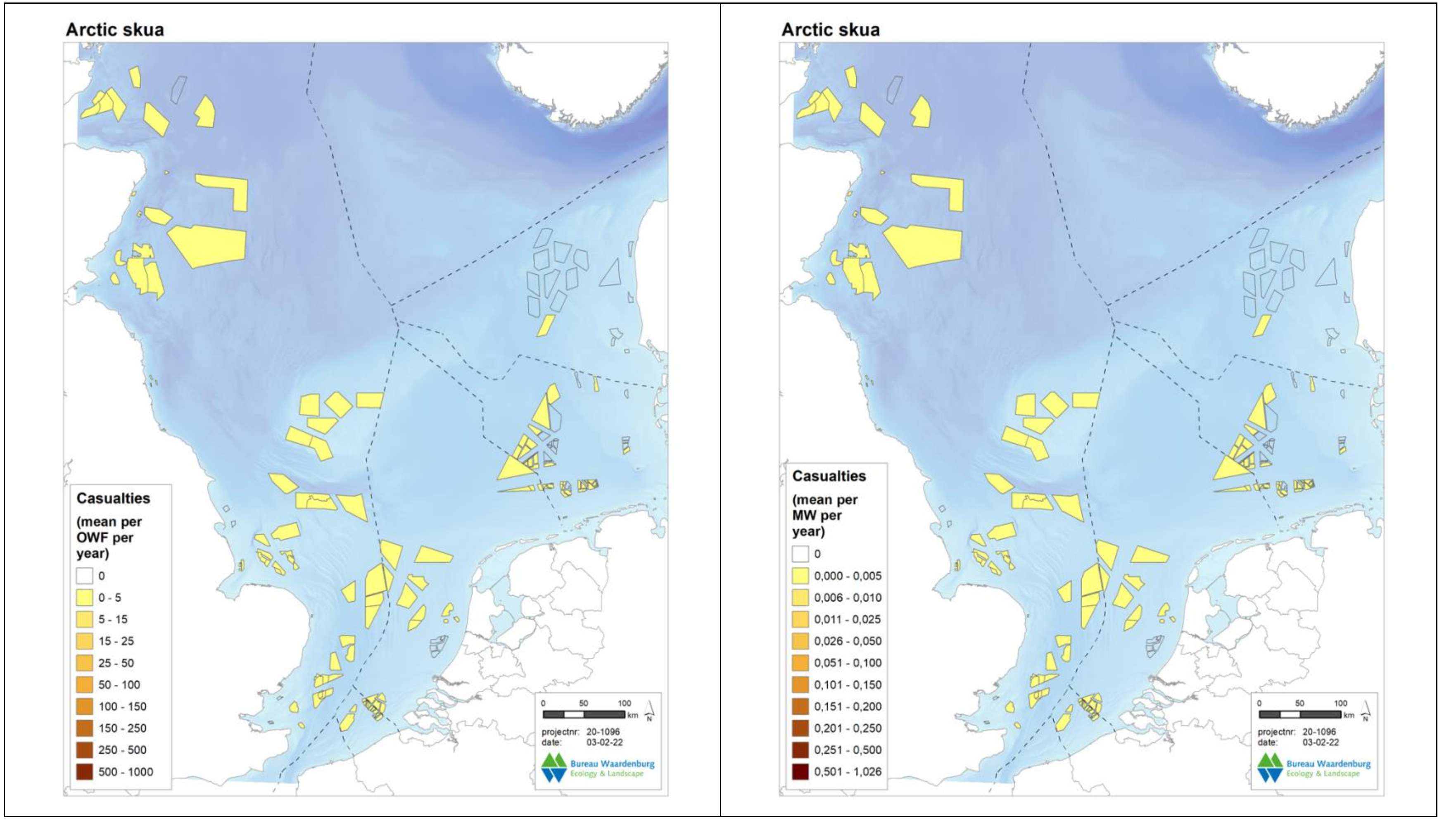

Figure 4.20 Mean estimated number of collision victims for Arctic skua based on international bird densities per windfarm (left) and per MW (right).

Table 4.18 *Summary Arctic skua population level effects; Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Mortality is the mortality probability due to collisions. The median, 5%and 95% percentiles of the population growth rates (lambda) are also reported. P causality represents the probability that a violation of the X threshold results from an OWF induced impact. The last column shows whether P causality violates the ALI threshold.*

Scenario	Mortality	Lambda median	5%	95%	P causality X = 15%	ALI 0.1
Null	0	0.961	0.873	1.018	NA	NA
Basic_2030	0.001	0.96	0.873	1.017	0.012	FALSE
Rekenvariant_III	0.001	0.96	0.873	1.017	0.005	FALSE
Rekenvariant_II	0.001	0.96	0.873	1.017	0.007	FALSE
Rekenvariant_I	0.001	0.96	0.872	1.017	0.012	FALSE
International	0.001	0.961	0.872	1.017	0.004	FALSE

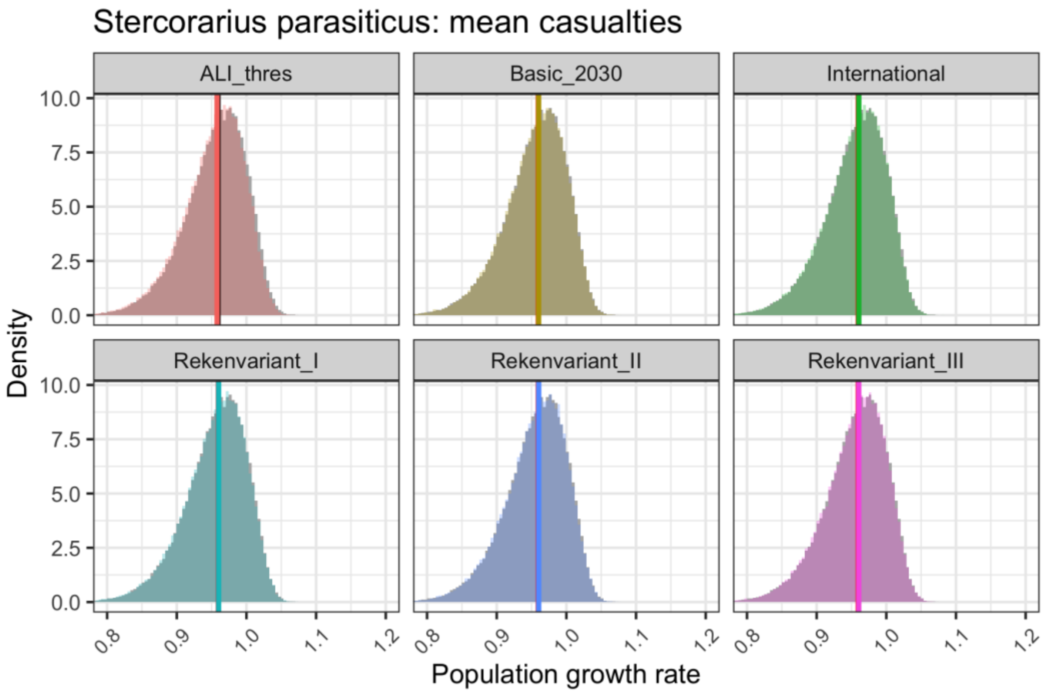

Figure 4.21 *Population growth rates per scenario for the Arctic skua* (Stercorarius parasiticus)*. Within each panel the distribution of the unimpacted population growth rate (grey bars) is compared with the distribution of the impacted population growth rate (coloured bars). Vertical lines indicate median population growth rates for unimpacted (black) and impacted (coloured) populations and the ALI threshold population growth rate (red).*

Great skua

The estimated number of collision victims per wind farm scenario, and the effect on the stage-specific survival rates are shown in Table 4.19. With low estimated numbers of collision victims, the effect on survival rates is small. As adults are more strongly impacted than other stages (Table 3.26), the effect on adult survival is more pronounced than on other survival rates.

Figure 4.22 shows the variation in annual number of collision victims per wind farm and per MW based for the national scenario. The highest number of collision victims is estimated for Zoekgebied 2 Noord, with a mean estimate of 1.62 victims per year.
Within the international scenario, based on international bird densities, the number of estimated collision victims are highest for Moray West (1.7), followed by Beatrice (1.6) (Figure 4.23).

This estimated level of additional mortality does not result in violation of the ALI threshold for this species.

Population growth rates change from 0.956 in the null scenario to 0.95 in the impacted scenarios. In Table 4.20, P causality gives the probability that the violation of the threshold population size (X, for this species 30% decline over 30 years compared to the null scenario) is caused by the impact and not by uncertainty in the population models. For this species, the probability that a population abundance is 30% lower than the null scenario as result of the impact is between 2.5% and 8.5%, depending on the scenario.

Table 4.19 *Mortality estimates of great skua per scenario, and the resulting change in stage-specific survival per scenario. Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Additional mortality is the mortality probability due to collisions.*

scenario	Mean annual casualties	Mean bimonthly casualties	Max abundance	Additional mortality	survival S0	survival SJ	survival SA
null				0	0.97	0.78	0.882
Basic_2030	2	1	1365	0.001	0.97	0.78	0.879
Rekenvariant_III	6	1	1365	0.004	0.97	0.78	0.875
Rekenvariant_II	5	1	1365	0.004	0.97	0.78	0.875
Rekenvariant_I	5	1	1365	0.003	0.97	0.78	0.876
International	29	5	12103	0.002	0.97	0.78	0.878

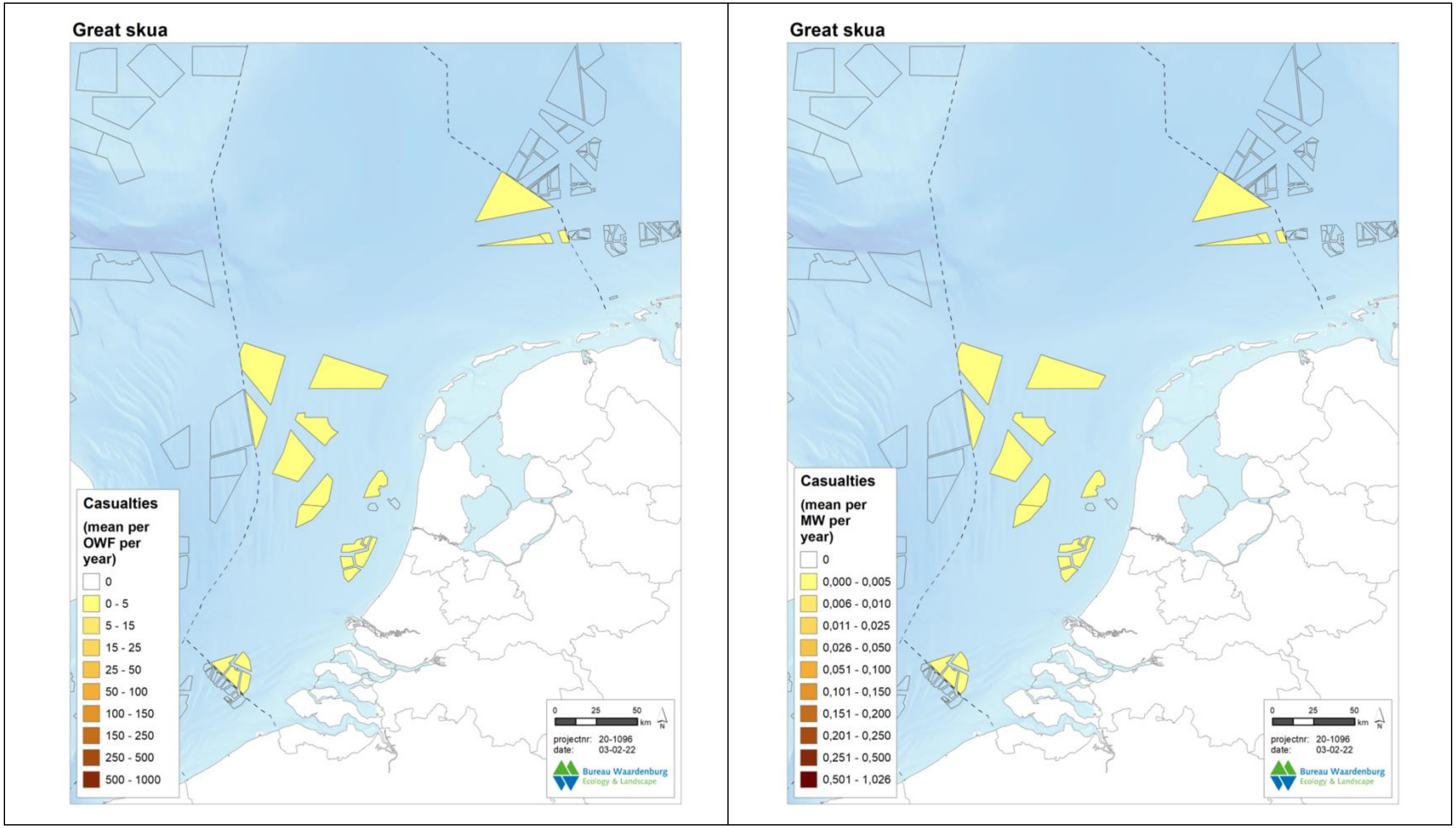

Figure 4.22 Mean estimated number of collision victims for great skua based on national bird densities per windfarm (left) and per MW (right).

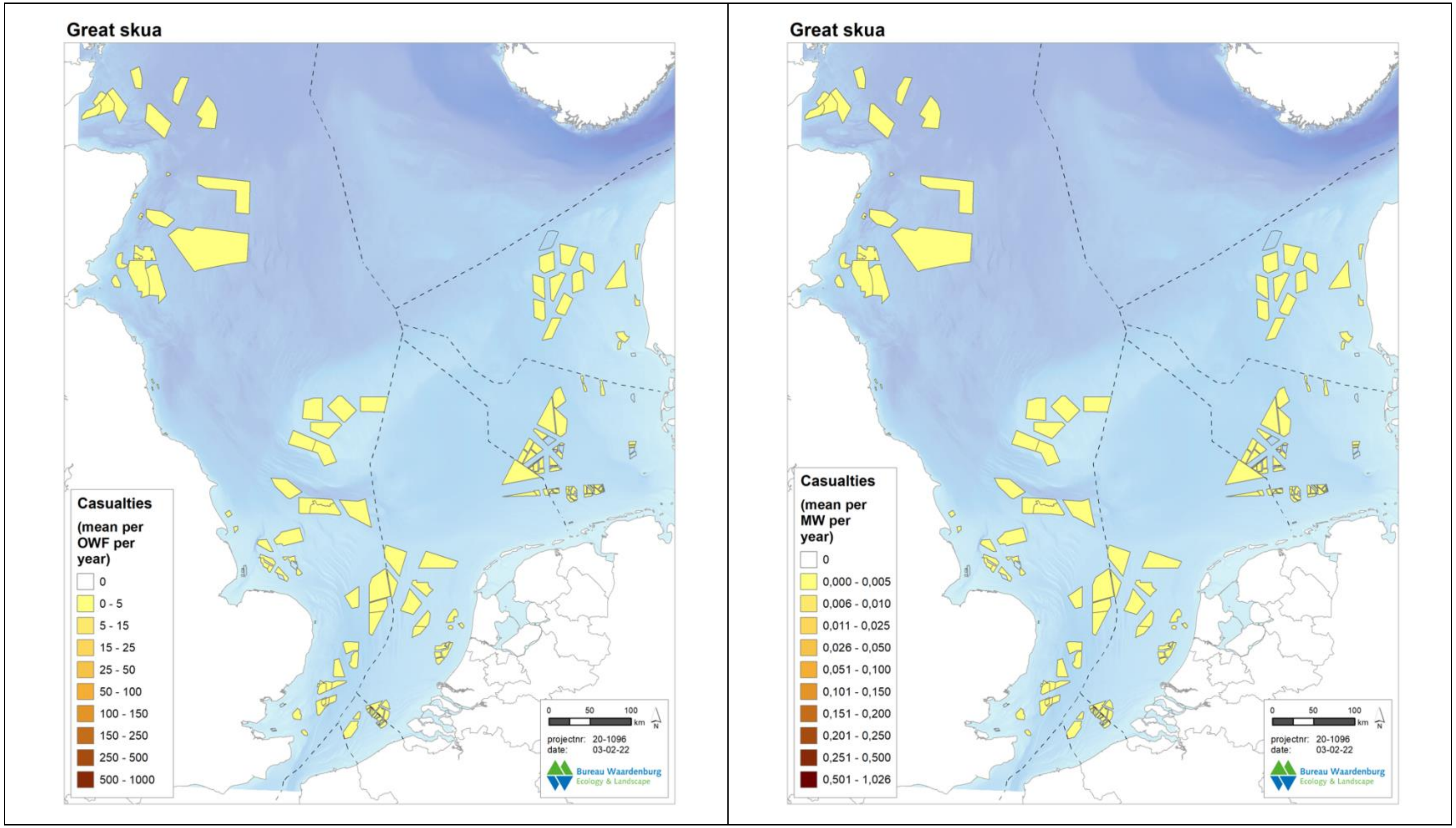

Figure 4.23 Mean estimated number of collision victims for great skua based on international bird densities per windfarm (left) and per MW (right).

Table 4.20 *Summary great skua population level effects; Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Mortality is the mortality probability due to collisions. The median, 5%and 95% percentiles of the population growth rates (lambda) are also reported. P causality represents the probability that a violation of the X threshold results from an OWF induced impact. The last column shows whether P causality violates the ALI threshold.*

Scenario	Mortality	Lambda median	5%	95%	P causality X = 30%	ALI 0.5
Null	0	0.956	0.856	1.029	NA	NA
Basic_2030	0.001	0.954	0.855	1.027	0.025	FALSE
Rekenvariant_III	0.004	0.95	0.852	1.024	0.085	FALSE
Rekenvariant_II	0.004	0.951	0.852	1.025	0.073	FALSE
Rekenvariant_I	0.003	0.951	0.852	1.025	0.07	FALSE
International	0.002	0.953	0.853	1.026	0.052	FALSE

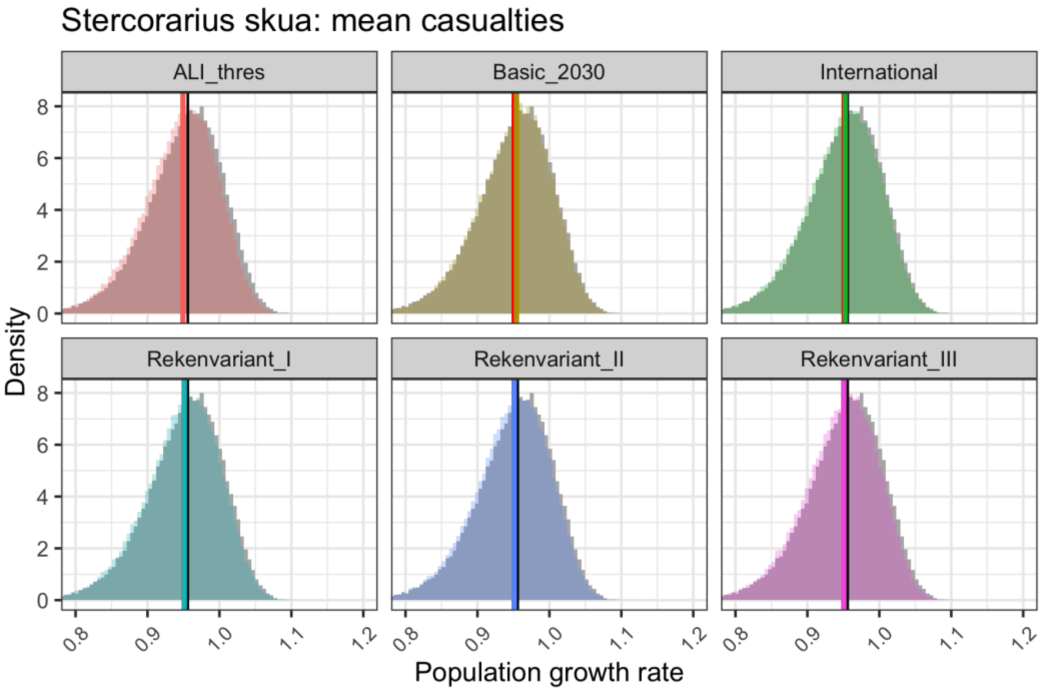

Figure 4.24 *Population growth rates per scenario for the great skua* (Stercorarius skua). *Within each panel the distribution of the unimpacted population growth rate (grey bars) is compared with the distribution of the impacted population growth rate (coloured bars). Vertical lines indicate median population growth rates for unimpacted (black) and impacted (coloured) populations and the ALI threshold population growth rate (red).*

Common tern

The estimated number of collision victims per wind farm scenario, and the effect on the stage-specific survival rates are shown in Table 4.21. With low estimated numbers of collision victims, the effect on survival rates is small. As adults are more strongly impacted than other stages (Table 3.27), the effect on adult survival is more pronounced than on other survival rates.

Figure 4.25 shows the variation in annual number of collision victims per wind farm and per MW based for the national scenario. The highest number of collision victims is estimated for Gemini Zee Energie and Gemini Buitengaats, with mean estimates of 15 resp. 12 victims per year.
Within the international scenario, based on international bird densities, the number of estimated collision victims are highest for Humber Gateway (15.8), followed by Triton Knoll (7.7) and Horns Rev 2 (7.6) (Figure 4.26).

This estimated level of additional mortality does not result in violation of the ALI threshold for this species.

Population growth rates change from 0.997 in the null scenario to 0.996 in the impacted scenarios. In Table 4.22, P causality gives the probability that the violation of the threshold population size (X, for this species 30% decline over 30 years compared to the null scenario) is caused by the impact and not by uncertainty in the population models. For this species, the probability that a population abundance is 30% lower than the null scenario as result of the impact is between 1.5% and 2.7%, depending on the scenario.

Table 4.21 Mortality estimates of common tern per scenario, and the resulting change in stage-specific survival per scenario. Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Additional mortality is the mortality probability due to collisions.

scenario	Mean annual casualties	Mean bimonthly casualties	Max abundance	Additional mortality	survival S0	survival SJ	survival SA
null				0	0.685	0.72	0.915
Basic_2030	43	8	59093	0.001	0.685	0.72	0.914
Rekenvariant_III	58	10	59093	0.001	0.685	0.72	0.914
Rekenvariant_II	56	10	59093	0.001	0.685	0.72	0.914
Rekenvariant_I	55	10	59093	0.001	0.685	0.72	0.914
International	99	17	74948	0.001	0.685	0.72	0.913

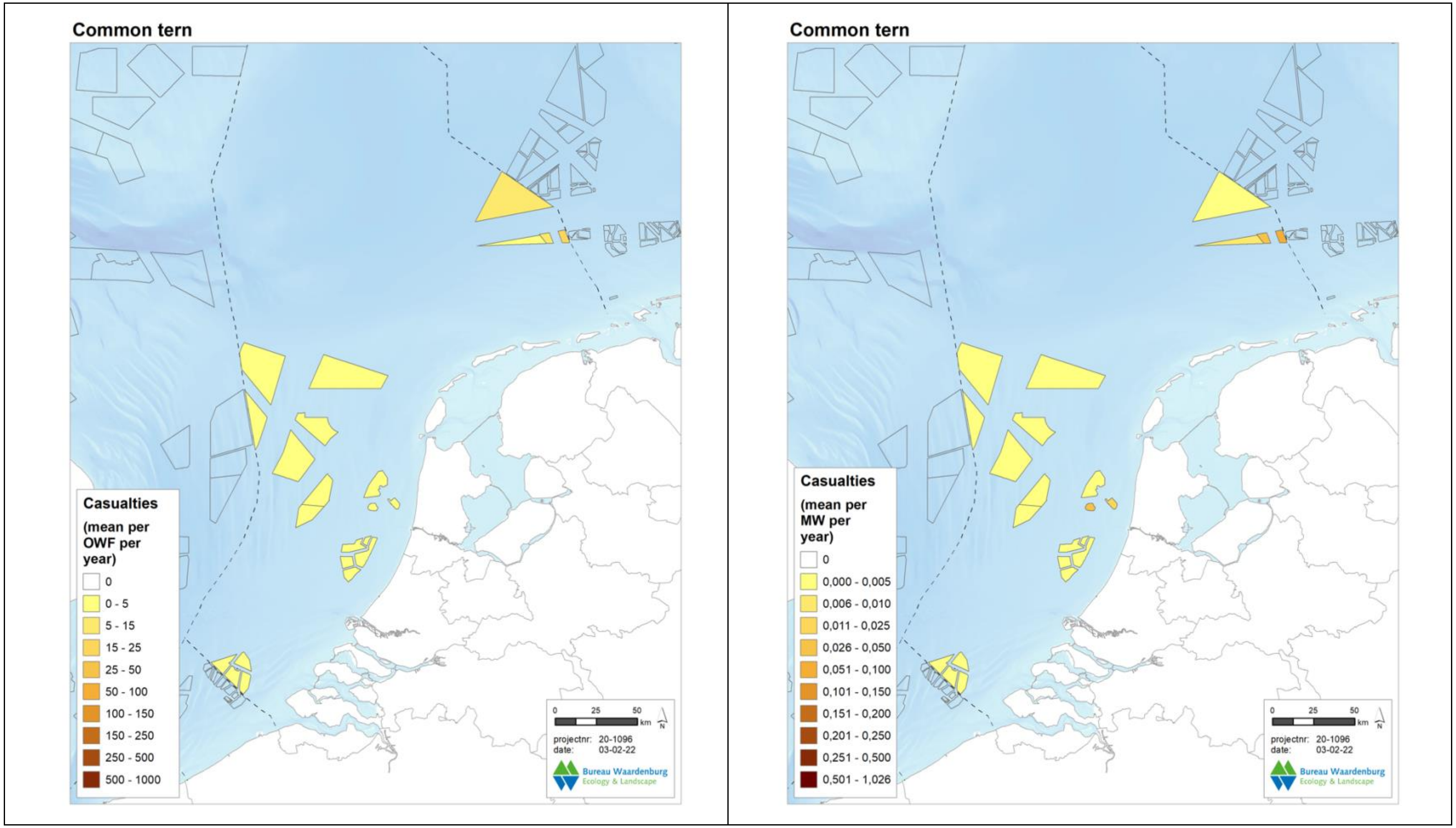

Figure 4.25 Mean estimated number of collision victims for common tern based on national bird densities per windfarm (left) and per MW (right).

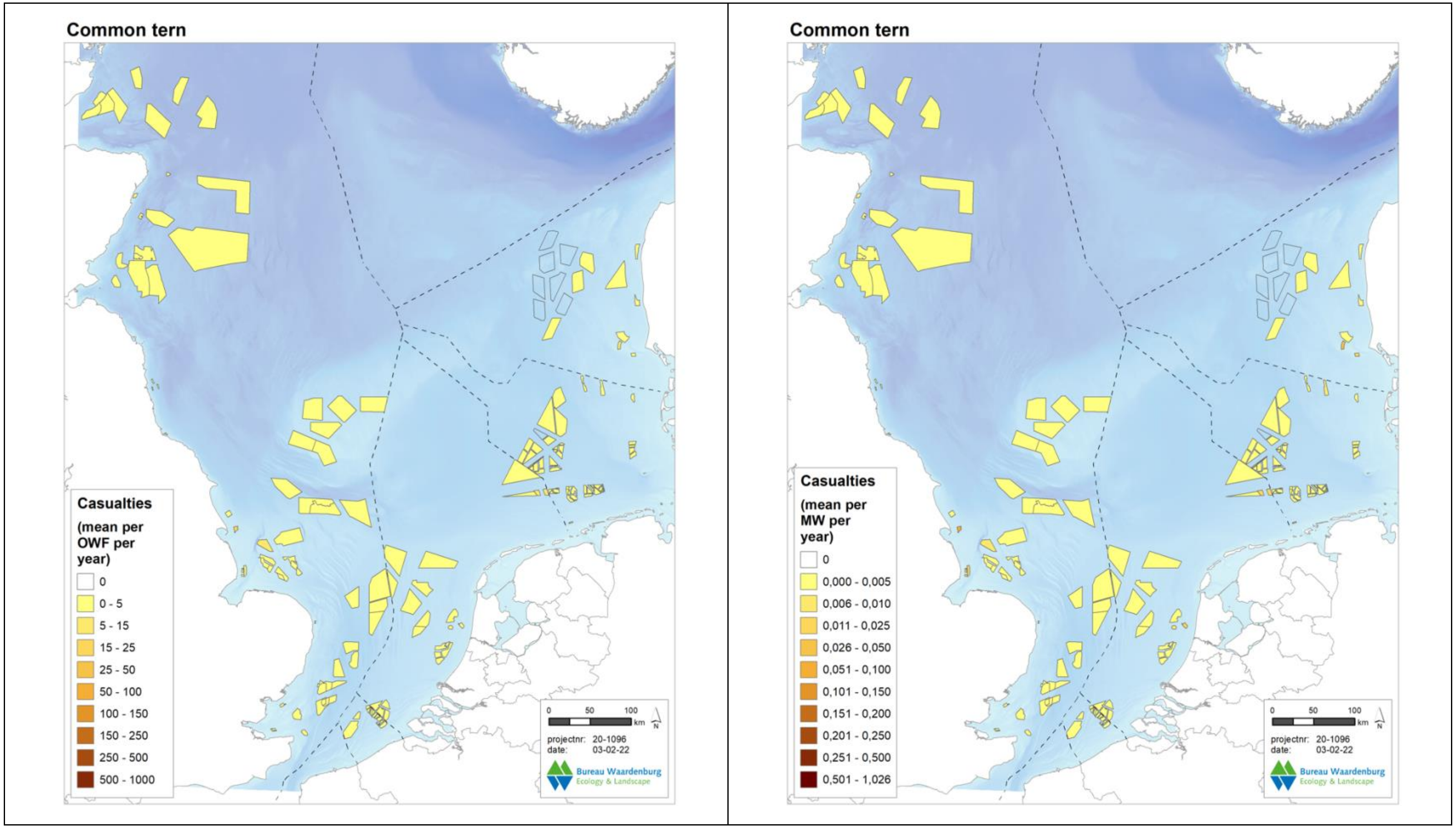

Figure 4.26 Mean estimated number of collision victims for common tern based on international bird densities per windfarm (left) and per MW (right).

Table 4.22 *Summary common tern population level effects; Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Mortality is the mortality probability due to collisions. The median, 5%and 95% percentiles of the population growth rates (lambda) are also reported. P causality represents the probability that a violation of the X threshold results from an OWF induced impact. The last column shows whether P causality violates the ALI threshold.*

Scenario	Mortality	Lambda median	5%	95%	P causality X = 30%	ALI 0.5
Null	0	0.997	0.905	1.058	NA	NA
Basic_2030	0.001	0.996	0.904	1.057	0.015	FALSE
Rekenvariant_III	0.001	0.996	0.904	1.057	0.025	FALSE
Rekenvariant_II	0.001	0.996	0.904	1.057	0.016	FALSE
Rekenvariant_I	0.001	0.996	0.903	1.057	0.018	FALSE
International	0.001	0.996	0.904	1.056	0.027	FALSE

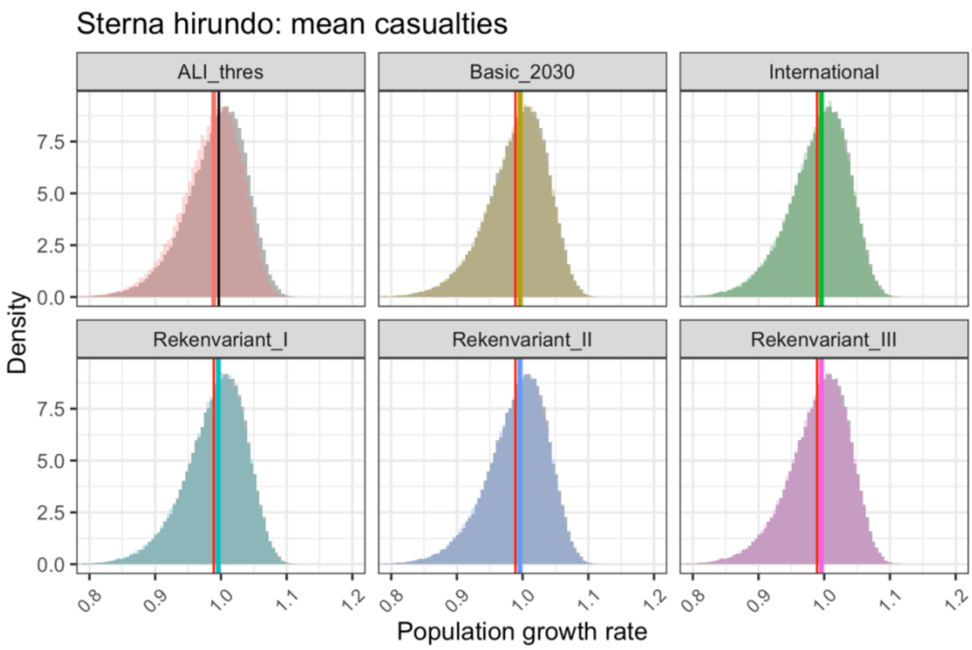

Figure 4.27 *Population growth rates per scenario for the common tern* (Sterna hirundo). *Within each panel the distribution of the unimpacted population growth rate (grey bars) is compared with the distribution of the impacted population growth rate (coloured bars). Vertical lines indicate median population growth rates for unimpacted (black) and impacted (coloured) populations and the ALI threshold population growth rate (red).*

Sandwich tern

The estimated number of collision victims per wind farm scenario, and the effect on the stage-specific survival rates are shown in Table 4.23. As only adults are impacted (Table 3.28), the effect of the impact is only observed in the average adult survival.

Figure 4.28Figure 4.25 shows the variation in annual number of collision victims per wind farm and per MW based for the national scenario. The highest number of collision victims is estimated for Hollandse Kust Noord, with a mean estimate of 5 victims per year.
Within the international scenario, based on international bird densities, the number of estimated collision victims are highest for Northwind (3.9) and Scroby Sands (3.6) (Figure 4.29).

This estimated level of additional mortality does not result in violation of the ALI threshold for this species.

Population growth rates change from 1.044 in the null scenario to 1.040 in the impacted scenarios. In Table 4.24, P causality gives the probability that the violation of the threshold population size (X, for this species 30% decline over 30 years compared to the null scenario) is caused by the impact and not by uncertainty in the population models. For this species, the probability that a population abundance is 30% lower than the null scenario as result of the impact from habitat loss as well as collision rate is between 1.7% and 5.7%, depending on the scenario.

Table 4.23 Mortality estimates of sandwich tern per scenario, and the resulting change in stage-specific survival per scenario. All victims from collision as well as habitat loss are assumed to be adults. Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Additional mortality is the mortality probability due to collisions.

scenario	Mortality source	Mean annual casualties	Mean bimonthly casualties	Max abundance	Additional mortality	survival SA
Null	Null					0.94200
Basic 2030	Collisions	32	6	22603	0.00142	0.94058
Basic 2030	HabLoss	21	4	22603	0.00091	0.94109
Basic 2030	Total	53	9	22603	0.00233	0.93967
Rekenvariant II	Collisions	40	7	22603	0.00176	0.94024
Rekenvariant II	HabLoss	27	5	22603	0.00119	0.94081
Rekenvariant II	Total	67	12	22603	0.00294	0.93906
Rekenvariant III	Collisions	41	7	22603	0.00183	0.94017
Rekenvariant III	HabLoss	28	5	22603	0.00122	0.94078
Rekenvariant III	Total	69	12	22603	0.00304	0.93896
Rekenvariant I	Collisions	40	7	22603	0.00176	0.94024
Rekenvariant I	HabLoss	27	5	22603	0.00119	0.94081
Rekenvariant I	Total	67	12	22603	0.00294	0.93906
International	Collisions	65	11	25882	0.00249	0.93951
International	HabLoss	46	8	25882	0.00178	0.94022

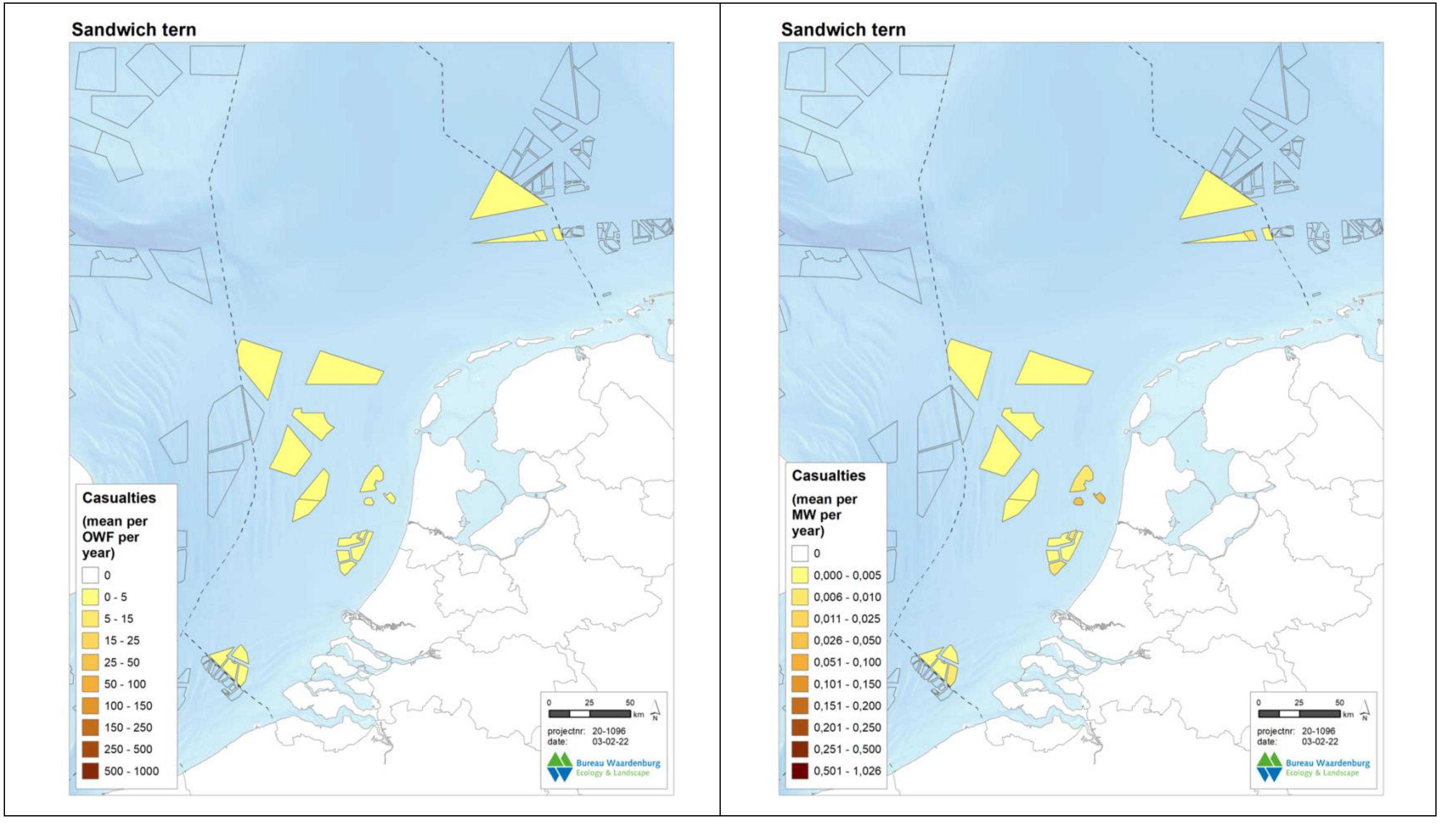

Figure 4.28 Mean estimated number of collision victims for sandwich tern based on national bird densities per windfarm (left) and per MW (right).

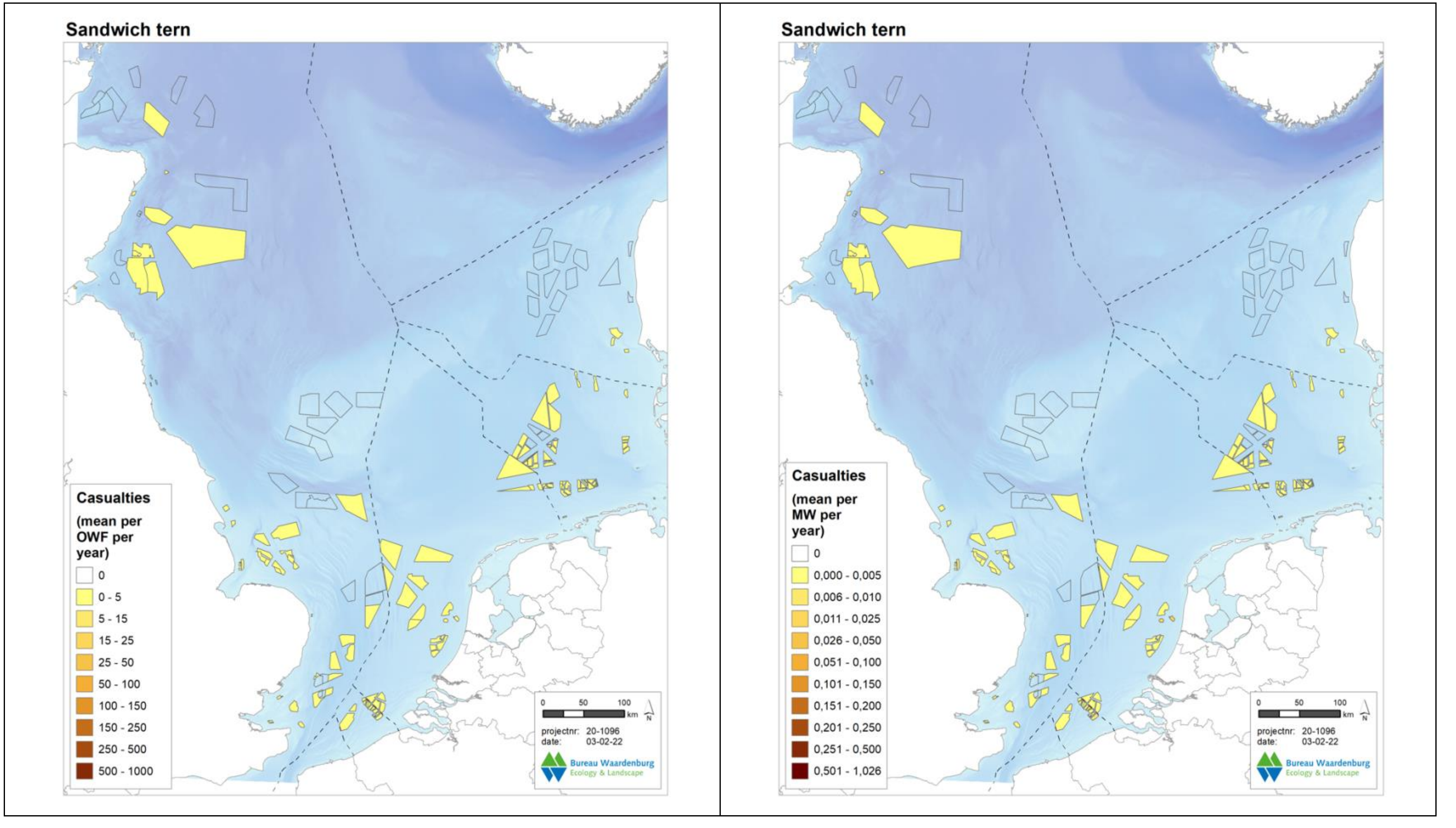

Figure 4.29 Mean estimated number of collision victims for sandwich tern based on international bird densities per windfarm (left) and per MW (right).

Table 4.24 *Summary Sandwich tern population level effects; Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Mortality is the mortality probability due to collisions. The median, 5%and 95% percentiles of the population growth rates (lambda) are also reported. P causality represents the probability that a violation of the X threshold results from an OWF induced impact. The last column shows whether P causality violates the ALI threshold.*

Scenario	Mortality	Lambda median	5%	95%	P causality X = 30%	ALI 0.5
Null		1.044	0.805	1.118		
Basic 2030	0.00142	1.043	0.805	1.117	0.021	FALSE
Basic 2030	0.00091	1.043	0.798	1.118	0.017	FALSE
Basic 2030	0.00233	1.041	0.801	1.117	0.038	FALSE
Rekenvariant II	0.00176	1.042	0.803	1.117	0.027	FALSE
Rekenvariant II	0.00119	1.043	0.802	1.117	0.020	FALSE
Rekenvariant II	0.00294	1.041	0.804	1.117	0.041	FALSE
Rekenvariant III	0.00183	1.042	0.803	1.117	0.028	FALSE
Rekenvariant III	0.00122	1.042	0.801	1.117	0.022	FALSE
Rekenvariant III	0.00304	1.042	0.803	1.117	0.037	FALSE
Rekenvariant I	0.00176	1.042	0.803	1.117	0.022	FALSE
Rekenvariant I	0.00119	1.043	0.803	1.118	0.019	FALSE
Rekenvariant I	0.00294	1.042	0.804	1.117	0.037	FALSE
International	0.00249	1.042	0.805	1.117	0.035	FALSE
International	0.00178	1.042	0.802	1.118	0.025	FALSE
International	0.00427	1.040	0.800	1.116	0.057	FALSE

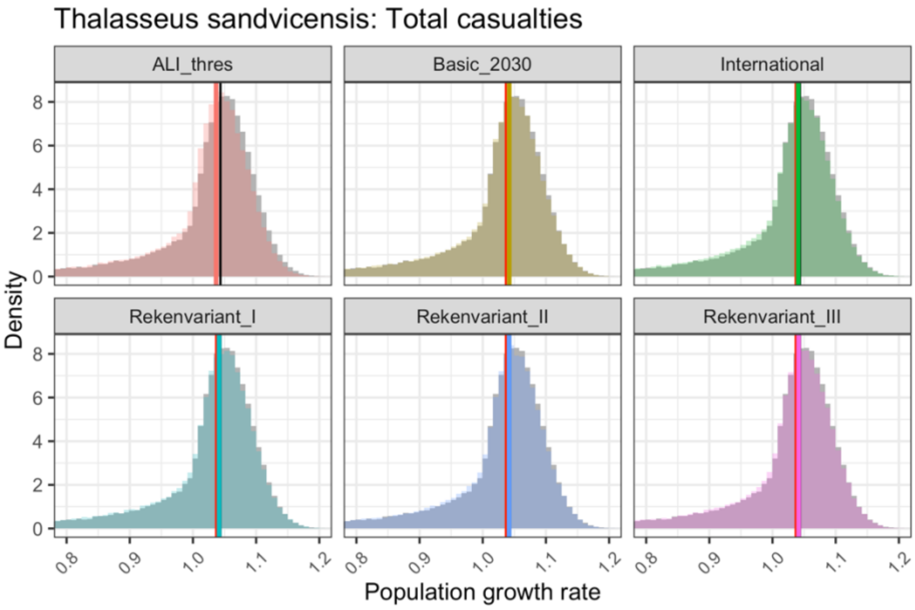

Figure 4.30 *Population growth rates per scenario for the Sandwich tern* (Thalasseus sandvicensis)*. Within each panel the distribution of the unimpacted population growth rate (grey bars) is compared with the distribution of the impacted population growth rate (coloured bars). Vertical lines indicate median population growth rates for unimpacted (black) and impacted (coloured) populations and the ALI threshold population growth rate (red).*

Bewick's swan

The estimated number of collision victims per wind farm scenario, and the effect on the stage-specific survival rates are shown in Table 4.25.

Figure 4.31 shows the variation in annual number of collision victims per wind farm and per MW. The highest number of collision victims is estimated for IJmuiden Ver, with a mean estimate of 1.2 victims per year.

This estimated level of additional mortality does not result in violation of the ALI threshold for this species.

Population growth rates do not clearly change between the null scenario and the impacted scenarios. In Table 4.26, P causality gives the probability that the violation of the threshold population size (X, for this species 15% decline over 30 years compared to the null scenario) is caused by the impact and not by uncertainty in the population models. For this species, the probability that a population abundance is 15% lower than the null scenario as result of the impact is between 0% and 0.08%, depending on the scenario.

Table 4.25 Mortality estimates of Bewick's swan *per scenario, and the resulting change in stage-specific survival per scenario. Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Additional mortality is the mortality probability due to collisions.*

scenario	Mean annual casualties	Max abundance	Additional mortality	survival S0	survival SJ	survival SA
null			0	0.908	0.936	0.873
Basic_2030	3	17450	0	0.908	0.936	0.873
Rekenvariant_III	5	17450	0	0.908	0.936	0.873
Rekenvariant_II	5	17450	0	0.908	0.936	0.873
Rekenvariant_I	4	17450	0	0.908	0.936	0.873
International	10	17450	0.001	0.908	0.935	0.873

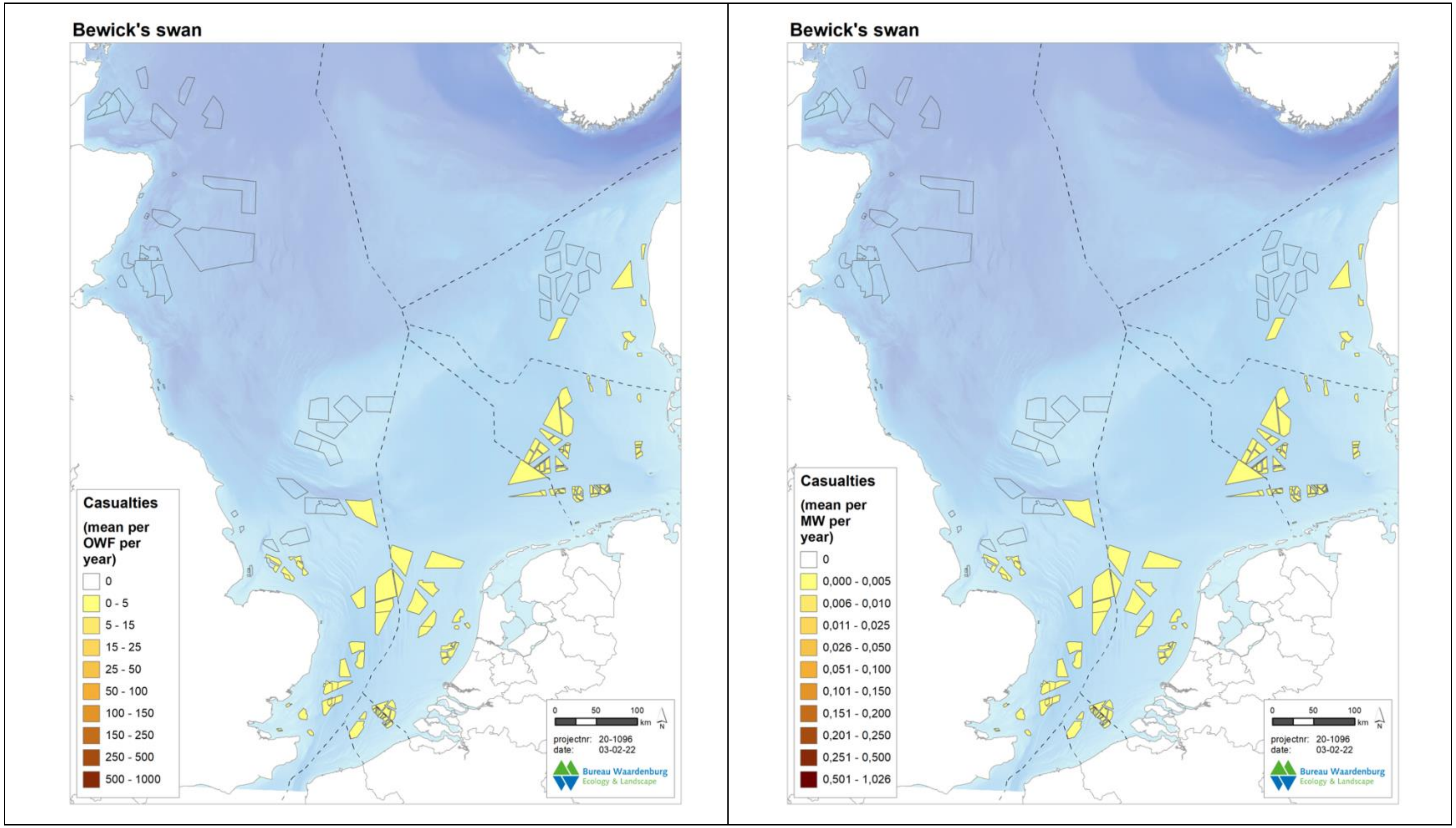

Figure 4.31 Mean estimated number of collision victims for Bewick's swan *per windfarm (left) and per MW (right).*

Table 4.26 Summary Bewick's swan population level effects; Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Mortality is the mortality probability due to collisions. The median, 5%and 95% percentiles of the population growth rates (lambda) are also reported. P causality represents the probability that a violation of the X threshold results from an OWF induced impact. The last column shows whether P causality violates the ALI threshold.

Scenario	Mortality	Lambda median	5%	95%	P causality X = 15%	ALI 0.1
null	0	0.993	0.889	1.084	NA	NA
Basic_2030	0	0.994	0.89	1.084	0	FALSE
Rekenvariant_III	0	0.994	0.89	1.084	0	FALSE
Rekenvariant_II	0	0.993	0.889	1.084	0.006	FALSE
Rekenvariant_I	0	0.993	0.889	1.084	0.007	FALSE
International	0.001	0.993	0.888	1.084	0.008	FALSE

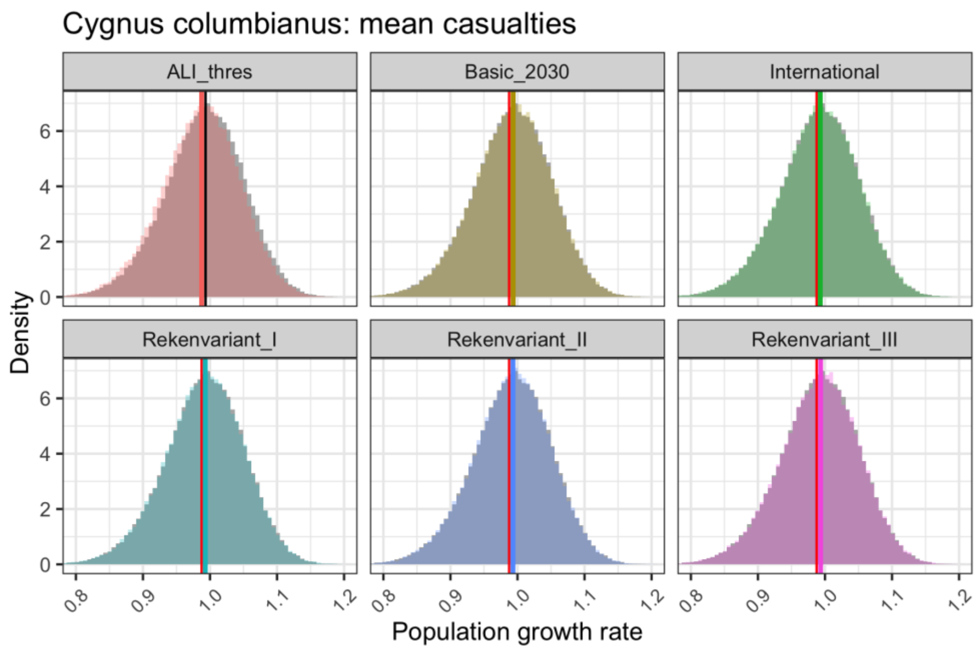

Figure 4.32 Population growth rates per scenario for the Bewick's swan (Cygnus (columbianus) bewickii). *Within each panel the distribution of the unimpacted population growth rate (grey bars) is compared with the distribution of the impacted population growth rate (coloured bars). Vertical lines indicate median population growth rates for unimpacted (black) and impacted (coloured) populations and the ALI threshold population growth rate (red).*

Brent goose

The estimated number of collision victims per wind farm scenario, and the effect on the stage-specific survival rates are shown in Table 4.27.

Figure 4.33 shows the variation in annual number of collision victims per wind farm and per MW. The highest number of collision victims is estimated for Zoekgebied 2 Noord (10 victims per year) and IJmuiden Ver (8 victims per year).

This estimated level of additional mortality does not result in violation of the ALI threshold for this species.

Population growth rates do not clearly change between the null scenario and the impacted scenarios. In Table 4.28, P causality gives the probability that the violation of the threshold population size (X, for this species 30% decline over 30 years compared to the null scenario) is caused by the impact and not by uncertainty in the population models. For this species, the probability that a population abundance is 30% lower than the null scenario as result of the impact is between 0% and 0.06%, depending on the scenario.

Table 4.27 *Mortality estimates of brent goose per scenario, and the resulting change in stage-specific survival per scenario. Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Additional mortality is the mortality probability due to collisions.*

scenario	Mean annual casualties	Max abundance	Additional mortality	survival S0	survival SJ	survival SA
null			0	0.51	0.849	0.868
Basic_2030	26	247286	0	0.51	0.849	0.868
Rekenvariant_III	51	247286	0	0.51	0.849	0.868
Rekenvariant_II	49	247286	0	0.51	0.849	0.868
Rekenvariant_I	44	247286	0	0.51	0.849	0.868
International	104	247286	0	0.51	0.849	0.868

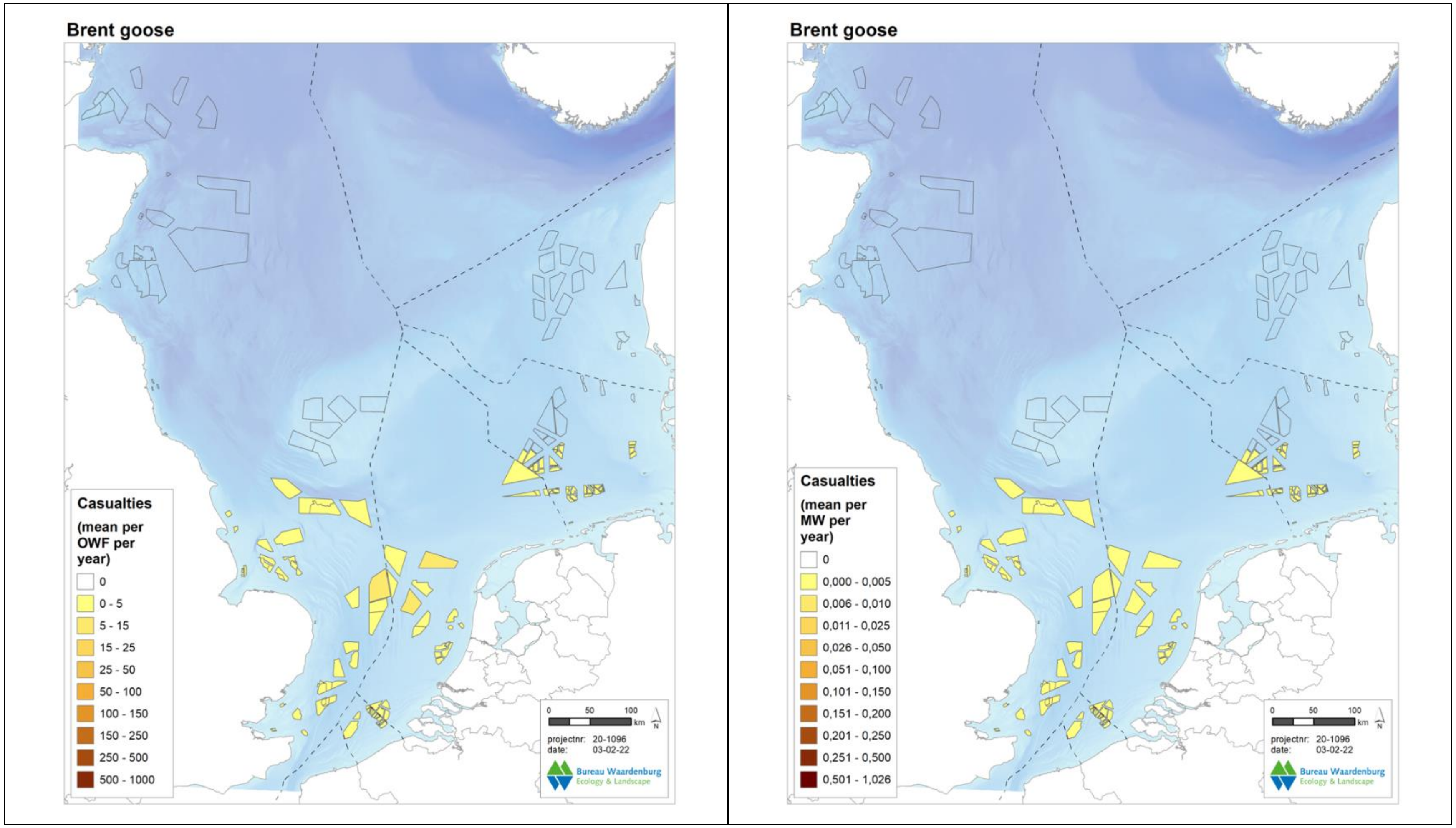

Figure 4.33 Mean estimated number of collision victims for brent goose per windfarm (left) and per MW (right).

Table 4.28 *Summary brent goose population level effects; Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Mortality is the mortality probability due to collisions. The median, 5%and 95% percentiles of the population growth rates (lambda) are also reported. P causality represents the probability that a violation of the X threshold results from an OWF induced impact. The last column shows whether P causality violates the ALI threshold.*

Scenario	Mortality	Lambda median	5%	95%	P causality X = 30%	ALI 0.5
null	0	0.996	0.935	1.052	NA	NA
Basic_2030	0	0.996	0.935	1.051	0.006	FALSE
Rekenvariant_III	0	0.996	0.935	1.052	0.004	FALSE
Rekenvariant_II	0	0.996	0.935	1.052	0.001	FALSE
Rekenvariant_I	0	0.997	0.935	1.052	0	FALSE
International	0	0.996	0.935	1.052	0	FALSE

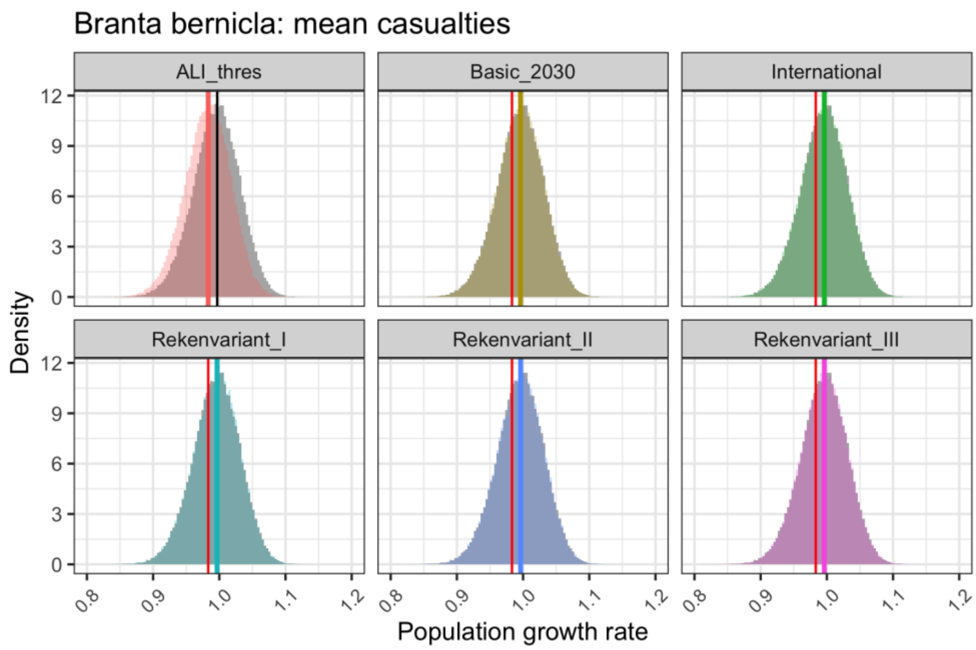

Figure 4.34 *Population growth rates per scenario for the brent goose (*Branta bernicla*). Within each panel the distribution of the unimpacted population growth rate (grey bars) is compared with the distribution of the impacted population growth rate (coloured bars). Vertical lines indicate median population growth rates for unimpacted (black) and impacted (coloured) populations and the ALI threshold population growth rate (red).*

Common shelduck

The estimated number of collision victims per wind farm scenario, and the effect on the stage-specific survival rates are shown in Table 4.29.

Figure 4.35 shows the variation in annual number of collision victims per wind farm and per MW. The highest number of collision victims is estimated for IJmuiden Ver and Zoekgebied 5 Oost origineel, with for both wind farms a mean estimate of 16 victims per year. As due to the lack of data we used a general flux for this species and not specified per wind farm, this higher number of casualties might be caused by the explicit hub height assumed for these wind farms in combination with the species-specific flight height distribution.

This estimated level of additional mortality does not result in violation of the ALI threshold for this species.

Population growth rates do not clearly change between the null scenario and the impacted scenarios. In Table 4.30, P causality gives the probability that the violation of the threshold population size (X, for this species 30% decline over 30 years compared to the null scenario) is caused by the impact and not by uncertainty in the population models. For this species, the probability that a population abundance is 30% lower than the null scenario as result of the impact is between 0.5% and 3.3%, depending on the scenario.

Table 4.29 Mortality estimates of common shelduck per scenario, and the resulting change in stage-specific survival per scenario. Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Additional mortality is the mortality probability due to collisions.

scenario	Mean annual casualties	Max abundance	Additional mortality	survival S0	survival SJ	survival SA
null			0	0.25	0.67	0.873
Basic_2030	64	302047	0	0.25	0.67	0.873
Rekenvariant_III	128	302047	0	0.25	0.67	0.873
Rekenvariant_II	114	302047	0	0.25	0.67	0.873
Rekenvariant_I	106	302047	0	0.25	0.67	0.873
International	473	302047	0.002	0.25	0.67	0.872

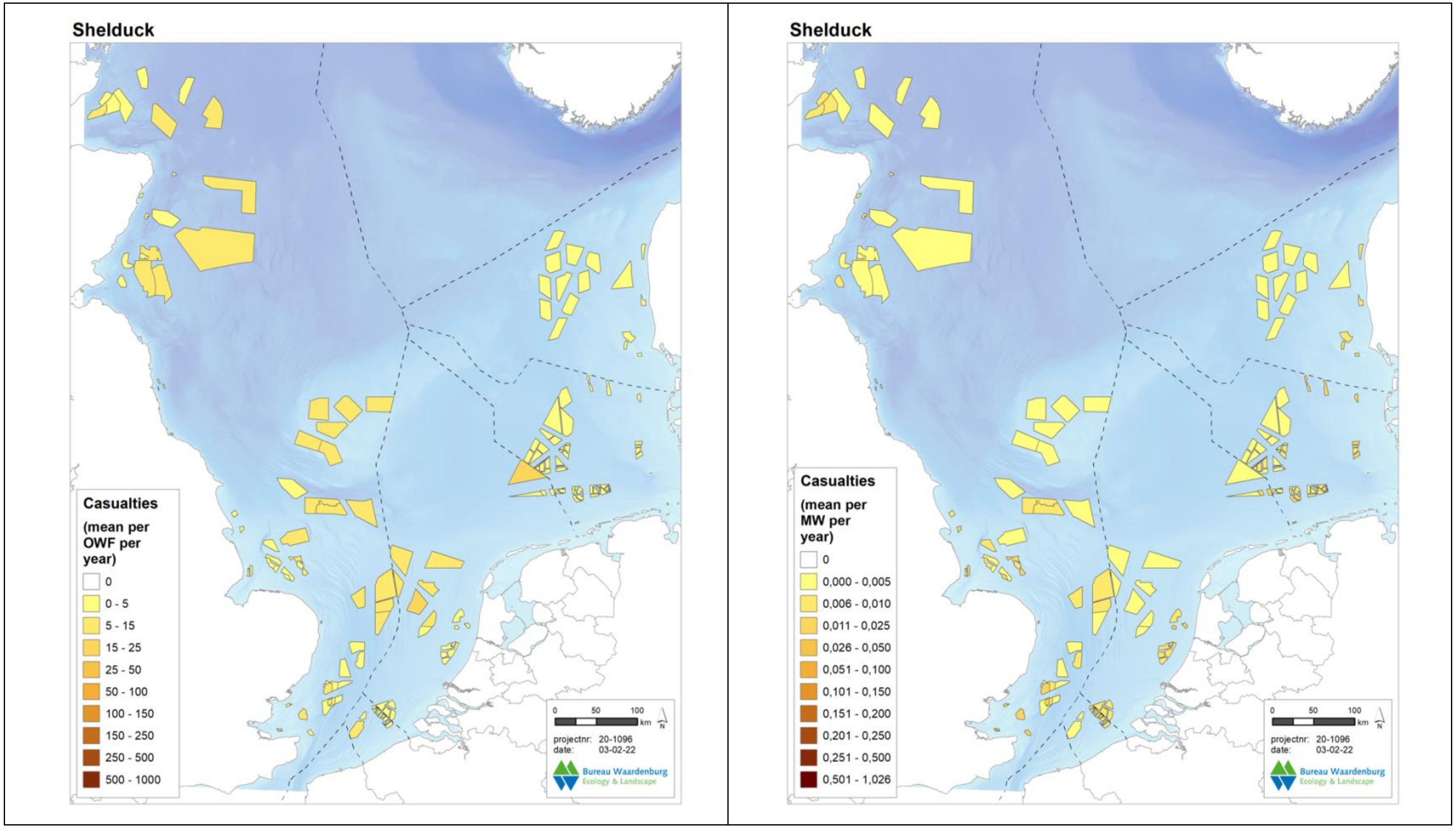

Figure 4.35 Mean estimated number of collision victims for common shelduck per windfarm (left) and per MW (right).

Table 4.30 *Summary common shelduck population level effects; Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Mortality is the mortality probability due to collisions. The median, 5%and 95% percentiles of the population growth rates (lambda) are also reported. P causality represents the probability that a violation of the X threshold results from an OWF induced impact. The last column shows whether P causality violates the ALI threshold.*

Scenario	Mortality	Lambda median	5%	95%	P causality X = 30%	ALI 0.5
null	0	1.064	0.966	1.15	NA	NA
Basic_2030	0	1.064	0.965	1.15	0.005	FALSE
Rekenvariant_III	0	1.063	0.965	1.149	0.013	FALSE
Rekenvariant_II	0	1.064	0.966	1.149	0.012	FALSE
Rekenvariant_I	0	1.064	0.965	1.149	0.011	FALSE
International	0.002	1.063	0.964	1.148	0.033	FALSE

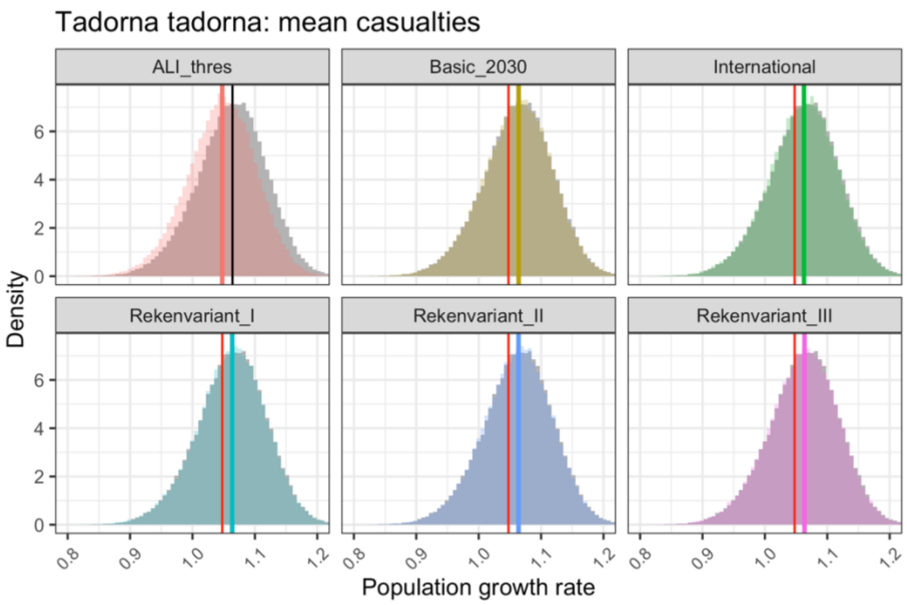

Figure 4.36 *Population growth rates per scenario for the common shelduck (*Tadorna tadorna*). Within each panel the distribution of the unimpacted population growth rate (grey bars) is compared with the distribution of the impacted population growth rate (coloured bars). Vertical lines indicate median population growth rates for unimpacted (black) and impacted (coloured) populations and the ALI threshold population growth rate (red).*

Eurasian curlew

The estimated number of collision victims per wind farm scenario, and the effect on the stage-specific survival rates are shown in Table 4.31.

Figure 4.37 shows the variation in annual number of collision victims per wind farm and per MW based for the national scenario. The highest number of collision victims is estimated for IJmuiden Ver and Zoekgebied 5 Oost Origineel, with for each wind farm a mean estimate of 23 victims per year.

This estimated level of additional mortality does not result in violation of the ALI threshold for this species.

Population growth rates change from 0.986 in the null scenario to 0.984 in the impacted scenarios. In Table 4.32, P causality gives the probability that the violation of the threshold population size (X, for this species 15% decline over 30 years compared to the null scenario) is caused by the impact and not by uncertainty in the population models. For this species, the probability that a population abundance is 15% lower than the null scenario as result of the impact is between 0.3% and 3.1%, depending on the scenario.

Table 4.31 Mortality estimates of Eurasian curlew per scenario, and the resulting change in stage-specific survival per scenario. Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Additional mortality is the mortality probability due to collisions.

scenario	Mean annual casualties	Max abundance	Additional mortality	survival S0	survival SJ	survival SA
null			0	0.559	0.771	0.912
Basic_2030	91	302273	0	0.559	0.771	0.912
Rekenvariant_III	182	302273	0.001	0.559	0.771	0.911
Rekenvariant_II	161	302273	0.001	0.559	0.771	0.912
Rekenvariant_I	151	302273	0	0.559	0.771	0.912
International	670	302273	0.002	0.558	0.769	0.91

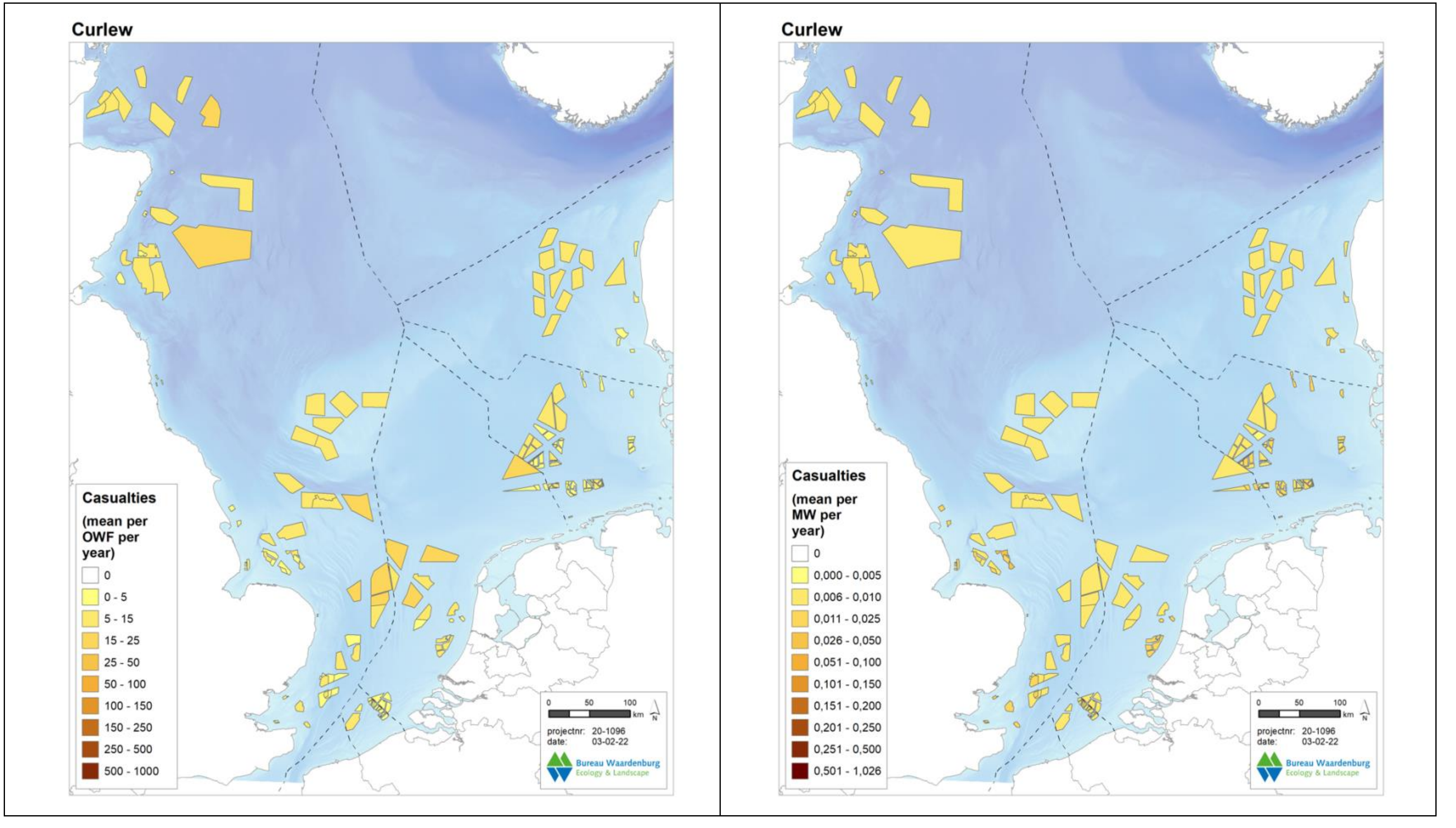

Figure 4.37 Mean estimated number of collision victims for Eurasian curlew per windfarm (left) and per MW (right).

Table 4.32 *Summary Eurasian curlew population level effects; Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Mortality is the mortality probability due to collisions. The median, 5%and 95% percentiles of the population growth rates (lambda) are also reported. P causality represents the probability that a violation of the X threshold results from an OWF induced impact. The last column shows whether P causality violates the ALI threshold.*

Scenario	Mortality	Lambda median	5%	95%	P causality X = 15%	ALI 0.1
null	0	0.986	0.885	1.05	NA	NA
Basic_2030	0	0.986	0.886	1.049	0.003	FALSE
Rekenvariant_III	0.001	0.986	0.885	1.049	0.004	FALSE
Rekenvariant_II	0.001	0.986	0.885	1.05	0.003	FALSE
Rekenvariant_I	0	0.985	0.885	1.05	0.005	FALSE
International	0.002	0.984	0.883	1.048	0.031	FALSE

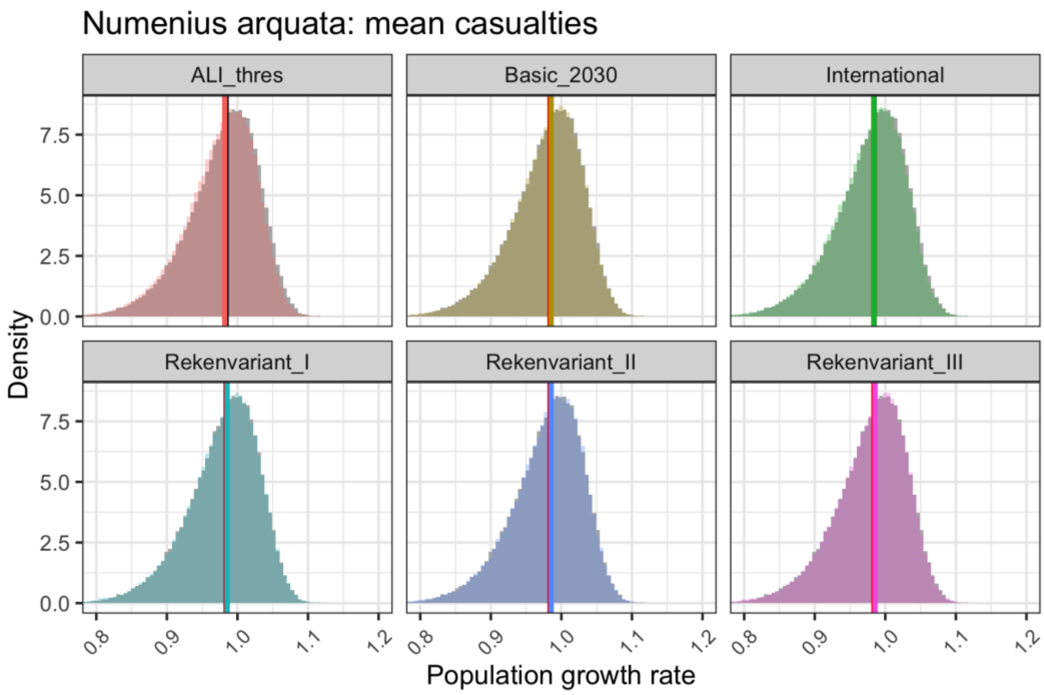

Figure 4.38 *Population growth rates per scenario for the Eurasian curlew (*Numenius arquata*). Within each panel the distribution of the unimpacted population growth rate (grey bars) is compared with the distribution of the impacted population growth rate (coloured bars). Vertical lines indicate median population growth rates for unimpacted (black) and impacted (coloured) populations and the ALI threshold population growth rate (red).*

Black tern

The estimated number of collision victims per wind farm scenario, and the effect on the stage-specific survival rates are shown in Table 4.33.

Figure 4.39 shows the variation in annual number of collision victims per wind farm and per MW based for the national scenario. The highest numbers of collision victims are estimated for IJmuiden Ver, Zoekgebied 5 Oost origineel, Zoekgebied 1 Noord, Zoekgebied 2 Noord, with for each wind farm a mean estimate of 2 victims per year.

This estimated level of additional mortality does not result in violation of the ALI threshold for this species.

Population growth rates do not clearly change between the null scenario and the impacted scenarios. In Table 4.34, P causality gives the probability that the violation of the threshold population size (X, for this species 30% decline over 30 years compared to the null scenario) is caused by the impact and not by uncertainty in the population models. For this species, none of the impacted simulations showed a population abundance of 30% lower than the null scenario, resulting in a P causality of 0 for each scenario.

Table 4.33 Mortality estimates of black tern per scenario, and the resulting change in stage-specific survival per scenario. Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Additional mortality is the mortality probability due to collisions.

scenario	Mean annual casualties	Max abundance	Additional mortality	survival S0	survival SJ	survival SA
null			0	0.595	0.595	0.846
Basic_2030	9	285482	0.00003	0.595	0.595	0.846
Rekenvariant_III	18	285482	0.00006	0.595	0.595	0.846
Rekenvariant_II	16	285482	0.00006	0.595	0.595	0.846
Rekenvariant_I	15	285482	0.00005	0.595	0.595	0.846
International	33	285482	0.00012	0.595	0.595	0.846

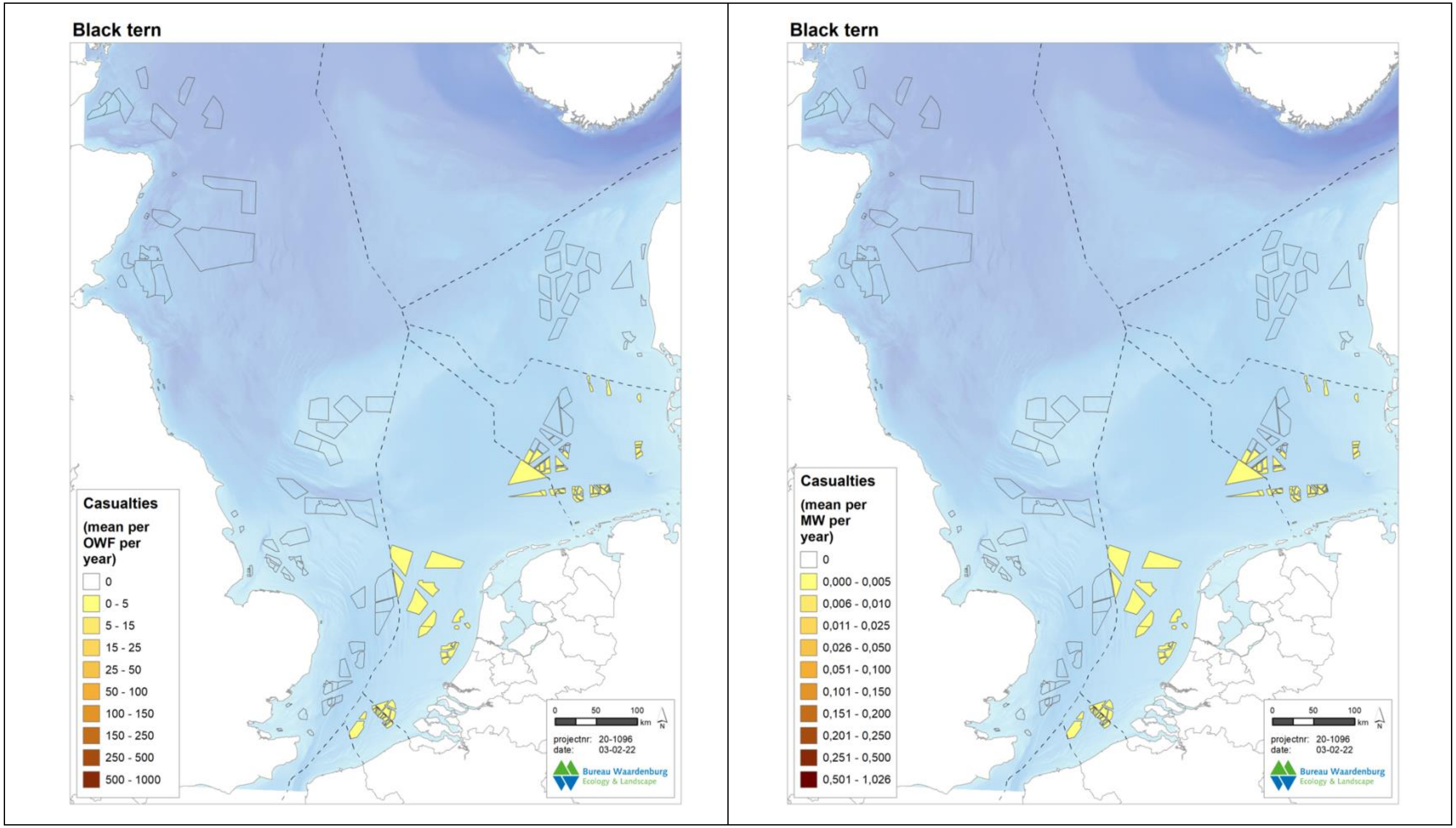

Figure 4.39 Mean estimated number of collision victims for black tern per windfarm (left) and per MW (right).

Table 4.34 *Summary black tern population level effects; Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Mortality is the mortality probability due to collisions. The median, 5% and 95% percentiles of the population growth rates (lambda) are also reported. P causality represents the probability that a violation of the X threshold results from an OWF induced impact. The last column shows whether P causality violates the ALI threshold.*

Scenario	Mortality	Lambda median	5%	95%	P causality X = 30%	ALI 0.5
null	0	0.951	0.869	1.017	NA	NA
Basic_2030	0	0.951	0.869	1.017	0	FALSE
Rekenvariant_III	0	0.951	0.869	1.016	0	FALSE
Rekenvariant_II	0	0.951	0.869	1.017	0	FALSE
Rekenvariant_I	0	0.951	0.869	1.016	0	FALSE
International	0	0.951	0.869	1.016	0	FALSE

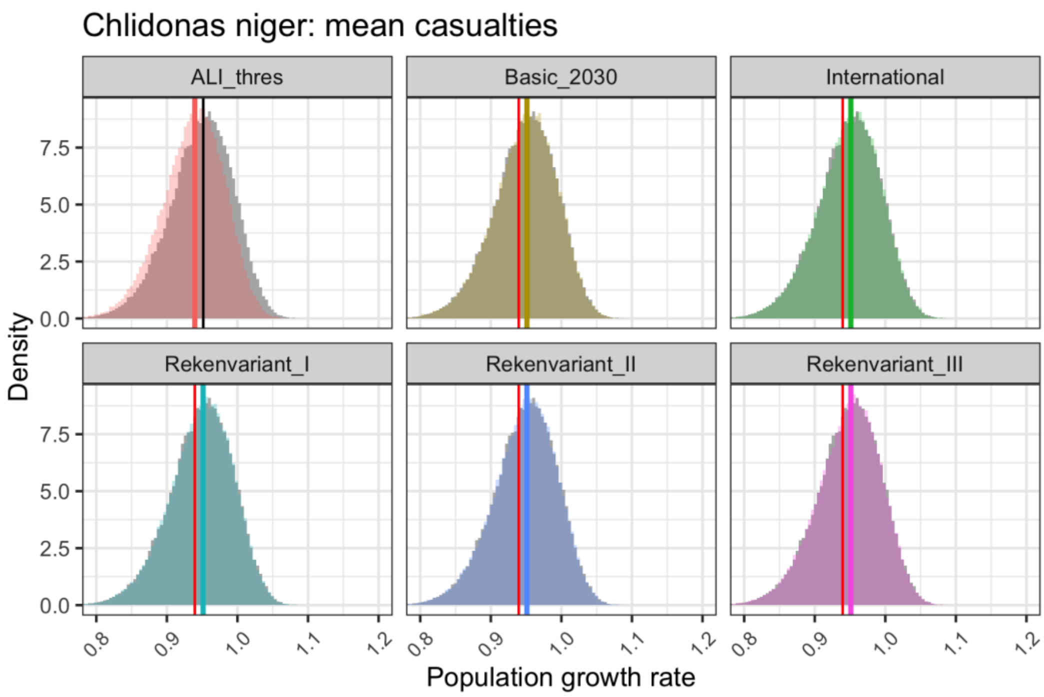

Figure 4.40 *Population growth rates per scenario for the black tern* (Chlidonias niger)*. Within each panel the distribution of the unimpacted population growth rate (grey bars) is compared with the distribution of the impacted population growth rate (coloured bars). Vertical lines indicate median population growth rates for unimpacted (black) and impacted (coloured) populations and the ALI threshold population growth rate (red).*

Common starling

The estimated number of collision victims per wind farm scenario, and the effect on the stage-specific survival rates are shown in Table 4.35.

Figure 4.41 shows the variation in annual number of collision victims per wind farm and per MW based for the national scenario. The highest numbers of collision victims are estimated for IJmuiden Ver (798 estimated victims per year), Zoekgebied 5 Oost origineel (797), Zoekgebied 1 Noord (717) and Zoekgebied 2 Noord (717). Note that numbers of victims are in general relatively high for this species, which is related to the large flux.

This estimated level of additional mortality does not result in violation of the ALI threshold for this species.

Population growth rates do not clearly change between the null scenario and the impacted scenarios. In Table 4.36, P causality gives the probability that the violation of the threshold population size (X, for this species 30% decline over 30 years compared to the null scenario) is caused by the impact and not by uncertainty in the population models. For this species, the probability that a population abundance is 30% lower than the null scenario as result of the impact is between 0% and 0.2%, depending on the scenario.

Note the strong variation in outcomes of the population model for this species. This is caused by the strong variation in breeding success (between years, individuals, and locations).

Table 4.35 *Mortality estimates of common starling per scenario, and the resulting change in stage-specific survival per scenario. Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Additional mortality is the mortality probability due to collisions.*

scenario	Mean bimonthly casualties	Max abundance	Additional mortality	survival S0	survival SJ	survival SA
null			0	0.102	0.607	0.836
Basic_2030	3,022	18501266	0.00016	0.102	0.607	0.836
Rekenvariant_III	6,154	18501266	0.00033	0.102	0.607	0.835
Rekenvariant_II	5,437	18501266	0.00029	0.102	0.607	0.836
Rekenvariant_I	5,078	18501266	0.00027	0.102	0.607	0.835
International	22,411	18501266	0.00121	0.102	0.606	0.835

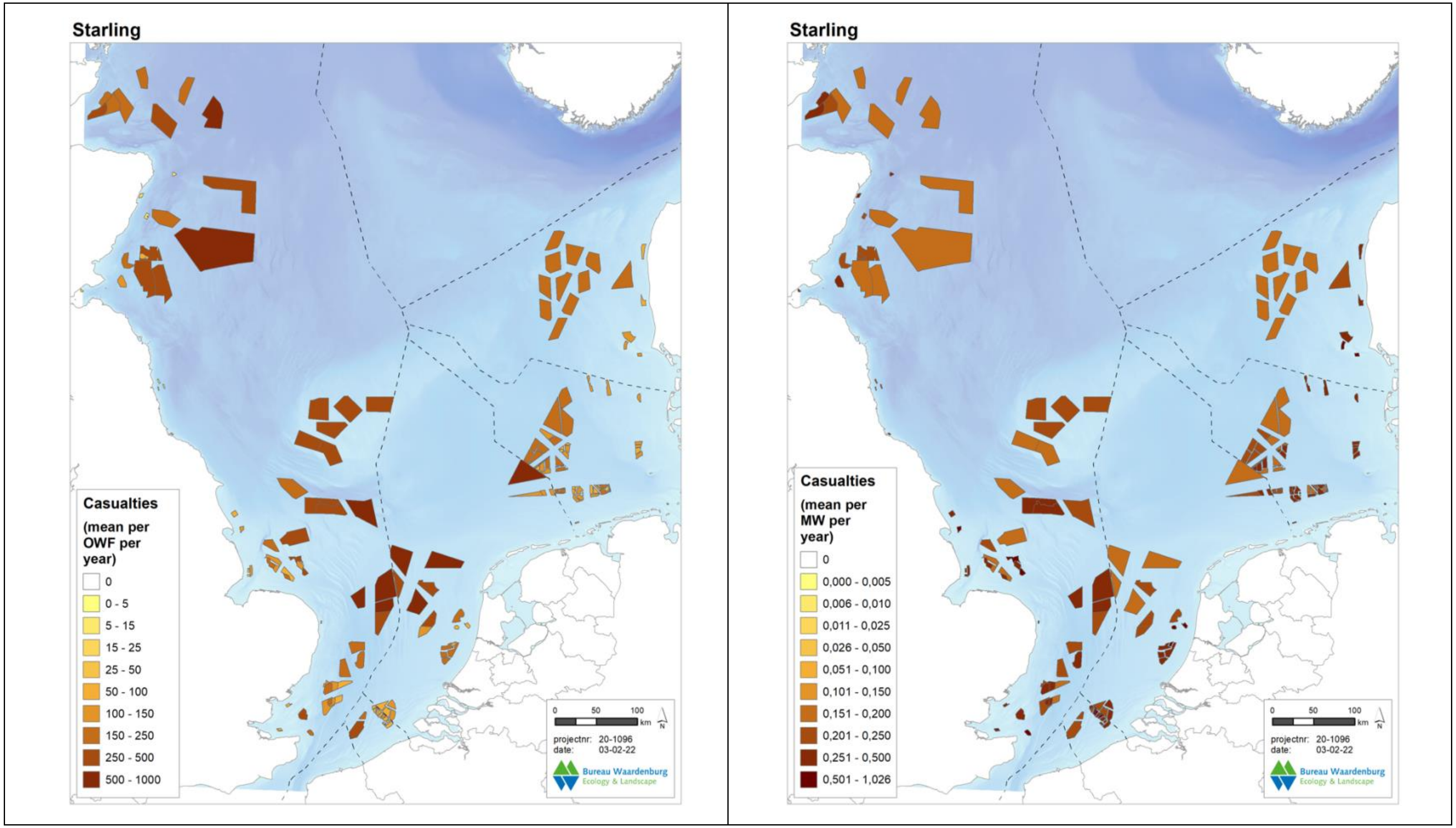

Figure 4.41 Mean estimated number of collision victims for common starling per windfarm (left) and per MW (right).

Table 4.36 *Summary common starling population level effects; Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Mortality is the mortality probability due to collisions. The median, 5% and 95% percentiles of the population growth rates (lambda) are also reported. P causality represents the probability that a violation of the X threshold results from an OWF induced impact. The last column shows whether P causality violates the ALI threshold.*

Scenario	Mortality	Lambda median	5%	95%	P causality X = 30%	ALI 0.5
Null	0	0.836	0.544	1.097	NA	NA
Basic_2030	0	0.836	0.545	1.099	0	FALSE
Rekenvariant_III	0	0.835	0.545	1.099	0.001	FALSE
Rekenvariant_II	0	0.837	0.545	1.098	0	FALSE
Rekenvariant_I	0	0.835	0.543	1.097	0.002	FALSE
International	0.001	0.835	0.544	1.099	0.002	FALSE

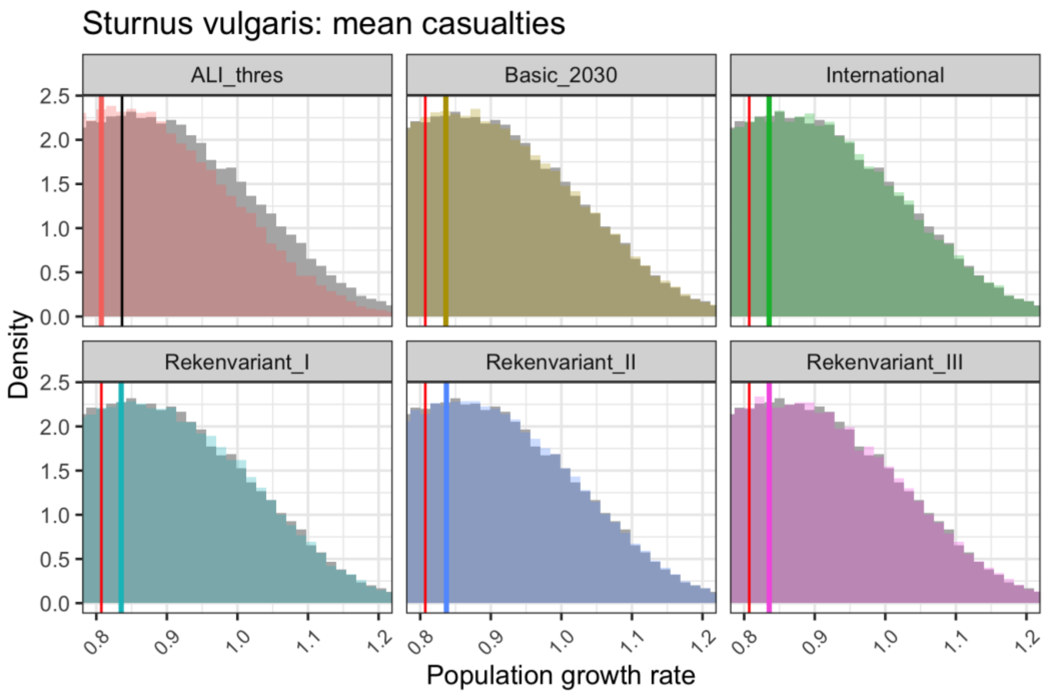

Figure 4.42 *Population growth rates per scenario for the common starling (*Sturnus vulgaris*). Within each panel the distribution of the unimpacted population growth rate (grey bars) is compared with the distribution of the impacted population growth rate (coloured bars). Vertical lines indicate median population growth rates for unimpacted (black) and impacted (coloured) populations and the ALI threshold population growth rate (red).*

Bar-tailed godwit

The estimated number of collision victims per wind farm scenario, and the effect on the stage-specific survival rates are shown in Table 4.37. As adults are more strongly impacted than other stages (Table 3.35), the effect on adult survival is more pronounced than on other survival rates.

Figure 4.43 shows the variation in annual number of collision victims per wind farm and per MW based for the national scenario. The highest numbers of collision victims are estimated for IJmuiden Ver (26), Zoekgebied 5 Oost origineel (26), Zoekgebied 1 Noord (23), Zoekgebied 2 Noord (23).

This estimated level of additional mortality does not result in violation of the ALI threshold for this species.

Population growth rates change from 0.998 in the null scenario to 0.996 in the impacted scenarios. In Table 4.38, P causality gives the probability that the violation of the threshold population size (X, for this species 15% decline over 30 years compared to the null scenario) is caused by the impact and not by uncertainty in the population models. For this species, the probability that a population abundance is 15% lower than the null scenario as result of the impact is between 1.5% and 8.6%, depending on the scenario.

Table 4.37 Mortality estimates of bar-tailed godwit per scenario, and the resulting change in stage-specific survival per scenario. Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Additional mortality is the mortality probability due to collisions.

Scenario	Mean annual casualties	Max abundance	Additional mortality	survival S0	survival SJ	survival SA
Null			0	0.57	0.828	0.828
Basic_2030	98	347671	0.00028	0.57	0.827	0.827
Rekenvariant_III	199	347671	0.00057	0.57	0.827	0.827
Rekenvariant_II	176	347671	0.00051	0.57	0.827	0.827
Rekenvariant_I	164	347671	0.00047	0.57	0.827	0.827
International	729	347671	0.00210	0.569	0.826	0.825

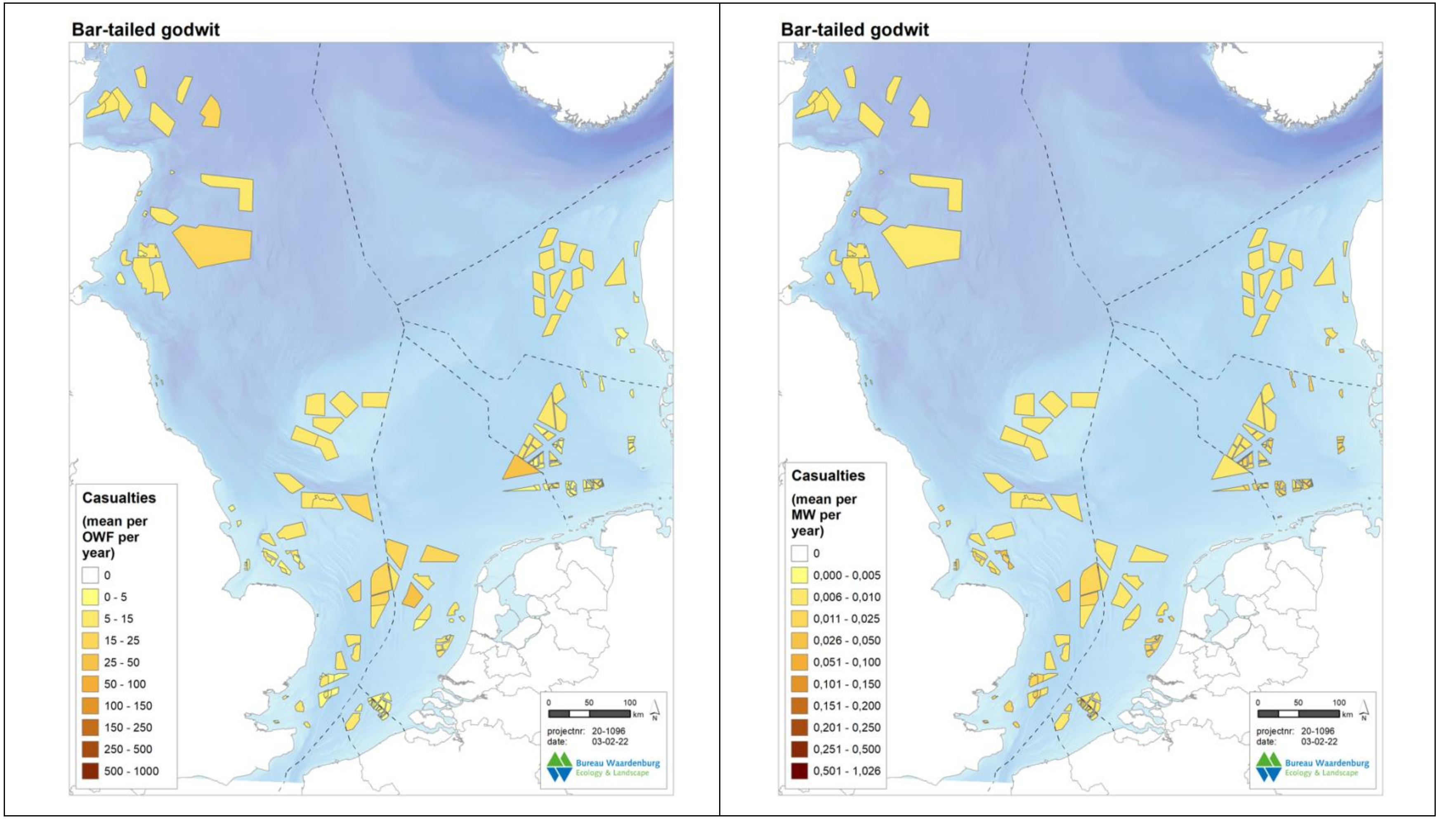

Figure 4.43 Mean estimated number of collision victims for bar-tailed godwit per windfarm (left) and per MW (right).

Table 4.38 *Summary bar-tailed godwit population level effects; Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Mortality is the mortality probability due to collisions. The median, 5% and 95% percentiles of the population growth rates (lambda) are also reported. P causality represents the probability that a violation of the X threshold results from an impact. The last column shows whether P causality violates the ALI threshold.*

Scenario	Mortality	Lambda median	5%	95%	P causality X = 15%	ALI 0.1
null	0	0.998	0.958	1.036	NA	NA
Basic_2030	0	0.998	0.958	1.036	0.015	FALSE
Rekenvariant_III	0.001	0.997	0.957	1.035	0.021	FALSE
Rekenvariant_II	0.001	0.997	0.957	1.035	0.024	FALSE
Rekenvariant_I	0	0.997	0.957	1.036	0.019	FALSE
International	0.002	0.996	0.956	1.034	0.086	FALSE

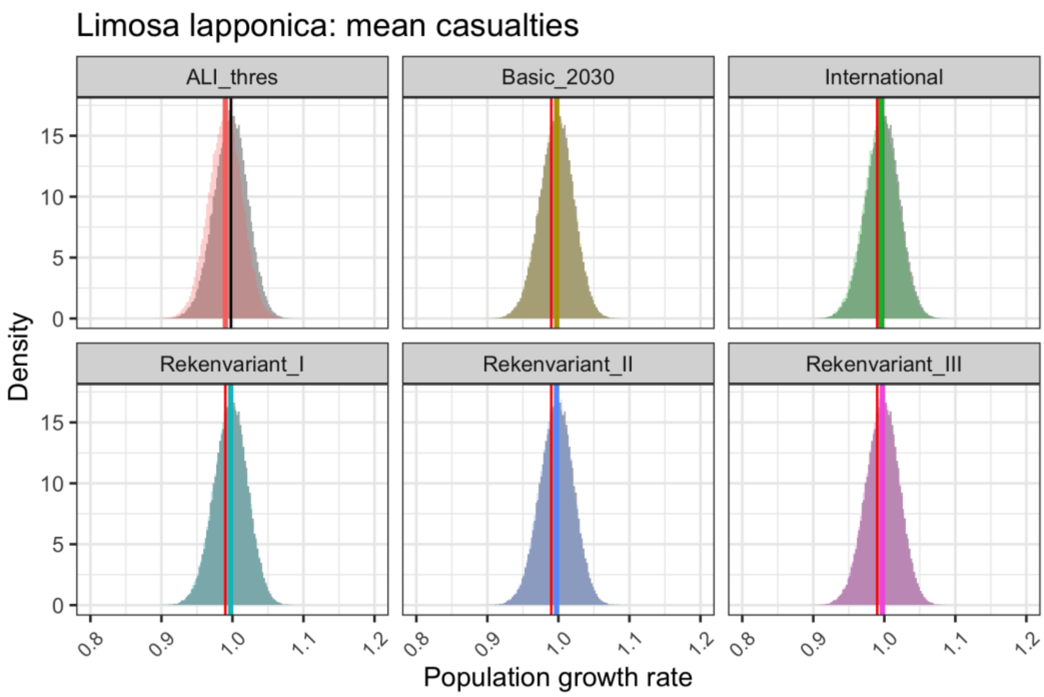

Figure 4.44 *Population growth rates per scenario for the bar-tailed godwit (*Limosa lapponica*). Within each panel the distribution of the unimpacted population growth rate (grey bars) is compared with the distribution of the impacted population growth rate (coloured bars). Vertical lines indicate median population growth rates for unimpacted (black) and impacted (coloured) populations and the ALI threshold population growth rate (red).*

Red knot

The estimated number of collision victims per wind farm scenario, and the effect on the stage-specific survival rates are shown in Table 4.39.

Figure 4.45 shows the variation in annual number of collision victims per wind farm and per MW based for the national scenario. The highest numbers of collision victims are estimated for IJmuiden Ver (44 victims per year), Zoekgebied 5 Oost origineel (44), Zoekgebied 1 Noord (40), Zoekgebied 2 Noord (40).

This estimated level of additional mortality does not result in violation of the ALI threshold for this species.

Population growth rates do not clearly change between the null scenario and the impacted scenarios. In Table 4.40, P causality gives the probability that the violation of the threshold population size (X, for this species 30% decline over 30 years compared to the null scenario) is caused by the impact and not by uncertainty in the population models. For this species, the probability that a population abundance is 30% lower than the null scenario as result of the impact is between 2.0% and 16.7%, depending on the scenario.

Table 4.39 Mortality estimates of red knot per scenario, and the resulting change in stage-specific survival per scenario. Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Additional mortality is the mortality probability due to collisions.

scenario	Mean annual casualties	Max abundance	Additional mortality	survival S0	survival SJ	survival SA
null			0	0.782	0.842	0.842
Basic_2030	168	672197	0.00025	0.782	0.842	0.842
Rekenvariant_III	341	672197	0.00051	0.782	0.842	0.842
Rekenvariant_II	302	672197	0.00045	0.782	0.842	0.842
Rekenvariant_I	282	672197	0.00042	0.782	0.842	0.842
International	1245	672197	0.00185	0.781	0.84	0.84

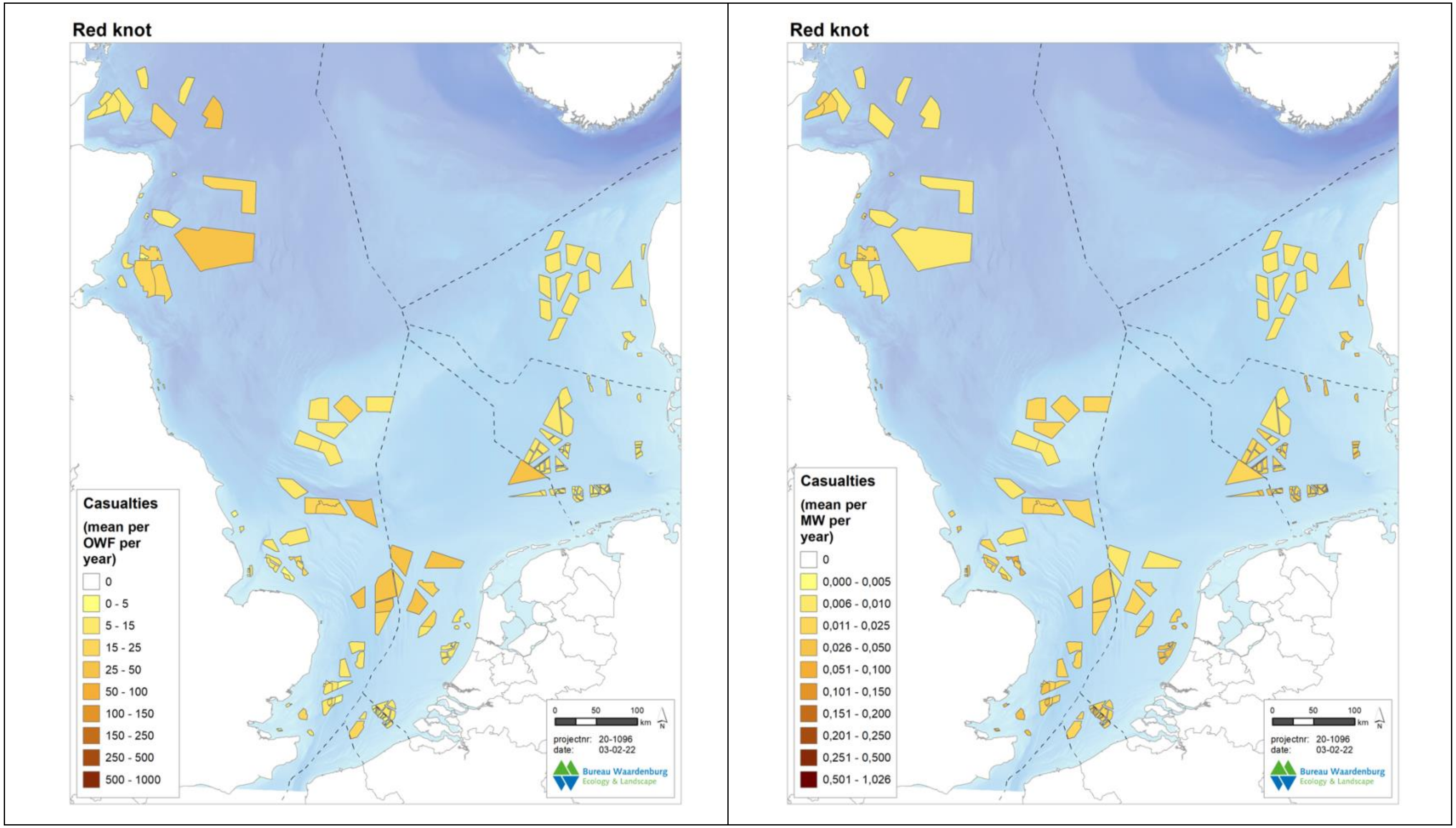

Figure 4.45 Mean estimated number of collision victims for red knot based per windfarm (left) and per MW (right).

Table 4.40 *Summary red knot population level effects; Casualties represent the mean number of casualties across time periods, Abundance represents the maximum number of birds across time periods used as population size, Mortality is the mortality probability due to collisions. The median, 5%and 95% percentiles of the population growth rates (lambda) are also reported. P causality represents the probability that a violation of the X threshold results from an OWF induced impact. The last column shows whether P causality violates the ALI threshold.*

Scenario	Mortality	Lambda median	5%	95%	P causality X = 30%	ALI 0.5
null	0	0.932	0.91	0.954	NA	NA
Basic_2030	0	0.932	0.91	0.954	0.02	FALSE
Rekenvariant_III	0.001	0.932	0.91	0.954	0.054	FALSE
Rekenvariant_II	0	0.932	0.91	0.954	0.037	FALSE
Rekenvariant_I	0	0.932	0.91	0.954	0.029	FALSE
International	0.002	0.93	0.909	0.952	0.167	FALSE

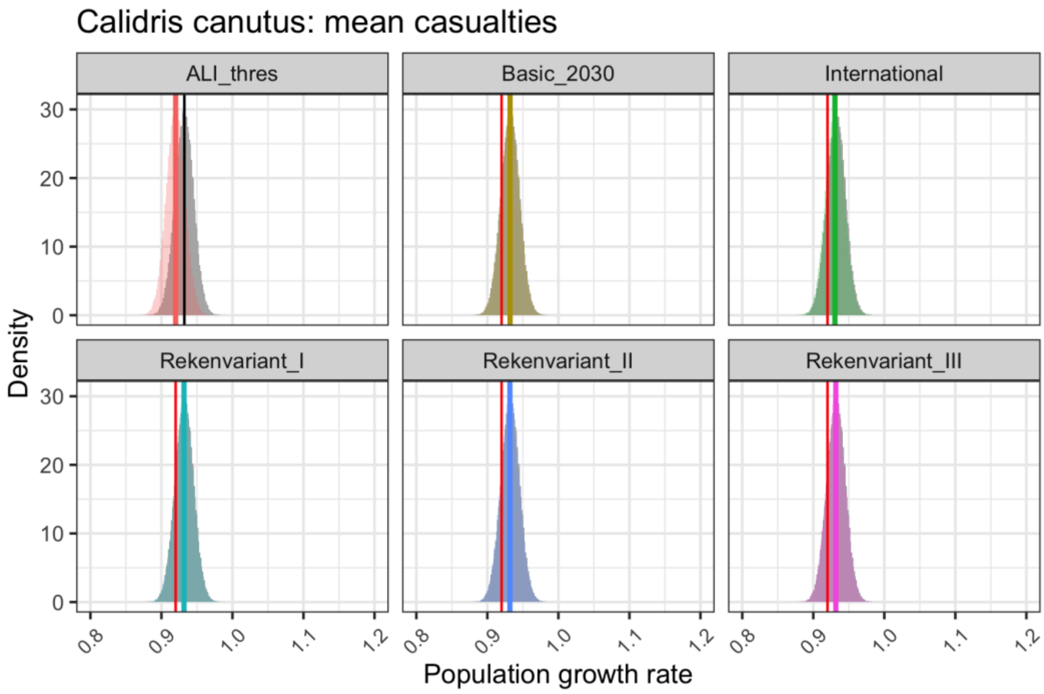

Figure 4.46 *Population growth rates per scenario for the red knot (*Calidris canutus*). Within each panel the distribution of the unimpacted population growth rate (grey bars) is compared with the distribution of the impacted population growth rate (coloured bars). Vertical lines indicate median population growth rates for unimpacted (black) and impacted (coloured) populations and the ALI threshold population growth rate (red).*

5 Summary of assessments based on Acceptable Levels of Impact

In Table 5.1 the summary of the species-specific assessments of §5.1 are summarised. For the herring gull and the northern gannet *all* scenarios result in a violation of the Acceptable Level of Impact (ALI). These results are currently being further analysed and will be added as an annex to this report. For the black-legged kittiwake as well as the great black-backed gull, the largest national scenario (16,7GW) violates the ALI. For all the other species, none of the scenarios violates the respective ALIs.

Table 5.1 Summary of assessments for the species-specific population level effects per scenario. TRUE = violation of the ALI threshold; FALSE = no violation of the ALI threshold.

Species	Scenario				
	Basic Nat 30	Rekenvariant III	Rekenvariant II	Rekenvariant I	Int 30
Great black-backed gull	FALSE	TRUE	FALSE	FALSE	FALSE
Lesser black-backed gull	FALSE	FALSE	FALSE	FALSE	FALSE
Herring gull	TRUE	TRUE	TRUE	TRUE	TRUE
Little gull	FALSE	FALSE	FALSE	FALSE	FALSE
Black-legged kittiwake	FALSE	TRUE	FALSE	FALSE	FALSE
Northern gannet	TRUE	TRUE	TRUE	TRUE	TRUE
Great skua	FALSE	FALSE	FALSE	FALSE	FALSE
Arctic skua	FALSE	FALSE	FALSE	FALSE	FALSE
Common tern	FALSE	FALSE	FALSE	FALSE	FALSE
Sandwich tern	FALSE	FALSE	FALSE	FALSE	FALSE
Bewick’s swan	FALSE	FALSE	FALSE	FALSE	FALSE
Brent goose	FALSE	FALSE	FALSE	FALSE	FALSE
Common shelduck	FALSE	FALSE	FALSE	FALSE	FALSE
Curlew	FALSE	FALSE	FALSE	FALSE	FALSE
Red knot	FALSE	FALSE	FALSE	FALSE	FALSE
Black tern	FALSE	FALSE	FALSE	FALSE	FALSE
Common starling	FALSE	FALSE	FALSE	FALSE	FALSE

6 Discussion

The results presented within this report show that the acceptable level of impact (ALI, defined by LNV) is violated for at least one scenario for the following species: northern gannet, herring gull, great black-backed gull and black-legged kittiwake. Additional analyses are being carried out for the northern gannet and herring gull, commissioned by Rijkswaterstaat. These results will be added as an annex to this report. Note that the methodology for defining the species-specific thresholds, as well as the methodology for assessing the probability of violation, are currently under review. Any change in this methodology has an effect on whether the threshold is violated for any species-scenario combination.

Density maps

Several of the study species showed strong variations in abundance, which in turn can greatly influence assessments of collision and displacement effects. In the current way of developing the **density maps** for seabird species, a single large group of individuals at a certain location can strongly impact the general outcome. As a result, the density maps of several species showed ‘hotspots’, which are often the result of birds following fishing vessels, survey effort or the result of pooling ESAS data on flying and local birds. The ESAS methodology follows requirements for Distance analysis for birds on the water and fixed-area ‘snap-shot’ counts for birds in flight. Distance analysis of these latter fixed-area counts would result in over-estimates of aerial bird densities. This can be further exacerbated by the movements of birds and pooling data can result in double counting of birds (Tasker *et al.* 1984). Ensuring consistency in the data selection in birds recorded as ‘in transect’ and in relation to associations with for instance fishing vessels can help reduce discrepancies between areas where variations in count methods may occur.

In addition, due to variation in **effort of bird surveys** among the different North Sea countries, the density maps for seabird species used for the international scenario were based on a longer period than the ones used for the national scenarios. As a result, any population trend is not directly comparable between the national and international scenario. For example, the numbers of northern gannets in the southern North Sea have strongly increased over the last decades. Consequently, bird densities were higher during more recent years, resulting in higher densities for the national density map. Other species, like the herring gull, have shown the opposite trend in recent years. Ideally, survey effort should be increased outside of the Netherlands, or alternative methods for assessing abundance should be used, by for example using monitoring data in combination with statistic models also incorporating other environmental factors, such as distance to shore or water depth.

Collision rate models

The calculated bird densities were subsequently used in collision rate modelling to estimate the number of collision victims per species. As a first step in this model, the densities of seabird species are transformed to **bird fluxes** to estimate the number of passages through the rotor-swept zone. How one can arrive from a snapshot number of birds counted at a certain moment to the number of birds passing through a certain area in a certain period of time, remains a large uncertainty in the collision rate models. However, the seabird densities providing the baseline of the collision rate models are in fact based on actual counts, while there is virtually no information available on offshore bird fluxes of migratory birds. Therefore, the current KEC methodology has to deal with simplistic approaches, where the number of birds per species passing the North Sea is derived from an estimated population size and the width of the potential migratory corridor. Current efforts in the Wozep program to measure and model migration intensities over the North Sea based on automated bird radar measurements can partially fill this knowledge gap but differentiating to species-specific fluxes and flight behaviour is still troublesome, and hence gaining more knowledge on migratory behaviour of landbirds over the North Sea remains crucial.

In contrast with the KEC 3.0 study, the current bird mortality estimates were calculated out by the stochastic collision risk model. Within this model, the input parameters are not only used with a mean value but also the **variation around the mean** can be entered. We made use of this feature of the model for the parameters having estimates on such variations, such as bird sizes, flight speed, fraction of time in flight and flight height distribution, based on actual measurement data. However, for two parameters, the nocturnal activity and avoidance rates actual measurements are largely lacking (Garthe & Hüppop 2004), while both of these parameters, but especially avoidance rates, have a tremendous effect on the outcomes of the collision risk models (Brabant & Vanermen 2020). Having more understanding of the uncertainty of these parameters and how they affect the model output, also in conjunction with each other, is persistently a main future objective of the research on the conflict between wind energy and wildlife.

Obviously, the collision rate models can further be improved by collecting more and better data on bird flight heights, flight speed and above all avoidance behaviour (Cook *et al.* 2012; Cook *et al.* 2018; Masden *et al.* 2021). Although the turbine-specific parameters are already quite detailed in the model, the aspect of **wind farm operationality** could be made more realistic in future exercises. Wind farm developers have precise measurements on the monthly operationality of their turbines. Improving the assumptions used in the models for this parameter can have a large influence on the outcome, as at any moment the wind turbines are not operational, they are evidently not causing a noteworthy number of bird casualties.

Population modelling

The product of the collision rate models is a wind farm- and species-specific number of casualties per month. However, for estimating the population level effects of a certain number of casualties, it is important to know the **age of the victims**, in other words whether these were adult or young birds. Namely, the population-level effect of the mortality of a bird in its reproductive life-phase is much larger than of young birds. Age is a factor that is recorded in the bird count databases but for not every single observation. In fact, some age categories are just simply easier to identify in the field than others. Consequently, it is likely that not all age categories are equally well recorded in the databases, which can have consequences on the age distribution used in the population models. Therefore, our approach to divide birds in the database without a known age to certain age groups may be too simplistic and could eventually be improved in the future. This holds especially for bird species in which juveniles leave the North Sea and only return to the area in later life stages and hence are not prone to collision risk of wind farms in our study area. Explicitly dealing with such specific characteristics needs a better understanding of the life history of each species in question.

The estimated number of victims always needs to be regarded in combination with the **relevant population size**. Within our analyses, both the estimation of the species-specific number of collision victims and corresponding population size are based on the same density maps. As described in Chapter 2, the average population estimate is calculated per bimonthly period, and the population is defined as the maximum of these averages. Although this represents a minimum population estimate and likely underestimates the actual biogeographical population size, this approach represents a worst-case scenario for various reasons: 1. The estimated number of individuals is based on the number of individuals present at any survey. This is likely to be an underestimation, as not all individuals will make use of the southern North Sea at any given time. 2. This approach assumes that no other individuals make use of the southern North Sea other than individuals present during the bimonthly period with the highest estimated number of individuals. Although this is an unrealistic assumption, this provides the worst-case scenario, in which all victims are attributed to the maximum number of individuals present at any time (maximum of bimonthly means). As a result, if the density is highest during the breeding season, the collision victims based on all bimonthly periods will be attributed to the number of individuals present during the breeding season, while it could be more appropriate to attribute these victims to the wintering population. For some species, it could be insightful to analyse the impact of collision victims during the breeding on the breeding population (either based on colony counts or bird densities during the summer half-year), and separately analyse the impact of collision victims during the non-breeding season on this sub-population.

In addition, **variation in collision risk between individuals** is not taken into account within the current approach. In a study on GPS-tagged northern gannets from Helgoland, Peschko *et al.* (2021) found that during the breeding season, only 3 out of 28 adults with loggers regularly used a nearby wind farm, while the others predominantly avoided this wind farm. Not-published data on lesser black-backed gulls from the Dutch Delta suggest similar individual differences per individual. Data on more colonies and age classes, as well as outside the breeding season, are necessary to get better insight into whether this pattern can be observed more widely. If this is the case, the actual number of susceptible individuals would be lower than the entire population, and only this subset of susceptible individuals could decline over time as these individuals would be lost from the population, eventually possibly even resulting in proportionately more individuals avoiding the wind farm. However, note that avoidance behaviour may also change over time, in either a positive or negative way. Individuals of certain species can also be attracted to wind farms, while even habituation may also take place, leading to a higher number of birds in and around wind farms over time.

Variation in the population models can be incorporated as variation between years (due to for example variation in weather or prey availability), or as uncertainty in the estimate through chance. Within the current approach, all variation is assumed to be due to uncertainty in the estimate (Potiek *et al*. 2019b). This is the worst-case scenario, which results in unrealistically high variation in the outcomes of the population model. As variation in the outcomes per scenario affects the impact assessment using the ALI-approach, we recommend looking into the effect of this method of incorporating variation.

Synthesis

Throughout the whole process from estimating collision-related mortality to defining population-level effects a **worst-case approach** has been adopted at various stages. These worst-case assumptions can be amplified across each step, leading to effects to be highly over-estimated. One aspect where assumptions can result in over-estimates of effects is the collision rate model. Figures used for avoidance, aerial bird density, flight heights can have a huge bearing on the estimated number of collisions and often rely on expert judgement or extrapolated data at best. These factors, particularly avoidance, is often highlighted as a key area for research. However, even if reliable avoidance figures were available, uncertainty would still remain in other input parameters and assumptions of the model. In fact, all modelling exercises of collision rates are currently undertaken because the most important knowledge gap remains the **direct measurements of collisions**, relative to the number of birds present in the area. Therefore, a thorough reassessment of how collisions estimates could be measured and potentially applied to future developments may help alleviate some of the uncertainty in evaluating the effects of offshore wind farms on birds.

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Appendix I Wind farm characteristics, used within collision rate modelling

Wind Farm	Capacity MW (Max)	Num Turbines (Max)
Borssele 1	376	47
Borssele 2	376	47
Borssele 3	366.0	39
Borssele 4 - Blauwwind	366.0	39
Borssele Site V -Two towers	19	2
Egmond aan Zee	108	36
Eneco Luchterduinen	129	43
Gemini Zee energie	300	75
Gemini Buitengaats	300	75
Hollandse Kust Noord (Tender 2019)	700	69
Hollandse Kust West - (Tender 2020/2021)	1400	117
Hollandse Kust Zuid Holland I	385	70
Hollandse Kust Zuid Holland II	385	70
Hollandse Kust Zuid Holland III	385	70
Hollandse Kust Zuid Holland IV	385	70
IJmuiden Ver	4000	267
Prinses Amaliawindpark	120	60
Ten noorden van de Waddeneilanden - (Tender 2022)	700	47
Hollandse Kust West zuidelijke punt	700	47
Zoekgebied 1 Noord	4000	200
Zoekgebied 1 Zuid	2000	100
Zoekgebied 2 Noord	4000	200
Zoekgebied 5 Oost origineel	4000	267
IJmuiden Ver Noord	2000	134
Thornton Bank phase I	30	6
Northwind	216	72
Belwind	165	55
Norther	370	44
Rentel	309.0	42
Seamade (SeaStar)	252	30
Seamade (Mermaid)	235	28
Nobelwind	165	50
Thornton Bank phase II	185	30
Thornton Bank phase III	110.7	18
Northwester 2	219.0	23
Princess Elisabeth - Noordhinder Noord - 2023 Tender	700	59
Princess Elisabeth - Fairybank/Nordhinder Zuid - 2025 Tender	1400	94
Albatros	112	16
Alpha Ventus	60	12

Wind Farm	Capacity MW (Max)	Num Turbines (Max)
Amrumbank West	302	80
BARD Offshore 1	400	80
Borkum Riffgrund 1	312	78
Borkum Riffgrund 2	450	56
Borkum Riffgrund 3	900	81
Butendiek	288	80
DanTysk	288	80
Deutsche Bucht	252	31
EnBW He Dreiht	900	70
Global Tech I	400	80
Gode Wind 1 and 2	582	97
Gode Wind 3	241.75	22
Hohe See	497	71
Kaskasi	342	38
Meerwind Süd/Ost	288	80
Merkur	396	66
N-10.1	1000	57
N-10.2	700	47
N-13-3	1000	50
N-3.5	420	28
N-3.6	480	32
N-3.7	225	15
N-3.8	433	29
N-6.6	630	42
N-6.7	270	18
N-7.2	930	62
N-8.4	425	28
N-9.1	1000	67
N-9.2	1000	67
N-9.3	1000	67
N-9.4	1000	67
Nordergründe	110.7	18
Nordsee One	332.1	54
Nordsee Ost	295.2	48
Riffgat	108	30
Sandbank	288	72
Trianel Windpark Borkum I	200	40
Trianel Windpark Borkum II	203	32
Veja Mate	402	67
Horns Rev 1	160	80
Horns Rev 2	209.3	91
Horns Rev 3	406.7	49
Thor - 2020 Tender	1000	75
Vesterhav Nord/Syd	344	41

Wind Farm	Capacity MW (Max)	Num Turbines (Max)
Dudgeon	402	67
Greater Gabbard	504	140
Gunfleet Sands	173	48
Dogger Bank B	1200	95
Humber Gateway	219.0	73
Inner Dowsing	97.2	27
Kentish Flats	90	30
Lincs	270	75
London Array	630	175
Lynn	97	27
Race Bank	573	91
Dogger Bank C	1200	95
Sofia	1400	100
Hornsea Project Three	2400	231
Hornsea Project Two	1386	165
Scroby Sands	60	30
Sheringham Shoal	317	88
Teesside	62	27
Thanet	300	100
East Anglia Hub - ONE North	800	58
Triton Knoll	857	90
Westermost Rough	210	35
East Anglia Hub - TWO	900	65
Scottish Sectoral Marine Plan - E3	1000	50
Moray East	950	100
Seagreen	1140	114
Aberdeen Offshore Wind Farm (EOWDC)	93.2	11
Race Bank Extension	573	38
Dudgeon Extension	402	115
Sheringham Shoal Extension	317	16
Five Estuaries	353	18
North Falls	504	34
Kincardine - Phase 2	48	5
Seagreen 1A	360	36
Beatrice	588	84
Inch Cape	1000	72
Neart na Gaoithe	448	54
Kentish Flats Extension	49.5	15
Galloper	353	56
East Anglia ONE	714	102
East Anglia Hub - THREE	1400	100
Norfolk Vanguard	1800	158
Norfolk Boreas	1800	158
Blyth Offshore Demonstrator Phase 1	41.5	5

Wind Farm	Capacity MW (Max)	Num Turbines (Max)
Berwick Bank	2300	115
Hywind Scotland Pilot Park	30	5
Moray West	950	85
Blyth Offshore Demonstrator Phase 2	58.4	5
Dogger Bank A	1200	95
Hornsea Project One	1218	174

Appendix II Knowledge base for determining demographic rates used in population models

Part of this KEC4.0 study was to update input parameters based on an extensive literature research for input parameters for the collision rate model, as well as demographic rates as input for the population models. The description of new parameters used within the collision rate modelling is given in Chapter 2, while this appendix presents an overview of new and old demographic rates.

The tables within this appendix formed the basis for the input parameters for the population model, as described in Chapter 3.

Each data source within this updated knowledge base is scored for representativeness and data quality, using the same approach as in Horswill and Robinson (2015) and Potiek *et al.* (2019a).

This approach of Horswill and Robinson (2015) is based on the following criteria to assess data quality:

- Q1) the number of years (>10),
- Q2) the number of individuals and
- Q3) whether an indication of variation between years or areas (standard deviation), or a range of error (standard error) has been reported.

Each of these criteria is scored with 0, 1, or 2: 0 for 'poor', 1 for 'intermediate/unknown' and 2 for 'good'.

In a similar way, we assess the representativeness of each data source. This representativeness is scored based on:

- R1) how recent the data are (score 2 for data of less than 10 years old; threshold between score 1 and 0 depends on the species and data availability),
- R2) how representative the area/site is for the Dutch part of the North Sea, and
- R3) how representative the data are for the current local trend in the Dutch part of the North Sea. In our study we used data on population trends since 1990 from Boele *et al*. (2021) to assess the current local trend of each species.

For each species, the defined stages are described using the following general structure:

- a first-year stage (stage J0),
- followed by one or more immature stages (stages starting with I, for example I1 to I4),
- and an adult stage (stage A).

Demographic rates are reported using the same stage indices, with for example SI1 being the survival of the I1 stage. Fecundity is presented as the number of fledglings per breeding pair. For most species, a fraction of floaters is assumed, if possible based on literature. This is depicted in the tables with demographic rates as prob. floater.

Table II.1 *Age-specific survival rates (II.1a) and fecundity rates (II.1b) of lesser black-backed gulls from different populations. Empty cells indicate no available information for this population. *: ringed as chicks. Local population trend: ++: strongly increasing; =: stable; -: declining. Data type: [a] Colour-ring resightings, [b] Review. Reference: [1] Camphuysen (2013); [2] Harris (1970); [3] Camphuysen & Gronert (2012); [4] Camphuysen (2011); [5] Wanless et al. (1996); [6] Horswill & Robinson (2015); [7] Gyimesi et al. (2011); [8] Camphuysen in Koffijberg et al. (2017); [9] Spaans et al. (1994); [10] Sellers & Shackleton (2011); [11] Perrins & Smith (2000); [12] Mavor et al. (2008); [13] Calladine & Harris (1997). Data quality and representation are assessed based on the criteria described in Chapter 1. * several projects are currently being carried out to determine additional estimates of especially survival rates (colour-ring programmes in Europe) but also fecundity rates, so this overview is not a complete inventory and additional analyses might yield better estimates.*

a.

Demographic rate	**Mean**	**n**	**SD**	**SE**	**Study period**	**Local population trend**	**Location**	**Data type**	**Reference**	**Data quality**	**Data representativeness**
Juvenile survival	*0.306*	*554**	*0.075*		*2006-2011*	++	*Texel, NL*	*[a]*	*[1], [3]*	*6*	*6*
	0.82					++	*UK*	*[a]*	*[2]*	*3*	*4*
	0.57	*343**			*1984-1996*	++	*NL (Delta + Wadden Isles)*	*[a]*	*[4]*	*6*	*4*
Immature survival	*0.825*	*554**	*0.052*		*2006-2009*	++	*Texel, NL*	*[a]*	*[1]*	*5*	*6*
	0.89	*343**	*0.02*		*1984-1996*	++	*NL (Delta + Wadden Isles)*	*[a]*	*[4]*	*6*	*4*
Adult survival	*0.91*	*554**		*0.036*	*2006-2011*	++	*Texel, NL*	*[a]*	*[3]*	*6*	*6*
	0.95					++	*Texel, NL*	*[a]*	*[4]*	*6*	*6*
	0.91			*0.017*	*1983-1994*	++	*UK*	*[a]*	*[5]*	*5*	*5*
	0.885	*Based on 2 studies*	*0.022*		*[review]*		*[UK, review]*	*[b]*	*[6]*	*6*	*6*

b.

Demographic Rate, location	Mean (fledg/bp, unless otherwise stated)	n	SD	SE	Study period	Local pop. trend	Reference	Data quality	Data representativeness
Lake Volkerak, NL:	1.62		0.96		2010		[7]	2	5
Lake Volkerak, NL:	0.8		0.4		2010		[7]	2	5
Texel, NL	0.49		0.18		2006-2016	++	[8]	6	6
Texel, NL	0.47		0.19		2006-2011	++	[3]	6	6
Terschelling, NL	0.85 (1992), 0.71 (1993)	1992: n=26; 1993: n=21	0.92		1992-1993	=	[9]	1	6
Several colonies UK	2.14 fledg per successful brood	96 broods			2009	-	[10]	1	4
UK	0.46			[strong variation]	1982-1998		[11]	3	1
Several colonies UK	UK average: 0.530; means per colony range from 0.17 to 0.88	6 colonies	0.325	variable, around 0.05 (0.17 +- 0.02;	1986-2005	variable	[12]	3	1
Isle of May, UK	0.813	5329 nests;	0		1989-1994	++	[5]	6	4
Age of first breeding	5 / 6 years						[3]		
Incidence of missed	50%						[1]		
	37%	109 of 292 attempts			1993-1994		[13]		

Table II.2 Age-specific survival rates (II.2a) and fecundity rates (II.2b) of great black-backed gulls from different populations. Empty cells indicate no available information for this population. Local population trend: +: increasing. References: [1] Collier et al. (2020); [2] Glutz von Blotzheim et al. (1984); [3] Barrett et al. (2015); [4] Mavor et al. (2008); [5] Verbeek (1979); [6] Schekkerman et al. (2017); [7] Butler and Trivelpiece (1981); [8] Robinson (2005). Data quality and representativeness are assessed based on the criteria described in Chapter 2.

a.

Demographic rate	**Mean (fledg/bp, unless otherwise stated)**	**n**	**SD**	**SE**	**Study period**	**Local pop. trend**	**Location**	**Data type**	**Reference**	**Data quality**	**Data Representativeness**
Juvenile survival	*0.3*			*0.021*	*1990-2018*			*[a]*	*[1]*	*6*	*6*
Immature survival	*0.79*			*0.011*	*1990-2018*			*[a]*	*[1]*	*6*	*6*
Adult survival											
	0.93								*[1]*	*3*	*3*
	0.82	*208*	*0.017*		*2001-2014*		*Norway*		*[2]*	*6*	*5*

b.

Demographic rate, location	Mean (fledg/bp, unless otherwise stated)	n	SD	SE	Study period	Local pop. trend	Reference	Data quality	Data representativeness
UK	1.109	10 colonies, 2-72 nests per colony	0.54	average SE: 0.156, per colony: 0.06-0.29	different colonies, per colony up to 13yrs (1986-2005)	variable	[3]	6	3
UK, Walney Island	0.645	56			1973-1974	+	[4]	2	3
NL, Deltagebied	1.0	several locations, 56 location-years			2006-2015		[5]	5	6
USA, Maine (little duck island)	Low density: 0.21; High density: 0.83				1979		[6]	1	1
Age of first breeding	*4 years*						*[7]*		
Incidence of missed breeding									

*Table II.3 Age-specific survival rates (II.3a) and fecundity rates (II.3b) of herring gull from different populations. Empty cells indicate no available information for this population. *: ringed as chick. Data type: [a] Colour-ring resightings. References: [1] Camphuysen (2013); [2] (Chabrzyk & Coulson 1976); [3] Wanless et al. (1996); [4] Camphuysen & Gronert (2012); [5] Glutz von Blotzheim et al. (1984); [6] Camphuysen in Koffijberg et al. (2017); [7] Koffijberg et al. (2017); [8] Mavor et al. (2008); [9] Sellers & Shackleton (2011). Data quality and representativeness are assessed based on the criteria described in Chapter 2.*

a.

Demographic rate	Mean	n	SD	SE	Study period	Local population trend	Location	Data type	Reference	Data quality	Data representativeness
Juvenile survival	0.25		0.06		2006-2011	-	Texel, NL	[a]	[1]	5	6
	0.63 from fledging to age 4						UK		[2]	0	2
	0.45 from fledging to age 4			0.07	1989-1994	strong fluctuations	Isle of May, UK		[3]	4	4
Immature survival	0.89					-	Texel, NL	[a]	[1]	4	6
	0.7	119 *		0.06	2006-2012	-	Texel, NL	[a]	[4]	5	6
	0.45 from fledging to age 4			0.07	1989-1994	strong fluctuations	Isle of May, UK		[3]	4	4
Adult survival	♀0.79 ♂ 0.86	119 *		♀ 0.049 ♂ 0.038	2006-2012	-	Texel, NL	[a]	[4]	5	6
	0.93								[5]	0	2
	0.935								[2]	0	2
	♂ 0.88; ♀0.858			♂ 0.013; ♀ 0.02	1989-1994		Isle of May, UK	[a]	[3]	4	3

b.

Demgroaphic rate, location	Mean (fledg/bp, unless otherwise stated)	N	SD	SE	Study period	Local pop. trend	Reference	Data quality	Data representativeness
Texel, NL	0.86		0.31	-	2006-2011	-	[4]	5	6
Texel (update), NL	0.68		0.29		2006-2016	=	[6]	6	6
Texel (Westerduinen),	0.41		0.15		2005-2015	=	[7]	6	6
Vlieland (Vliehors), NL	0.82				2009-2016	=	[7]	3	6
Schiermonnikoog	0.69		0.29		2006-2016		[7]	6	5
UK, several colonies	0.914	up to 17 years per colony, 7	0.207	Between 0.08 and	1986-2005	variable	[8]	5	4
UK, Isle of May	1.378	10270 nests	0.303		1989-1994	strong	[3]	4	4
UK, two colonies	2.02	98			2009	-	[9]	0	4
Age of first breeding	4-6						[4]		
	4						[3]		
	5.25						[2]		
Incidence of missed breeding	Breeding frequency once every 1.5 (Texel) to 1.6 years (IJmuiden)						[1]		

Table II.4 *Age-specific survival rates (II.1a) and fecundity rates (II.1b) of kittiwakes from different populations. Empty cells indicate no available information for this population. Local population trend: +: increasing; -: declining; =: stable. Data type: [a] Ringing programme; [b] Review. References: [1] Coulson and White (1959); [2] Horswill & Robinson (2015); [3] Thomas and Coulson (1988); [4] Harris et al. (2000); [5] Frederiksen et al. (2004); [6] Cam et al. (2002); [7] Sandvik et al. (2005); [8] Coulson and Wooller (1976); [9] Reiertsen et al. (2014); [10] del Hoyo et al. (1996); [11] Mavor et al. (2008); [12] JNCC Seabird Monitoring Programme Database, www.jncc.gov.uk/smp; [13] Coulson (2011); [14] Searle et al. (2020); [15] Freeman et al. (2014); [16] Jitlal (2017); [17] Christensen-Dalsgaard et al. (2019); [18] Christensen-Dalsgaard et al. (2018); [19] Horswill et al. (2021); [20] Rothery et al. (2002); [21] Oro and Furness (2002); [22] Coulson and Strowger (1999). Data quality and representativeness are assessed based on the criteria described in Chapter 2.*

a.

Demographic rate	Mean	n	SD	SE	Study period	Local population trend	Location	Data type	Reference	Data quality	Data representativeness
Juvenile survival	1st year: 0.79				1954-1958	+	UK	[a]	[1], [2]	0	2
Immature survival	0.9				1954-1958	+	UK	[a]	[1], [3]	0	2
	0.697			0.054	?-2016		UK	[a]	[14], [15], [16]	2	2
	0.605			0.045	?-2016		UK	[a]	[14], [15], [16]	2	2
	0.637			0.036	?-2016		UK	[a]	[14], [15], [16]	2	2
	0.738			0.05	?-2016		UK	[a]	[14], [15], [16]	2	2
Adult survival	0.9				1954-1958	+	UK	[a]	[1], [3]	0	2
(cont. next page)	0.882	359 ringed		0.017	1986-1996		UK	[a]	[4]	6	3
	0.854		0.051		[review]	[review]	[review]	[b]	[2]	6	5
	0.908				1986-2002	+, then -	UK	[a]	[5]	5	4
	0.81			0.017	1987-1999		France	[a]	[6]	6	2
	0.88		0.09		data 1990-2002		Norway	[a]	[7]	6	4

Demographic rate	Mean	n	SD	SE	Study period	Local population trend	Location	Data type	Reference	Data quality	Data representativeness
Adult survival *cont.*	0.842	based on 8 studies		0.7	variable	-	variable	[b]	[7]	6	5
	♀ 0.86, ♂ 0.81			♀0.008, ♂0.010	1954-1974	=	UK	[a]	[8]	5	2
	0.85		0.66-0.98	0.04-0.05	1990−2011	--	Norway	[a]	[9]	6	6
	0.81								[10]	2	2
	0.83				1986-1997		UK (Fair Isle)	[a]	[20]	4	2
	0.81				1987-1997		UK (Foula)	[a]	[21]	4	2
	0.86				1986-2016		UK (Isle of May)	[a]	[19]	4	4
	0.85				1955-1980		UK (North Shields)	[a]	[22]	4	2
	0.86				1989-2016		UK (Skomer)	[a]	[19]	4	4
	0.857		0.067		?-2016		UK	[a]	[14], [15], [16]	2	2

b.

Demographic rate, location	**Mean (fledg/bp, unless otherwise stated)**	**n**	**SD**	**SE**	**Study period**	**Local pop. trend**	**Reference**	**Data quality**	**Data representativeness**
	1.16					+	[1], [3]	0	2
UK (several colonies)	0.68 (avg per colony 0.21-1.25)			0.03	1986-2005	variable	[11]	6	4
UK (Saltburn cliffs)	0.62	9 years, >200 bp per year	0.2		2000-2008	=	[12]	5	3
UK (Isle of May)	1990-1999: 0.3 2000-2002: 0.68			1990-1999: SE=0.04 2000-2002: SE=0.11	1986-2002	+, then -	[5]	6	4
UK (Forth Islands)	0.55		0.35		?-2016		[14], [15], [16]	2	2
UK (St Abbs)	0.63		0.33		?-2016		[14], [15], [16]	2	2
UK (Fowlsheugh)	0.78		0.33		?-2016		[14], [15], [16]	2	2
UK (Buchan Ness)	0.61		0.34		?-2016		[14], [15], [16]	2	2
Norway (coastal colonies)	chicks/nest: 0.44 (range 0 – 1.21)	54-916	0.00-0.06		2018-2019		[17]	4	4
Norway (on oil riggs)	chicks/nest: 0.80 (range 0.61 – 1.02)	39-280	0.03-0.09		2018-2019		[17]	4	4
Norway (Anda)	Hatchlings/nest: 1.45 – 1.66	13-52 nests	0.07-0.14		2007-2016		[18]	6	3
Age of first breeding	*4*						*[11], [6]*		
	Males 4.0 females 4.7						*[13]*		
	4						[14], [15], [16]		
Incidence of missed breeding									

Table II.5 *Age-specific survival rates (II.5a) and fecundity rates (II.5b) of little gulls from different populations. Empty cells indicate no available information for this population. Local population trend: +: increasing. References: [1] Garthe & Hüppop (2004); [2] Koks (1998); [3] Putkonen (1939); [4] Cramp and Simmons (1983); [5] Haverschmidt (1942) ;[6] Veen (1978); [7] Veen (1980); [8] Moller (1978); [9] Sandvik et al. (2012); [10] Berg and Meyer-Lüne (1937); [11] Majoor et al. (2005). No estimates found for juvenile survival.*

a.

Demographic rate	Mean	n	SD	SE	Study period	Local population trend	Location	Data type	Reference	Data quality	Data representativeness
Juvenile survival											
Immature survival	0.37			0.13	>20 jr		NL	metalring [estimate for black-headed gull]	[11]		
	0.587			0.02	>20 jr		NL	colour-ring [estimate for black-headed gull]	[11]		
Adult survival	0.8							[estimate based on closely related species]	[1]	0	1
	0.795			0.07	>20 jr		NL	metal ring [estimate for black-headed gull]	[11]		
	0.827			0.01	>20 jr		NL	colour-ring [estimate for black-headed gull]	[11]		

b.

Demgroaphic rate, location	Mean (fledg/bp, unless otherwise stated)	n	SD	SE	Study period	Local pop. trend	Reference	Data quality	Data representativeness
NL	Clutch size: 2,6 eggs/nest	163 nests	0.6		1942-1996	fluctuations	[2]	6	4
Finland	Clutch size: 2,71 eggs/nest	214 nests					[3]; [4]	4	3
NL	Clutch size: 2,17 eggs/nest	29 nests					[4]; [5]	0	3
NL, Lauwerszee	0	3 years (resp. 25, 44, 30 breeding pairs per year)			1975-1977		[6]; [7]	2	3
NL, Lauwerszee	0.1	5 colonies, 59 nests			1978		[7]	1	3
Denmark, Vejlerne	Clutch size: 2.7 eggs/nest	16 years, number of nests unknown			1961-1976		[8]; [9]	2	0
Meta-analysis Black-headed gull	0.5	meta-analysis							
Age of first breeding	*2-3*						*[4]; [10]*		
	>2 calendar yr						*[7]*		
	2.45						*[9]*		
Incidence of missed breeding									

Table II.6 Age-specific survival rates (II.6a) and fecundity rates (II.6b) of great skua from different populations. Empty cells indicate no available information for this population. Data type [a]: ring recoveries. References: [1] Machado dos Santos (2018); [2]. Snell (pers. comm.); [3] Collier et al (2020); [4] Furness (1978); [5] Balmer & Peach (1997); [6] Ratcliffe et al. (2002); [7] Catry et al. (1998); [8] Del Hoyo et al. (1996); [9] JNCC Seabird Monitoring Programme Database, www.jncc.gov.uk/smp; Fair Isle; [10] Jones et al. (2008); [11] Phillips et al. (1999); [12] Mavor et al. (2008); [13] Robinson (2005); [14] Horswill & Robinson (2015). Data quality and representativeness are assessed based on the criteria described in Chapter 2.

a.

Demographic rate	Mean	n	SD	SE	Study period	Local population trend	Location	Data type	Reference	Data quality	Data representativeness
Juvenile survival	0.84 (first 6 months)	4 years			?, <1978		UK	[a]	[4]	0	3
	0.8	4 years			?, <1978		UK	[a]	[4], [5]	0	3
	0.97	1826 ringed birds			1924-2017				[1], [2], [3]	2	6
Immature survival	0.93				?, <1978			[a]	[4]	0	3
	0.73	0-5 years (juv + imm survival			1988-1999	-	UK	[a]	[1], [2], [3]	5	3
Adult survival	0.89, age effect				1988-1999	-	UK	[a]	[6]	5	3
	0.93	236 recoveries		0.02	?, <1978		UK		[4], [5]	0	3
	0.87; range 0.8-0.93	8 years, 1224 recoveries	0.055		1989-1996		UK	[a]	[7]	5	3
	0.9								[8]	2	2
	0.86	1826 ringed birds			1924-2017				[1], [2], [3]	2	6

b.

Demographic rate, location	Mean (fledg/bp, unless otherwise stated)	n	SD	SE	Study period	Local pop. trend	Reference	Data quality	Data representativeness
UK	0.45	29466 nests	0.29		2000-2017	+	[9]	6	6
UK	0.49	433 nests		0.06	2003-2006	=	[10]	4	4
UK	St. Kilda: 0.96 (1996); Foula: 1.09 (1994-1996)	St. Kilda: 184 nests; Foula: 383 nests			1994-1996	+	[11]	2	4
UK	0.69 chicks per pair	767 nests	0.34		1989-1995		[7]	5	3
UK, 9 different sites	0.64 (site-specific estimates 0.33-0.88)	9 sites			1986-2005	variable	[12]	6	4
Age of first breeding	7 years						[13], [14]		
Incidence of missed breeding	8.9 %	1020 birds		1.4 %	1989-1996		[7]		

Table II.7 Age-specific survival rates (II.7a) and fecundity rates (II.7b) of Arctic skuas from different populations. Empty cells indicate no available information for this population. Local population trend: +: increasing. Data type: [a] Ringing programme. References: [1] O'Donald (1983); [2] Robinson (2005); [3] Cook and Robinson (2010); [4] Horswill & Robinson (2015); [5] Phillips & Furness (1998); [6] O'Donald (1974); [7] Phillips et al. (1996); [8] Dawson et al. (2011); [9] Perkins et al. (2018); [10] Mavor et al. (2008); [11] Jones (2003); [12] Baber (1989); [13] Baber (1990); [14] Furness and Aitken (1992); [15] Catry et al. (1998); [16] van Bemmelen et al. (2021); [17] Snell (pers. comm.).

a.

Demographic rate	Mean	n	SD	SE	Study period	Local population trend	Location	Data type	Reference	Data quality	Data representativeness
Juvenile survival	0.68								[1]; [2]	3	2
	0.74								[3]	3	3
	0.43	1060 individuals	0.14		1985-2008				[17]	6	5
Immature survival	0.346								[1]; [4]	3	2
Adult survival	0.9	324 individuals	0,009		1993-1995		UK (Foula)	[a]	[5]	5	3
	0.886								[1]; [2]	3	2
	0.92	1060 individuals	0.07		1985-2008				[17]	6	6
	0.883	112 (n♀ = 68, n♂ = 44			2014-2018	decreasing	Norway (Sletness)	[a]	[16]	5	5

b.

Demographic rate, location	Mean (fledg/bp, unless otherwise stated)	n	SD	SE	Study period	Local pop. Trend	Reference	Data quality	Data representation
UK (Fair Isle)	1,4385	488 nests	0,6538		1949-1963	++	[6]	6	2
UK (Foula)	1,17	352 nests	0,1065		1993-1995		[5]	5	3
UK (Foula)	0,54 (range: 0,09 to 0,97)	9 years			1986-1994	-	[7]	5	4
UK (Fetlar)	0,399 (range: 0 to 1,6)	22 years (n=8-31)			1986-2007	-- until 2001, then stable	[8]	6	6
UK (several colonies)	0,91-0,29				1992-2015	-	[9]	5	6
UK (Shetland/Orkney)	0,4868	120 nests			1986-2005		[10]	5	4
UK	0,52				1986-2008		[3]	5	5
UK (Handa Island)	1,22	32 nests	0,1		2003		[11]	2	3
UK (Handa Island)	1,28	3 years (n=20-28)			1989-1991		[12]; [13]; [14]; [11]	2	3
Norway (Sletness)					2014-2018	decreasing	[16]		
UK (several colonies)					till 2020				
Age of first breeding	*4*						*[2]*		
	4.396	*101 individuals*			*1948-1959; 1970-1976*		*[1]*		
Incidence of missed breeding	1993: 8% of experienced breeders skipped breeding; 1994: 3% of experienced breeders skipped breeding	196 individuals			1993-1994		[15]		

Table II.8 *Age-specific survival rates (II.8a) and fecundity rates (II.8b) of common terns from different populations. Empty cells indicate no available information for this population. Local population trend: -: decreasing. Data type: [a] ring recoveries. References: [1] (Van der Jeugd et al. 2014); [2] Becker and Ludwigs (2004); [3] Becker et al. (2001); [4] Schekkerman et al. (2021); [5] Schekkerman et al. (2017); [6] Stienen et al. (2009), based on reports Griend study area; [7] Becker et al. (1994); [8] JNCC (2020); [9] Becker (1998); [10] van der Winden et al. (2018); [11] van der Winden et al. (2019a); [12] Thorup and Koffijberg (2015); [13] Becker (1998); [14] Walsh et al. (1991); [15] Zintl (1998); [16] Koffijberg et al. (2017); [17] van der Winden et al. (2019b).*

a.

Demographic rate	Mean	n	SD	SE	Study period	Local population trend	Location	Data type	Reference	Data quality	Data representativeness
Juvenile survival	0.685 from fledging to following spring	5743 ringed individuals			1991-2010	- (since 2000)	Wadden Sea	[a]	[1]	5	6
Immature survival	0.646 during second year	5743 ringed individuals			1991-2010	- (since 2000)	Wadden Sea	[a]	[1]	5	6
	0.47 survival in first 2 years after fledging						Germany		[2]; [3]	3	2
	0.70 survival in first 2 years after fledging		95% CI: 0.658-0.733	0.019	1990-2019		Dutch/Belgian Delta	[a]	[4]	6	6
cont. next page	0.47 survival in first 2 years after fledging			0.17	2010-2019		Dutch-Belgian Delta	[a]	[4]	6	6
Adult survival	0.85 survival during the third year						Germany		[2]; [3]	3	2

Demographic rate	Mean	n	SD	SE	Study period	Local population trend	Location	Data type	Reference	Data quality	Data representativeness
	0.885, from 3rd calendar year onwards	5743 ringed individuals			1991-2010	- (since 2000)	Wadden Sea	[a]	[1]	5	6
	0.93		95% CI: 0.919-0.941	0.006	1990-2019	-	Dutch/Belgian Delta	[a]	[4]	6	6
	0.96		95% CI: 0.851-0.991	0.029	2010-2019	-	Dutch/Belgian Delta	[a]	[4]	6	6
	0.9						Germany		[2]; [3]	3	2

b.

Demographic rate, location	Mean (fledg/bp, unless otherwise stated)	n	SD	SE	Study period	Local pop. Trend	Reference	Data quality	Data representation
Delta area (NL + BE), coastal	0.60	501 site-year combinations			1994-2016	variable, overall stable	[4]	5	6
Wadden Sea, Netherlands	0.42	12 yr	0.26		2005-2016	-	[16]	6	6
Delta, Netherlands	0.39	10 yr	0.22		2010-2019	-	[4]	6	6
De Kreupel, Netherlands	0.34	13 yr	0.24		2005-2017	-	[17]	6	6
Dutch Wadden Sea, coastal	0.33	10 yr	0.0-0.8		1991-2010	- (since 2000)	[1]	5	6
Germany	1.30	11 yr					[3]	3	2
Griend (NL), island	0.41 (min-max 0.00-1.00)	16 yr	0.35		1992-2007	variable, overall stable	[5]	6	5
Age of first breeding	*3 (first breeding in 4th calendar year)*								
Incidence of missed breeding	*9% floaters among experienced breeders*								

Table II.9 *Age-specific survival rates (II.9a) and fecundity rates (II.9b) of black terns from different populations. Empty cells indicate no available information for this population. Data type: [a] fit to observed population trend given measured fecundity data; Monte Carlo estimation. References: [1] van der Winden and van Horssen (2008); [2] Tinbergen & Heemskerk (2016); [3] Van der Winden (2008); [4] van der Winden (2005); [5] Golawski and Mroz (2019), [6] van der Winden & van Horssen, unpublished data. Data quality and representativeness are assessed based on the criteria described in Chapter 2.*

a.

Demographic rate	Mean	n	SD	SE	Study period	Local population trend	Location	Data type	Reference	Data quality	Data representativeness
Juvenile survival [year 1, 2, 3; indirect estimate]	0.595				Based on population sizes 1993-1999	=	Netherlands	[a]	[1]	3	6
Immature survival [same as above] [year 1, 2, 3; indirect estimate]	0.595				Based on population sizes 1993-1999	=	Netherlands	[a]	[1]	3	6
Adult survival [>= year 4; indirect estimate]	0.849				Based on population sizes 1993-1999	=	Netherlands	[a]	[1]	3	6
	0.843			0.032	1999-2018		Netherlands	[a]	[6]	6	6

b.

Demographic rate, location	Mean (fledg/bp, unless otherwise stated)	n	SD	SE	Study period	Local pop. trend	Reference	Data quality	Data representativeness
Netherlands	0.99	7 colonies	0.2		2010-2015	=	[2]	6	6
Netherlands	0.66 (overall, also habitat-specific estimates)	721 bp	0.55		1993-1999	- or =, depending on habitat type	[1]	5	4
Netherlands	1.2 (in 2006, good year)	83 bp			2006	"= (+) stable, slight recovery	[3]	2	5
Netherlands	0.9 (before 1999 lower: <0.4 in 1995 and 1996)				1996-2003	=	[4]	2	5
Poland	Hatching success: 0.667	153 nests			2007, 2009-2010, 2016		[5]	3	3
Age of first breeding	3						[1]		
Incidence of missed breeding									

Table II.10 Age-specific survival rates (II.10a) and fecundity rates (II.10b) of Bewick's swan from different populations. Empty cells indicate no available information for this population. Data type: [a] neck collar resightings (alive and dead); Cormack-Jolly-Seber Mark Recapture; [b] leg ring and neck collar resightings. References: [1a] neck collar resightings, Wood et al. (2018); [1b] leg ring resightings, Wood et al. (2018); [2] Beer and Ogilvie (1972); [3] Nichols et al. (1992); [4] Wood et al. (2016); [5] Evans (1979); [6] Rees (2006); [7] Nuijten et al. (2020). Data quality and representativeness are assessed based on the criteria described in Chapter 2.

a.

Demographic rate	Mean	n	SD	SE	Study period	Local population trend	Location	Data type	Reference	Data quality	Data representativeness
Juvenile survival	♂ 0.72 ♀ 0.73	94 neck collars (1988-2014)		0.04	1970-2015; used data from 2000-2015	- [increase until 1995, then decline]	wintering grounds NW Europe	[a]	[1a]	6	6
	♂ 0.77 ♀ 0.78	3900 rings (1970-2014)		0.04	1970-2015; used data from 2000-2015	- [increase until 1995, then decline]	wintering grounds NW Europe	[a]	[1b]	6	6
	0.908	909		0.891-0.926 95% CI	1960-2015	- [increase until 1995, then decline]	wintering grounds NW Europe	[a]	[7]	6	6
Yearlings	0.936	562		0.917-0.954 95% CI	1960-2015	- [increase until 1995, then decline]	wintering grounds NW Europe	[a]	[7]	6	6
Immature survival *[cont. next page]*	♂ 0.79 ♀ 0.8	35 neck collars (1988-2014)		0.04	1970-2015; used data from 2000-2015	- [increase until 1995, then decline]	wintering grounds NW Europe	[a]	[1a]	6	6

Demographic rate	Mean	n	SD	SE	Study period	Local population trend	Location	Data type	Reference	Data quality	Data representativeness
[continued]	♂ 0.83 ♀ 0.83	568 leg rings (1970-2014)		0.04	1970-2015; used data from 2000-2015	- [increase until 1995, then decline]	wintering grounds NW Europe	[a]	[1b]	6	6
Adult survival	♂ 0.77 ♀ 0.79	475 neck collars (1988-2014)		0.02	1970-2015; used data from 2000-2015	- [increase until 1995, then decline]	wintering grounds NW Europe	[a]	[1a]	6	6
	♂ 0.81 ♀ 0.83	1890 ringed adults (1970-2014)		0.02	1970-2015; used data from 2000-2015	- [increase until 1995, then decline]	wintering grounds NW Europe	[a]	[1b]	6	6
	0.85	-							[2]	2	2
	0.873	2265		0.869-0.877 95% CI	1960-2015	- [increase until 1995, then decline]	wintering grounds NW Europe	[a]	[7]	6	6
	0.92	5963 marked individuals		0.035	1966-1990	+	USA (North Carolina, Alaska)	[b]	[3]	6	0

b.

Demographic rate, location	**Mean (fledg/bp, unless otherwise stated)**	**n**	**SD**	**SE**	**Study period**	**Local pop. trend**	**Reference**	**Data quality**	**Data representativeness**
NW Europe	2.05 juv/bp (wintering grounds)		0.4		1988-2013	-	[4]	6	6
UK	2.1 juv/bp (wintering grounds)				1963-1978		[5]	4	3
NW Europe	0.378	fem. fledgling/female		0.184-0.194 95 % CI	1960-2015	- [increase until 1995, then decline]	Nuijten *et al.* 2020	6	6
NW Europe	0.29	fem. fledgling/female		0.184-0.194 95 % CI	1995-2015	- [increase until 1995, then decline]	Nuijten *et al.* 2020	6	6
NW Europe	1.78 juv/bp (wintering grounds)	ca. 27.500	1.6-1.9 95% CI		1995-2015	- [increase until 1995, then decline]	Nuijten *et al.* 2020	6	6
Age of first breeding	*2 - 4 yrs*						*[5]*		
	♂ 3.18 yrs ♀ 3.05 yrs		*♂ 1.35 ♀ 1.12*				*[6]*		
Incidence of missed breeding									

Table II.11 Age-specific survival rates (II.11a) and fecundity rates (II.6b) of dark-bellied brent goose from different populations. Empty cells indicate no available information for this population. Data type: [a] ring recoveries; [b] estimated based on wintering population sizes. References: [1] Sedinger et al. (2007); [2] Robinson (2005); [3] Ebbinge et al. (2001); [4] Boyd (1962); [5] Balmer & Peach (1997); [6] Sedinger et al. (2002); [7] Cramp and Simmons (1983); [8] Desholm (2009); [9] Nolet et al. (2013); [10] Nicolai (2003), Chapter 2; [11] WWT monitoring programme; https://monitoring.wwt.org.uk/our-work/goose-swan-monitoring-programme/species-accounts/dark-bellied-brent-goose; [12] (Sedinger et al. 2006); [13] Cleasby et al. (2017). Data quality and representativeness are assessed based on the criteria described in Chapter 2.

a.

Demographic rate	Mean	n	SD	SE	Study period	Local population trend	Location	Data type	Reference	Data quality	Data representativeness
Juvenile survival	0.51, black brent	>17,000 ringed; >500 recovered		0.05	1986-2002	-	Alaska	[a]	[1]	2	2
	"no data"								[2]	0	2
	0.318			95%-CI: 0.216-04.22	2007		Breeding: Canada, Wintering: Ireland	[a]	[13]	2	2
Immature survival	0.83 from age 1 onwards)	>600 recovered (from age 1 onwards)		0.01	1986-2002	-	Alaska	[a]	[1]	6	2
	0.86 (survival on winter grounds)		0.05		1988-1998	<1990: + >1990: =	Several areas	[b]	[3]	6	4
	0.86 (first winter to breeding age (2))						UK		[4], [5]	0	3

Demographic rate	Mean	n	SD	SE	Study period	Local population trend	Location	Data type	Reference	Data quality	Data representativeness
continued											
Adult survival	0.83	since 1990 >600 recovered (from age 1		0.01	1986-2002	-	Alaska	[a]	[1]	6	2
	0.86 (from 1988-1998)		0.05		1988-1998	+	Several areas	[b]	[3]	6	4
	0.9	210 unique individuals		0.036	1991-1996	=	Individuals from Arctic	[a]	[2], [6]	4	2
	0.85								[7], [8]	1	2
	0.895/0.893 (female/male specific)	3213 individuals		95%-CI: 0.866/0.873 – 0.923/0.917	2003-2014		Ireland	[a]	[13]	6	3

b.

Demographic rate, location	Mean (fledg/bp, unless otherwise stated)	n	SD	SE	Study period	Local pop. trend	Reference	Data quality	Data representativeness
	0.21 1-year old individuals per adult	Based on counts on wintering grounds, 26 years	0.19		1990-2016	+, then -	[9]	5	6
Alaska	1.43 goslings per brood	699 goslings, 459 broods; several locations	0.26		1999-2000		[10]	4	2
Several areas	Average family size since 1988: 2.645; is nr of offspring per family in winter	Note: entire period is 1955-1998			used data from 1988-1998		[3]	5	5
UK	2.25 young per successful brood				2010-2017		[11]	3	5
	1.3						[7], [8]	0	2
Ireland	Number of juveniles per adult female in wintering area: 0.107			CI 0.057-0.279	2003-2014		[13]	6	3
Age of first breeding	*2*						*[12]*		
	2						*[2]*		
Incidence of missed breeding	*[Not applicable, incorporated in fecundity measure]*								

Table II.12 Age-specific survival rates (II.12a) and fecundity rates (II.12b) of shelducks from different populations. Empty cells indicate no available information for this population. Data type: [a] Observations, number of ducklings vs number of fledglings; [b] ringing, combined with identification using paint; [c] colour rings. References: [1] Patterson (1983); [2] Robinson (2005); [3] Pienkowski & Evans (1982); [4] Lensink (2001). Data quality and representativeness are assessed based on the criteria described in Chapter 2.

a.

Demographic rate	Mean	n	SD	SE	Study period	Local population trend	Location	Data type	Reference	Data quality	Data representativeness
Duckling survival up to fledging	isolated: 0.167; colonies: 0.73	colony: 482 ducklings; isolated: 160 ducklings			1977-1979	=	Scotland, Firth of Forth	[a]	[1]	1	3
Juvenile survival	0.166 to age 2				1962-1979		Scotland, Aberdeenshire	[b]	[2], [3]	3	3
Immature survival	-- (0.166 to age 2)				1962-1979		Scotland, Aberdeenshire	[b]	[2], [3]	3	3
Adult survival	0.886 (M 0.909, F 0.880)				1962-1979		Scotland, Aberdeenshire	[b]	[2], [3]	2	3
	Successful breeders (colony): 0.893; Summer residents: 0.826	187 successful breeders; 483 summer residents			1971-1978	=	Scotland, Firth of Forth	[c]	[1]	2	3

b.

Demographic rate, location	Mean (fledg/bp, unless otherwise stated)	n	SD	SE	Study period	Local pop. trend	Reference	Data quality	Data representativeness
NL, river Waal	0.7-1.1 over all pairs; 2.8-4.6 per successful breeding pair	276 breeding attempts (successful + unsuccessful)			1971-1975; 1992-2001	+	[4]	5	5
Scotland, Firth of Forth	Colony: 0.207 Isolated sites: 0.943	colony: 65; isolated 24 (over 3 years)	colony 0.1 isolated 0.19		1976-1979	=	[1]	3	3
Age of first breeding	2						[2], [3]		
Incidence of missed breeding									

Table II.13 Age-specific survival rates (II.13a) and fecundity rates (II.13b) of curlews from different populations. Empty cells indicate no available information for this population. Data type: [a] review; [b] dead recoveries, Lack method; [c] ringing recoveries, Lack method, amended by Haldane; [d] live resightings. References: [1] Roodbergen et al. (2012); [2] Glutz von Blotzheim (1984); [3] Bainbridge and Minton (1978); [4] Kipp (1982); [5] Berg (1991); [6] (Grant et al. 1999); [7] (Evans & Pienkowski 1984); [8] Robinson (2005). Data quality and representativeness are assessed based on the criteria described in Chapter 2.

a.

Demographic rate	**Mean**	**n**	**SD**	**SE**	**Study period**	**Local population trend**	**Location**	**Data type**	**Reference**	**Data quality**	**Data representativeness**
Chick survival (up to fledging)	0.49	3 studies		6.08	[review]; between 1996-2006	[review]	[review]	[a]	[1]	6	4
Juvenile survival	0.34				1969-1974		NL	[b]	[2]	1	3
	0.47 (from fledging to 1yr old)	153 recoveries			1909-1975		UK	[c]	[3]	3	2
	0.52	2.458 ringing records		0.033						6	6
	0.559			0.238						6	6
Immature survival *(cont. next page)*	0.63 (2nd cy)	50 recoveries			1909-1975		UK	[c]	[3]	3	2
	0.8	2.458 ringing records		0.034						6	6

Demographic rate	Mean	n	SD	SE	Study period	Local population trend	Location	Data type	Reference	Data quality	Data representativeness
(continued)	0.742			0.238						6	6
Adult survival	0.885				1973-1980	-	Germany	[d]	[4]	2	4
	0.82				1985-1992	+	Sweden	[d	[5]	2	2
	0.72				1969-1974		Netherlands	[b]	[2]	2	3
	0.82-0.88				[meta-analysis]	variable	variable	[a]	[6]	3	2
	0.74 (>2nd cy)	74 recoveries		0.025	1909-1975		UK	[c]	[3]	3	2
	0.736 ± 0.025	66 years					UK	[b]	[7]	4	2
	0.88	2.458 ringing records		0.009						6	6
	0.925			0.035						6	6
	0.93									6	6

b.

Demographic rate, location	Mean (fledg/bp, unless otherwise stated)	n	SD	SE	Study period	Local pop. trend	Reference	Data quality	Data representativeness
[review]	0.34	based on 250 studies		0.02	1996-2006	[review]	[1]	6	3
Germany	0.3				?, <1982	-	[4]	2	4
Sweden	0.25				?, <1991		[5]	2	3
N-Ireland	0.29 (variation between years: 0.14-0.56)	352 breeding pairs (102 fledglings)	0.17		1993-1995	-	[6]	3	3
Age of first breeding	2 or (more likely) 3						[3]		
	2						[8]		
Incidence of missed breeding									

Table II.14 *Age-specific survival rates (a) and fecundity rates (b) of common starlings. Data type: [a] colour rings; [b] metal rings. Local population trend: -: declining (Boele et al. 2021). References: [1] Versluijs et al. (2016); [2] Schippers et al. (2020); [3] Freeman et al. (2007); [4] Kania & Chyllarecki (unpublished); [5] Heldbjerg et al. (2019); [6] Siriwardena et al. (1998); [7] Rintala and Tiainen (2008); [8] Smith et al. (2012)).*

a.

Demographic rate	Mean	n	SD	SE	Study period	Local pop. trend	Location	Data type	Reference	Data quality	Data representativeness
First year survival	0.102		0.034		1990-2012	-	Netherlands	[a]	[1]; [2]	6	6
	0.339		0.082		data 1985-1999	-	UK	[b]	[3]	6	4
	0.45				unknown	variable / +	Poland		[4]; [5]	2	2
	0.518			0.007	1962-1994	=, followed by -	UK	[b]	[6]		
Adult survival	0.607		0.151		1990-2012	-	Netherlands	[a]	[1]; [2]	6	6
	0.619		0.085		data 1985-1999	-	UK	[b]	[3]	6	4
	0.687			0.004	1962-1994	=, followed by -	UK	[b]	[6]		

b.

Demographic rate, location	Mean (fledg/bp, unless otherwise stated)	n	SD	SE	Study period	Local pop. trend	Reference	Data quality	Data representativeness
Netherlands	4.43 fledglings per successful nest	269 nests	0,075		1990-2012	-	[1]	6	6
Netherlands	3.73 fledglings per breeding pair (incl unsuccessful nests)	269 nests	0,546		1990-2012	-	[2]; based on [1]	6	6
Finland	4.33 chicks of the age of 5 to 15 days per nest	5881 nests	1,24		1995-2005	-	[6]	5	3
UK	3.473 fledglings per breeding attempt		0,353		data 1985-1999	-	[3]	6	4
meta-analysis	1.7 – 4.1 fledglings per brood					-	[7]	3	3
Age of first breeding	*1*								
Incidence of missed breeding	*0%*						*[2]; based on [1]*		
Incidence of second breeding	*In 2010, 2011 and 2012 the frequency of second clutches was 9% (n=143 nests), 5% (n=237 nests) and 4% (n=237 nests), respectively*								

Table II.15 *Age-specific survival rates (a) and fecundity rates (b) of bar-tailed godwit from different populations. Empty cells indicate no available information for this population. Local population trend: stable (sovon.nl). References: [1] Spaans et al. (2011); [2] Piersma et al. (2016); [3] Evans & Pienkowski (1984); [4] Larsen and Moldsvor (1992); [5] Cramp & Simmons (1983).*

a.

Demographic rate	Mean	n	SD	SE	Study period	Local pop. trend	Location	Data type	Reference	Data quality	Data representativeness
Juvenile survival	0.57	in total 1903 individuals marked (juveniles + adults)			2000-2007		stopover sites and wintering grounds: NL, Germany, Mauritania	colour rings	[1]	4	6
Immature survival		-	-	-	-	-	-	-	-	-	-
Adult survival	0.81	in total 1903 individuals marked (juveniles + adults)		0.02	2000-2007	-	stopover sites and wintering grounds: NL, Germany, Mauritania	colour rings	[1]	5	6
	0.88										
	0.855		0.015		2007-2012		Australia		[2]	4	3

b.

Demographic rate, location	Mean (fledg/bp, unless otherwise stated)	n	SD	SE	Study period	Local pop. trend	Reference	Data quality	Data representativeness
Hatching success	72%	53					[4]		
Nest success	73%	15					[4]		
Age of first breeding	*4*								
	2						*[5]*		
Incidence of missed breeding									

Table II.16 *Age-specific survival rates (a) and fecundity rates (b) of red knot from different populations. Data type: [a] colour rings; [b] metal rings. Local population trend: stable / fluctuating (van Roomen et al. 2014). References: [1] Leyrer et al. (2013); [2] Spaans et al. (2011); [3] Brochard et al. (2002); [4] Rakhimberdiev et al. (2015); [5] Cramp and Simmons (1983); [6] Robinson (2005); [7] Piersma et al. (2016); [8] Boyd and Piersma (2001); [9] Atkinson et al. (2003); [10] Meltofte et al. (2008). *: total sample size, over all ages and years.*

a.

Demographic rate	Mean	Subspecies	n	SD	SE	Study period	Local pop. trend	Location	Data type	Reference	Data quality	Data representativeness
Juvenile survival	0.81	canutus	1007 individuals ringed *	[range 0.75–0.86]	0.03	2002-2005	unknown	Mauritania	[a]	[1]	4	3
	0.69	canutus	1007 individuals ringed *	[range 0.61–0.77]	0.04	2006-2009	unknown	Mauritania	[a]	[1]	4	4
	0.79	canutus	1090 individuals ringed *			2002-2008	unknown	Germany	[a]	[2]	4	6
	0.8	islandica	2465 individuals ringed *			2002-2008	unknown	Germany	[a]	[2]	4	6
Adult survival	0.841		1603 adults ringed, 486 adults resighted at least once		0.066	1998-2001		Waddensea		[3]	5	5
	0.85	canutus	1090 individuals ringed *		0.03	2002-2008	unknown	Germany	[a]	[2]	5	6
	0.87	islandica	2465 individuals ringed *		0.01	2002-2008	unknown	Germany	[a]	[2]	5	6

Demographic rate	Mean	Subspecies	n	SD	SE	Study period	Local pop. trend	Location	Data type	Reference	Data quality	Data representativeness
	0.81	islandica	2448 adults ringed		0.01	1998-2013	unknown	Waddensea	[a]	[4]	6	6
	0.715	unknown	unknown	unknown	0.079	unknown	unknown	unknown		[5]; [6]	2	2
	0.808			0,015		2007-2012	-	Australia		[7]	4	1
	0.764		750 individuals resighted			1969-1977	-	UK		[8]	2	2
	0.804		237 individuals resighted			1977-1985	+	UK		[8]	2	4
	0.858		186 individuals resighted			1985-1995	=	UK		[8]	2	2
	0.87		1007 individuals ringed *		0.01	2002-2005	unknown	Mauritania, West Africa	[a]	[1]	4	3
	0.78		1007 individuals ringed *		0.02	2006-2009	unknown	Mauritania, West Africa	[a]	[1]	4	4
	0.88		36,500 individuals ringed *		0.12	1968-1997	variable	UK, the Wash	[b]	[7]	6	3

b.

Demographic rate, location	Mean (fledg/bp, unless otherwise stated)	n	SD	SE	Study period	Local pop. trend	Reference	Data quality	Data representativeness
UK, the Wash	0.25 juveniles per adult from October through March		0.075; range 0.05 - 0.4		1968-1997	variable	[9]	6	3
Greenland, Zackenberg	0.25 fledg/bp	6 broods			1995-2005		[10]	0	0
Age of first breeding	*2*	*[6]*							
	2	*[1]*							
Incidence of missed breeding									

Appendix III Sensitivity analysis of species-specific population models

For each species, we report the results of the sensitivity analysis of the population models. Each panel within the figure presents the sensitivity of individual demographic rates, as indicated in the title of each panel. On the vertical axis, the modelled population growth rate is reported following the changes in the tested parameter. The x-axis, with values varying between 0 and 1, indicates changes in the tested parameter. Note that these values do not necessarily resemble a realistic range. The sensitivity analysis is presented for each stage-specific survival, breeding success (number of fledglings per breeding pair) and probability of floaters. A steeper trend indicates a stronger effect on the population growth rate by a modification of the parameter.

The results show that for all species except common starling, a change in adult survival has the strongest impact on the outcome of the population models. In case of common starling, the sensitivity of the population model to a change in first-year survival is slightly higher. For most species, the impact of a change in fecundity (breeding success and probability of floaters) is smaller than of a change in survival rates. In case of Bewick's swan, the sensitivity of the population model for a change in breeding success is relatively high. This gives some insight in the expected effect of conservation effort to improve these demographic rates. However, note that changing certain parameters may be more difficult to changing others, depending on the species ecology and threats.

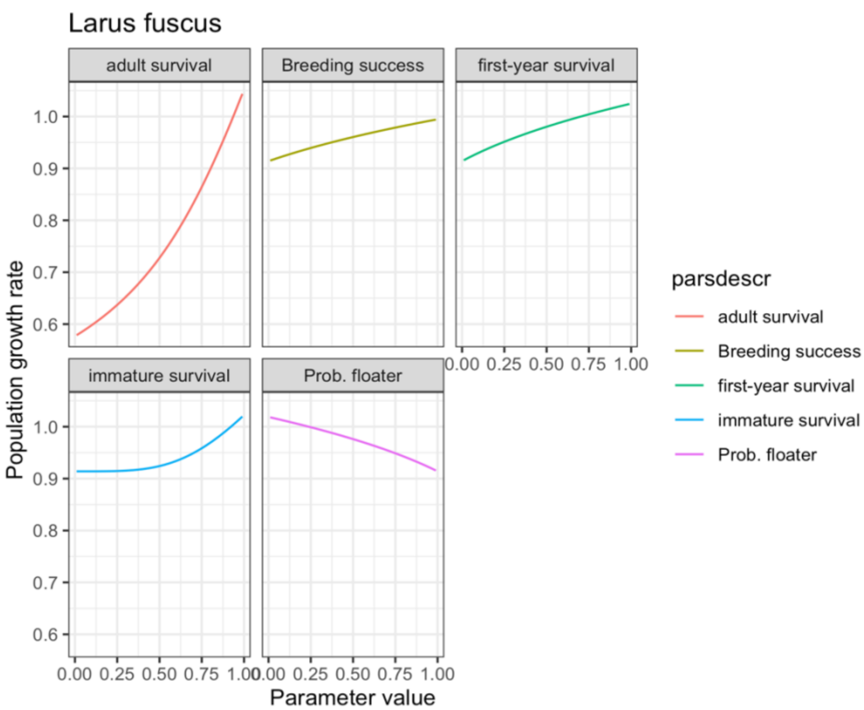

Figure 6.1 *Results of the sensitivity analysis for lesser black-backed gull (*Larus fuscus*). A steeper trend indicates a stronger effect on the population growth rate by a modification of the parameter.*

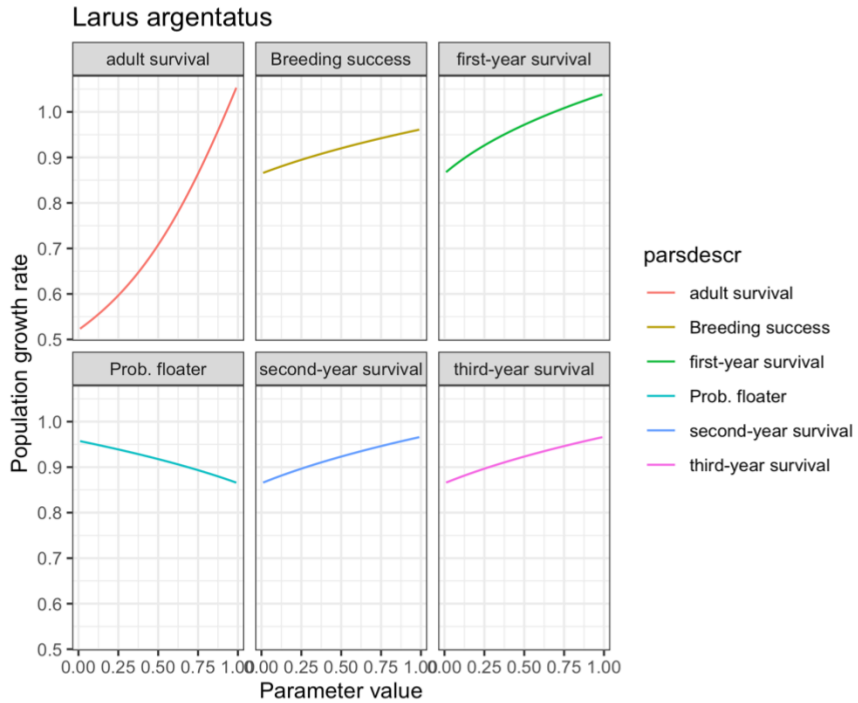

Figure 6.2 *Results of the sensitivity analysis for herring gull (Larus argentatus). A steeper trend indicates a stronger effect on the population growth rate by a modification of the parameter.*

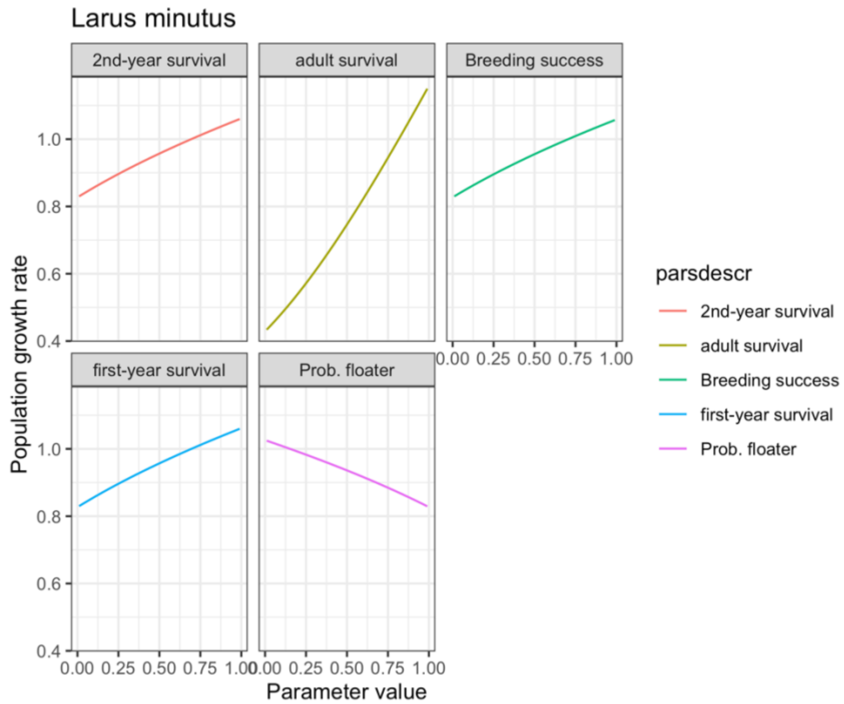

Figure 6.3 *Results of the sensitivity analysis for the little gull (*Hydrocoloeus minutus*). A steeper trend indicates a stronger effect on the population growth rate by a modification of the parameter.*

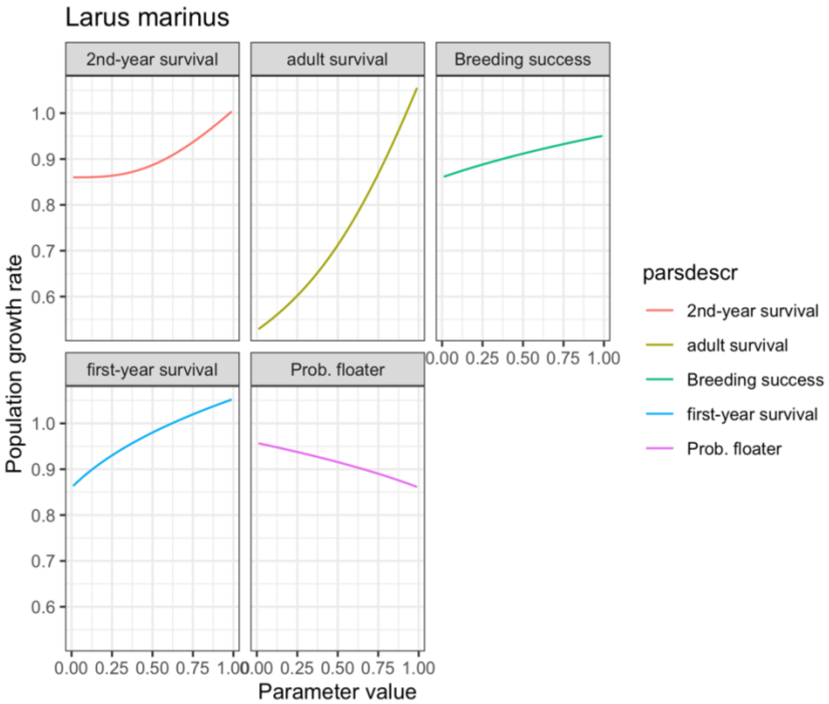

Figure 6.4 *Results of the sensitivity analysis for the great black-backed gull (*Larus marinus*). A steeper trend indicates a stronger effect on the population growth rate by a modification of the parameter.*

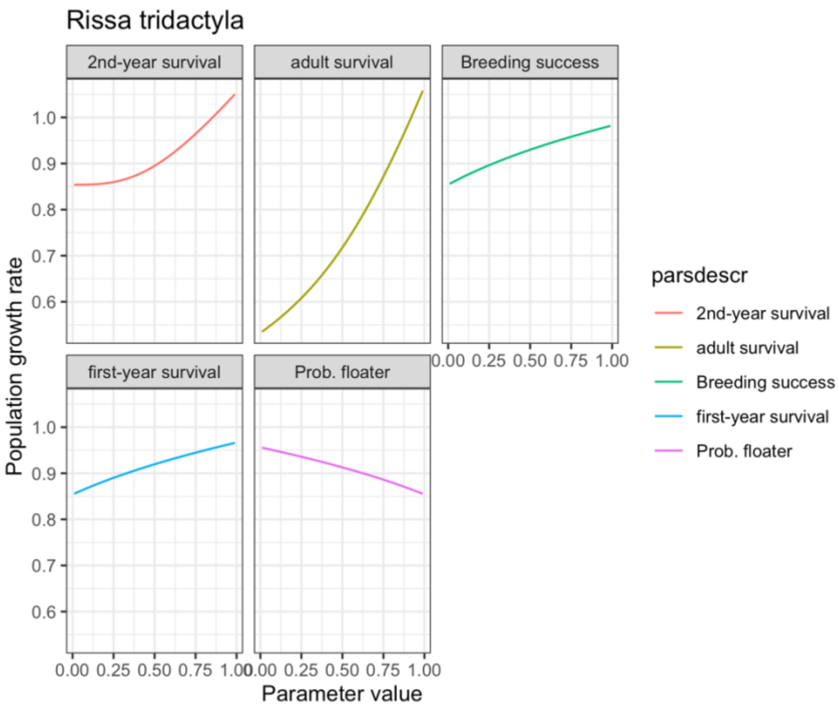

Figure 6.5 *Results of the sensitivity analysis for black-legged kittiwake (*Rissa tridactyla*). A steeper trend indicates a stronger effect on the population growth rate by a modification of the parameter.*

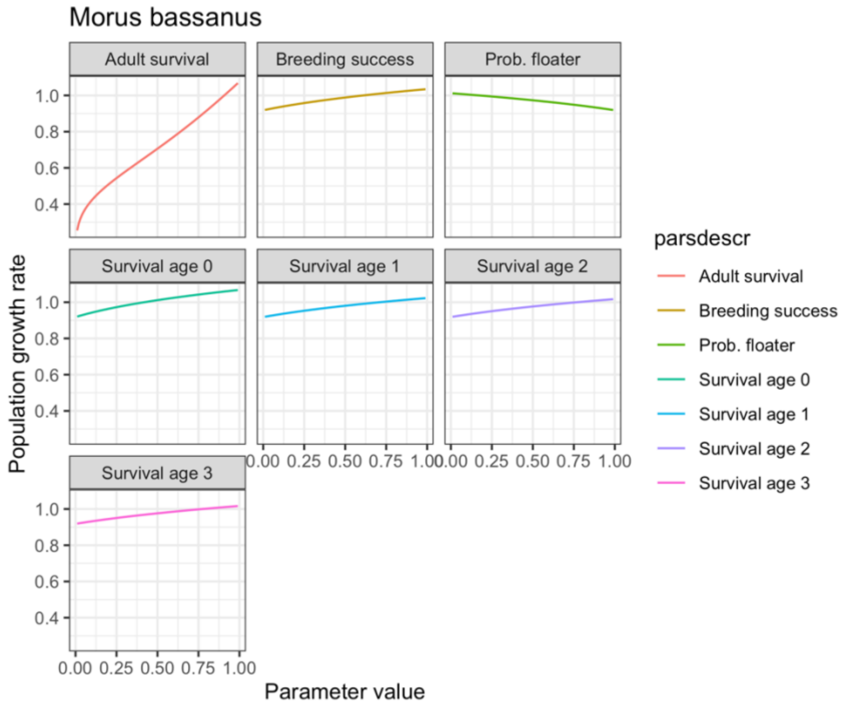

Figure 6.6 *Results of the sensitivity analysis for the northern gannet (*Morus bassanus*). A steeper trend indicates a stronger effect on the population growth rate by a modification of the parameter.*

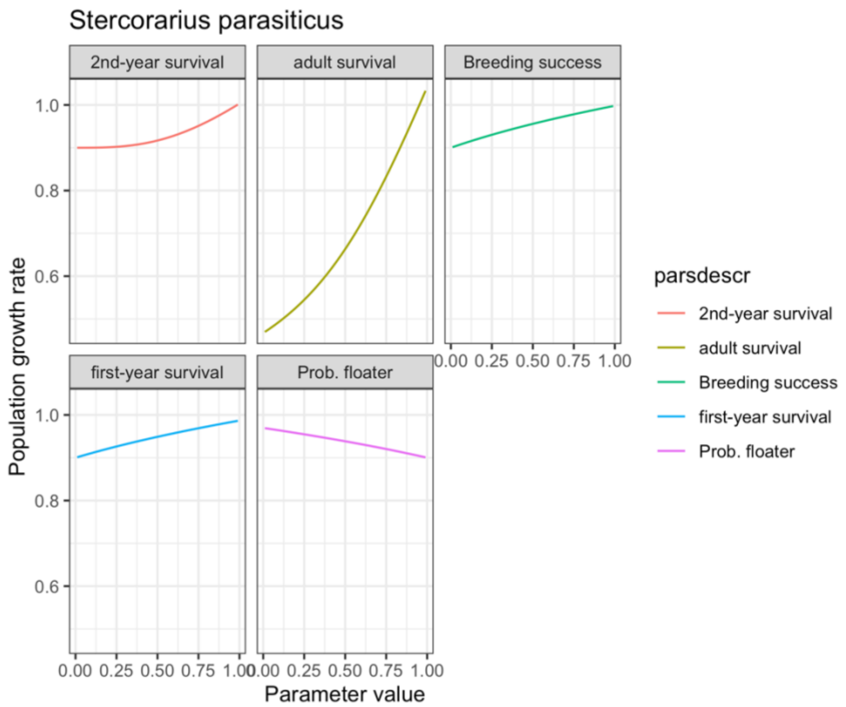

Figure 6.7 *Results of the sensitivity analysis for the Arctic skua* (Stercorarius parasiticus)*. A steeper trend indicates a stronger effect on the population growth rate by a modification of the parameter.*

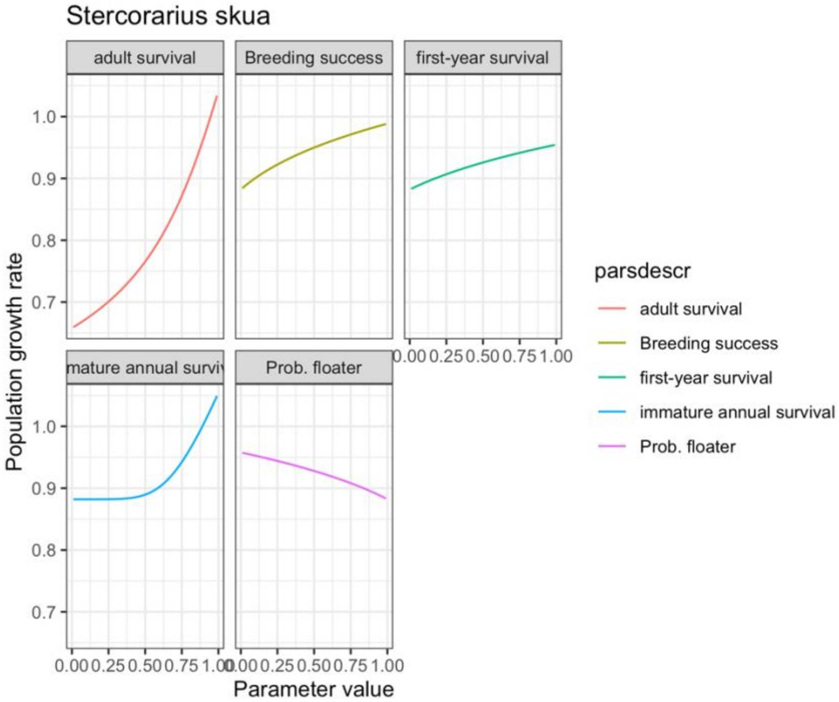

Figure 5.14 *Results of the sensitivity analysis for the great skua* (Stercorarius skua). *A steeper trend indicates a stronger effect on the population growth rate by a modification of the parameter.*

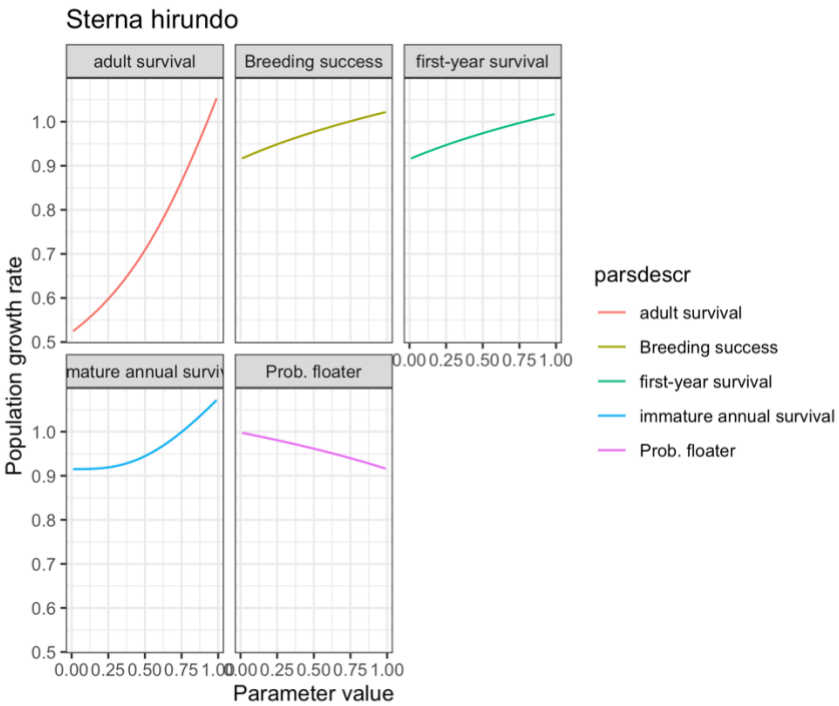

Figure 5.16 *Results of the sensitivity analysis for the common tern* (Sterna hirundo)*. A steeper trend indicates a stronger effect on the population growth rate by a modification of the parameter.*

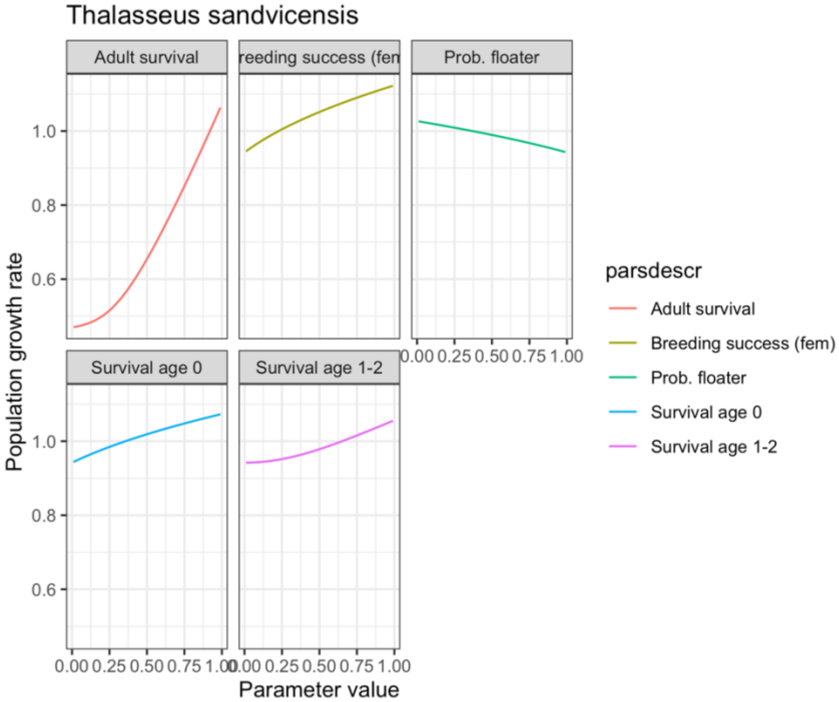

Figure 6.8 *Results of the sensitivity analysis for the Bewick's swan (*Cygnus (columbianus) bewickii*). A steeper trend indicates a stronger effect on the population growth rate by a modification of the parameter.*

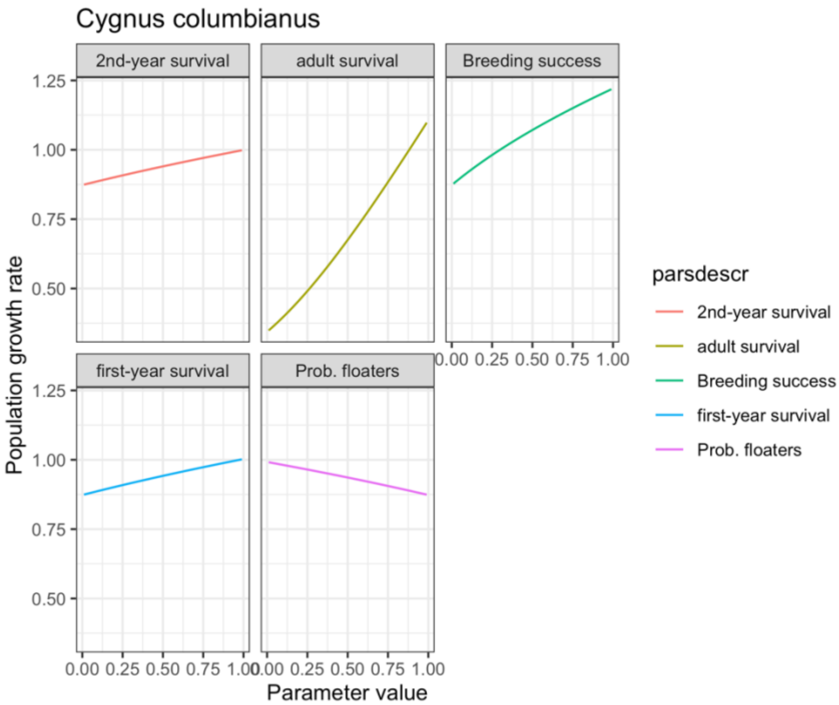

Figure 6.9 *Results of the sensitivity analysis for the Bewick's swan (*Cygnus (columbianus) bewickii*). A steeper trend indicates a stronger effect on the population growth rate by a modification of the parameter.*

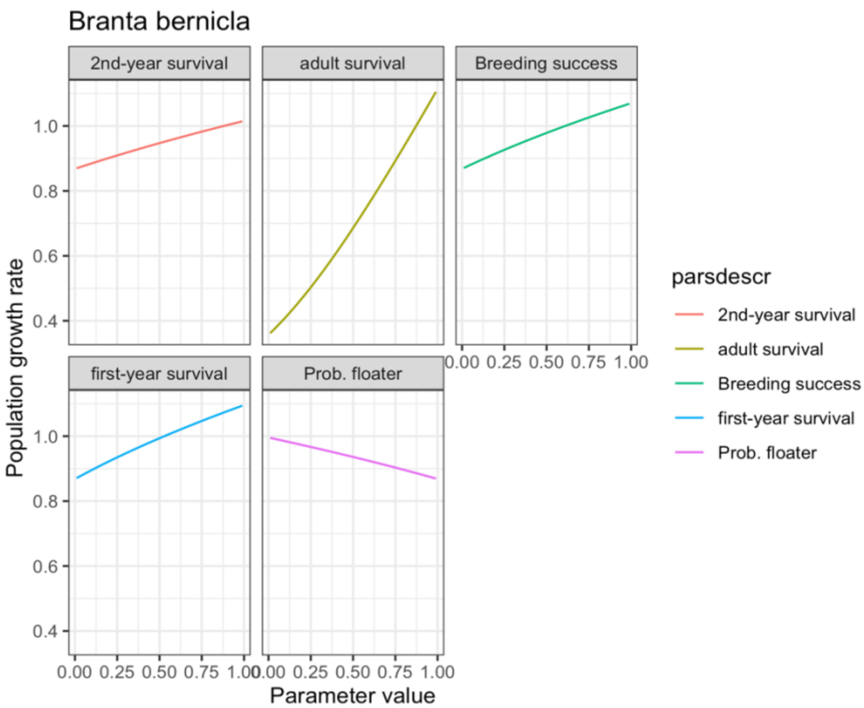

Figure 6.10 *Results of the sensitivity analysis for the brent goose (*Branta bernicla*). A steeper trend indicates a stronger effect on the population growth rate by a modification of the parameter.*

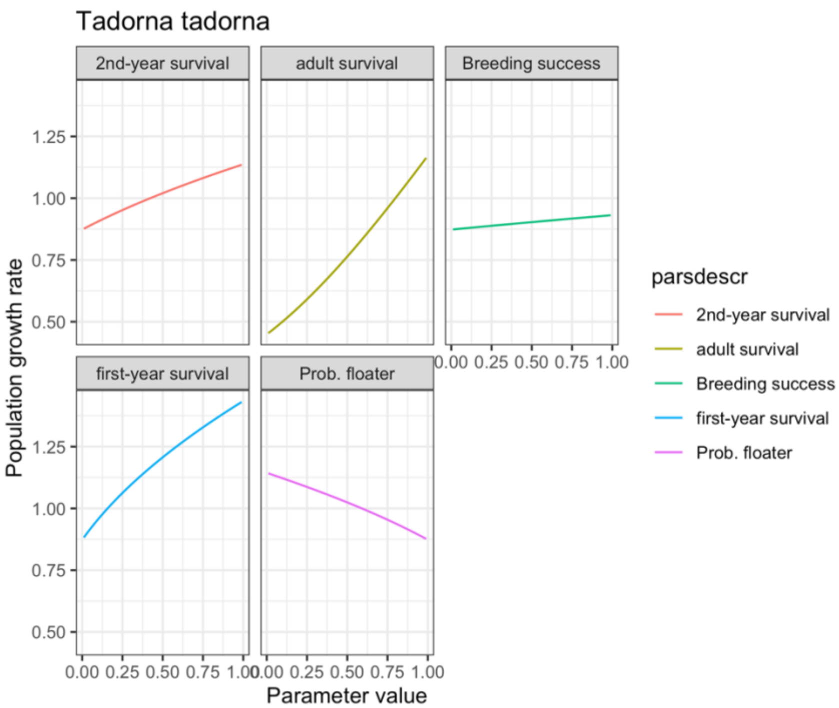

Figure 6.11 *Results of the sensitivity analysis for the common shelduck* (Tadorna tadorna)*. A steeper trend indicates a stronger effect on the population growth rate by a modification of the parameter.*

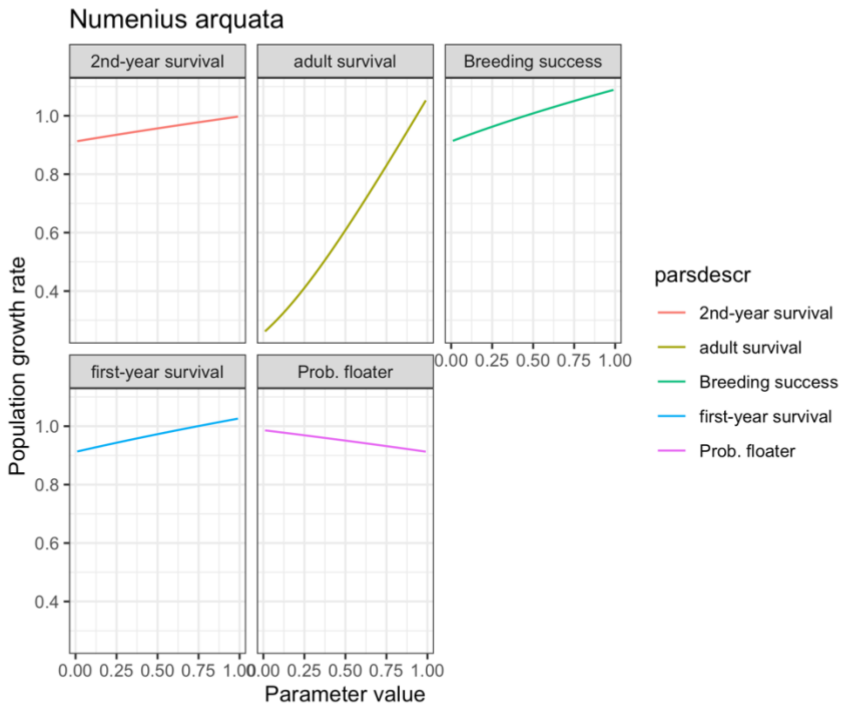

Figure 6.12 *Results of the sensitivity analysis for the Eurasian curlew* (Numenius arquata)*. A steeper trend indicates a stronger effect on the population growth rate by a modification of the parameter.*

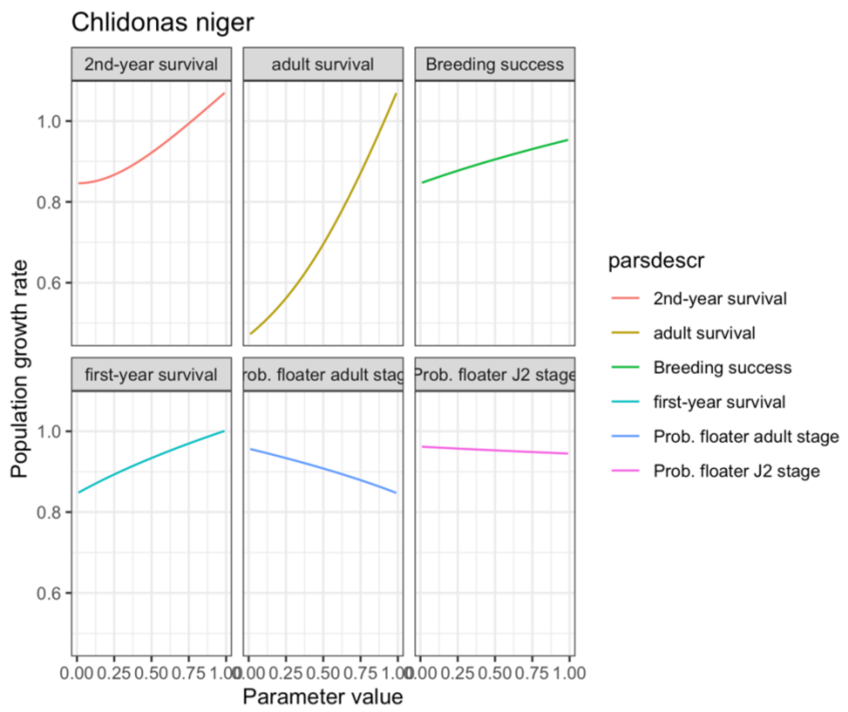

Figure 6.13 *Results of the sensitivity analysis the black tern (*Chlidonias niger*). A steeper trend indicates a stronger effect on the population growth rate by a modification of the parameter.*

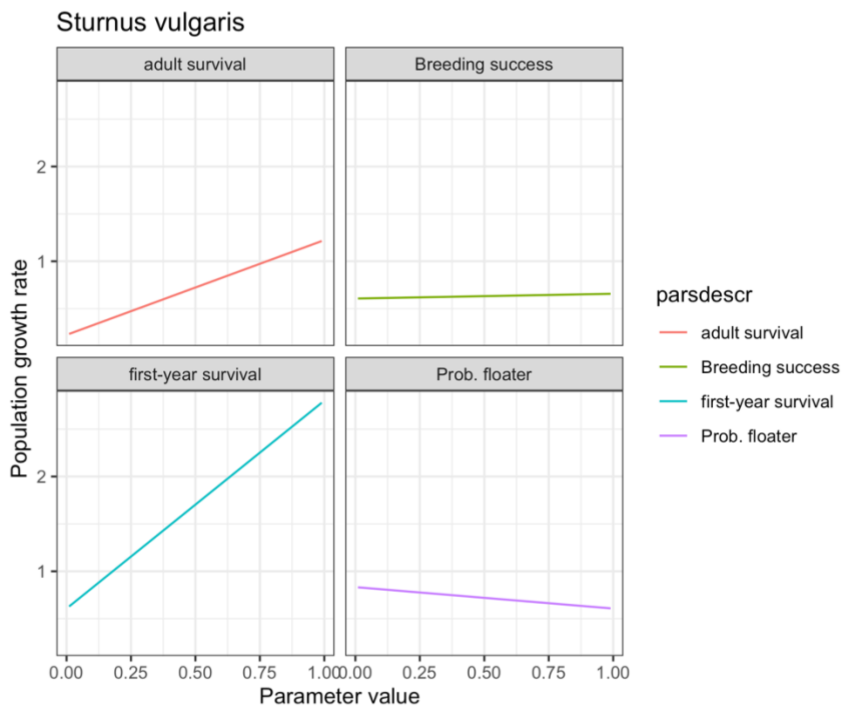

Figure 6.14 *Results of the sensitivity analysis for the common starling* (Sturnus vulgaris). *A steeper trend indicates a stronger effect on the population growth rate by a modification of the parameter.*

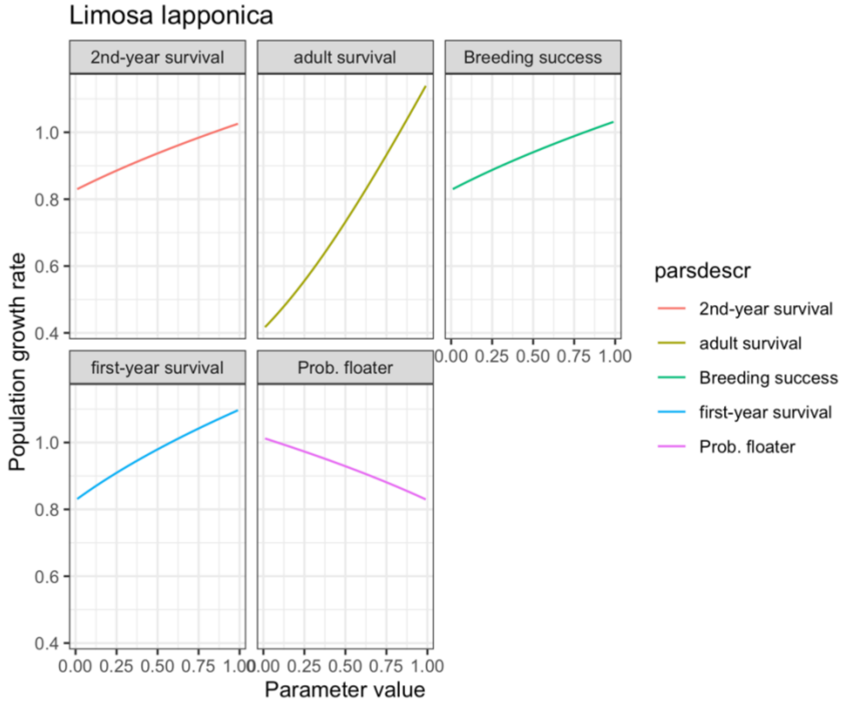

Figure 6.15 *Results of the sensitivity analysis for the bar-tailed godwit (*Limosa lapponica*). A steeper trend indicates a stronger effect on the population growth rate by a modification of the parameter.*

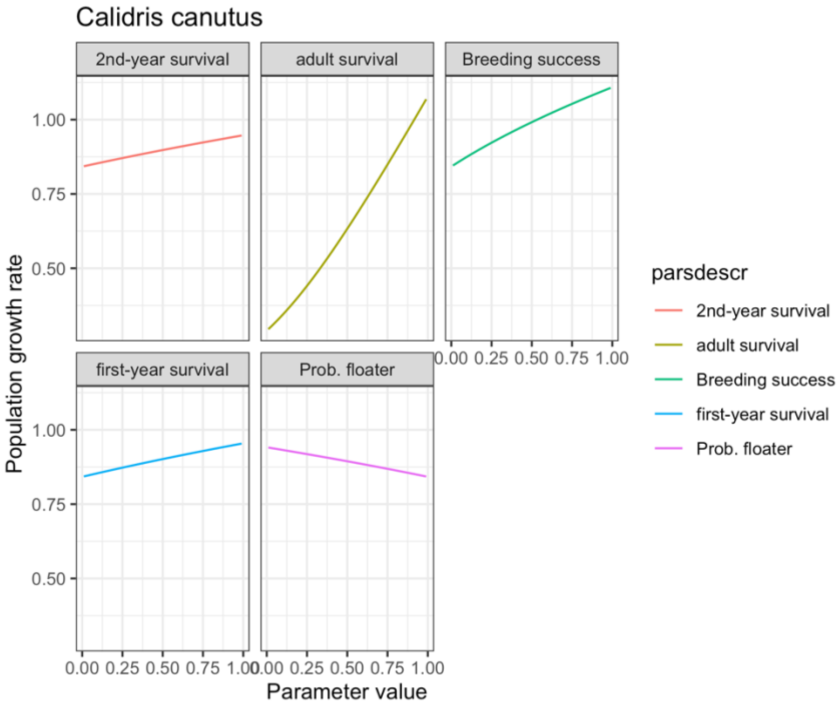

Figure 6.16 *Results of the sensitivity analysis for the red knot (*Calidris canutus*). A steeper trend indicates a stronger effect on the population growth rate by a modification of the parameter.*

Appendix IV Collision victims per wind farm

IV.1. Seabirds – international densities – absolute numbers

Wind farm	Kittiwake	Little gull	Great skua	Great B-b gull	Sandwich tern	Northern gannet	Arctic skua	Lesser b-b gull	Common tern	Herring gull
Thornton Bank phase I	0	1	0	2	0	4	0	1	0	1
Northwind	32	7	0	38	4	184	0	15	1	10
Belwind	8	1	0	19	0	80	0	6	0	3
Norther	8	7	0	21	2	55	0	8	2	7
Rentel	4	2	0	17	0	42	0	5	0	5
Seamade (SeaStar)	4	1	0	14	0	38	0	4	0	3
Seamade (Mermaid)	4	1	0	12	0	37	0	3	0	2
Nobelwind	11	1	0	21	0	90	0	7	0	4
Thornton Bank phase II	2	2	0	10	0	22	0	3	0	3
Thornton Bank phase III	1	1	0	6	0	11	0	2	0	1
Northwester 2	4	1	0	11	0	32	0	3	0	2
Pr. Elisabeth - Noordhinder Noord - 2023	9	1	1	29	0	73	0	7	0	5
Pr. Elisabeth - Fairybank Nordhinder Zuid	12	2	1	50	1	128	0	12	1	9
Alpha Ventus	1	0	0	1	0	6	0	0	0	0
DanTysk	13	0	0	15	0	51	0	2	2	5
Borkum Riffgrund 3	10	2	0	21	1	58	0	4	3	4
Borkum Riffgrund 1	8	1	0	11	1	66	0	3	0	4
Amrumbank West	23	1	0	15	1	64	0	6	0	9
Nordsee Ost	12	0	0	11	0	42	0	3	0	6
Meerwind Süd Ost	19	0	0	20	0	77	0	4	0	9
Butendiek	6	1	0	10	0	42	0	4	0	7
Global Tech I	16	1	0	17	0	99	0	2	0	2
Gode Wind 3	3	0	0	4	0	17	0	1	0	2
Trianel Windpark Borkum II	3	0	0	5	0	23	0	1	0	1
Hohe See	10	1	0	19	0	65	0	2	0	2
Sandbank	16	0	0	15	0	50	0	2	0	3
Gode Wind 1 and 2	6	0	0	13	0	44	0	4	1	8
EnBW He Dreiht	11	0	0	24	0	53	0	3	0	3
Nordergründe	3	1	0	4	2	11	0	1	1	2
Riffgat	2	1	0	5	1	6	0	2	1	5
BARD Offshore 1	11	1	0	24	0	44	0	3	0	3
Deutsche Bucht	4	0	0	11	0	15	0	1	0	1
Merkur	6	0	0	9	0	43	0	3	0	3
Trianel Windpark Borkum I	3	0	0	5	0	22	0	1	0	1
Nordsee One	5	1	0	8	0	43	0	2	0	3
N-3.5	3	0	0	6	0	25	0	2	0	2
N-3.6	3	0	0	6	0	28	0	2	0	3

Wind farm	Kittiwake	Little gull	Great skua	Great B-b gull	Sandwich tern	Northern gannet	Arctic skua	Lesser b-b gull	Common tern	Herring gull
N-3.7	2	0	0	3	0	10	0	1	0	2
N-3.8	4	0	0	6	0	26	0	2	0	3
N-6.6	4	1	0	15	0	27	0	2	0	2
N-6.7	4	0	0	9	0	10	0	1	0	1
N-7.2	8	1	0	20	0	54	0	3	0	3
N-8.4	6	0	0	8	0	27	0	1	0	1
Borkum Riffgrund 2	7	1	0	10	1	47	0	3	0	3
Kaskasi	17	0	0	10	0	39	0	3	0	6
Veja Mate	8	1	0	22	0	35	0	3	0	3
Albatros	3	0	0	5	0	14	0	0	0	1
N-9.1	17	0	0	35	0	29	0	3	0	4
N-9.2	23	0	0	27	0	35	0	3	0	4
N-10.1	13	0	0	14	0	39	0	2	0	3
N-11-1	13	0	0	19	0	65	0	3	0	3
N-12.1	14	0	0	23	0	65	0	3	0	4
N-10.2	11	0	0	11	0	25	0	1	0	2
N-12.2	14	0	0	23	0	65	0	3	0	4
N-12.3	14	0	0	23	0	65	0	3	0	4
N-12.4	14	0	0	23	0	65	0	3	0	4
N-11-2	13	0	0	19	0	65	0	3	0	3
N-13-2	18	0	0	32	0	65	0	5	0	7
N-13-3	18	0	0	32	0	65	0	5	0	7
N-9.3	17	0	0	37	0	27	0	3	0	4
N-9.4	21	0	0	28	0	32	0	3	0	4
Horns Rev 1	5	0	0	11	0	7	0	3	3	5
Nordsøen - Tender 1	1	0	0	8	0	11	0	2	0	1
Nordsøen - Tender 3	2	0	0	6	0	20	0	1	0	3
Nordsøen - Tender 2	1	0	0	5	0	15	0	1	0	1
Nordsøen - Tender 4	1	0	0	6	0	7	0	2	0	1
Nordsøen - Tender 5	2	0	0	6	0	20	0	1	0	2
Horns Rev 2	17	2	0	12	0	33	0	4	8	4
Horns Rev 3	5	1	0	8	0	16	0	3	1	3
Nordsøen - Tender 6	1	0	0	6	0	11	0	0	0	2
Nordsøen - Tender 7	2	0	0	4	0	16	0	0	0	5
Nordsøen - Tender 8	2	0	0	5	0	30	0	0	0	3
Nordsøen - Tender 9	3	0	0	9	0	21	0	0	0	2
Nordsøen - Tender 10	4	0	0	12	0	28	0	3	0	5
Thor - 2020 Tender	1	0	1	14	0	25	0	1	0	5
Vesterhav Nord Syd	0	0	0	9	0	11	0	1	0	4
Dudgeon	3	0	0	2	0	7	0	0	0	0
Greater Gabbard	7	0	0	17	0	58	0	10	0	3

Wind farm	Kittiwake	Little gull	Great skua	Great B-b gull	Sandwich tern	Northern gannet	Arctic skua	Lesser b-b gull	Common tern	Herring gull
Gunfleet Sands	5	0	0	6	1	20	0	3	0	4
Dogger Bank B	8	0	0	5	0	60	0	0	1	0
Humber Gateway	16	1	0	10	1	106	0	2	16	1
Inner Dowsing	4	0	0	0	0	37	0	0	2	0
Kentish Flats	1	0	0	3	1	7	0	2	0	3
Lincs	13	0	0	1	1	106	0	1	5	0
London Array	18	0	0	25	3	81	0	10	1	8
Lynn	4	0	0	0	0	35	0	0	2	0
Race Bank	5	0	0	1	1	25	0	1	0	0
Dogger Bank C	10	0	0	7	0	70	0	1	0	2
Sofia	10	0	1	13	0	99	0	1	0	1
Hornsea Project Four	7	0	1	12	0	49	0	1	0	2
Hornsea Project Three	9	0	1	37	0	126	0	5	0	9
Hornsea Project Two	8	1	1	15	0	107	0	1	0	1
Scroby Sands	3	0	0	9	4	9	0	1	1	0
Sheringham Shoal	6	0	0	0	1	8	0	0	0	1
Teesside	2	2	0	5	0	11	0	0	0	2
Thanet	20	1	0	19	1	92	0	6	0	5
East Anglia Hub - ONE North	2	0	0	15	0	12	0	3	0	1
ForthWind Demonstration Project Phase 2	1	0	0	2	0	6	0	0	0	1
Triton Knoll	13	0	0	5	1	73	0	1	8	1
Westermost Rough	5	1	0	10	0	22	0	1	1	2
East Anglia Hub - TWO	3	0	0	8	0	17	0	5	0	2
Scottish Sectoral Marine Plan - E3	16	0	0	8	0	94	0	0	0	14
Scottish Sectoral Marine Plan - E2	23	0	1	10	0	123	0	0	1	3
Scottish Sectoral Marine Plan - E1	39	0	0	14	0	238	0	0	0	8
Scottish Sectoral Marine Plan - NE6	12	0	1	114	0	103	0	0	0	10
Scottish Sectoral Marine Plan - NE7	14	0	1	200	0	117	0	0	0	17
Scottish Sectoral Marine Plan - NE8	3	0	0	27	0	40	0	0	0	4
Scottish Sectoral Marine Plan - NE3	5	0	1	11	0	26	0	0	0	3
Scottish Sectoral Marine Plan - NE4	6	0	1	20	0	33	0	1	0	4
Moray East	18	0	1	44	0	126	0	5	0	8
Seagreen	6	0	0	6	0	68	0	0	0	9
Aberdeen Offshore Wind Farm (EOWDC)	3	0	0	2	0	20	0	0	0	2
Race Bank Extension	4	0	0	1	1	15	0	0	0	0
Dudgeon Extension	9	0	0	5	2	18	0	1	0	1
Sheringham Shoal Extension	1	0	0	0	0	2	0	0	0	0
Five Estuaries	1	0	0	8	0	9	0	1	0	1
North Falls	1	0	0	8	0	14	0	3	0	1
Kincardine - Phase 2	2	0	0	1	0	13	0	0	0	1
Seagreen 1A	2	0	0	2	0	22	0	0	0	3

Wind farm	Kittiwake	Little gull	Great skua	Great B-b gull	Sandwich tern	Northern gannet	Arctic skua	Lesser b-b gull	Common tern	Herring gull
Round 4 - Area 1 (RWE Renewables)	26	0	1	10	0	97	0	0	1	1
Round 4 - Area 2 (RWE Renewables)	18	0	0	11	0	75	0	1	0	0
Round 4 - Area 3 (GIG & Total)	10	0	0	11	1	29	0	1	0	1
Beatrice	8	0	2	23	0	30	0	2	0	4
Inch Cape	28	0	0	11	0	211	0	1	0	15
Neart na Gaoithe	2	0	0	5	0	59	0	0	0	4
Kentish Flats Extension	0	0	0	2	0	3	0	1	0	2
Galloper	2	0	0	12	0	21	0	4	0	2
East Anglia ONE	22	0	0	19	0	102	0	9	0	5
East Anglia Hub - THREE	6	0	0	33	0	71	0	5	0	5
Norfolk Vanguard	3	0	1	48	0	41	0	4	0	5
Norfolk Boreas	60	1	1	87	0	228	0	10	2	11
Blyth Offshore Demonstrator Phase 1	1	0	0	1	0	6	0	0	0	0
Berwick Bank	32	0	0	8	1	236	0	1	0	5
Marr Bank	26	0	0	9	1	233	0	2	0	9
Hywind Scotland Pilot Park	1	0	0	1	0	5	0	0	0	0
Moray West	12	0	2	41	0	104	0	5	0	8
Blyth Offshore Demonstrator Phase 2	1	0	0	1	0	8	0	0	0	0
Dogger Bank A	6	0	0	4	0	49	0	0	0	0
Hornsea Project One	9	1	1	18	0	133	0	1	0	1
Borssele 2	6	3	0	21	2	67	0	7	0	7
Borssele 3	5	2	0	18	1	52	0	5	0	5
Borssele 4 - Blauwwind	4	1	0	17	0	58	0	4	0	4
Borssele Site V -Two towers	0	0	0	1	0	3	0	0	0	0
Egmond aan Zee	3	4	0	10	2	22	0	3	2	5
Prinses Amaliawindpark	9	7	0	16	1	53	0	5	1	6
Eneco Luchterduinen	9	6	0	13	1	29	0	3	0	7
Gemini Zee energie	16	1	0	15	1	60	0	4	5	2
Gemini Buitengaats	14	2	0	14	1	52	0	4	6	3
Hollandse Kust Zuid Holland IV	11	7	0	22	1	32	0	5	1	15
Hollandse Kust Zuid Holland III	7	4	0	21	1	36	0	5	0	16
Hollandse Kust Zuid Holland II	7	3	0	21	1	37	0	5	0	15
Hollandse Kust Zuid Holland I	10	5	0	22	1	42	0	5	0	13
Borssele 1	6	1	0	18	1	80	0	6	0	7
Hollandse Kust Noord (Tender 2019)	9	5	0	29	2	69	0	6	1	15
Ten noorden van de Waddeneilanden	7	1	0	12	0	32	0	3	2	2
IJmuiden Ver	33	11	1	62	2	219	0	16	1	32
Hollandse Kust West - (Tender 2020 2021)	15	3	0	33	0	81	0	8	1	11
Hollandse Kust West zuidelijke punt	5	1	0	12	0	38	0	4	0	4
Zoekgebied 1 Noord	34	2	1	84	1	134	0	8	1	15
Zoekgebied 5 Oost origineel	48	5	1	105	1	151	0	13	3	13

Wind farm	Kittiwake	Little gull	Great skua	Great B-b gull	Sandwich tern	Northern gannet	Arctic skua	Lesser b-b gull	Common tern	Herring gull
IJmuiden Ver Noord	15	3	1	29	1	104	0	9	3	35
Zoekgebied 1 Zuid	14	1	1	30	0	68	0	5	0	6
Zoekgebied 2 Noord	39	7	1	66	2	164	0	12	2	37

IV.2. Collision victims per wind farm – seabirds – international densities – per GW

Wind farm	Kittiwake	Little gull	Great skua	Great B-b gull	Sandwich	Northern gannet	Arctic skua	Lesser b-b gull	Common	Herring gull
Thornton Bank phase I	12	19	1	67	3	141	0	21	2	17
Northwind	150	34	2	175	18	850	0	71	3	48
Belwind	51	7	1	117	2	486	0	38	1	21
Norther	22	18	1	57	5	149	0	21	4	19
Rentel	13	7	1	57	2	136	0	17	1	15
Seamade (SeaStar)	16	3	1	55	1	152	0	16	0	13
Seamade (Mermaid)	16	2	0	53	1	159	0	13	0	8
Nobelwind	65	8	1	129	2	544	0	43	1	23
Thornton Bank phase II	11	10	1	56	2	119	0	17	1	15
Thornton Bank phase III	9	11	1	53	1	97	0	16	1	13
Northwester 2	18	2	0	49	0	148	0	14	0	8
Pr. Elisabeth - Noordhinder Noord - 2023	12	1	1	41	0	104	0	9	0	8
Pr. Elisabeth - Fairybank Nordhinder Zuid	9	1	1	35	1	91	0	9	1	7
Alpha Ventus	11	1	0	24	1	95	0	7	0	7
DanTysk	46	1	0	54	2	176	0	7	5	17
Borkum Riffgrund 3	11	2	0	23	1	64	0	4	3	4
Borkum Riffgrund 1	27	4	0	36	3	213	0	11	1	13
Amrumbank West	76	2	0	49	2	211	0	19	1	30
Nordsee Ost	42	1	0	39	1	141	0	9	1	22
Meerwind Süd Ost	67	1	0	70	1	266	0	13	1	32
Butendiek	22	3	0	36	2	147	0	16	1	26
Global Tech I	39	2	0	42	0	247	0	6	1	6
Gode Wind 3	13	1	0	17	0	71	0	5	2	10
Trianel Windpark Borkum II	16	1	0	24	1	113	0	6	0	6
Hohe See	19	1	0	37	0	131	0	5	0	5
Sandbank	56	1	0	52	1	175	0	8	1	11
Gode Wind 1 and 2	10	1	0	22	0	76	0	6	1	13
EnBW He Dreiht	13	0	0	26	0	59	0	3	0	3
Nordergründe	24	6	0	33	16	97	0	8	9	20
Riffgat	19	9	0	43	10	56	0	14	11	42
BARD Offshore 1	28	1	0	60	0	109	0	8	0	7
Deutsche Bucht	16	2	0	45	1	58	0	5	0	6
Merkur	15	1	0	23	0	110	0	7	0	7
Trianel Windpark Borkum I	15	1	0	24	1	111	0	7	0	7
Nordsee One	15	2	0	24	1	129	0	7	1	10
N-3.5	7	0	0	13	0	59	0	4	0	6
N-3.6	7	1	0	13	0	59	0	4	0	5
N-3.7	9	0	0	13	0	46	0	4	2	8
N-3.8	8	0	0	13	0	61	0	4	0	7

Wind farm	Kittiwake	Little gull	Great skua	Great B-b gull	Sandwich	Northern gannet	Arctic skua	Lesser b-b gull	Common	Herring gull
N-6.6	7	2	0	23	0	42	0	3	0	4
N-6.7	13	0	0	32	0	37	0	3	0	4
N-7.2	9	1	0	22	0	58	0	3	0	4
N-8.4	13	0	0	19	0	63	0	2	0	3
Borkum Riffgrund 2	16	3	0	22	2	105	0	6	1	8
Kaskasi	50	1	0	29	1	114	0	9	1	17
Veja Mate	21	2	0	56	1	88	0	7	0	7
Albatros	26	1	0	44	0	124	0	4	0	5
N-9.1	17	0	0	35	0	29	0	3	0	4
N-9.2	23	0	0	27	0	35	0	3	0	4
N-10.1	13	0	0	14	0	39	0	2	0	3
N-11-1	13	0	0	19	0	65	0	3	0	3
N-12.1	14	0	0	23	0	65	0	3	0	4
N-10.2	16	0	0	15	0	36	0	2	0	3
N-12.2	14	0	0	23	0	65	0	3	0	4
N-12.3	14	0	0	23	0	65	0	3	0	4
N-12.4	14	0	0	23	0	65	0	3	0	4
N-11-2	13	0	0	19	0	65	0	3	0	3
N-13-2	18	0	0	32	0	65	0	5	0	7
N-13-3	18	0	0	32	0	65	0	5	0	7
N-9.3	17	0	0	37	0	27	0	3	0	4
N-9.4	21	0	0	28	0	32	0	3	0	4
Horns Rev 1	34	2	0	70	0	45	0	18	20	32
Nordsøen - Tender 1	1	0	0	8	0	11	0	2	0	1
Nordsøen - Tender 3	2	0	0	6	0	20	0	1	0	3
Nordsøen - Tender 2	1	0	0	5	0	15	0	1	0	1
Nordsøen - Tender 4	1	0	0	6	0	7	0	2	0	1
Nordsøen - Tender 5	2	0	0	6	0	20	0	1	0	2
Horns Rev 2	80	11	0	58	0	159	0	17	36	20
Horns Rev 3	13	3	0	19	0	39	0	7	3	7
Nordsøen - Tender 6	1	0	0	6	0	11	0	0	0	2
Nordsøen - Tender 7	2	0	0	4	0	16	0	0	0	5
Nordsøen - Tender 8	2	0	0	5	0	30	0	0	0	3
Nordsøen - Tender 9	3	0	0	9	0	21	0	0	0	2
Nordsøen - Tender 10	4	0	0	12	0	28	0	3	0	5
Thor - 2020 Tender	1	0	1	14	0	25	0	1	0	5
Vesterhav Nord Syd	1	0	1	27	0	33	0	4	0	11
Dudgeon	6	0	0	4	1	18	0	0	0	1
Greater Gabbard	14	0	1	34	0	115	0	21	0	7
Gunfleet Sands	30	0	0	36	7	114	0	19	1	24
Dogger Bank B	6	0	0	4	0	50	0	0	0	0
Humber Gateway	75	6	0	48	4	482	0	7	72	4

Wind farm	Kittiwake	Little gull	Great skua	Great B-b gull	Sandwich	Northern gannet	Arctic skua	Lesser b-b gull	Common	Herring gull
Inner Dowsing	44	1	0	5	5	380	0	3	18	1
Kentish Flats	14	0	0	36	9	76	0	18	1	32
Lincs	49	1	0	5	5	392	0	3	17	1
London Array	28	0	0	39	5	129	0	16	1	12
Lynn	44	1	0	5	4	356	0	3	16	1
Race Bank	9	0	0	1	1	44	0	1	0	1
Dogger Bank C	8	0	0	6	0	58	0	1	0	1
Sofia	7	0	0	9	0	71	0	1	0	1
Hornsea Project Four	7	0	1	12	0	49	0	1	0	2
Hornsea Project Three	4	0	0	15	0	52	0	2	0	4
Hornsea Project Two	6	1	1	11	0	77	0	1	0	1
Scroby Sands	48	0	0	154	60	143	0	22	11	5
Sheringham Shoal	19	0	0	1	3	25	0	1	0	2
Teesside	38	25	1	81	0	172	0	1	6	36
Thanet	68	2	1	63	2	308	0	20	1	16
East Anglia Hub - ONE North	2	0	1	19	0	15	0	4	0	2
ForthWind Demonstration Project Phase 2	17	0	0	30	0	110	0	1	0	17
Triton Knoll	15	0	0	6	2	85	0	1	9	1
Westermost Rough	22	4	1	49	0	102	0	3	4	10
East Anglia Hub - TWO	3	0	0	9	0	19	0	6	0	3
Scottish Sectoral Marine Plan - E3	16	0	0	8	0	94	0	0	0	14
Scottish Sectoral Marine Plan - E2	11	0	0	5	0	62	0	0	0	1
Scottish Sectoral Marine Plan - E1	13	0	0	5	0	79	0	0	0	3
Scottish Sectoral Marine Plan - NE6	6	0	0	57	0	51	0	0	0	5
Scottish Sectoral Marine Plan - NE7	5	0	0	67	0	39	0	0	0	6
Scottish Sectoral Marine Plan - NE8	3	0	0	27	0	40	0	0	0	4
Scottish Sectoral Marine Plan - NE3	5	0	1	11	0	26	0	0	0	3
Scottish Sectoral Marine Plan - NE4	6	0	1	20	0	33	0	1	0	4
Moray East	19	0	1	46	0	132	0	6	0	9
Seagreen	5	0	0	5	0	60	0	0	0	7
Aberdeen Offshore Wind Farm (EOWDC)	28	0	0	19	3	218	0	0	1	23
Race Bank Extension	7	0	0	1	1	26	0	1	0	0
Dudgeon Extension	24	0	0	12	4	46	0	2	1	2
Sheringham Shoal Extension	4	0	0	1	1	5	0	0	0	1
Five Estuaries	3	0	0	22	0	26	0	4	0	2
North Falls	3	0	0	17	0	28	0	6	0	3
Kincardine - Phase 2	43	0	0	14	0	264	0	0	1	22
Seagreen 1A	5	0	0	6	0	62	0	0	0	9
Round 4 - Area 1 (RWE Renewables)	17	0	0	7	0	65	0	0	1	1
Round 4 - Area 2 (RWE Renewables)	12	0	0	7	0	50	0	0	0	0
Round 4 - Area 3 (GIG & Total)	7	0	0	8	0	19	0	1	0	1
Beatrice	13	0	3	38	0	51	0	3	0	7

Wind farm	Kittiwake	Little gull	Great skua	Great B-b gull	Sandwich	Northern gannet	Arctic skua	Lesser b-b gull	Common	Herring gull
Inch Cape	28	0	0	11	0	211	0	1	0	15
Neart na Gaoithe	4	0	0	12	0	132	0	1	0	9
Kentish Flats Extension	10	0	0	36	6	57	0	15	0	31
Galloper	7	0	0	34	0	59	0	10	0	4
East Anglia ONE	30	0	0	27	0	143	0	13	0	7
East Anglia Hub - THREE	4	0	0	23	0	51	0	4	0	4
Norfolk Vanguard	1	0	1	27	0	23	0	2	0	3
Norfolk Boreas	33	0	1	48	0	127	0	6	1	6
Blyth Offshore Demonstrator Phase 1	12	0	0	17	0	149	0	3	1	7
Berwick Bank	14	0	0	3	1	102	0	1	0	2
Marr Bank	14	0	0	5	0	126	0	1	0	5
Hywind Scotland Pilot Park	36	0	0	29	0	160	0	0	1	15
Moray West	12	0	2	43	0	110	0	6	0	9
Blyth Offshore Demonstrator Phase 2	17	0	0	16	0	130	0	2	1	5
Dogger Bank A	5	0	0	4	0	41	0	0	0	0
Hornsea Project One	8	1	1	15	0	109	0	1	0	1
Borssele 2	17	9	1	55	4	178	0	19	1	19
Borssele 3	12	5	1	49	2	141	0	14	0	13
Borssele 4 - Blauwwind	12	2	0	45	1	159	0	11	0	11
Borssele Site V -Two towers	12	2	1	45	1	167	0	14	0	14
Egmond aan Zee	30	39	0	96	20	199	0	24	16	46
Prinses Amaliawindpark	79	57	1	132	11	445	0	45	9	53
Eneco Luchterduinen	73	46	0	98	5	226	0	23	2	51
Gemini Zee energie	52	4	0	49	3	202	0	12	18	7
Gemini Buitengaats	47	6	0	48	3	173	0	13	22	9
Hollandse Kust Zuid Holland IV	29	19	0	58	3	82	0	13	2	38
Hollandse Kust Zuid Holland III	18	10	0	54	4	94	0	13	1	41
Hollandse Kust Zuid Holland II	19	7	0	54	3	97	0	14	1	38
Hollandse Kust Zuid Holland I	25	14	0	57	2	109	0	14	1	35
Borssele 1	16	3	1	49	2	213	0	16	1	18
Hollandse Kust Noord (Tender 2019)	12	7	0	41	3	99	0	9	1	21
Ten noorden van de Waddeneilanden	10	1	0	18	0	46	0	4	3	2
IJmuiden Ver	8	3	0	15	0	55	0	4	0	8
Hollandse Kust West - (Tender 2020 2021)	11	2	0	24	0	58	0	6	1	8
Hollandse Kust West zuidelijke punt	7	1	0	18	1	54	0	6	0	6
Zoekgebied 1 Noord	9	0	0	21	0	33	0	2	0	4
Zoekgebied 5 Oost origineel	12	1	0	26	0	38	0	3	1	3
IJmuiden Ver Noord	8	2	0	15	1	52	0	4	1	18
Zoekgebied 1 Zuid	7	0	0	15	0	34	0	2	0	3
Zoekgebied 2 Noord	10	2	0	16	0	41	0	3	0	9

IV.3. Collision victims per wind farm – seabirds – national densities – absolute

Wind farm	Kittiwake	Little gull	Great skua	Great B-b gull	Sandwich tern	Northern gannet	Arctic skua	Lesser b-b gull	Common tern	Herring gull
Borssele 2	8	2	0	8	2	98	0	4	0	7
Borssele 3	5	1	0	7	1	85	0	3	0	5
Borssele 4 - Blauwwind	5	1	0	7	1	85	0	3	0	4
Borssele Site V -Two towers	0	0	0	0	0	5	0	0	0	0
Egmond aan Zee	7	11	0	16	4	30	0	3	1	10
Prinses Amaliawindpark	14	12	0	28	4	73	0	7	4	16
Eneco Luchterduinen	14	8	0	14	1	32	0	4	0	8
Gemini Zee energie	20	1	0	8	2	46	0	3	12	2
Gemini Buitengaats	20	1	0	7	1	24	0	3	15	2
Hollandse Kust Zuid Holland IV	17	11	0	24	2	37	0	7	1	17
Hollandse Kust Zuid Holland III	9	5	0	18	2	52	0	6	1	17
Hollandse Kust Zuid Holland II	9	3	0	18	1	44	0	6	1	15
Hollandse Kust Zuid Holland I	13	7	0	21	1	43	0	7	0	15
Borssele 1	7	2	0	8	1	107	0	4	0	6
Hollandse Kust Noord (Tender 2019)	12	8	0	38	5	65	0	6	1	26
Ten noorden van de Waddeneilanden	8	1	0	12	1	30	0	2	4	1
IJmuiden Ver	42	14	0	70	2	244	0	19	1	16
Hollandse Kust West - (Tender 2020 2021)	20	4	0	35	0	85	0	9	1	11
Hollandse Kust West zuidelijke punt	6	1	0	15	1	32	0	5	0	5
Zoekgebied 1 Noord	44	5	1	89	2	154	0	9	2	12
Zoekgebied 5 Oost origineel	67	8	1	100	3	176	0	15	7	11
IJmuiden Ver Noord	18	3	0	35	1	109	0	11	2	8
Zoekgebied 1 Zuid	17	2	0	27	0	81	0	5	1	4
Zoekgebied 2 Noord	44	8	2	62	3	190	0	12	2	15

IV.4. Collision victims per wind farm – seabirds – national densities – per GW

Wind farm	Kittiwake	Little gull	Great skua	Great B-b gull	Sandwich tern	Northern gannet	Arctic skua	Lesser b-b gull	Common tern	Herring gull
Borssele 2	20	6	1	21	6	260	0	10	0	19
Borssele 3	14	3	0	18	1	233	0	8	0	13
Borssele 4 - Blauwwind	14	1	0	19	1	232	0	9	0	10
Borssele Site V -Two towers	14	3	0	18	2	253	0	7	0	14
Egmond aan Zee	64	100	0	149	35	276	0	28	12	94
Prinses Amaliawindpark	114	101	0	231	36	611	0	55	30	134
Eneco Luchterduinen	106	59	0	112	8	246	0	34	3	65
Gemini Zee energie	65	4	0	27	6	153	0	11	40	5
Gemini Buitengaats	66	3	0	22	5	79	0	10	51	6
Hollandse Kust Zuid Holland IV	45	30	0	63	5	95	0	17	2	45
Hollandse Kust Zuid Holland III	24	12	0	46	6	134	0	15	2	45
Hollandse Kust Zuid Holland II	24	9	0	48	3	114	0	16	2	40
Hollandse Kust Zuid Holland I	33	17	0	54	3	113	0	18	1	39
Borssele 1	19	5	1	22	3	285	0	10	0	16
Hollandse Kust Noord (Tender 2019)	17	11	0	54	7	93	0	9	2	37
Ten noorden van de Waddeneilanden	12	1	0	17	1	42	0	3	6	2
IJmuiden Ver	10	3	0	18	1	61	0	5	0	4
Hollandse Kust West - (Tender 2020 2021)	14	3	0	25	0	60	0	7	1	8
Hollandse Kust West zuidelijke punt	9	1	0	22	1	46	0	6	0	7
Zoekgebied 1 Noord	11	1	0	22	0	38	0	2	1	3
Zoekgebied 5 Oost origineel	17	2	0	25	1	44	0	4	2	3
IJmuiden Ver Noord	9	2	0	18	1	54	0	5	1	4
Zoekgebied 1 Zuid	8	1	0	14	0	41	0	3	0	2
Zoekgebied 2 Noord	11	2	0	16	1	47	0	3	1	4

IV.5. Collision victims per wind farm – migratory birds - absolute

Wind farm	Shelduck	Red knot	Bewick' s swan	Bar-tailed godwit	Brent goose	Starling	Curlew	Black tern
Thornton Bank phase I	0	1	0	0	0	11	0	0
Northwind	3	7	0	4	1	123	4	0
Belwind	2	5	0	3	1	91	3	0
Norther	2	5	0	3	1	98	3	0
Rentel	2	5	0	3	0	88	3	0
Seamade (SeaStar)	1	4	0	2	0	67	2	0
Seamade (Mermaid)	1	3	0	2	0	63	2	0
Nobelwind	2	5	0	3	1	87	3	0
Thornton Bank phase II	1	3	0	2	0	59	2	0
Thornton Bank phase III	1	2	0	1	0	36	1	0
Northwester 2	1	3	0	2	0	54	2	0
Pr. Elisabeth - Noordhinder Noord - 2023	3	9	0	5	1	155	5	0
Pr. Elisabeth - Fairybank Nordhinder Zuid	6	16	0	9	2	281	8	1
Alpha Ventus	0	1	0	1	0	23	1	0
DanTysk	3	8	0	5	0	142	5	0
Borkum Riffgrund 3	4	11	0	7	0	205	6	1
Borkum Riffgrund 1	3	8	0	5	0	141	4	0
Amrumbank West	3	8	0	5	0	143	5	0
Nordsee Ost	2	5	0	3	0	95	3	0
Meerwind Süd Ost	3	8	0	5	0	142	5	0
Butendiek	3	8	0	5	0	142	5	0
Global Tech I	3	8	0	5	0	150	5	0
Gode Wind 3	1	3	0	2	0	56	2	0
Trianel Windpark Borkum II	1	4	0	2	0	66	2	0
Hohe See	3	8	0	5	0	150	5	0
Sandbank	3	7	0	5	0	132	4	0
Gode Wind 1 and 2	4	11	0	7	2	199	6	1
EnBW He Dreiht	4	9	0	5	0	169	5	0
Nordergründe	1	2	0	1	0	36	1	0
Riffgat	1	3	0	2	0	53	2	0
BARD Offshore 1	3	8	0	5	0	151	5	0
Deutsche Bucht	1	4	0	2	0	69	2	0
Merkur	3	7	0	4	0	132	4	0
Trianel Windpark Borkum I	2	4	0	2	0	75	2	0
Nordsee One	2	6	0	4	0	107	3	0
N-3.5	2	5	0	3	0	84	2	0
N-3.6	2	5	0	3	0	96	3	0
N-3.7	1	2	0	1	0	45	1	0
N-3.8	2	5	0	3	0	87	3	0
N-6.6	3	7	0	4	0	126	4	0

Wind farm	Shelduck	Red knot	Bewick's swan	Bar-tailed godwit	Brent goose	Starling	Curlew	Black tern
N-6.7	1	3	0	2	0	54	2	0
N-7.2	4	10	0	6	0	185	5	1
N-8.4	2	5	0	3	0	84	2	0
Borkum Riffgrund 2	3	7	0	4	0	125	4	0
Kaskasi	2	5	0	3	0	87	3	0
Veja Mate	3	8	0	4	0	135	4	0
Albatros	1	2	0	1	0	34	1	0
N-9.1	4	11	0	6	0	200	6	1
N-9.2	4	11	0	6	0	200	6	0
N-10.1	4	9	0	5	0	170	5	0
N-11-1	4	10	0	6	0	179	5	0
N-12.1	4	10	0	6	0	179	5	0
N-10.2	3	8	0	5	0	140	4	0
N-12.2	4	10	0	6	0	179	5	0
N-12.3	4	10	0	6	0	179	5	0
N-12.4	4	10	0	6	0	179	5	0
N-11-2	4	10	0	6	0	179	5	0
N-13-2	4	10	0	6	0	179	5	0
N-13-3	4	10	0	6	0	179	5	0
N-9.3	4	11	0	6	0	200	6	1
N-9.4	4	11	0	6	0	200	6	0
Horns Rev 1	3	7	0	4	0	123	4	0
Nordsøen - Tender 1	4	10	0	6	0	179	5	0
Nordsøen - Tender 3	4	10	0	6	0	179	5	0
Nordsøen - Tender 2	4	10	0	6	0	179	5	0
Nordsøen - Tender 4	4	10	0	6	0	179	5	0
Nordsøen - Tender 5	4	10	0	6	0	179	5	0
Horns Rev 2	3	8	0	5	0	146	5	0
Horns Rev 3	2	6	0	4	0	109	3	0
Nordsøen - Tender 6	4	10	0	6	0	179	5	0
Nordsøen - Tender 7	4	10	0	6	0	179	5	0
Nordsøen - Tender 8	4	10	0	6	0	179	5	0
Nordsøen - Tender 9	4	10	0	6	0	179	5	0
Nordsøen - Tender 10	4	10	0	6	0	179	5	0
Thor - 2020 Tender	5	13	0	7	0	233	7	0
Vesterhav Nord Syd	2	5	0	3	0	92	3	0
Dudgeon	3	8	0	4	0	135	4	0
Greater Gabbard	5	14	0	8	2	244	8	0
Gunfleet Sands	2	5	0	3	1	84	3	0
Dogger Bank B	5	14	0	8	0	260	8	0
Humber Gateway	3	7	0	4	0	125	4	0
Inner Dowsing	1	3	0	2	0	47	1	0

Wind farm	Shelduck	Red knot	Bewick' s swan	Bar-tailed godwit	Brent goose	Starling	Curlew	Black tern
Kentish Flats	1	3	0	2	0	49	2	0
Lincs	3	7	0	5	0	133	4	0
London Array	7	17	0	11	3	311	10	0
Lynn	1	3	0	2	0	47	1	0
Race Bank	4	10	0	6	0	187	6	0
Dogger Bank C	5	15	0	9	0	269	8	0
Sofia	6	16	0	9	0	284	8	0
Hornsea Project Four	4	10	0	6	0	179	5	0
Hornsea Project Three	12	32	0	18	1	570	16	0
Hornsea Project Two	8	21	0	12	0	370	11	0
Scroby Sands	1	3	0	2	0	46	1	0
Sheringham Shoal	3	9	0	5	0	153	5	0
Teesside	1	2	0	1	0	43	1	0
Thanet	4	9	0	6	1	165	5	0
East Anglia Hub - ONE North	3	9	0	5	1	165	5	0
ForthWind Demonstration Project Phase 2	0	1	0	1	0	18	1	0
Triton Knoll	4	12	0	7	0	209	6	0
Westermost Rough	2	4	0	2	0	70	2	0
East Anglia Hub - TWO	4	10	0	6	1	184	5	0
Scottish Sectoral Marine Plan - E3	4	10	0	6	0	179	5	0
Scottish Sectoral Marine Plan - E2	7	20	0	11	0	359	11	0
Scottish Sectoral Marine Plan - E1	11	30	0	17	0	538	16	0
Scottish Sectoral Marine Plan - NE6	7	20	0	11	0	359	11	0
Scottish Sectoral Marine Plan - NE7	11	30	0	17	0	538	16	0
Scottish Sectoral Marine Plan - NE8	4	10	0	6	0	179	5	0
Scottish Sectoral Marine Plan - NE3	4	10	0	6	0	179	5	0
Scottish Sectoral Marine Plan - NE4	4	10	0	6	0	179	5	0
Moray East	5	13	0	7	0	233	7	0
Seagreen	6	15	0	9	0	270	8	0
Aberdeen Offshore Wind Farm (EOWDC)	1	1	0	1	0	25	1	0
Race Bank Extension	2	6	0	4	0	114	3	0
Dudgeon Extension	8	23	0	13	1	412	12	0
Sheringham Shoal Extension	1	3	0	2	0	57	2	0
Five Estuaries	1	4	0	2	1	65	2	0
North Falls	2	6	0	3	1	102	3	0
Kincardine - Phase 2	0	1	0	0	0	12	0	0
Seagreen 1A	2	5	0	3	0	85	2	0
Round 4 - Area 1 (RWE Renewables)	6	15	0	9	0	269	8	0
Round 4 - Area 2 (RWE Renewables)	6	15	0	9	0	269	8	0
Round 4 - Area 3 (GIG & Total)	6	15	0	9	1	269	8	0
Beatrice	4	10	0	6	0	177	5	0
Inch Cape	4	12	0	7	0	217	6	0

Wind farm	Shelduck	Red knot	Bewick's swan	Bar-tailed godwit	Brent goose	Starling	Curlew	Black tern
Neart na Gaoithe	3	7	0	4	0	120	4	0
Kentish Flats Extension	1	1	0	1	0	26	1	0
Galloper	2	6	0	4	1	113	3	0
East Anglia ONE	5	12	0	7	2	215	7	0
East Anglia Hub - THREE	6	16	0	9	2	284	8	0
Norfolk Vanguard	12	32	0	19	3	573	17	0
Norfolk Boreas	12	32	1	19	6	573	17	0
Blyth Offshore Demonstrator Phase 1	0	1	0	0	0	11	0	0
Berwick Bank	8	23	0	13	0	412	12	0
Marr Bank	7	18	0	11	0	334	10	0
Hywind Scotland Pilot Park	0	1	0	0	0	10	0	0
Moray West	5	14	0	8	0	253	7	0
Blyth Offshore Demonstrator Phase 2	0	1	0	0	0	14	0	0
Dogger Bank A	5	14	0	8	0	260	8	0
Hornsea Project One	8	20	0	12	0	366	11	0
Borssele 2	2	6	0	3	1	104	3	0
Borssele 3	2	5	0	3	1	91	3	0
Borssele 4 - Blauwwind	2	5	0	3	1	91	3	0
Borssele Site V -Two towers	0	0	0	0	0	5	0	0
Egmond aan Zee	1	3	0	2	1	59	2	0
Prinses Amaliawindpark	2	5	0	3	1	93	3	0
Eneco Luchterduinen	2	4	0	3	1	74	2	0
Gemini Zee energie	3	8	0	5	0	138	4	0
Gemini Buitengaats	3	8	0	5	0	138	4	0
Hollandse Kust Zuid Holland IV	4	10	0	6	2	176	5	1
Hollandse Kust Zuid Holland III	4	10	0	6	1	176	5	1
Hollandse Kust Zuid Holland II	4	10	0	6	2	176	5	1
Hollandse Kust Zuid Holland I	4	10	0	6	2	176	5	1
Borssele 1	2	6	0	3	1	104	3	0
Hollandse Kust Noord (Tender 2019)	4	10	0	6	2	174	5	1
Ten noorden van de Waddeneilanden	3	8	0	5	0	140	4	0
IJmuiden Ver	16	44	1	26	8	798	23	2
Hollandse Kust West - (Tender 2020 2021)	6	17	0	10	3	308	9	1
Hollandse Kust West zuidelijke punt	3	8	0	5	1	140	4	0
Zoekgebied 1 Noord	15	40	0	23	2	717	21	2
Zoekgebied 5 Oost origineel	16	44	0	26	1	798	23	2
IJmuiden Ver Noord	8	22	1	13	4	400	12	1
Zoekgebied 1 Zuid	7	20	0	11	5	359	11	1
Zoekgebied 2 Noord	15	40	0	23	10	717	21	2

I.6. Collision victims per wind farm – migratory birds – per GW

Wind farm	Shelduck	Red knot	Bewicks swan	Bar-tailed godwit	Brent goose	Starling	Curlew	Black tern
Thornton Bank phase I	8	21	0	13	2	380	12	1
Northwind	13	32	0	20	5	572	18	2
Belwind	12	31	0	18	3	550	17	2
Norther	6	15	0	9	2	266	8	1
Rentel	6	16	0	9	1	286	9	1
Seamade (SeaStar)	6	15	0	9	2	267	8	1
Seamade (Mermaid)	6	15	0	9	2	267	8	1
Nobelwind	12	29	0	18	4	526	17	2
Thornton Bank phase II	7	18	0	11	2	322	10	1
Thornton Bank phase III	7	18	0	11	2	322	10	1
Northwester 2	5	14	0	8	1	244	7	1
Pr. Elisabeth - Noordhinder Noord - 2023	5	12	0	7	1	222	7	1
Pr. Elisabeth - Fairybank Nordhinder Zuid	4	11	0	6	1	201	6	1
Alpha Ventus	8	21	0	12	0	376	12	1
DanTysk	11	28	0	17	0	494	16	2
Borkum Riffgrund 3	5	13	0	7	0	227	7	1
Borkum Riffgrund 1	10	25	0	15	1	452	14	1
Amrumbank West	11	27	0	16	1	475	15	1
Nordsee Ost	7	18	0	11	0	322	10	1
Meerwind Süd Ost	11	28	0	17	1	494	16	2
Butendiek	11	28	0	17	0	494	16	2
Global Tech I	8	21	0	12	1	374	11	0
Gode Wind 3	5	13	0	7	2	230	7	1
Trianel Windpark Borkum II	7	18	0	11	0	324	10	1
Hohe See	6	17	0	10	0	301	9	1
Sandbank	10	26	0	16	0	459	15	1
Gode Wind 1 and 2	8	19	0	11	3	342	11	1
EnBW He Dreiht	4	10	0	6	0	188	6	1
Nordergründe	7	18	0	11	4	322	10	1
Riffgat	11	28	0	17	5	494	16	2
BARD Offshore 1	8	21	0	13	0	377	12	1
Deutsche Bucht	6	15	0	9	0	275	8	1
Merkur	7	19	0	11	0	334	10	1
Trianel Windpark Borkum I	8	21	0	12	0	374	11	1
Nordsee One	7	18	0	11	0	322	10	1
N-3.5	4	11	0	6	0	199	6	1
N-3.6	4	11	0	6	0	199	6	1
N-3.7	4	11	0	6	0	199	6	1

Wind farm	Shelduck	Red knot	Bewicks swan	Bar-tailed godwit	Brent goose	Starling	Curlew	Black tern
N-3.8	4	11	0	6	0	200	6	1
N-6.6	4	11	0	6	0	199	6	1
N-6.7	4	11	0	6	0	199	6	1
N-7.2	4	11	0	6	0	199	6	1
N-8.4	4	11	0	6	0	197	6	0
Borkum Riffgrund 2	6	15	0	9	0	277	8	1
Kaskasi	5	14	0	8	0	254	8	1
Veja Mate	7	19	0	11	0	335	10	1
Albatros	6	17	0	10	0	301	9	0
N-9.1	4	11	0	6	0	200	6	1
N-9.2	4	11	0	6	0	200	6	0
N-10.1	4	9	0	5	0	170	5	0
N-11-1	4	10	0	6	0	179	5	0
N-12.1	4	10	0	6	0	179	5	0
N-10.2	4	11	0	6	0	201	6	0
N-12.2	4	10	0	6	0	179	5	0
N-12.3	4	10	0	6	0	179	5	0
N-12.4	4	10	0	6	0	179	5	0
N-11-2	4	10	0	6	0	179	5	0
N-13-2	4	10	0	6	0	179	5	0
N-13-3	4	10	0	6	0	179	5	0
N-9.3	4	11	0	6	0	200	6	1
N-9.4	4	11	0	6	0	200	6	0
Horns Rev 1	17	44	0	26	0	771	24	0
Nordsøen - Tender 1	4	10	0	6	0	179	5	0
Nordsøen - Tender 3	4	10	0	6	0	179	5	0
Nordsøen - Tender 2	4	10	0	6	0	179	5	0
Nordsøen - Tender 4	4	10	0	6	0	179	5	0
Nordsøen - Tender 5	4	10	0	6	0	179	5	0
Horns Rev 2	16	39	0	24	0	698	22	0
Horns Rev 3	6	15	0	9	0	268	8	0
Nordsøen - Tender 6	4	10	0	6	0	179	5	0
Nordsøen - Tender 7	4	10	0	6	0	179	5	0
Nordsøen - Tender 8	4	10	0	6	0	179	5	0
Nordsøen - Tender 9	4	10	0	6	0	179	5	0
Nordsøen - Tender 10	4	10	0	6	0	179	5	0
Thor - 2020 Tender	5	13	0	7	0	233	7	0
Vesterhav Nord Syd	6	15	0	9	0	267	8	0
Dudgeon	7	19	0	11	0	335	10	0
Greater Gabbard	11	27	0	16	4	484	15	0
Gunfleet Sands	11	27	0	16	5	484	15	0

Wind farm	Shelduck	Red knot	Bewicks swan	Bar-tailed godwit	Brent goose	Starling	Curlew	Black tern
Dogger Bank B	4	12	0	7	0	217	6	0
Humber Gateway	13	32	0	20	1	572	18	0
Inner Dowsing	11	27	0	16	1	484	15	0
Kentish Flats	12	31	0	18	5	550	17	0
Lincs	11	28	0	17	1	494	16	0
London Array	11	28	0	17	4	494	16	0
Lynn	11	27	0	16	1	484	15	0
Race Bank	7	18	0	11	0	326	10	0
Dogger Bank C	5	12	0	7	0	224	7	0
Sofia	4	11	0	6	0	203	6	0
Hornsea Project Four	4	10	0	6	0	179	5	0
Hornsea Project Three	5	13	0	8	0	238	7	0
Hornsea Project Two	6	15	0	9	0	267	8	0
Scroby Sands	17	44	0	26	7	771	24	0
Sheringham Shoal	11	27	0	16	1	484	15	0
Teesside	16	39	0	24	0	698	22	0
Thanet	12	31	0	18	5	550	17	0
East Anglia Hub - ONE North	4	11	0	7	1	206	6	0
ForthWind Demonstration Project Phase 2	7	19	0	11	0	344	10	0
Triton Knoll	5	14	0	8	0	244	7	0
Westermost Rough	7	19	0	11	0	335	10	0
East Anglia Hub - TWO	4	11	0	7	1	205	6	0
Scottish Sectoral Marine Plan - E3	4	10	0	6	0	179	5	0
Scottish Sectoral Marine Plan - E2	4	10	0	6	0	179	5	0
Scottish Sectoral Marine Plan - E1	4	10	0	6	0	179	5	0
Scottish Sectoral Marine Plan - NE6	4	10	0	6	0	179	5	0
Scottish Sectoral Marine Plan - NE7	4	10	0	6	0	179	5	0
Scottish Sectoral Marine Plan - NE8	4	10	0	6	0	179	5	0
Scottish Sectoral Marine Plan - NE3	4	10	0	6	0	179	5	0
Scottish Sectoral Marine Plan - NE4	4	10	0	6	0	179	5	0
Moray East	5	14	0	8	0	245	7	0
Seagreen	5	13	0	8	0	237	7	0
Aberdeen Offshore Wind Farm (EOWDC)	6	15	0	9	0	268	8	0
Race Bank Extension	4	11	0	6	0	198	6	0
Dudgeon Extension	21	57	0	33	2	1,026	30	0
Sheringham Shoal Extension	4	10	0	6	0	181	5	0
Five Estuaries	4	10	0	6	2	183	5	0
North Falls	4	11	0	6	2	202	6	0
Kincardine - Phase 2	5	14	0	8	0	243	7	0
Seagreen 1A	5	13	0	8	0	237	7	0
Round 4 - Area 1 (RWE Renewables)	4	10	0	6	0	179	5	0

Wind farm	Shelduck	Red knot	Bewicks swan	Bar-tailed godwit	Brent goose	Starling	Curlew	Black tern
Round 4 - Area 2 (RWE Renewables)	4	10	0	6	0	179	5	0
Round 4 - Area 3 (GIG & Total)	4	10	0	6	0	179	5	0
Beatrice	6	17	0	10	0	301	9	0
Inch Cape	4	12	0	7	0	217	6	0
Neart na Gaoithe	6	15	0	9	0	268	8	0
Kentish Flats Extension	12	29	0	18	5	526	17	0
Galloper	7	18	0	11	3	319	10	0
East Anglia ONE	6	17	0	10	3	301	9	0
East Anglia Hub - THREE	4	11	0	6	1	203	6	0
Norfolk Vanguard	7	18	0	10	2	318	9	0
Norfolk Boreas	7	18	0	10	4	318	9	0
Blyth Offshore Demonstrator Phase 1	6	15	0	9	0	268	8	0
Berwick Bank	4	10	0	6	0	179	5	0
Marr Bank	4	10	0	6	0	180	5	0
Hywind Scotland Pilot Park	7	19	0	11	0	335	10	0
Moray West	5	15	0	9	0	267	8	0
Blyth Offshore Demonstrator Phase 2	5	14	0	8	0	245	7	0
Dogger Bank A	4	12	0	7	0	217	6	0
Hornsea Project One	6	17	0	10	0	301	9	0
Borssele 2	6	15	0	9	2	278	8	1
Borssele 3	5	14	0	8	2	248	7	1
Borssele 4 - Blauwwind	5	14	0	8	2	248	7	1
Borssele Site V -Two towers	5	14	0	8	2	245	7	1
Egmond aan Zee	12	31	1	18	5	550	17	2
Prinses Amaliawindpark	17	44	1	26	6	771	24	2
Eneco Luchterduinen	13	32	0	20	6	572	18	2
Gemini Zee energie	10	26	0	16	1	459	15	1
Gemini Buitengaats	10	26	0	16	1	459	15	1
Hollandse Kust Zuid Holland IV	9	25	0	15	4	457	13	1
Hollandse Kust Zuid Holland III	9	25	0	15	3	457	13	1
Hollandse Kust Zuid Holland II	9	25	0	15	4	457	13	1
Hollandse Kust Zuid Holland I	9	25	0	15	4	457	13	1
Borssele 1	6	15	0	9	2	278	8	1
Hollandse Kust Noord (Tender 2019)	5	14	0	8	2	249	7	1
Ten noorden van de Waddeneilanden	4	11	0	6	0	201	6	1
IJmuiden Ver	4	11	0	6	2	199	6	1
Hollandse Kust West - (Tender 2020 2021)	5	12	0	7	2	220	6	1
Hollandse Kust West zuidelijke punt	4	11	0	6	2	201	6	1
Zoekgebied 1 Noord	4	10	0	6	0	179	5	1
Zoekgebied 5 middenberm	4	10	0	6	0	179	5	1
Zoekgebied 5 Oost klein	4	11	0	6	0	200	6	1

Wind farm	Shelduck	Red knot	Bewicks swan	Bar-tailed godwit	Brent goose	Starling	Curlew	Black tern
Zoekgebied 5 Oost origineel	4	11	0	6	0	199	6	1
IJmuiden Ver Noord	4	11	0	6	2	200	6	1
Zoekgebied 1 Zuid	4	10	0	6	2	179	5	1
Zoekgebied 2 Noord	4	10	0	6	2	179	5	1

Appendix V Lower tip height

The SOSS Band model and subsequent sCRM use hub height and rotor diameter as a means to calculate, along with other parameters, the number of birds passing through the rotor-swept area. Changing the lower tip height can be achieved by increasing the hub height or reducing the rotor diameter, ultimately affecting the numbers of birds passing through the airgap below the rotor-swept area, and consequently through the rotor-swept area itself. These changes in numbers of birds flying through the airgap or through the rotor-swept area are directly related to the flight height distributions and are hence species-specific. In the extended Band model and in the sCRM, collision risk varies through the rotor-swept area (highest at hub height and lowest towards the tip heights) and therefore the change in numbers of collisions is not directly proportional to the change in numbers through the rotor-swept area, although the broad pattern is followed that with a larger airgap the number of collisions decreases.

In table V.1 we report on a preliminary calculation on the effect on the number of species-specific collisions in a future wind farm by increasing the airgap from 25 m to 40 m. As an example, we have used the wind farm Zoekgebied 5 Oost that is at this moment planned to be filled with 267 turbines with a capacity of 15 MW. The hub height of these turbines was set at 143 m in the KEC 4.0 simulations, in order to create a 25 m airgap below the rotor-swept area in combination with a 118 m rotor radius. In table V.1 the results of the sCRM calculations are presented with an increased hub height to 158 m, in order to have a 40 m airgap.

The results clearly illustrate the general effect of reduced numbers of collisions, but also that the changes are strongly species-specific. While the casualties are reduced by 14 – 16% for the herring gull and lesser black-backed gull, respectively, and slightly more for the closely related great black-backed gull (*i.e.* 22%), the reduction is much more for the little gull and northern gannet (56% and 57%, respectively), with the highest decline of 77% reached for the black-legged kittiwake. Of these species, we have used flight height distributions based on GPS-tracks for the three large gull species and the northern gannet, while the flight height distributions for the little gull and black-legged kittiwake were based on modelled values (cf. Johnston *et al.* 2014). Hence, the differences in casualty numbers are not due to methodological differences in the flight height distributions as larger reductions are reached both for species with and without GPS data. More likely, the preferred species-specific flight heights have a larger influence on the outcome. Namely, for species that fly relatively low (especially little gull and black-legged kittiwake) or have a higher flight height particularly during specific behaviour (*e.g.* foraging plunges by gannets from an elevated altitude) increasing the airgap can mean that most of the birds get out of the danger zone of the rotor-swept area. The large gull species have commonly a higher flight altitude, and hence still a relatively large fraction of birds enter the rotor-swept area even by an increased airgap. In addition to the larger airgap without risk of collisions, increasing the hub height also leads to a reduced number of casualties because the collision risk is the highest at hub height and the lowest towards the tip heights. Therefore, having the hub height at a higher altitude where less birds fly, also leads to a reduced number of collisions.

Table V.1 Estimated number of annual collisions for six seabird species for the Dutch future wind farm Zoekgebied 5 Oost with the lowest tip height raised to 40 m above mean sea level (MSL) relative to the KEC 4.0 estimations with lowest tip height at 25 m, based both on bird densities from the international scenario.

	Annual collisions calculated with lowest tip height at:		**Decrease in number of casualties**
Species	**40 m**	**25 m**	
herring gull	11	13	14%
great black-backed gull	82	105	22%
lesser black-backed gull	11	13	16%
little gull	2	5	56%
northern gannet	65	151	57%
black legged kittiwake	11	48	77%

Reference

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

Bureau Waardenburg
Ecology & Landscape

Varkensmarkt 9, 4101 CK Culemborg, The Netherlands
Tel. +31 345 51 27 10
www.buwa.nl, info@buwa.nl