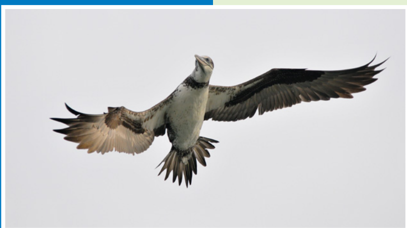
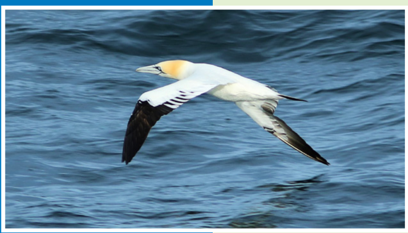
Spatial and temporal distribution of different age classes of seabirds in the North Sea

Analysis of ESAS database





A. Potiek,
N. Vanermen,
R.P. Middelveld,
J. de Jong,
E.W.M. Stienen,
R.C. Fijn

INSTITUUT NATUUR- EN BOSONDERZOEK

Vlaanderen is wetenschap

Bureau Waardenburg
Ecologie & Landschap

Spatial and temporal distribution of different age classes of seabirds in the North Sea. Analysis of ESAS database.

A. Potiek, N. Vanermen, R.P. Middelveld, J. de Jong, E. Stienen, R.C. Fijn

Status: final report

Report nr:	19-129
Project nr:	19-0197
Date of publication:	18 October 2019
Photo credits cover page:	Daniel Beuker, Jan Dirk Buizer / Bureau Waardenburg bv
Project manager:	R.C. Fijn *MSc.*
Reviewer:	Camiel Heunks
Name & address client:	Rijkswaterstaat WVL – G. Hakobian Postbus 2232 3500 GE Utrecht
Reference client:	Zaaknummer: 31147546 Bestelnummer: 4500285376
Signed for publication:	Team manager Bird Ecology Bureau Waardenburg bv drs. C. Heunks
Signature:	

Please cite as: Potiek, A., N. Vanermen, R.P. Middelveld, J. de Jong, E.W.M. Stienen & R.C. Fijn. 2019 Spatial and temporal distribution of different age classes of seabirds in the North Sea. Analysis of ESAS database. Bureau Waardenburg report 19-129. Bureau Waardenburg, Culemborg.

Keywords: North Sea, Seabirds, Kader Ecologie en Cumulatie, ESAS, age distribution

Bureau Waardenburg
Ecology & Landscape

Bureau Waardenburg, Varkensmarkt 9, 4101 CK Culemborg, 0345 51 27 10, info@buwa.nl, www.buwa.nl

Preface

This report describes the results of a study on spatio-temporal patterns of seabird occurrence in the North Sea in order to gain a better understanding of the distribution and abundance of different age-classes of a selection of species. These data will feed into population models that were constructed for these seabird species as part of the Wind Op Zee Ecological Programme (Wozep).

This work is part of the contract commisioned by Rijkswaterstaat Water, Verkeer en Leefomgeving and contracted to Bureau Waardenburg (BuWa) and the Instituut voor Natuur en Bos Onderzoek (INBO).

This project would not have been possible without the data, help and assistance of all European Seabirds At Sea (ESAS) partners and specifically Nele Markones (German dataset) and Mardik Leopold (Dutch dataset).

The project team for this task was formed by

Astrid Potiek	BuWa	Analysis, Report
Nicolas Vanermen	INBO	Analysis, Report
Robert Middelveld	BuWa	Analysis
Job de Jong	BuWa	Analysis
Eric Stienen	INBO	Analysis, Coordination
Ruben Fijn	BuWa	Report, overall Project management

We are also thankful to the support and contributions from Maarten Platteeuw (Rijkswaterstaat Water, Verkeer en Leefomgeving) and Suzanne Lubbe (Rijkswaterstaat Zee & Delta).

Camiel Heunks (BuWa) provided helpful comments on a previous version of this report.

The authors thank all people who have contributed to this report.

Table of contents

1 Introduction

The Dutch Offshore Wind Ecological Program (Wozep) is part of the assignment from the Ministry of Economic Affairs to Rijkswaterstaat (RWS) to investigate the (cumulative) effects of multiple new wind farms in the Dutch North Sea. This integrated monitoring and research program studies specific knowledge gaps relating to the impact of offshore wind farms on the North Sea ecosystem and its inhabitants.

As part of Wozep population models of 17 critical species of seabirds were developed in two separate programs in relation to questions over the potential impacts of offshore wind developments (Potiek *et al.* 2019; van Kooten *et al.* 2019). These species include amongst others great black-backed gull, black-legged kittiwake, great skua, black tern, northern gannet, arctic skua, common tern and little gull, although a population model of the latter could not be made due to lack of data. These population models can be used to assess the sensitivity to changes in demographic rates, such as shifts in mortality caused by human pressures. The starting point for a good assessment is a model that reflects the population in question.

In the population models the numbers of collision victims from the KEC (Rijkswaterstaat 2015, 2019) were used and these were added as additional mortality to the population models to predict the population trajectory for the selected species. However, these mortality rates are generic and it is not clear how these victims are divided among the age classes. Offshore area use of juvenile, immature and adult seabirds differs in many species (Wakefield *et al.* 2009). For example, breeding adults are restricted to the area around the breeding site during the breeding season, whereas immatures are not bound to colonies yet. Immatures may even prefer to use areas further offshore in order to avoid competition with adults or with individuals of other species. In addition, for some species, subadult age classes even stay in wintering areas and do not come back to the breeding grounds at all. This can also result in a different age distribution in the North Sea compared with the age distribution of the population as a whole.

A limited amount of data is available on the distribution of age classes in the North Sea and for some species these scarce data are used in the models. For example, data on distribution of different age classes of lesser black-backed gull and herring gull are available from Camphuysen and Leopold (1994). In population models for these species, it is assumed that the distribution of age classes among victims follows the distribution of age classes in the area of interest (North Sea).

However, for many species these data on distribution of age classes are not readily available. In those cases, it is assumed that the collision risk is not age-specific. As a result, the distribution of age classes among victims is assumed to follow the distribution of age classes in the population. This distribution of age classes in the population can be calculated based on the stable stage structure of the population model. But for example in lesser black-backed gulls, it is known that there are proportionally more adults offshore than sub-adults, which means that certain age classes spend more time offshore, and are thus at higher risk of collision with offshore wind turbines than those who stay closer to the shore. The outcome of the population model for each of the selected species is particularly sensitive to additional adult mortality. In other words, the impact of adult victims on the population level is stronger than of other age classes. This means that if the proportion of victims among adults is underestimated, the assessed impact is also an underestimation.

The European Seabirds At Sea (ESAS) database holds information on age-specific distribution of seabird species in space and time, and has thus the potential to fill in a few of the knowledge gaps present in the current Wozep population models. The project at hand aims to fill in these gaps by analysing the ESAS database specifically for spatio-temporal patterns of different age classes for great black-backed gull, black-legged kittiwake, great skua, black tern, northern gannet, arctic skua, common tern and little gull. Knowledge of the age-specific distribution in space and time of these birds is likely to improve the reliability of the age distribution among victims, and thereby improves the quality of the impact assessment for these species.

2 Materials and methods

2.1 ESAS

The European seabirds at sea (ESAS) database is organised in a way that suits the targeted analysis of spatio-temporal variation in the occurrence of different age-classes of seabirds across the North Sea. The last ESAS-database version 5 includes a large number of surveys and counts up until 2011, yet for some countries the last update dates back to many years before 2011. Especially Belgium, the Netherlands and Germany hold a substantial amount of additional data. For this project we collected and added these data to the ESAS database (§2.2). In the framework of environmental impact assessments regarding wind farm developments many more data were collected throughout the North Sea, especially in UK waters, yet these are generally owned by the industry itself and therefore often not publicly available.

2.2 Additional data from Belgium, the Netherlands and Germany

Seabirds at sea (SAS) data collection in Belgium is exclusively done by INBO and therefore all Belgian data collected after their last update in 2007 (29,052 additional counts) could readily be added to the current ESAS database version 5. For the Dutch data, we obtained an agreement with Wageningen Marine Research (WMR) (contact person: Mardik Leopold) to use the SAS data from WMR and the Royal Netherlands Institute for Sea Research (NIOZ) collected since their last ESAS update in 2006 (58,200 additional counts). Lastly, the use of German SAS data collected between 2011 and 2016 (24,926 additional counts) was agreed upon with the Christian-Albrechts-Universität zu Kiel, Research and Technology Centre Westcoast (FTZ) (contact person: Nele Markones).

2.3 Age tables

This study encompasses an analysis of the following eight species: northern gannet, arctic skua, great skua, little gull, great black-backed gull, black-legged kittiwake, black tern and common tern.

The generation of the 'age tables' (where all further analyses are based upon) followed a series of selections regarding:

- period: 2004-2018 (the last 15 years)
- count method: only ship-based surveys applying a combination of snapshot and transect counts (Tasker *et al.* 1984)
- transect information: for the scarcer species (both skuas and black tern) we used all counted birds (number observed per km sailed), for the other (more common) species we only used birds counted inside the transect (numbers observed per km² counted)

Finally, for each species, a cross table is obtained with the number of counted individuals per count location (rows) for each age class (columns) (Figure 2.1, example for northern gannet).

```
'data.frame':       318765 obs. of  19 variables:
 $ POSKEY        : int  10267844 10267845 10267847 10267849 10267850 10267851 ...
 $ TRIPKEY       : int  10012336 10012336 10012336 10012336 10012336 10012336 ...
 $ ORIGIN        : int  10 10 10 10 10 10 10 10 10 10 ...
 $ Day           : int  28 28 28 28 28 28 28 28 28 28 ...
 $ Month         : int  6 6 6 6 6 6 6 6 6 6 ...
 $ Year          : int  2005 2005 2005 2005 2005 2005 2005 2005 2005 2005 ...
 $ Latitude      : num  57.2 57.2 57.2 57.2 57.2 ...
 $ Longitude     : num  -1.94 -1.9 -1.87 -1.83 -1.79 -1.75 -1.71 -1.67 -1.63 ...
 $ Area_surveyed : num  0.91 0.91 0.67 0.85 0.85 0.85 0.85 0.85 0.97 0.76 ...
 $ Juvenile      : int  0 0 0 0 0 0 0 0 0 0 ...
 $ X2nd_yr       : int  0 0 0 0 0 0 0 0 0 0 ...
 $ X3rd_yr       : int  0 0 0 0 0 0 0 0 0 0 ...
 $ X4th_yr       : int  0 0 0 0 0 0 0 0 0 0 ...
 $ X5th_yr       : int  0 0 0 0 0 0 0 0 0 0 ...
 $ IMM_unspec    : int  0 0 0 0 0 1 0 0 0 2 ...
 $ IMM_all       : int  0 0 0 0 0 1 0 0 0 2 ...
 $ Adult         : int  1 0 0 0 0 0 0 0 8 0 ...
 $ Unknown       : int  0 0 0 0 0 0 0 0 0 0 ...
 $ Total         : int  1 0 0 0 0 1 0 0 8 2 ...
```

Figure 2.1 Example of the structure of the 'age table' for northern gannet, which contains information on the time (day, month and year), location (longitude and latitude), area surveyed and the number of individuals per age class for each count (defined by the unique key number in the 'POSKEY' column).

Importantly, age class was not always registered during counting ("Unknown"), or individuals were recorded as 'immature' without further age information ("IMM_unspec") (Table 2.1 & Figure 2.1). We therefore based all analyses on the total number of immatures (by summing all classes of immature birds - "IMM_all") and the number of adults, thereby leaving out individuals without age information. Using this approach gives a larger sample size of immature birds opposed to looking at separate immature age classes, but no distinction can be made between different year classes of immature birds. This strategy further implies that numbers and densities listed in the results section cannot be regarded as absolute. For great skua and black tern in particular, percentages of individuals of unknown age in the database are high (Table 2.1), highlighting that the age proportions reported in this study should be interpreted with care.

Table 2.1 Percentage of individuals of unknown age in the database per species. Bold text refers to species for which a high percentage of registered individuals (>70%) lack information on age class.

Species	Percentage of individuals of unknown age
Northern gannet	18%
Arctic skua	42%
Great skua	**74%**
Little gull	36%
Great black-backed gull	43%
Black-legged kittiwake	53%
Common tern	43%
Black tern	**82%**

2.4 Spatial variation in effort

Some of the selected species are expected to use the area close to Great Britain in a different way than the area around Germany, the Netherlands and Belgium, for example due to proximity to breeding colonies. Age distribution may further vary with distance from the coast. Therefore, the North Sea was divided in the different zones as shown in Figure 2.2.

Table 2.2 shows the number of data points in the database per month and per zone, and area-month combinations with relatively low effort (<500 data points) are highlighted in grey. The effort varied strongly between zones as well as throughout the year. Moreover, months with low effort in one area are not necessarily months with low effort in another area. The 'BE, NL' and the 'GE' zones show good effort throughout the year. For the UK, effort was low outside the periods February-March and July-September, and also appeared considerably higher in the northern compared to the southern part. In Danish and Norwegian waters, effort was strongly concentrated in the months of July and August, and mostly confined to the 22-100 km subarea. In the 'open sea' area, effort was good (>1000 data points) from January until September.

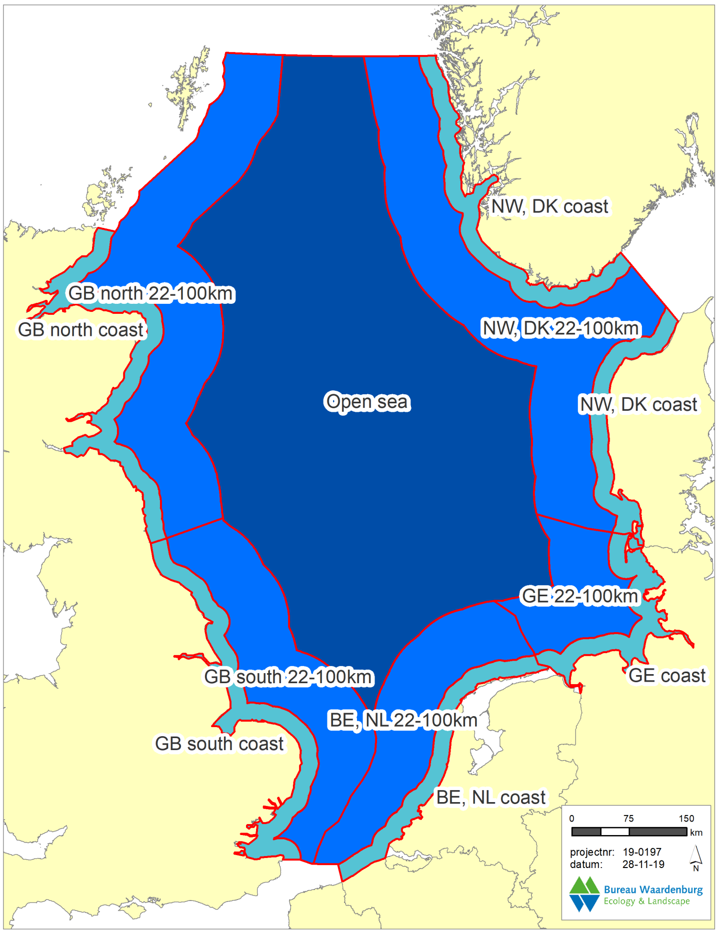


Figure 2.2 Zonation of the North Sea based on distance from the coast, and further distinguishing between south and north, as well as between west and east.

Table 2.2 Total number of data points per geographical zone per month; cells in grey highlight area-month combinations with less than 500 point counts.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BE, NL												
Coast	5424	4484	1248	4110	1307	3821	1813	3424	1910	2697	3247	3523
22-100km	4442	3949	4319	4555	2542	4656	5662	7061	4431	4072	5319	3373
GE												
Coast	1510	786	5737	7637	9086	8753	4721	5674	4946	2859	1748	762
22-100km	620	1777	6039	12666	14535	7296	9438	12878	4007	3068	1178	1082
GB north												
Coast	106	872	1279	0	0	91	217	602	1569	0	0	0
22-100km	282	2980	2253	0	0	134	962	4623	2375	0	0	0
GB south												
Coast	0	0	0	14	1		140	513	681	0	0	0
22-100km	215	32	158	150	136	36	419	1508	236	18	167	66
NW, DK												
Coast	0	35	284	0	81	54	123	172	0	0	0	0
22-100km	0	76	28	0	58	228	1570	1600	1	0	0	0
Open sea												
> 100 km	1036	3801	6549	2090	2965	2617	12983	16704	16938	148	48	90

Table 2.3 Number of individuals registered per species (with known age class) within the selected database. Note that 1. effort differs between the zones, 2. zones differ in size, and 3. not all observed individuals have registered age classes.

Species	Number of individuals in database with registered age class	BE, NL		GE		GB, north		GB, south		NW, DK		Open sea
		coast	22-100 km	coast	22-100 km	coast	22-100 km	coast	22-100 km	coast	22-100 km	
Northern gannet	14631	2151	6135	35	528	747	1703	100	490	8	36	2698
Great skua	676	58	253	3	15	19	133	3	33	3	5	151
Arctic skua	419	125	111	5	26	38	24	9	40	0	0	41
Great black-backed gull	11147	4836	5359	160	219	50	87	34	94	4	16	288
Little gull	10918	5169	3834	617	1150	61	0	42	15	2	0	28
Black-legged kittiwake	19603	3192	8478	27	1469	1084	1556	154	697	2	15	2929
Black tern	108	72	12	18	5	1	0	0	0	0	0	0
Common tern	4438	3029	326	482	407	4	10	18	92	2	9	59

Figure 2.3 visualizes the number of available data per grid cell of 10x10 km throughout the North Sea. Data availability and area coverage near Norway and Denmark, and in the southern zones of the UK are clearly lower than for other areas.

The resulting database consists of over 313,000 seabird counts collected between 2004 and 2018, providing age information on no less than 61,940 individuals across all eight study species. The number of encountered individuals of known age appears to be rather low (< 1,000) for both species of skua and black tern, but ranges between 4,000 and 20,000 individuals for the five more common species (Table 2.3).

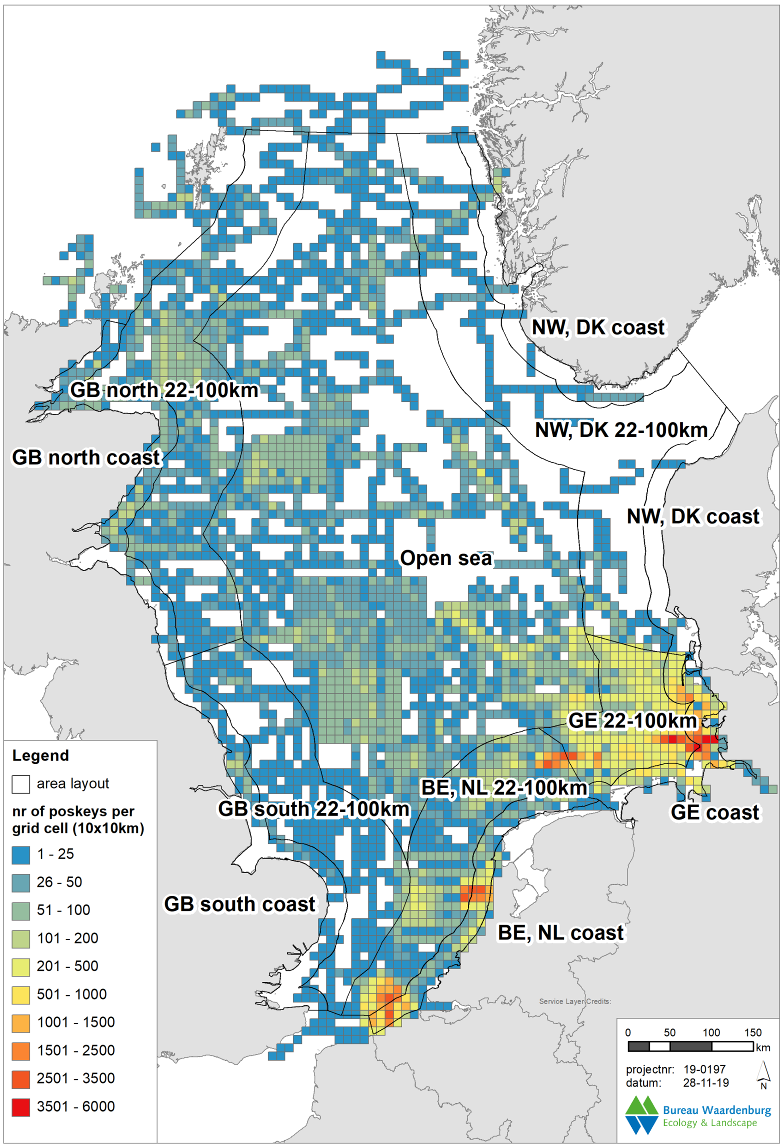


Figure 2.3 Number of counts per grid cell (10x10 km). Colours indicate effort. Zonation represents areas used for the analysis of spatial variation.

2.5 Spatial analyses

For the analysis of spatial variation in age distribution, the area is divided into different zones as presented in Figure 2.2. This zonation is based on ecology with species using different areas for different purposes. Some of the study species breed in the UK, but not in the zones in the eastern part of the study area. In addition, immatures may use areas further away from the coast to a different extent than adults. For those reasons, the zonation is based on the distance to the coast, as well as an east-west and a north-south component.

For each data point, the density of adults is calculated from the number of adults observed and the total area surveyed at that data point. Similarly, the density of immatures is calculated based on the number of immatures observed and the total area surveyed. The area surveyed is specified in the database for each position within each trip (poskey and tripkey; see Figure 2.1). By averaging per zone and per month, monthly densities of immatures and adults are calculated for each zone. Note that the calculation of immature densities is based on the column IMM_all from the database, which includes all immatures with given age class as well as immatures without specified age class (IMM_unspec) (see Chapter 2.3). This means that individuals without any specification of age class (UNKNOWN) are excluded from the analysis.

Only data recorded in the ESAS database as 'in transect' were used. Combined with the survey area, the resulting densities are given in numbers of individuals per 100 km^2. However, in case of great skua, arctic skua and black tern, the use of only transect data resulted in a very small sample size. For these three species, all registered individuals are analysed. As a result, densities of these three species are given in numbers of individuals per 100 km sailing.

Subsequently, the proportion of adults for each zone is calculated based on the densities of immatures and adults per zone. Note that the spatial coverage and the effort throughout the year differ between the zones due to different measurement campaigns. This likely affects the age distribution (see temporal analysis) (Table 2.2). In particular, note that the effort in the southern UK is very limited, especially during winter.

2.6 Temporal analyses

For the temporal analyses we considered five areas, by discarding Norwegian & Danish waters and lumping the 'coast' and '22-100 km' subzones, resulting in the following units: 'BE & NL', 'GE', 'GB north', 'GB south' & 'open sea'. We calculated monthly densities of adult and immature birds for each zone, by performing two subsequent data aggregations. First, we calculated the mean densities per month and per year, after which we calculated the mean densities per month, hereby ensuring minimal effect of year-to-year variation in survey effort. We mainly focused on the area in front of the Belgian and Dutch coast ('BE, NL'), where effort was high throughout the year (Table 2.2). For each species we show a graph with the occurrence of both age classes throughout the year, as well as the seasonal pattern in the proportion of adult birds in this specific area.

The same calculations were performed for all five areas, and the resulting area-specific monthly adult proportions are included in a table, again generated for each study species. Based on the effort overview in Table 2.2, we only calculated adult proportions for area-month combinations with over 500 counts. The tables often indicate 'NA', meaning that the density for that specific area-month combination was zero, which does not allow to calculate an adult proportion.

Note that for both species of skua and black tern, we did not calculate actual densities, but calculated the (mean) number of individuals counted per km instead.

3 Results

3.1 General patterns

Table 3.1 shows the overall age distribution for each species (Percentage adults based on ESAS data). This is calculated based on all data in the compiled database, before taking into account variation in space or time. Spatial and temporal patterns are discussed in Chapter 3.2 and 3.3.

In comparison, Table 3.1 shows the age distributions that were used in the population models. It can be concluded that for each of the selected species except for black tern, the proportion of adults based on ESAS data is much higher than the percentage of adults assumed in the population models (mostly based on the stable stage distribution). This may be partly due to the fact that ESAS data is collected throughout the year, whereas the stable stage distribution is determined directly after the breeding season, including all first year individuals. After the (first) winter, and just before the breeding season, the proportion of adults is always higher, as mortality of immatures (and particularly first winter birds) throughout the year is higher than the adult mortality. In Chapter 3.3, we discuss the temporal variation in age distribution in more detail. Spatial variation in age distribution is discussed in Chapter 3.2.

Table 3.1 Percentage of adults based on field observations (ESAS database 2004-2018, without taking into account variation in space and time), and percentage of adults assumed in population models (Potiek et al. *2019). * For northern gannet, the stable stage distribution from the population model by Kooten* et al. *(2019) is reported.*

Species	Percentage adults based on ESAS data	Percentage adults among victims in population models	Apportionment collision victims in population model
Northern gannet	73%	Population model only for habitat loss*; stable age distribution: 61%	-
Great skua	82%	43%	Stable age distribution
Arctic skua	63%	50%	Stable age distribution
Great black-backed gull	58%	51%	Stable age distribution
Little gull	87%	No population model	-
Black-legged kittiwake	88%	57%	Stable age distribution
Black tern	66%	73%	Stable age distribution, adjusted based on presence in North Sea
Common tern	89%	76%	Stable age distribution, adjusted based on presence in North Sea

3.2 Spatial patterns

For each of the species of interest, we visualized the spatial variation in age distribution, as well as the density in each of the zones. Note that for both species of skua and black tern, we used the (mean) number of individuals counted per 100 km (due to limited data availability, see methods), whereas for the other species we calculated the actual density (individuals per 100 km^2). For clarity, we refer to both measures as ‘density’. Although this means that densities should not be compared between species, they can be compared within species. The comparison of densities between zones for a given species gives an impression of spatial variation in the density of the species of interest.

If the density of a given species in a given zone is low, this age distribution is based on relatively few registered individuals, which results in the age distribution being less reliable (higher probability of 100% adults or 100% immatures). Note that given the temporal variation in age distribution within a year, variation in the moment of ESAS counts between zones may result in a different age distribution (Figure 4.1). This variation in effort throughout the year between the zones is presented in Table 2.2.

3.2.1 Northern gannet

The highest densities of adult northern gannets are registered in northern UK waters (>75 individuals per 100 km^2, Figure 3.1) followed by southern UK, 22-100 km from the BE and NL coast, and open sea with 25-35 ind. per 100 km^2. In all other areas, densities are clearly lower (<14 ind. per 100 km^2). Due to the low density in the NW, DK and GE zones, age distributions in these zones are less reliable, and should not be considered due to the strong impact of individual observations (especially of groups). Excluding these NW, DK and GE zones, the age distribution slightly varies between the zones. Whereas the overall age distribution is 27% adults and 73% immatures (Table 3.1), the proportion of adults is higher in GB zones further than 22 km from the coast and at open sea.

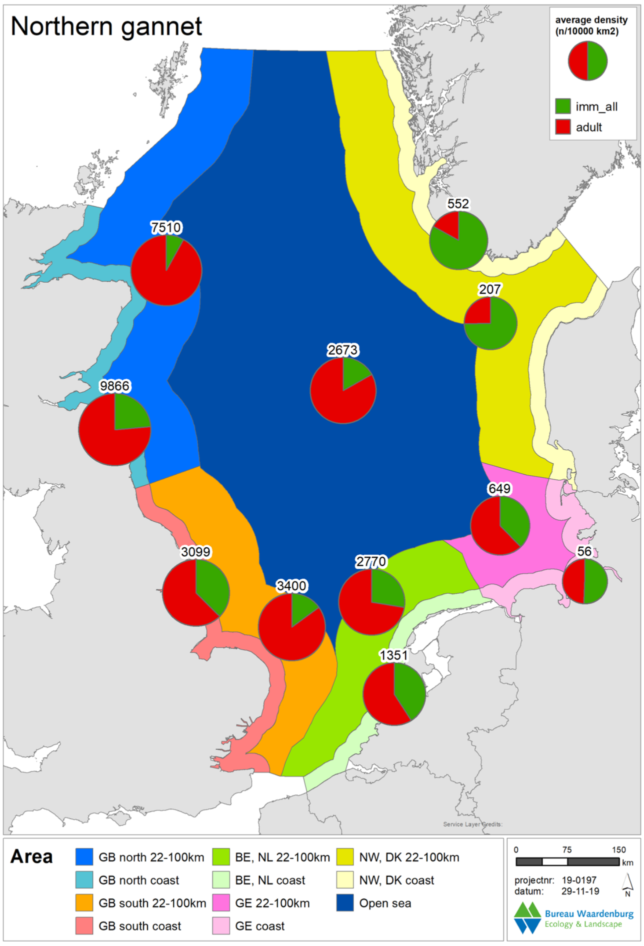


Figure 3.1 Spatial variation in age distribution of northern gannet. Pie charts indicate for the corresponding zone the proportion adults (red) and the proportion immatures (green) and size of the pie represents the log transformed densities of birds. Average density in months with species presence is given for each zone above the pie chart (number of individuals per 10,000 km^2). Different background colours indicate different zones. Note that the densities in the NW, DK and GE zones are very low, resulting in unreliable age distributions.

3.2.2 Great skua

According to Figure 3.2 highest densities of great skuas are registered in the two zones within 100 km from the northern UK coast (>1.36 ind. / 100 km), and between 22 and 100 km from the southern UK coast (0.98 ind. / 100 km). Densities in the other zones are clearly lower. The age distributions strongly vary between the zones. Compared to the other zones, the proportions of immatures seem to be higher in the BE, NL zones, the southern UK coastal zone, and between 22 and 100 km from the GE and southern UK coast. Note that sample size is relatively low in these zones, which means that a single observation can have a strong impact on the age distribution.

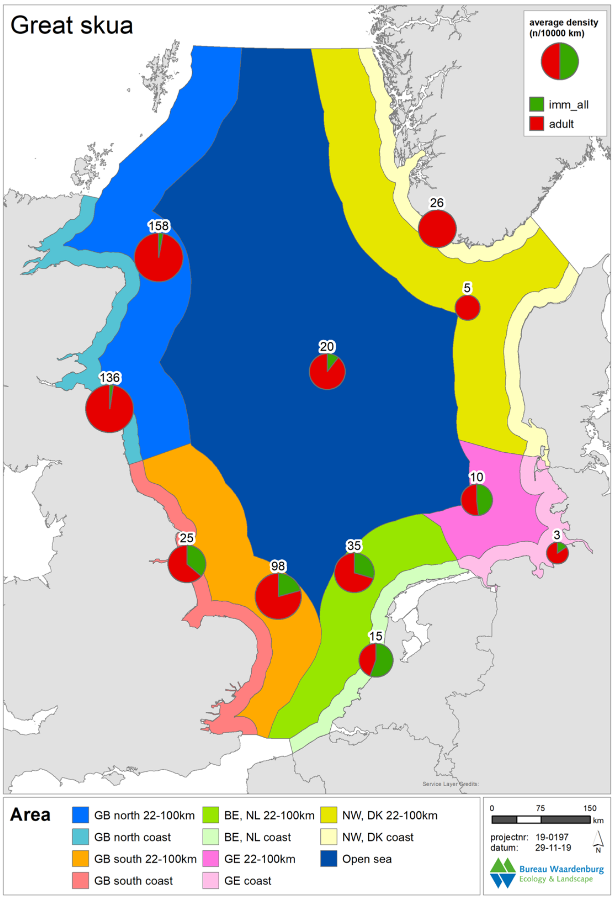


Figure 3.2 Spatial variation in age distribution of great skua. Pie charts indicate for the corresponding zone the proportion adults (red) and the proportion immatures (green) and size of the pie represents the log transformed densities of birds. Average density in months with species presence is given for each zone above the pie chart (number of individuals per 10,000 km). Different background colours indicate different zones.

3.2.3 Arctic skua

Figure 3.3 shows that the highest densities of arctic skuas are registered within 22 km from the northern UK coast. The age distributions strongly vary between the zones. Within 100 km from the northern UK coast, the proportion of adults is much higher (>90% adults) than the overall age distribution (67% adults). In contrast, the proportions of adults in the open sea, BE, NL, zones, GE zone between 22 and 100 km from the coast, and the southern UK coastal zone are clearly lower.

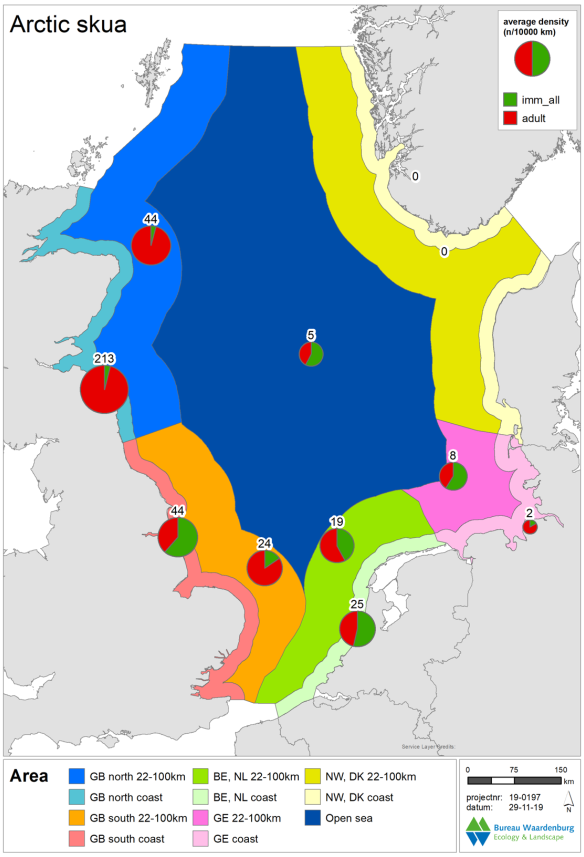


Figure 3.3 Spatial variation in age distribution of arctic skua. Pie charts indicate for the corresponding zone the proportion adults (red) and the proportion immatures (green) and size of the pie represents the log transformed densities of birds. Average density in months with species presence is given for each zone above the pie chart (number of individuals per 10,000 km). Different background colours indicate different zones.

3.2.4 Great black-backed gull

Highest densities of great black-backed gulls are registered in the two zones within 100 km from the Dutch and Belgian coast (Figure 3.4). The age distributions in these zones indicate approximately two-thirds of the reported individuals being adult, which coincides with the overall age distribution among registered individuals (65% adults, Table 3.1). A comparable age distribution is found for the open sea zone (>100 km from shore) and the two zones at between 22 and 100 km from the GB shore. In the GB coastal zones and the GE coastal zone, the proportion of adults seems to be lower (approximately half of the individuals, or less). The proportions of adults NW, DK zones seem to be somewhat higher, but note the lower densities in these zones.

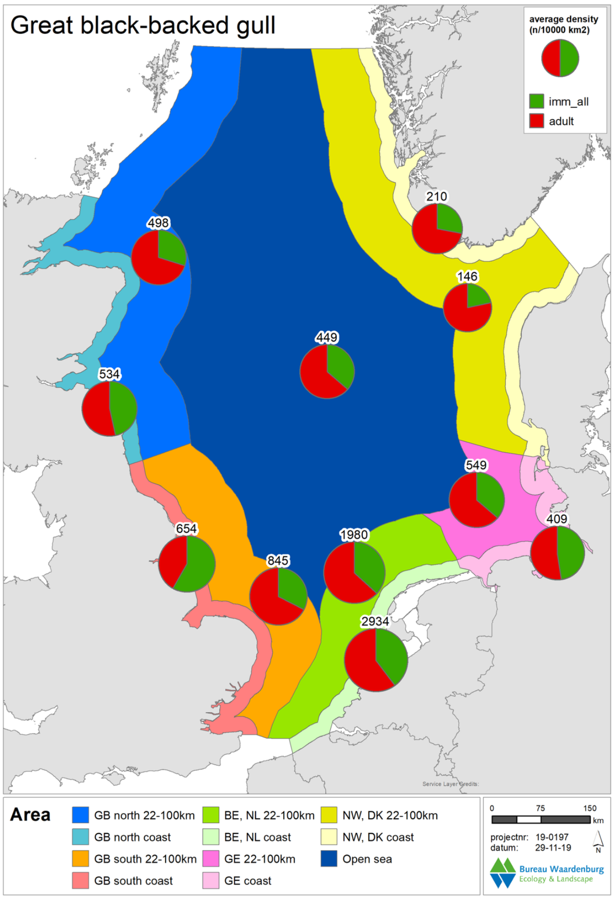


Figure 3.4 Spatial variation in age distribution of great black-backed gull. Pie charts indicate for the corresponding zone the proportion adults (red) and the proportion immatures (green) and size of the pie represents the log transformed densities of birds. Average density in months with species presence is given for each zone above the pie chart (number of individuals per 10,000 km²). Different background colours indicate different zones.

3.2.5 Little gull

For little gull highest densities are registered in the two zones within 100 km from the BE, NL coast (Figure 3.5). The age distributions strongly differ between the zones. Around 80% of the registered individuals are adults in the zones within 100 km from the BE, NL coast, within 100 km from the GE coast, and in the open sea. In the other zones, the age distributions are clearly different. The proportion of adults seems to be somewhat lower in the southern GB coastal region. For the remaining zones, age distributions are less reliable due to fewer data points (Table 2.2). For example, the age distribution in the NW, DK coastal zone may be caused by a few individuals or small groups of immatures.

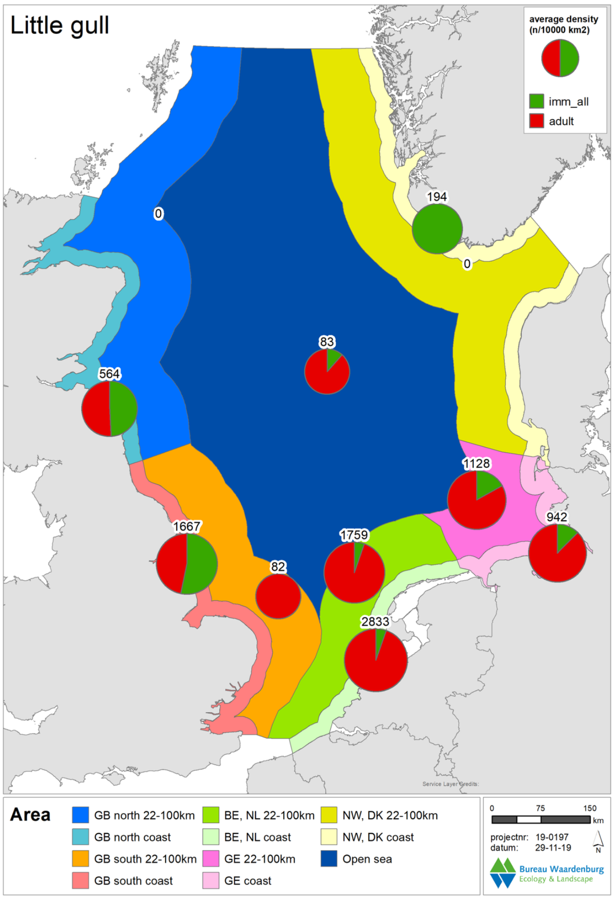


Figure 3.5 Spatial variation in age distribution of little gull. Pie charts indicate for the corresponding zone the proportion adults (red) and the proportion immatures (green) and size of the pie represents the log transformed densities of birds. Average density in months with species presence is given for each zone above the pie chart (number of individuals per 10,000 km^2). Different background colours indicate different zones. Note that densities are very low for several zones, giving unreliable estimates. In zones with a zero density, no individuals have been registered during surveys, which may to some extent be due to low effort.

3.2.6 Black-legged kittiwake

Highest densities of black-legged kittiwake are registered within 22 km from the northern UK coast (Figure 3.6). Intermediate densities were found for the other UK zones, at open sea, between 22 and 100 km from the BE, NL coast, and between 22 and 100 km from the GE coast. Age distributions from the NW, DK zones are less reliable due to fewer data points. The overall age distribution shows that 88% of registered individuals were adults (Table 3.1). If NW, DK zones are not considered (due to fewer data points), the age distributions in the remaining zones varied between 75% and 96% adults (Figure 3.6). The highest fraction of adults is registered in the UK areas, where overall kittiwake density is highest.

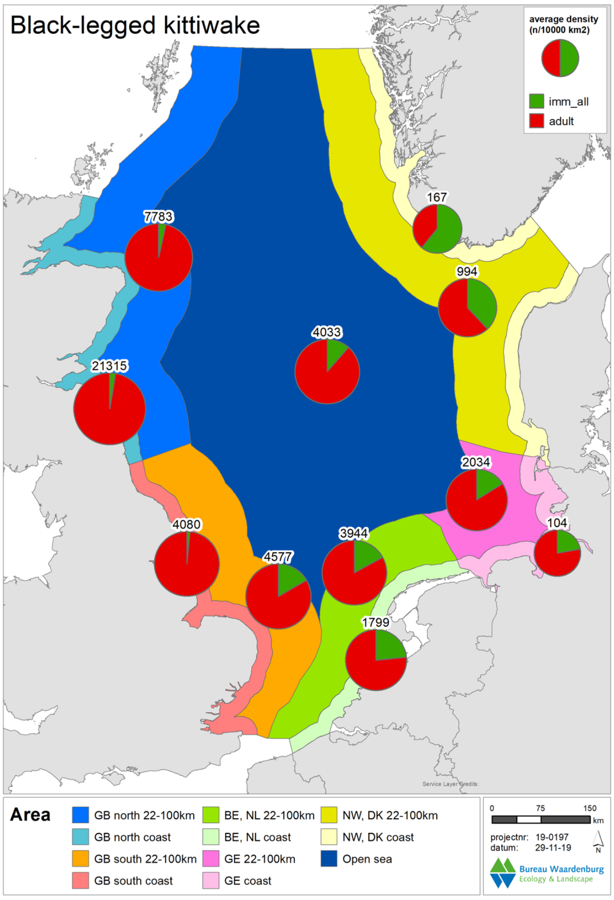


Figure 3.6 Spatial variation in age distribution of black-legged kittiwake. Pie charts indicate for the corresponding zone the proportion adults (red) and the proportion immatures (green) and size of the pie represents the log transformed densities of birds. Average density in months with species presence is given for each zone above the pie chart (number of individuals per 10,000 km²). Different background colours indicate different zones. Note the strong variation in density between zones. As a result of fewer data points, age distributions for the NW, DK zones are less reliable than for other zones.

3.2.7 Black tern

Densities of black tern are very low all over the North Sea (Figure 3.7). The database includes registrations in only the zones within 100 km from the BE, NL coast, within 100 km from the GE zones, and GB coastal zone. The overall age distribution is estimated as 66% adults (Table 4). However, the age distributions for the different zones strongly vary, which is likely caused by low numbers of registered individuals (Table 2.3).

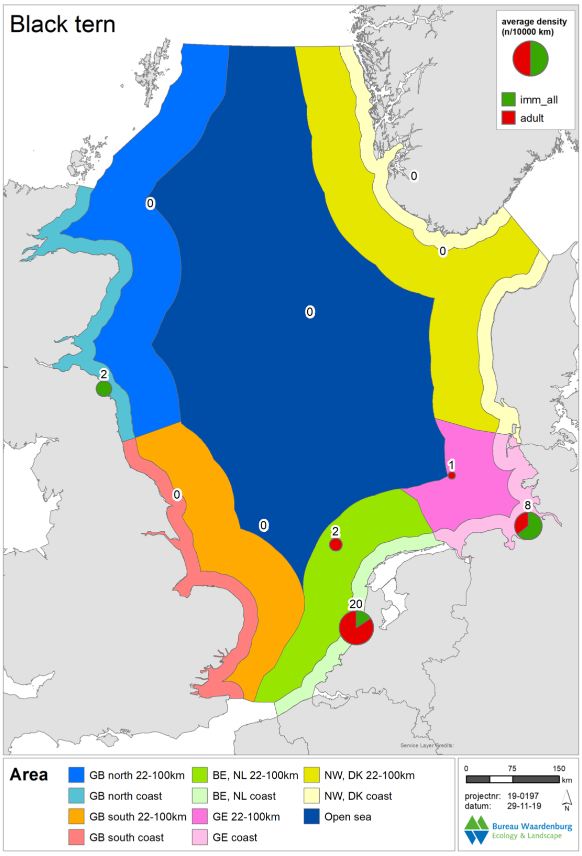


Figure 3.7 Spatial variation in age distribution of black tern. Pie charts indicate for the corresponding zone the proportion adults (red) and the proportion immatures (green) and size of the pie represents the log transformed densities of birds. Average density in months with species presence is given for each zone above the pie chart (number of individuals per 10,000 km). Different background colours indicate different zones. Note the very low densities. Zero densities indicate that no individuals (with known age class) have been registered in these zones.

3.2.8 Common tern

Highest densities of common tern are registered in the coastal zone of BE and NL, the coastal zone of GE and the southern coastal zone of GB (Figure 3.8). Densities of common terns in the zone between 22 and 100 km from the coast of BE, NL, GE are intermediate, and densities in the other zones are low. The overall age distribution of all registered individuals contains 89% adults, and 11% immatures (Table 3.1). Age distribution varies to some extent between the different zones. The age distribution in zones with a density of at least 1 individual per 100 km^2 varies between 80% to >90% adults. Age distributions for other zones are less reliable.

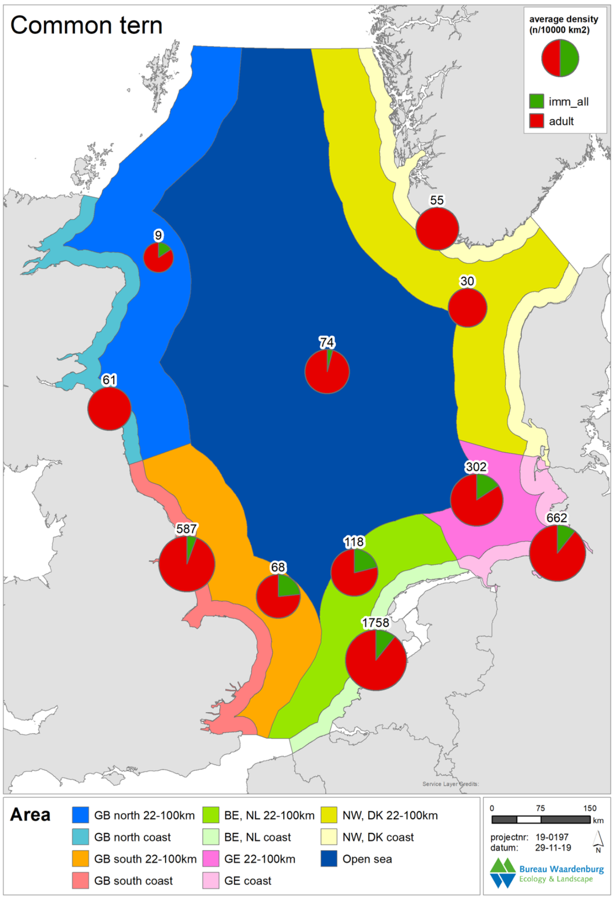


Figure 3.8 Spatial variation in age distribution of common tern. Pie charts indicate for the corresponding zone the proportion adults (red) and the proportion immatures (green) and size of the pie represents the log transformed densities of birds. Average density in months with species presence is given for each zone above the pie chart (number of individuals per 10,000 km^2). Different background colours indicate different zones. Note that densities are relatively low for several zones.

3.3 Temporal patterns

3.3.1 Northern gannet

In the south-eastern part of the North Sea, northern gannets show a distinct seasonal pattern in adult proportion, which is high (>80%) from November until April, and much lower in between, reaching its minimum of 25% in September (Figure 3.9). Adult birds are most abundant in February and October, coinciding with their migration to and from the breeding areas. Immature densities start building up from May on, due to the return of 'prospecting' 2nd to 4th calendar year birds (Cramp & Simmons 1977; Camphuysen & Leopold 1994; Vanermen *et al.* 2014), and peak in September and October when the population is further supplemented with juveniles.

In the 'GE' and 'GB south' areas, adult proportions also reach a minimum in September, down to percentages of 24 and 38% respectively (Table 3.2). In contrast, adult proportions in northern UK waters during the period July to September are considerably higher than in other parts of the North Sea (73-93%), likely explained by the presence of multiple large breeding colonies.

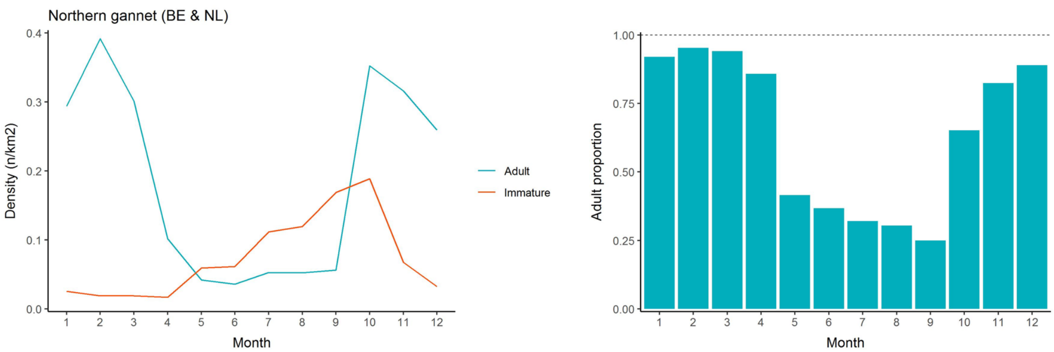


Figure 3.9. Seasonality in age-specific occurrence (left panel) and adult proportion (right panel) of northern gannets in the 'BE & NL' area.

Table 3.2. Monthly adult proportions (%) of northern gannet in five different areas in the North Sea (empty fields reflect low data availability).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BE & NL	92.1	95.3	94.1	85.8	41.5	36.7	32.0	30.4	25.0	65.2	82.4	88.9
GE	66.7	100	94.8	88.6	71.0	52.3	33.8	39.0	23.8	43.2	93.2	62.5
Open sea	100.0	97.4	98.7	78.6	24.6	63.7	51.6	52.1	68.7			
GB south							81.9	48.5	37.7			
GB north		100.0	100.0				93.3	91.4	72.9			

3.3.2 Great skua

Great skuas are generally scarce in the south-eastern part of the North Sea, but do occur in increased numbers during autumn migration, which peaks in September both for adult and immature birds (Figure 3.10). While their absolute numbers gradually diminish towards the end of the year, the proportion of immature birds increases up to more than 90% in November. Based on these age-specific seasonality patterns it could thus be argued that adult birds pass by on migration more concentrated and slightly earlier compared to immature birds (mostly juveniles).

The adult proportion in the ‘BE & NL’ area varies between 100% in April and 0% in January and March (Table 3.3). From January to May, however, overall numbers in the ‘BE & NL’ area are extremely low and the resulting adult proportions should therefore be interpreted with care. It should further be noted that the age of great skuas is often hard to assess (apart from fresh juveniles in autumn), illustrated by the fact that only 26% of the recorded individuals in the ESAS database were of specified age (Table 2.1).

Despite these inevitable data issues, adult proportions in the ‘GE’, ‘open sea’ and ‘GB north’ areas accordingly show high proportions of adult birds (>90%) from April to August, opposed to lower proportions in September and October (64-73%).

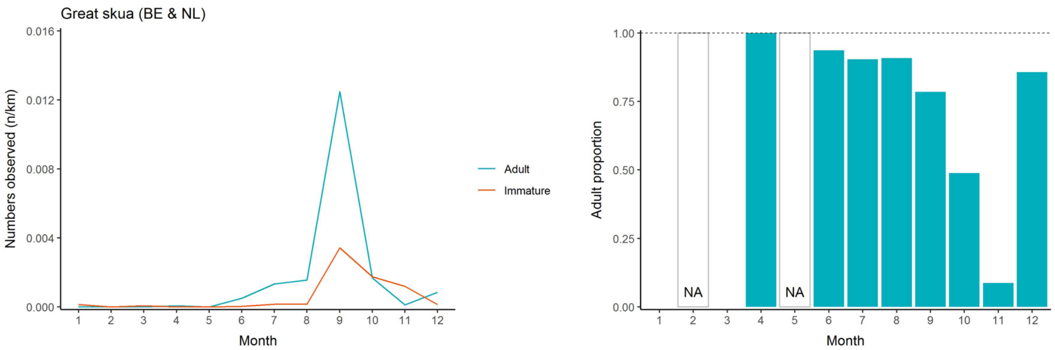


Figure 3.10 Seasonality in age-specific occurrence (left panel) and adult proportion (right panel) of great skuas in the ‘BE & NL’ area.

Table 3.3 Monthly adult proportions (%) of great skua in five different areas in the North Sea (empty fields reflect low data availability, while an ‘NA’ field reflects a zero ‘number per km’ value for the respective area-month combination).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BE & NL	0.0	NA	0.0	100.0	NA	93.6	90.4	90.9	78.5	48.9	8.7	85.7
GE	NA	NA	NA	100.0	100.0	NA	NA	100.0	NA	63.8	0.0	NA
Open sea	NA	NA	NA	100.0	NA	NA	92.7	95.9	63.6			
GB south							20.3	NA	91.4			
GB north		NA	NA				100.0	98.8	72.7			

3.3.3 Arctic skua

As for great skua, the arctic skua is a scarce migrant in the 'BE & NL' area, with numbers peaking in spring and autumn migration. While spring migration mainly concern adults (92-100%), the population is supplemented with juveniles in autumn, resulting in lower adult proportions of about 50% in August and September (Figure 3.11). The high proportion of adults in spring is explained by the fact that 2nd calendar year birds tend to stay in the wintering areas (Cramp & Simmons 1983). In the course of late autumn and early winter the adult proportion, as well as overall numbers, decreases further to about 10%.
Adult proportions in other parts of the North Sea are highly variable (ranging from 22 to 100% between April and October), but these figures should be interpreted with care considering the low number of recordings (Table 2.3; Table 3.4).

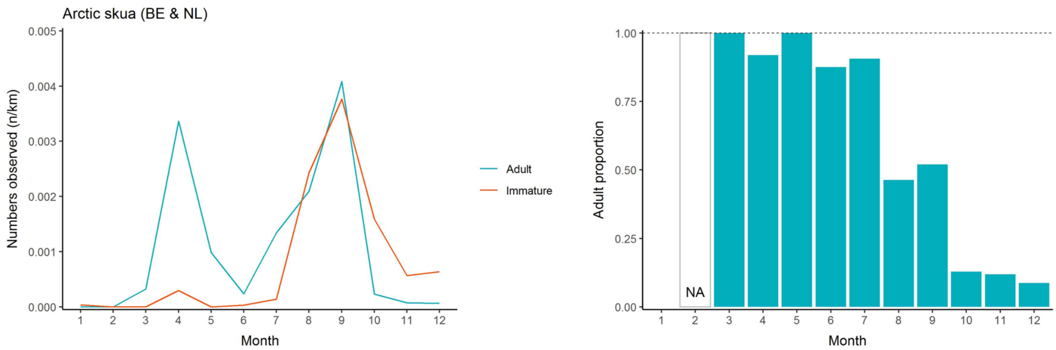


Figure 3.11 Seasonality in age-specific occurrence (left panel) and adult proportion (right panel) of arctic skuas in the 'BE & NL' area.

Table 3.4 Monthly adult proportions (%) of arctic skua in five different areas in the North Sea (empty fields reflect low data availability, while an 'NA' field reflects a zero 'number per km' value for the respective area-month combination).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BE & NL	0.0	NA	100.0	92.0	100.0	87.6	90.6	46.3	52.0	12.8	11.9	8.7
GE	NA	NA	NA	100.0	100.0	NA	NA	83.1	27.7	33.3	NA	NA
Open sea	NA	NA	NA	NA	100.0	100.0	57.8	75.7	69.2			
GB south							64.7	79.8	76.1			
GB north		NA	NA				93.6	21.8	50.0			

3.3.4 Great black-backed gull

The great black-backed gull is a typical winter visitor in the south-east North Sea, with peak densities of both age classes occurring in January (Figure 3.12). But while adult birds are largely absent during the breeding season, small numbers of immature birds remain in the area. This is reflected by a strong seasonal pattern in the adult proportion, with around 80% adults in mid-winter dropping to 5-10% between April and July.
In the 'open sea' and 'GE' areas as well, the adult proportion shows a marked decrease from at least 65% during winter months, down to 0-24% from April to July (Table 3.5). In northern UK waters, where great black-backed gull also occurs as a breeding bird, the adult proportion appears to be more constant (65-79%), at least in those months with sufficient data (February-March & July-September).

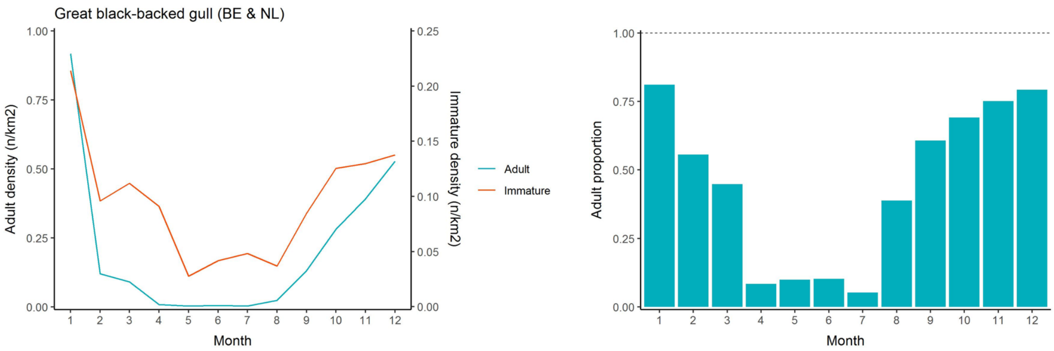


Figure 3.12 Seasonality in age-specific occurrence (left panel - note that immature densities are scaled according to a secondary axis) and adult proportion (right panel) of great black-backed gulls in the 'BE & NL' area.

Table 3.5 Monthly adult proportions (%) of great black-backed gull in five different areas in the North Sea (empty fields reflect low data availability, while an 'NA' field reflects a zero density for the respective area-month combination).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BE & NL	81.1	55.6	44.8	8.3	9.9	10.2	5.2	38.8	60.8	69.1	75.1	79.3
GE	65.4	93.3	60.1	24.0	19.2	2.9	13.3	40.6	39.1	28.6	82.9	77.3
Open sea	65.6	72.2	51.2	16.3	0.0	0.0	24.2	40.9	23.3			
GB south							0.0	47.7	58.6			
GB north		64.5	75.0				NA	78.6	69.7			

3.3.5 Little gull

The data for little gull in the ‘BE & NL’ area show a distinctive migratory pattern, with peak densities in March-April as well as in October. In contrast, the species is virtually absent in June and July, and only small numbers are observed in winter (Figure 3.13). While adult spring migration occurs over a period of 2 months (March-April), migration of immature birds is highly concentrated in April. This reflects age-related differential migration, and a corresponding pattern has been observed during land-based seawatch counts (pers. comm. Maarten Platteeuw). The proportion of adult birds in the south-eastern part of the North Sea is consistently high and above 90% from January to April, quite variable from May to August (71-100%) and higher again (above 80%) from September on (Table 3.6). Note that the variable adult proportions in May-August coincide with very low presence, and the resulting figures should therefore be regarded as rather unreliable.
In German waters too, the adult proportion is highest and most constant from October to April (>80%), yet highly variable from May to September (0-100%), again likely due to low numbers encountered (Table 3.6). Adult proportion in the ‘GB south’ area ranges between 53 and 84% from July to September, which is considerably lower than in the ‘BE & NL’ area the same time of year. Finally, in the ‘open sea’ and ‘GB north’ areas, adult proportions could only be calculated for 4 out of 14 area-month combinations, reflecting the low occurrence of little gulls outside the southern part of the North Sea (Stone *et al.* 1995).

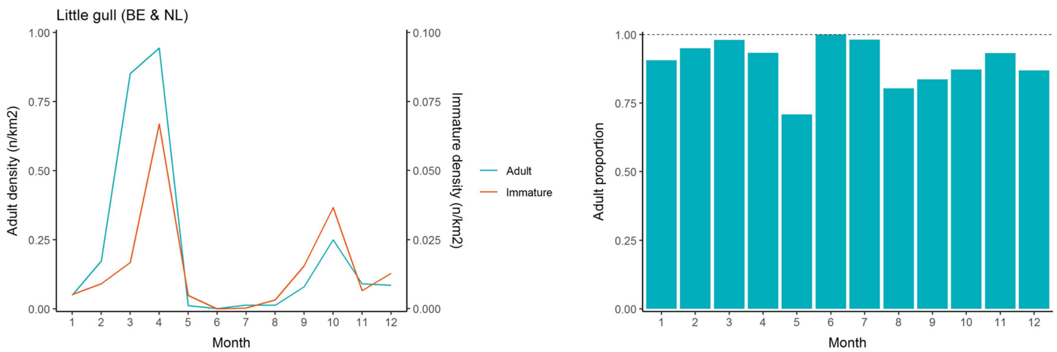


Figure 3.13 Seasonality in age-specific occurrence (left panel - note that immature densities are scaled according to a secondary axis) and adult proportion (right panel) of little gulls in the ‘BE & NL’ area.

Table 3.6 Monthly adult proportions (%) of little gull in five different areas in the North Sea (empty fields reflect low data availability, while an ‘NA’ field reflects a zero density for the respective area-month combination).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BE & NL	90.7	95.0	98.1	93.4	70.9	100.0	98.2	80.4	83.6	87.2	93.3	87.0
GE	100.0	81.3	95.0	83.7	52.4	0.0	100.0	33.1	61.5	82.7	87.2	100.0
Open sea	NA	NA	NA	90.5	NA	NA	NA	35.6	75.0			
GB south							84.2	64.8	52.9			
GB north		NA	NA				NA	NA	50.8			

3.3.6 Black-legged kittiwake

In the 'BE & NL' area, the black-legged kittiwake is a pronounced winter visitor, with peak densities occurring in December, and particularly low numbers from April to September. Throughout the year, the seasonal variation in the occurrence of immature and adult birds runs strikingly parallel (Figure 3.14). Adult proportion is relatively constant from October until April, varying between 79 and 86%, but fluctuates between 63 and 96% from May to September (when numbers are low, and age proportions therefore less reliable).
Most of the time, a comparably high level of adult proportion (generally above 80%) is observed in other parts of the North Sea, yet relatively low proportions (51-78%) occur in September due to increased presence of juvenile kittiwakes (Table 3.7). Interestingly, when considering the age-specific seasonality in German waters, adult proportion is particularly high (93-100%) from April to July, possibly related to the presence of a local breeding colony at Helgoland.

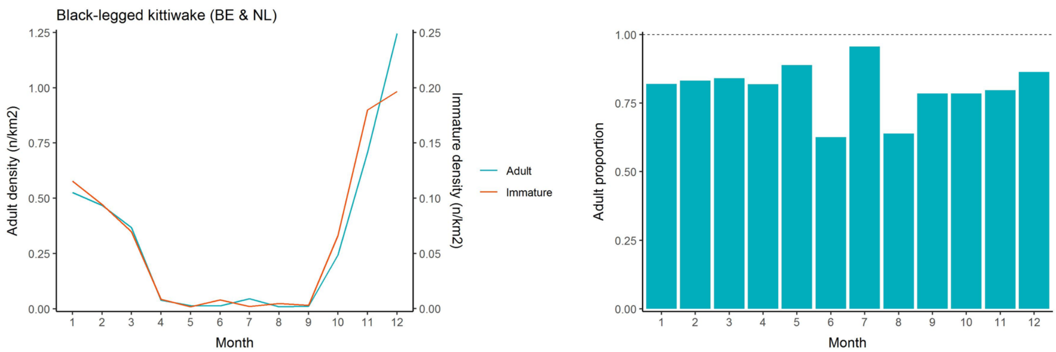


Figure 3.14 Seasonality in age-specific occurrence (left panel - note that immature densities are scaled according to a secondary axis) and adult proportion (right panel) of black-legged kittiwakes in the 'BE & NL' area.

Table 3.7 Monthly adult proportions (%) of black-legged kittiwake in five different areas in the North Sea (empty fields reflect low data availability).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BE & NL	82.0	83.2	84.0	81.9	88.8	62.6	95.7	63.9	78.5	78.6	79.7	86.4
GE	80.1	77.1	77.6	93.0	97.9	100.0	93.7	89.6	72.2	77.5	86.9	60.5
Open sea	100.0	91.4	92.8	70.2	80.3	82.7	93.3	80.5	50.8			
GB south							98.7	67.3	68.6			
GB north		83.4	93.3				98.7	89.3	78.2			

3.3.7 Black tern

The migration of black terns in the 'BE & NL' area appears to be most intense and concentrated in spring. Most adult birds pass by on migration in the months of May and July, while peak migration of juvenile birds occurs in August (Figure 3.15). Thus, while adult proportion is generally very high, it drops to only 36% in August. Immature birds are known to stay in the wintering areas during their 2nd calendar year (Cramp 1985), explaining the 100% adult proportion in spring.

A highly comparable seasonality in adult proportion was obtained for German waters (Table 3.8). Apart from the generally low numbers encountered, it should be noted that of all species discussed in this study, black tern has the highest percentage of unknown age (82%, see Table 2.1) which has obvious implications for the reliability of the figures presented here. As for little gull, black tern distribution is mostly confined to the south-eastern part of the North Sea (Stone *et al.* 1995), further explaining the many missing values in Table 3.8.

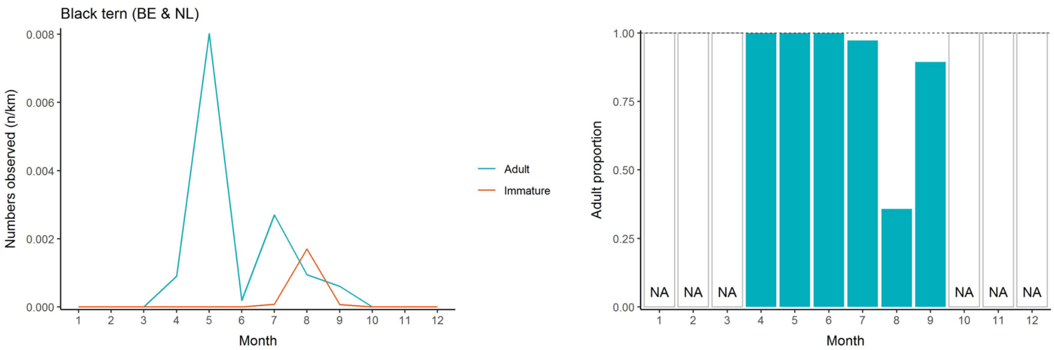


Figure 3.15 Seasonality in age-specific occurrence (left panel) and adult proportion (right panel) of black terns in the 'BE & NL' area.

Table 3.8 Monthly adult proportions (%) of black tern in five different areas in the North Sea (empty fields reflect low data availability, while an 'NA' field reflects a zero 'number per km' value for the respective area-month combination).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BE & NL	NA	NA	NA	100.0	100.0	100.0	97.2	35.7	89.5	NA	NA	NA
GE	NA	NA	NA	NA	100.0	100.0	NA	26.4	100.0	NA	NA	NA
Open sea	NA	NA	NA	NA	NA	NA	NA	NA	NA			
GB south							NA	NA	NA			
GB north		NA	NA				NA	NA	0.0			

3.3.8 Common tern

The common tern is a summer visitor in the North Sea. In the 'BE & NL' area, adult migration is most prominent in the month of May. From July onwards, the population is supplemented with immature (mostly juvenile) birds and immature densities strongly peak in August and September (Figure 3.16). Hence, while adult proportion is nearly 100% from March to June, it drops gradually to 36% in September after which it increases again to 65% in October (but note the low number of encounters in the latter month). Only a minority of 2nd calendar year common terns return to European waters, but not until after mid-June (Cramp 1985), explaining the nearly 100% adult proportion in spring.
A highly parallel pattern in adult proportion was observed for German waters (Table 3.9). Elsewhere in the North Sea, numbers observed were low (Table 2.3), possibly affecting reliability, but even so adult proportion was found to be 100% in May and July, with generally lower proportions in August and September (50-100%).

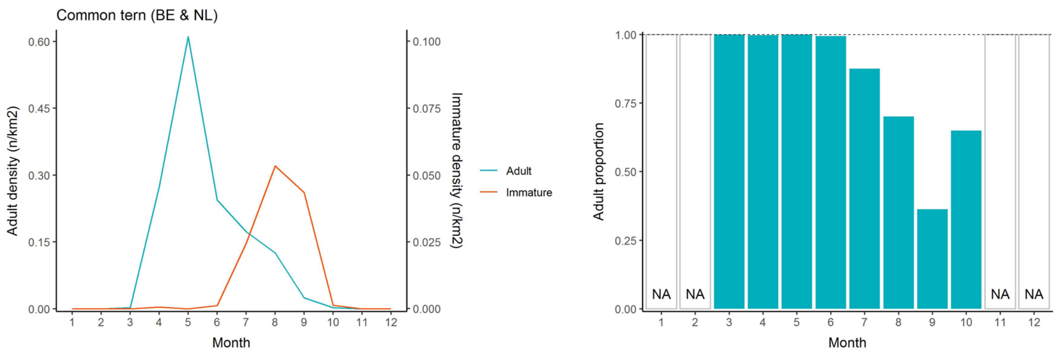


Figure 3.16 Seasonality in age-specific occurrence (left panel - note that immature densities are scaled according to a secondary axis) and adult proportion (right panel) of common terns in the 'BE & NL' area.

Table 3.9 Monthly adult proportions (%) of common tern in five different areas in the North Sea (empty fields reflect low data availability, while an 'NA' field reflects a zero density for the respective area-month combination).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BE & NL	NA	NA	100.0	99.8	100.0	99.5	87.6	70.1	36.3	65.0	NA	NA
GE	NA	NA	NA	100.0	100.0	100.0	95.6	79.6	43.6	NA	NA	NA
Open sea	NA	NA	NA	NA	100.0	NA	100.0	73.5	50.0			
GB south							100.0	71.5	66.7			
GB north		NA	NA				100.0	77.8	100.0			

4 Interpretation of results and discussion

4.1 Overall age distribution

For all species, except for black tern, the overall proportion of adults in the data exceeds the presumed proportion of adults used in the population models of Potiek *et al.* (2019) (Table 3.1). In the population models, the age distribution at sea is assumed to follow the stable age distribution, with for some species some adjustment based on absence in the area due to migration. Various factors may explain this discrepancy. First of all, the age distribution at sea may differ from the age distribution on land. For example, Camphuysen and Leopold (1994) analysed the age distribution of lesser black-backed gulls on the North Sea, and found a clearly higher proportion of adults at sea than based on the stable age distribution determined by Potiek *et al.* (2019). Secondly, due to the structure of the population model, and the time step of 1 year, the stable age distribution based on the population model is determined directly after the breeding season. At that moment in time, the proportion of immatures is relatively high due to many first-year individuals. This variation in age composition within a year is also described in Chapter 3.3.

4.2 Dependency spatial and temporal variation

The moment at which seabird surveys have been carried out differs between the different zones (Figure 4.1). If most surveys in a zone have been carried out shortly after the breeding season, the proportion of immatures in that specific zone is likely to be higher than when most surveys are carried out shortly before the breeding season. The effort is not constant throughout the year for any of the zones (Figure 4.1). The effort in the two 'BE & NL' zone and the 'GE' zone is spread more or less evenly over the year, with a peak in the summer half year. In all other zones, the effort is less homogeneous throughout the year.

As a result, spatial and temporal variation are intertwined. Despite the large dataset used within this project, it is not feasible to analyse species-specific temporal variation for each zone. For that reason, this possible dependency should be kept in mind when interpreting the results.

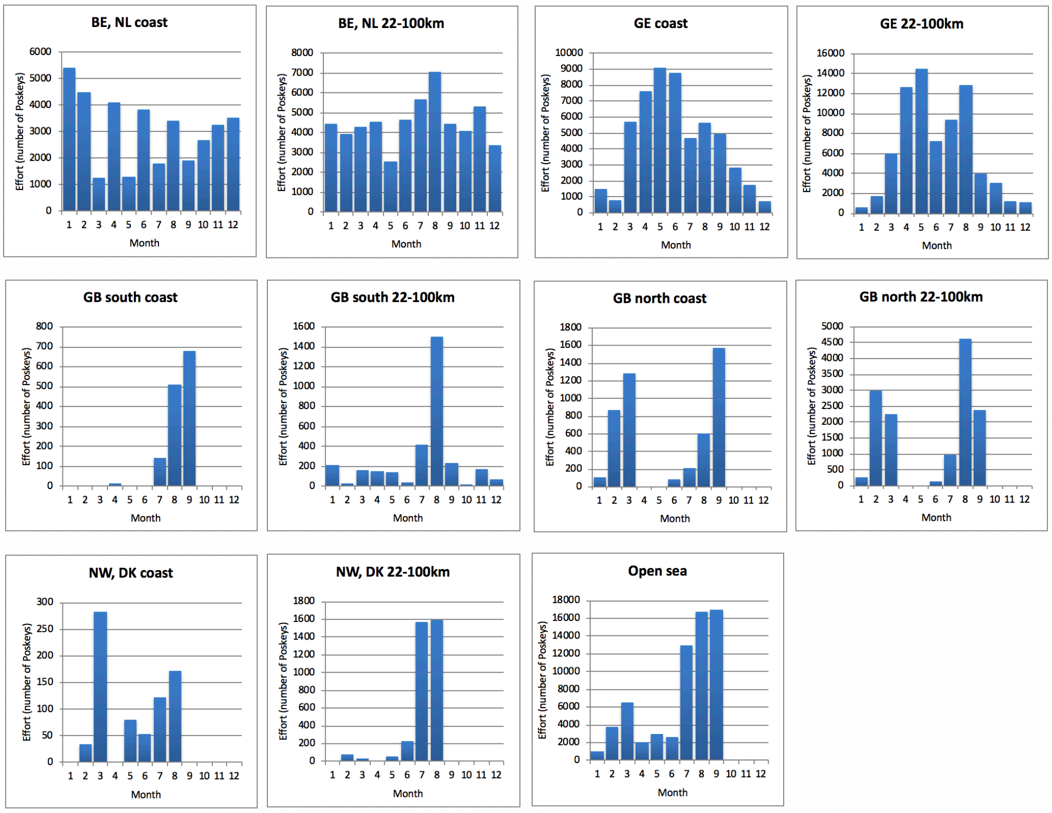


Figure 4.1 Effort per month (1 for January) in different spatial zones. Effort is given in number of Poskeys, which are the number of observation points, including points with absence of a species.

4.3 Spatial patterns

Due to temporal variation in effort between the different zones, it is in many cases difficult to distinguish between temporal and spatial patterns. For some study species, results suggest similar age distributions in the different zones (for example common tern), whereas in other cases age distributions strongly differ between zones (for example great black-backed gull). In some cases, results were less clear due to low sample size (for example black tern).

For northern gannet, the proportion of adults within 22 km from the coast is clearly lower than further offshore (for the BE, NL coast, GE coast as well as for the northern and southern UK coastal zones. Pettex *et al.* (2019) analysed habitat use of immature versus adult gannets in the Bay of Biscay, Celtic Sea and English Channel using data from aerial surveys, and found spatial segregation between these age classes during summer. Adults concentrated foraging in areas around breeding colonies, whereas immatures avoided these areas. Although Pettex *et al.* (2019) did not test on an effect of distance to coast on the age distribution, based on published figures such an effect does not appear to exist in their dataset. However, C.J. Pollock (unpublished data) found that immatures stay closer to the UK coast than adults. Our results suggest a similar pattern, with larger fractions of immatures closer to the coast (Figure 3.1).

For little gull, data availability is limited for some of the zones. At least part of the spatial variation in age distribution is likely due to the small number of individuals registered. For regions with small sample sizes, one group of immatures strongly impacts the age distribution. In the German Bight, the peak in migration of little gull occurs during the last week of April and the first week of May (Schwemmer & Garthe 2006). During these months, the effort in the (northern and southern) GB coast zone and GB 22-100km zone, as well as the NW, DK zones was very limited (Figure 4.1). And although numbers of little gull in the GB zones are lower anyway, this limited effort during this peak migration did also contributed to a lower number of registered individuals, most particular in the DK zones. For this species, spatial variation is likely intertwined with temporal variation, as discussed in Chapter 4.2.

Similarly, the spatial variation for great black-backed gull may be explained by the difference in effort throughout the year in the different zones. Based on the presented results, the proportion of adults in the southern UK coastal zone seems to be lower than all other zones. This may be due to nearly all surveys in this zone carried out between July and September, whereas in other zones the effort is more spread throughout the year (Figure 4.1). Between July and September, the relative proportion of immatures is higher (see Chapter 3.3.4, Figure 3.4).

For great skua as well as arctic skua, we found profound spatial variation in age distributions. For both species, the proportions of immatures seem to be higher within 100 km from the BE, NL coast, GE coast and the southern UK coast compared to the other zones. Note that sample size is relatively low in these zones, which means that a single observation strongly impacts the age distribution. Distance to breeding colonies may play a role, with the zones in northern UK being located closer to the breeding colonies. Subadults may avoid competition by staying away from those areas in breeding season. Alternatively, the higher proportion of immatures in the 'BE, NL' zones and 'GE' zones may be explained by immatures being more strongly impacted by stormy weather than adults due to inexperience (Hake *et al.* 2003; Thorup *et al.* 2003; Newton 2008) and/or migration later in the season (Rob van Bemmelen, pers. comm). Based on tracking data, adult birds seem to be better able to detect and compensate for wind drift than juveniles (Hake *et al.* 2003; Thorup *et al.* 2003; Newton 2008). This may explain the higher proportions of immatures in the 'BE, NL' zones and 'GE' zones. However, this does not explain the similar pattern in the southern GB zone.

Spatial variation in age distribution in black-legged kittiwake is limited. The proportion of adults is between 75 and 95% in all zones except the NW, DK zones. In the NW, DK zones, the effort and densities are clearly lower, allowing less reliable estimates. The proportions of adults might be somewhat higher in the northern UK zones (coastal region and 22-100 km) and the coastal region of the southern UK zone. This may be due to the proximity to breeding areas.

Similarly, spatial variation seems to be limited for common tern. Although the proportion of immatures seems to be higher in the zones between 22 and 100 km from the UK coast (north and south), this age distribution is based on relatively few individuals, and may therefore seem different due to chance.

For black tern, estimated age distributions are relatively unreliable due to low numbers of registered individuals.

4.4 Temporal patterns

Looking at the different areas, count effort showed strong variation throughout the year (Table 2.2), with very limited effort in the period October-December for the 'open sea' area and for the months of January, April to June and October to December for UK bound waters. As a result, full temporal patterns could only be generated for the 'BE & NL' & 'GE' subzones. Focusing on the 'BE & NL' area showed that the seasonal fluctuation in adult proportion is particularly strong for northern gannet (25-95%), arctic skua (0-100%), great black-backed gull (5-81%) and common tern (36-100%), yet more moderate for little gull (71-100%) and black-legged kittiwake (63-96%). Data for great skua and black tern also showed strong fluctuation in adult proportion but the calculated percentages should be interpreted with care considering the low number of recordings (Table 2.3) as well as the low percentage of age-classified individuals (Table 2.1). Except for little gull, the ranges in adult proportion obtained for the 'GE' area largely correspond to those observed in the 'BE & NL' area, and except for some minor differences (e.g. a higher adult proportion of kittiwakes in summer) seasonality patterns of both areas run quite parallel.

As mentioned above, other areas only allowed the generation of partial temporal patterns due to data deficiency. Compared to the proportions observed in the south-eastern part of the North Sea, these limited data do seem to suggest higher adult proportions of northern gannet and great black-backed gull in 'GB north' area. But considering the inconsistent count effort outside the 'BE & NL' and 'GE' areas, as well as the fact that the distribution of little gull, black tern and to a lesser extent also common tern is highly concentrated in the south-eastern part of the North Sea, further comparison of temporal patterns between species and areas is considered unfeasible.

5 Application in population models and species-specific recommendation

5.1 Application of results

The overall age distribution of the selected species based on the ESAS database clearly differs from the age distribution in the population models (Table 3.1, Potiek *et al.* (2019)). For each of the selected species except for black tern, the proportion of adults based on ESAS data is (much) higher than the percentage of adults assumed in the population models (mostly based on the stable stage distribution). This may indicate that the age distribution at sea differs from the theoretical age distribution used in the population models. Alternatively, this difference may be (partly) due to the fact that ESAS data is collected throughout the year, whereas the stable stage distribution is determined directly after the breeding season, including all first-year individuals. The proportion of immatures is highest during or directly after the breeding season, and then declines through the season due to mortality of immatures being higher than the adult mortality (see Chapter 3.3).

For the long-lived species in this study, the population growth rate is more sensitive to a change in adult survival than to a change in immature survival (Sæther *et al.* 1996; Potiek *et al.* 2019). As a result, if the proportion of adults in the population models is proven to be higher than currently assumed, the impact of additional mortality at the population level will be larger.

For each of the species of interest, the number of expected victims in windfarm effect/impact assessments is estimated per bimonthly period (Rijkswaterstaat 2015, 2019). The temporal variation in age distribution as presented in Chapter 3.3 can be used to get a better idea of the age distribution among these collision victims. For several of the study species, the moment in the year can strongly affect the age distribution in the North Sea. Note that the figures within this chapter present temporal patterns for the 'BE & NL' and 'GE' region. For other zones, the effort throughout the year was not homogeneous, and overall effort was lower.

Similarly, spatial variation can be taken into account. For several species, age distribution varied between the spatial zones. Depending on where a wind farm is planned, the age distribution of the corresponding zone can be used in population models.

In general, the age distribution in the population models should match the age distribution in the **area of interest** and **during months in which victims are expected** as closely as possible.

In other words, if the impact of a windfarm is to be assessed, temporal and/or spatial variation can be taken into account. Due to limited data in the ESAS database regarding temporal variation, only results for the BE & NL zone and the GE zone are reliable.

Temporal variation in these zones can be compared. For the ‘GB-zones’, it was not possible to assess temporal variation due to limited effort throughout the year. As a result, based on the dataset used within this project it is not possible to conclude whether temporal variation differs between the eastern range of the study area (BE, NL; GE) and the western part (northern and southern GB).

Results presented in this report show spatial variation, and temporal variation within the BE, NL zone and the GE zone. Depending on the species, a decision can be made on which age distribution to be used in population modelling approaches of windfarm induced impacts. For each case study, we recommend considering the following points:

1. to what extent does the collision risk vary throughout the year?
2. does the age distribution vary throughout the year?
3. does the age distribution vary between spatial zones?

To answer the first question, results from collision victims calculated in the impact assessment can be consulted (for example Rijkswaterstaat (2019)).

Considering the second question: If the collision risk is strongly concentrated in a few months, and the age distribution varies throughout the year, one should consider using the age distribution presented in this report for the months with high collision risk. If the collision risk is evenly distributed throughout the year, the age distribution among collision victims is less affected by temporal variation in age distribution within a year. In comparison, if for example 80% of the victims are expected in July, when the proportion of adults is low for a given species, few adults are expected among the victims. In contrast, if victims are expected throughout the year, the expected age distribution among victims is based on all months, and one month with a contrasting age distribution plays a smaller role.

With regards to the third question: If the age distribution strongly varies between spatial zones, the use of the age distribution for that particular zone should be considered. However, note that for several species, data availability is limited for some of the zones, resulting in less reliable estimates of age distribution. If reliable estimates are available, one should consider using the age distribution for the zone in which the wind park is planned.

All in all, we summarized for each of the species discussed in this report, the answers on the three questions above in

Table 5.1. This resulted in a classification of the importance of spatial variation in age distribution, temporal variation in age distribution in BE, NL, GE, and temporal variation in collision victims based on Rijkswaterstaat (2019).

Table 5.1 Indication of spatial and temporal variation in age distribution, and temporal variation in collision victims. Classification of variation in age distribution is based on the results presented in this report. Temporal variation in collision victims is based on Rijkswaterstaat (2019). For each species, bold text indicates whether spatial variation in age distribution (second column bold) or temporal variation in age distribution (third and fourth column bold) plays a stronger role. For black tern, no conclusions can be drawn due to limited data availability.

Species	Spatial variation age distribution	Temporal variation age distribution in BE, NL	Temporal variation in collision victims
Northern gannet	Moderate	**High**	**Moderate – High**
Great skua	**High**	Unclear, poor data availability	High
Arctic skua	**High**	High	High
Great black-backed gull	**High**	High	Moderate – High
Little gull	**High (but only for a few zones reliable data)**	Moderate	High
Black-legged kittiwake	Low / some	**Moderate**	**Moderate**
Black tern	Unclear, limited data	Unclear, limited data	High (during migration)
Common tern	Low	**High**	**High (during migration)**

5.2 Species-specific recommendations

For each of the species discussed in this report, we give a recommendation on how to define the age distribution among collision victims. This recommendation depends on the area of interest.

Impact assessment for 'BE & NL' zones:
If a wind farm is planned in the 'BE & NL' zones, the temporal variation within this zone can be used. Hence, for this zone, spatial variation as well as temporal variation can be taken into account. For common tern for example, the expected number of victims is high during migration (Rijkswaterstaat 2015). In this case, for the impact assessment of a wind farm in the 'BE & NL' region, we recommend the use of the age distribution of the 'BE & NL' region during months with migration. This age distribution should therefore be based on Table 3.9.

Impact assessment for other spatial zones:
For the other spatial zones, data were too limited to assess zone-specific temporal variation. If the wind farm to be assessed is planned outside the 'BE & NL' zones, either spatial variation or temporal variation can be taken into account. Note that the temporal variation is based on the data from the 'BE & NL' and 'GE' zones (see paragraph 4.4). Within these recommendations it is therefore implicitly assumed that temporal variation is comparable between the zones. The decision on which age distribution to use depends on

the individual case study. For some species, temporal variation plays a larger role, whereas for other species spatial variation is more profound.

Based on Table 5.1, this leads to the following recommendations:

For northern gannet, black-legged kittiwake and common tern, the age distribution varies more strongly on a temporal scale than on a spatial scale. Based on Rijkswaterstaat (2019), the variation in number of collision victims within a year is classified as strong, with victims in offshore wind farms during migration periods. For these species, we recommend the use of an age distribution among victims similar to the age distribution during months of migration.

For great skua on the other hand, data availability for temporal variation in age distribution is very limited. Therefore, we recommend the use of the age distribution for the spatial zone of interest.

For arctic skua as well as little gull, the temporal variation in collision victims is high due to the distinct timing in passage rates. Therefore, we again recommend the use of the age distribution specific for the spatial zone of interest. However, note that data availability is low for little gull, resulting in less reliable data for several of the zones.

For great black-backed gull, the variation in age distribution on a spatial and temporal scale are high. In addition, the numbers of collision victims also shows a moderate – strong variation between months (Rijkswaterstaat 2019). Although age distribution varies strongly between zones, the differences are small between the BE, NL, GE regions, open sea, or UK 22-100 km offshore. If the wind farm is to be constructed in one of these zones, temporal variation is expected to have a stronger effect on the age distribution. Most victims are expected between August and November, and only few victims between April and July (Rijkswaterstaat 2019). If the age distribution is estimated based on temporal variation, leaving out the months with few victims (April – July, when the proportion of adults is very low; Figure 3.12), this results in a clearly higher proportion of adults compared to the age distribution calculated over the entire year.

For black-legged kittiwake, the age distribution seems to be more strongly affected by temporal variation compared to spatial variation. In addition, most collision victims are expected during winter (Rijkswaterstaat 2019). Therefore, we recommend assuming the age distribution among victims based on the age distribution during winter.

Note that for black tern, no conclusions can be drawn due to limited data availability. Data for little gull are limited as well. In these cases, the overall age distribution presented in this report can be used. However, note that the effort varies throughout the year, which may affect the age distribution. For each of the study species except for black tern, the overall age distribution shows a higher proportion of adults than the age distribution based on the stable stage distribution of the population models used in (Potiek *et al.* 2019). This may indicate that the age distribution at sea differs from the age distribution on land, due to certain age classes being less abundant at sea. Alternatively, this difference may be (partly) due to the fact that ESAS data is collected throughout the year, whereas the stable stage distribution is determined directly after the breeding season, including all first-year individuals (see Chapter 3.3).

Concluding remark:

In some cases, a cumulative impact assessment concerns several of our defined spatial zones. This is for example the case in Potiek *et al.* (2019) and van Kooten *et al.* (2019). In those cases, we recommend considering variation of expected numbers of victims between the zones. If most victims fall within the ‘BE & NL’ zones, recommendations given above for the ‘BE & NL’ zones should be followed. If victims are expected to fall in several of the zones, the recommendations for other zones should be followed. Hence, in these cases, the questions given in Chapter 5.1 should be regarded, and the age distribution among victims should be based on the strength of spatial and temporal variation.

References

Camphuysen, C.J. & M.F. Leopold, 1994. Atlas of seabirds in the southern North Sea. NIOZ

Cramp, S. & K.E.L. Simmons, 1977. Handbook of the Birds of Europe, the Middle East and North Africa. Vol I: Ostrich to ducks. Oxford University Press

Cramp, S. & K.E.L. Simmons, 1983. Handbook of the Birds of Europe, the Middle East and North Africa. Vol III: Waders to gulls. Oxford University Press

Cramp, S., 1985. Handbook of the Birds of Europe, the Middle East and North Africa. Vol IV: Terns to woodpeckers. Oxford University Press

Hake, M., N. Kjellén & T. Alerstam, 2003. Age-dependent migration strategy in honey buzzards Pernis apivorus tracked by satellite. Oikos 103(2): 385-396.

Newton, I., 2008. The migration ecology of birds. Elsevier

Pettex, E., C. Lambert, J. Fort, G. Dorémus & V. Ridoux, 2019. Spatial segregation between immatures and adults in a pelagic seabird suggests age-related competition. Journal of Avian Biology 50(5).

Potiek, A., M.P. Collier, H. Schekkerman & R.C. Fijn, 2019. Effects of turbine collision mortality on population dynamics of 13 bird species. Bureau Waardenburg Report 18-342, Bureau Waardenburg, Culemborg.

Rijkswaterstaat, 2015. Kader Ecologie en Cumulatie t.b.v. uitrol windenergie op zee Deelrapport B - Bijlage Imares onderzoek Cumulatieve effecten op vogels en vleermuizen. Ministerie van Economische Zaken en Ministerie van Infrastructuur en Milieu, Den Haag

Rijkswaterstaat, 2019. Kader Ecologie en Cumulatie t.b.v. uitrol windenergie op zee Deelrapport B - Actualisatie van KEC vogelaanvaring berekeningen volgens Routekaart 2030. Ministerie van Economische Zaken en Ministerie van Infrastructuur en Milieu, Den Haag

Sæther, B.-E., T.H. Ringsby & E. Røskaft, 1996. Life history variation, population processes and priorities in species conservation: towards a reunion of research paradigms. Oikos 77(2): 217-226.

Schwemmer, P. & S. Garthe, 2006. Spatial patterns in at-sea behaviour during spring migration by little gulls (Larus minutus) in the southeastern North Sea. Journal of Ornithology 147(2): 354-366.

Stone, C.J., A. Webb, C. Barton, N. Ratcliffe, T.C. Reed, M.L. Tasker, C.J. Camphuysen, M.W. Pienkowski & O. Consult, 1995. An atlas of seabird distribution in north-west European waters.

Tasker, M.L., P.H. Jones, T.I.M. Dixon & B.F. Blake, 1984. Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized approach. The Auk 101(3): 567-577.

Thorup, K., T. Alerstam, M. Hake & N. Kjellén, 2003. Bird orientation: compensation for wind drift in migrating raptors is age dependent. Proceedings of the Royal Society of London. Series B: Biological Sciences 270(suppl_1): S8-S11.

van Kooten, T., F. Soudijn, I. Tulp, C. Chen, D. Benden & M. Leopold, 2019. The consequences of seabird habitat loss from offshore wind turbines: displacement and population level effects in 5 selected species. Wageningen Marine Research

Vanermen, N., E.W.M. Stienen, W. Courtens, M. van de Walle & H. Verstraete, 2014. Zeevogel uit het sop gelicht: jan-van-gent. Vogelnieuws 23: 8-13.

Wakefield, E.D., R.A. Phillips & J. Matthiopoulos, 2009. Quantifying habitat use and preferences of pelagic seabirds using individual movement data: a review. Marine Ecology Progress Series 391: 165-182.

Bureau Waardenburg bv
Onderzoek en advies voor ecologie en landschap
Varkensmarkt 9, 4101 CK Culemborg
Telefoon 0345-512710
E-mail info@buwa.nl, www.buwa.nl