Survival rates of birds for use in population models

Analysis of ringing data

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Preface

The Offshore Wind Ecological Programme (Wozep), commissioned by the Dutch Ministry of Economic Affairs and Climate to Rijkswaterstaat (RWS), aims to better understand the ecological impacts of offshore wind energy developments. Population models have been developed to assess impacts on certain bird species at the population level. These rely on various life-history parameters. For a number of the species of interest the existing information needed for these models was categorised as poor, which can ultimately limit the reliability of the model outcomes.

The aim of this project was to obtain additional information on survival rates for different life stages of the bird species of interest; specifically, through the analyses of ringing data. This report describes the ringing and colour-ringing data available for the species of interest and the analysis of survival rates for use in the population models that were constructed for these seabird species as part of the Offshore Wind Ecological Programme.

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

The project team consisted of Mark Collier, Ruben Fijn and Astrid Potiek (all BuWa) and Wouter Courtens, Toon Van Daele, Eric Stienen and Pieter Verschelde (all INBO). Jan van der Winden and Peter van Horssen (GreenStat) analysed their data on black terns and made survival estimates available for this report. Data for skuas were made available by Katherine Snell and fellow researchers at the University of Copenhagen.

We are also grateful to the numerous bird ringers and colour-marking project coordinators who answered our queries as to the availability of ringing data and provided insight and advice on the data, suitability and on survival estimates for the species concerned.

This project would not have been possible without the data, help and assistance of EURING and its member ringing schemes. We are grateful to the European Union for Bird Ringing (EURING) which made the recovery data available through the EURING Data Bank and to the many ringers and ringing scheme staff who have gathered and prepared the data. We’re also grateful to all volunteer bird-banders and members of the public who have contributed to the EURING and national schemes archives by banding birds or returning worn bands and helped finance the ringing schemes.

We’re especially thankful to the Belgian Ringing Scheme (BeBirds) of the Royal Belgian Institute of Natural Sciences (OD Nature) and the Vogeltrekstation at the Netherlands Institute of Ecology, the Netherlands, for making all raw ringing data available. We are grateful to the British Trust for Ornithology in the UK; the Danish Bird Ringing Centre at the Natural History Museum of Denmark, University of Copenhagen and the Norwegian Bird Ringing Scheme at the Museum Stavanger, Norway for providing ringing data.

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Summary

A recent study to develop population models for a number of species around the North Sea area highlighted gaps in the information relating to the survival rates for several species. For eight of these species, survival estimates for juvenile, immature and/or the adult life-stages were deemed important for improving the models. Ringing data were highlighted as a potential source for improving survival estimates for these species through survival analyses.

An inventory of available data from national ringing schemes and relevant colour-marking projects revealed that few suitable data are available for survival analyses of these specific life-stages for the species concerned. Nevertheless, an attempt was made to produce survival estimates for the juvenile, immature and adult life-stages for curlew and for the juvenile and immature life-stages for great black-backed gull and kittiwake using data from national ringing schemes.

Survival estimates for juvenile and adult Arctic and great skuas were available from researchers in Denmark and adult black tern estimates following an analysis of colour-marking data by researchers in the Netherlands. Too few data exist to make any attempt at estimating survival rates for juvenile brent goose, immature Arctic skua or great skua, juvenile or immature black tern, or juvenile, immature or adult little gull.

Survival estimates were in some cases similar (Arctic skua, great skua and black tern) to earlier estimates used in population models, whereas some differed (curlew, great black-backed gull and kittiwake). Some of these differences can be explained by differences in the ages used in the analyses for the juvenile and immature life-stages. A correction could be applied to the estimates for the immature life-stage before use in population models.

1 Introduction

The European Union (including the UK) is aiming to double its offshore wind energy capacity from the current 22 GW (Walsh 2020) to around 43 GW in the near future, which is equivalent to more than 14,000 3 MW turbines (Brabant *et al.* 2015). The majority of these turbines are planned as part of large-scale developments that will be located in the North Sea region. In the Dutch sector of the North Sea, the total capacity of offshore wind farms will reach 4.5 GW in the years leading up to 2023. Recently, the Dutch government has unveiled an Offshore Wind Energy Roadmap setting out plans for the further development of offshore wind energy, including an additional 7 GW between 2023 and 2030 (Potiek *et al.* 2019).

Offshore wind farms have potential consequences for many marine organisms, including seabirds. Overall, the effects on seabirds can be divided into direct mortality as a result of collisions with turbines, and more indirect effects due to displacement and barrier effects (or effective habitat loss), or because of changes to food conditions (van Kooten *et al.* 2019). The effects of collisions could be expected to be first visible at the population level for many species due to the immediate consequence. Assessments of bird collisions are generally made at the scale of individual wind farms, and while these assessments already hold several assumptions, even bigger challenges exist on estimating the cumulative impact of multiple wind farms (Brabant *et al.* 2015).

The Dutch Governmental Offshore Wind Ecological Programme (Wozep) is part of an assignment by the Dutch Ministry of Economic Affairs and Climate Policy to Rijkswaterstaat (RWS) to investigate the (cumulative) effects of multiple new wind farms planned in the Dutch North Sea between 2017 and 2021. This integrated monitoring and research programme aims to study gaps in the knowledge relating to the impact of offshore wind farms on the North Sea ecosystem and its inhabitants.

As part of Wozep, population models of 17 bird species (too few data were available to allow a model for little gull to be created) were developed in two separate programmes in relation to questions over the potential impacts of offshore wind developments (van Kooten *et al.* 2019; Potiek *et al.* 2019). These population models can be used to assess the sensitivity to changes in demographic parameters, such as those resulting from wind farm related mortality. During the development of these models, Potiek *et al.* (2019) identified eight species for which survival estimates for at least one life-stage were identified as being poor, including one species for which no estimates were available. These eight species (Table 1) have been selected for further investigation as to whether survival estimates can be improved through the analysis of ringing data.

Table 1. Species and life-stages for which good estimates were not available for use in population models: adapted from Potiek et al. (2019).

Species	Life-stage
Brent goose	Juvenile
Curlew	Juvenile, Immature, Adult
Arctic skua	Juvenile, Immature, Adult
Great skua	Juvenile, Immature, Adult
Little gull	Juvenile, Immature, Adult
Great black-backed gull	Juvenile, Immature
Kittiwake	Juvenile, Immature
Black tern	Juvenile, Immature, Adult

Potiek *et al.* (2019) describe three life-stages:

- Juvenile – from fledging until the following breeding season;
- Immature – first breeding season after hatching until *n* years[1] later until bird reaches breeding age;
- Adult – bird of breeding age.

In the population models, each life-stage has specific survival estimates. Improvement of these age-specific survival estimates, from relevant populations and geographical areas, can therefore increase confidence in the models' ability to predict changes in the actual population. For the long-lived species in this study, adult survival has most influence on the model (Potiek *et al.* 2019).

Ringing and colour-ringing data from areas around the North Sea have the potential to provide information on the age-specific survival rates of birds for use in the Wozep population models. The aim of the current project is to produce age-specific survival rates for the species of interest through analyses of ringing data. These survival estimates can then be used to improve the confidence of the impact assessment for these species.

[1] Where *n* is the species-specific number of years before a bird reaches breeding age.

2 Methods

2.1 Data required

The survival analyses require data on the number of birds encountered (alive or dead; known as 'recapture' or 'recovery data' and in the survival analysis as 'encounters data') as well as the initial number marked in each cohort; for example, each year (known as 'ringing totals').

2.2 Sources of ringing data

Within Europe, bird ringing is coordinated by national schemes; most recently, this consists of typically one scheme per country (*'National ringing data'*). In most cases, individual ringers, or ringing groups, submit information of their ringing activity to their national schemes, usually on an annual basis. This information includes details as to the numbers of each species ringed, and often a simple breakdown by age-class, and is reported as the 'ringing totals'.

More recently, several ringing schemes have developed systems allowing them to receive data electronically, including full details for all birds ringed, which were previously only entered once a bird had been reported as a recovery (found bird either alive, i.e. recapture or read in field, or dead). Ringing data held by most national schemes include ringing details only for birds that were subsequently reported as a recovery ('encounters data'), and in some countries for all birds ringed in recent years (which includes both 'encounters data' and 'ringing totals' data.

In addition to the ringing data held by national ringing schemes, many colour-marking project data are held by individual project coordinators (*'Colour-marking data'*). These data are less frequently, or not at all, included in the national ringing data of recovery data. In these cases, data are managed by individual project coordinators, although some data are also included in the national ringing data.

2.3 National ringing data

Ringing data from national schemes from countries in which relevant populations of the species of interest are likely to occur were requested via EURING (the coordinating organisation for European bird ringing schemes). This request included data from extant schemes in Belgium (BLB), Britain and Ireland[1] (GBT), the Netherlands (NLA), Denmark (DKC[2]) and Norway (NOO, NOS).

An initial search of the EURING database revealed that very few data existed for little gull, with very few having been ringed and no recoveries in at least the last ten years. Requests

[1] Excluding the Channel Islands, which falls under a separate ringing scheme.
[2] Data from all schemes within Denmark were requested but only the Copenhagen scheme (DKC) held data relevant to this project.

to the coordinators of colour-ringing projects registered in Sweden and Norway were met with no response (see 2.4, 2.5). Most ringing data for brent goose are gathered from colour-ringing, with often no metal ring being used. EURING reported holding no brent goose ringing data in at least the last ten years, likely as most colour-ringing projects on this species do not use a metal ring. Most colour-ringing is concentrated outside the breeding season in wintering areas and as such these data are unlikely to help improve current estimates for juvenile survival. Contact with coordinators of colour-ringing projects on brent geese over the possibility of calculating juvenile survival were met with little positive response (see 2.4, 2.5). Consequently, little gull and brent goose were excluded from the data search at an early stage.

Encounters data

Encounters data were requested through EURING from those schemes for which relevant data were available (EURING Data Bank, du Feu *et al.* 2009). These data included the ringing and subsequent encounter data (re-sighting[1,2], recapture and recovery of alive or dead birds) for birds for which at least one alive or dead subsequent encounter event is available. Due to the availability of data, we requested all records for Arctic skua, black tern, curlew and great skua ringed since 1990, and for great black-backed gull and kittiwake those records of birds ringed as non-adult only since 1990. The number of records for each species is given in Table 2.

Table 2. Number of ringing and subsequent encounter records (including colour-ring sightings where these have been submitted to the national scheme by the ringer) for the species of interest from national ringing schemes in Belgium, Britain and Ireland, Denmark, the Netherlands and Norway.

Species	Number of ringing records	Number of subsequent encounter records
Curlew	2,458	5,953
Arctic skua	353	607
Great skua	1,610	2,786
Great black-backed gull	7,808	32,863[2]
Kittiwake	2,515	6,391
Black tern	12	13

Data from the ringing scheme in the Netherlands were refused through the official EURING request so were requested and subsequently supplied directly from the national ringing scheme coordinator. Data from the Dutch ringing scheme include records for curlew and great black-backed gull only. Data from the Dutch ringing scheme included all ringing records, also for birds with zero subsequent encounters. This was also the case for data

[1] Sightings of colour-ringed birds are only included if submitted to the national ringing scheme by the specific ringer. In some countries these data are not routinely gathered or held by national ringing schemes, which is more commonly the case in earlier years prior to computerization of database submissions or for many larger ongoing colour-ringing projects.
[2] Some multiple within-year encounters of colour-ring re-sightings for great black-backed gull are excluded from the current EURING data.

later received from the Belgian ringing scheme for curlew, great black-backed gull and kittiwake.

Ringing totals

The numbers of birds ringed annually are presented by schemes as 'ringing totals'. Ringing totals are not available for all schemes for all years as they are dependent on individual ringers reporting the numbers and age-classes of each species ringed. Most data only present figures for the number of pulli and full-grown birds ringed. In more recent years, some schemes present figures for the numbers of pulli, juvenile (i.e. first calendar year - from time of fledging onwards) and adult (after first calendar year) birds ringed. Furthermore, only in recent years has this information been collated digitally by some ringing schemes. Although ringing totals for some schemes are held by EURING, these are often incomplete and do not include data submitted after the annual submission deadline. We therefore obtained ringing totals directly from schemes themselves, either from published figures or by requesting these data directly. For schemes around the North Sea, ringing totals were available for Belgium (BLB), Britain and Ireland (GBT), Denmark (DKC), the Netherlands (NLA) and Norway (NOO, NOS). The years since 1990 for which these figures are available are given in Table 3.

Despite the lack of specific age-class information in the ringing totals of most schemes, this information was obtained from ringing data where possible. This was the case for where complete ringing data (data for all birds ringed including those without subsequent encounter[1]) were made available, including: curlew in Belgium, Denmark and the Netherlands, great black-backed gull in Belgium, Denmark and the Netherlands; and kittiwake in Belgium and Denmark.

Table 3. Availability of ringing totals, and where applicable age-classes, since 1990 for ringing schemes around the North Sea.

Scheme	Years available	Ringing ages present since
Belgium (BLB)	1990 - 2018	Limited for some species and years, only from recovery data.
Britain and Ireland (GBT)	1990 - 2018	Pulli, juv. ad. from 2002 onwards.
Denmark (DKC)	1990 - 2018	Limited for some species and years, only from recovery data.
Netherlands (NLA)	1990 - 2017	Limited for some species and years, only from recovery data.
Norway (NOO, NOS)	1990 - 2018	Pulli, juv. ad. from 1990 onwards (only for NOO scheme and not for NOS scheme).

2.4 Colour-marking data

Availability and suitability

A total of 84 project coordinators for colour-marking projects on brent goose, curlew, Arctic skua, great skua, little gull, great black-backed gull, kittiwake or black tern were contacted. Replies were received from 61 (72%), including four failed responses (incorrect or old email

[1] Cf. encounters data, which only includes records of ringed birds with at least on subsequent encounter.

address or that the contact person concerned had left the organisation). Of the remaining 57 responses, 33 people indicated that data existed and of these 17 indicated that they were potentially willing to make these data available for the current analysis, although many of these were smaller projects. When bearing in mind the amount of data available, both numbers ringed, re-sighted and numbers of years of the study, relatively few data are available suitable for the current analyses (Table 4).

Table 4. Number of colour-marking projects and those with a potentially suitable amount of data for which data could ostensibly be made available for the current analysis.

Species	Number of colour-ringing projects	Number of projects with suitable data
Curlew	5	2
Arctic skua	1	0
Great skua	1	0
Great black-backed gull	8	5
Kittiwake	1	0
Black tern	1	1

Most colour-marking data are available for species for which relatively comparable amounts of metal ringing data exist. One exception however is for black tern, for which very few metal ringing data are available. The majority of black terns have been ringed under the umbrella of one single project led by Jan van der Winden. A survival analysis of the black tern based on this dataset is currently ongoing with the aim of publication in the near future. To ensure the availability of the survival estimates for black tern, GreenStat were commissioned to carry out the analysis under the current project (see 2.7).

Existing survival estimates

Contact with colour-marking project coordinators afforded information on the availability and suitability of data for calculating survival estimates as well as information on survival estimates themselves. For some species (Arctic and great skua), survival estimates have been produced and are not yet broadly published. Where possible, these figures have been obtained and are presented within this report (see 2.5). As the methods used to analyse these data differ, as may the definitions of age-classes used, we encourage the reader to refer to the original sources when these are published. Similarly, contact with experts working on some species (brent goose juvenile, kittiwake juvenile and immature) revealed that no estimates exist for certain age-classes or that available colour-marking data are not suitable.

2.5 Data and survival estimate availability

Following the search of availability of ringing data (national ringing data and colour-marking), it became apparent that too few data were available to carry out analyses of survival estimates for juvenile brent goose, immature Arctic and great skuas, little gull, or juvenile or immature black tern. Contact with species experts revealed survival estimates for juvenile and adult Arctic and great skuas, and for adult black tern – the latter being analysed parallel to this report. Suitable ringing data were available for the remaining species life-stages and consequently estimates were produced for this report for juvenile, immature and adult curlew, and juvenile and immature great black-backed gull and kittiwake (table 5).

Table 5. Overview of data availability and sources of estimates for survival estimates for species and life-stage classes presented in this report.

Species	Life-stage	Survival estimate based on
Brent goose	Juvenile	Too few data.
Curlew	Juvenile, Immature, Adult	Based on national ringing data.
Arctic skua	Juvenile, Adult	Estimate from K.R.S. Snell (pers. comm.).
	Immature	Too few data.
Great skua	Juvenile, Adult	Estimate from K.R.S. Snell (pers. comm.).
	Immature	Too few data.
Little gull	Juvenile, Immature, Adult	Too few data.
Great black-backed gull	Juvenile, Immature	Based on national ringing data.
Kittiwake	Juvenile, Immature	Based on national ringing data.
Black tern	Adult	Estimate from analysis by GreenStat.
	Juvenile, Immature	Too few data.

Analyses methods for survival rates based on metal ring and colour-marking data differ due to varying encounter rates. For curlew and great black-backed gull, for which colour-marking data were available, it was decided to base the analysis on data from national ringing schemes (metal ringing and colour-marking data; see 2.6). Since the models based on these data gave reliable results, we chose not to add extra colour-marking data since it was expected to improve these models. For black tern, the analyses were carried out for both metal and colour-marking data (see 2.7).

2.6 Survival analysis for curlew, great black-backed gull and kittiwake

Data

Survival models typically need data on the number of ringed birds per year and age-class, as well as information on the life-histories for all re-encountered birds (be it alive or dead). Two datasets were compiled for the survival analysis:

1) *Ringing totals data*: containing the total number of ringed pulli and full-grown birds for all years in each ringing scheme (see 2.3). In more recent years the full-grown category was divided into 1CY (first calendar year) and 2CY+ (after first calendar year[1]).
2) *Encounters data*: containing all ringed birds for which at least one live and/or dead encounter event is available. Here, 'encounters' is used as the collective term for recaptures, re-sightings and recoveries. (see 2.3).

[1] See below '*Definition of age-classes used in current analysis*' for definitions of age-class classifications used for this part of the analysis.

Numbers ringed per year and age-class

Although ringing data from the last decade are largely computerized, earlier data are often not. One of the consequences of this is that while the total number of birds ringed is usually known, historical information of age at ringing (the number of birds in each age-class) is often not available (Robinson 2010, Jimenez-Muñoz *et al.* 2019). More specifically, in most years only the number of birds ringed as 'pullus' and 'full-grown' are known. The full-grown category contains all fledged birds, without any indication of how old they were at the time of ringing, and thus including juvenile, immature and adult birds. For most bird species survival, and often encounter probability, varies with age. Juvenile and immature birds generally have a lower probability of survival than older birds. In order to estimate survival and recovery probabilities for different age-classes, it is necessary to separate the number of ringed full-grown birds into 1CY (first calendar year) and 2CY+ (second calendar year and older) birds as a first step.

The total number of juvenile (first year) birds and immature and adult birds (older than 12 months) were calculated following Robinson (2010). This involved using the proportions of 1CY (first calendar year) and 2CY+ (second calendar year and older) birds ringed for those years for which data are available[1]. The mean proportions were calculated separately for each scheme and species. These proportions were applied to the numbers of full-grown birds ringed in those years for which no distinction was made between 1CY (first calendar year) and 2CY+ (second calendar year and older) birds.

Furthermore, many standard survival models estimate yearly survival for 'years' running from June of one year to May the following year (cf. Robinson 2010, Lok *et al.* 2013). This differs from the calendar years used in the ringing totals database in which 1CY (first calendar year) includes birds from fledging until 31st December in the year of hatching, after which these become 2CY+ (second calendar year and older) on 1st January. Accordingly, the ages of birds were converted from calendar years into age years (from June through May) for use in the survival models.

The numbers of juvenile birds ringed (first year of life) were calculated based on the data from the encounter (national ringing) database. The proportion of birds in the national ringing data that were ringed from January through May in their second calendar year was compared to those ringed after this period (i.e. as second calendar year from June onwards and older). This proportion was used to estimate the number of second calendar year birds that were ringed in their first year of life and, when added to the number of 1CY (first calendar year), birds gives the number of birds ringed in their first year of life (from fledging through to the following May). In addition, the number of pulli ringed was also added to this figure.

Life-histories of re-encountered birds

Encounter data for curlew, great black-backed gull and kittiwake were requested from relevant national ringing schemes through EURING (see 2.3), and contained data for

[1] For great black-backed gull data from GBT in 2018, there was an obvious biased age sample, so these data were excluded from the calculation of the mean proportion of 1CY:2CY+ birds.

curlew, great black-backed gull and kittiwake ringed since 1990 in Belgium, Denmark, Britain and Ireland, the Netherlands and Norway. Data from the Dutch ringing scheme (NLA) were received directly from the scheme and relevant data added to the data supplied through EURING.

These national ringing data included a number of re-sightings of colour-marked birds. Despite the fact that these might have a confounding effect on the survival estimates, we chose not to omit re-sightings of colour-marked birds for the survival analyses but used models with time-dependent re-sighting probabilities to maximize the use of this data type.

Each row consists of a ringing or encounter record and includes the information on each bird (ring number, date and location of event, type of event, age, sex etc.). After data cleaning and the removal of duplicate records and those prior to 1990, the encounter data contained a total of 57,708 records for the three species (Table 6). This includes multiple sightings of living birds so any individual may have more than one encounter record, which can result in the number of encounter records exceeding the number ringed.

Table 6. Number of birds ringed and subsequently re-encountered (alive and/or dead) as held in the national ringing data for Belgium (BLB), Denmark (DKC), Britain and Ireland (GBT), the Netherlands (NLA) and Norway (NOO/NOS). No encounter data for Kittiwake ringed in the Netherlands were available.

Species	Number of records	BLB	DKC	GBT	NLA	NOO/ NOS	Total
Curlew	Ringed	1800	59	21979	2877	1159	27874
	Encountered	59	2	2094	152	35	2342
	Alive*	25	3	5192	70	19	5309
	Dead*	40	0	350	113	20	523
Great black-backed gull	Ringed	44	14139	41442	298	25057	80980
	Encountered	1	874	2632	121	4166	7794
	Alive*	0	512	3947	179	25435	30091
	Dead*	1	587	1228	45	883	2744
Kittiwake	Ringed	17	1966	53782	255	24413	80433
	Encountered	2	55	1440	-	1018	2515
	Alive*	2	121	3211	-	2510	5844
	Dead*	1	10	474	-	61	546

** Refers to the total number of encountered were an individual bird can be encountered (alive) more than once. A bird can have a maximum of one dead encounter.*

Data cleaning included removing certain records or removing correcting anomalies in the data, including:

1) Birds reported as being manipulated at the time of ringing (hand-reared, fledging provoked, ringing accident or euthanized) or transported.
2) Birds with a reporting data accuracy of > 6 weeks (to minimise effect of inaccurate dates on life-histories).

3) Records for birds with a ringing date after recovery date.
4) Records of dead recovery when bird had already been reported as dead (this can occasionally happen when ring is found by multiple finders).
5) For re-sightings at a date after that when a bird had been reported as dead it was assumed that the prior reports of dead birds were erroneous, and where possible to infer from the data available these were changed to re-sightings.

In addition, as pulli are included in the analysis of juvenile birds in this instance, those pulli that died before fledging have also been removed. These records can be indicated in the data by record type (‘P’), reported dead and age 1 (pullus), bird ringed as age 1 (pullus) with a finding date the same as ringing date, or died within 10 days and reported as having a ringing age of 1 (pullus), and finding age of 1 or 0 (unknown). Furthermore, in the current analysis birds that were ringed as pulli and that died before 15 July were also removed. This is an arbitrary date selected as a proxy for the high mortality of pulli in an attempt to remove pulli that died before fledging.

After the removal of these additional data, the remaining encounter data consisted of 56,474 rows (Table 7).

Table 7. Number of birds ringed and subsequently re-encountered (alive and/or dead) for age-classes first year of life (1Y) and older (2Y+) selected for analysis from the national ringing data obtained for Belgium (BLB), Denmark (DKC), Britain and Ireland (GBT), the Netherlands (NLA) and Norway (NOO/NOS). No encounter data for kittiwake ringed in the Netherlands were available.

		BLB		DKC		GBT		NLA		NOO/NOS		Total
Species	Number of records	1Y	2Y+	1Y	2Y+	1Y	2Y+	1Y	2Y+	1Y	2Y+	
Curlew	Ringed	915	885	33	26	9932	12047	1952	925	1150	9	27874
	Encountered	36	22	1	1	284	1791	103	43	34	0	2315
	Alive*	9	9	1	2	389	4788	52	13	19	0	5282
	Dead*	28	14	0	0	117	216	74	31	19	0	499
Great black-backed gull	Ringed	3	41	13502	637	39070	2372	145	153	24068	989	80980
	Encountered	1	0	827	23	2465	112	80	33	4110	37	7688
	Alive*	0	0	518	12	3815	171	118	41	25112	132	29919
	Dead*	1	0	518	15	1103	18	28	12	855	5	2555
Kittiwake	Ringed	1	16	978	988	38324	15458	86	169	13027	11386	80433
	Encountered	2	0	27	21	1099	49	-	-	224	783	2205
	Alive*	2	0	90	21	3041	146	-	-	321	2143	5764
	Dead*	1	0	6	2	181	1	-	-	41	15	247

** Refers to the total number of encountered were an individual bird can be encountered (alive) more than once. A bird can have a maximum of one dead encounter.*

Definition of age-classes used in current analysis
Ringing data record ages of birds at the time of ringing and relevant to the calendar year of hatching. This results in the age-classes of ringed birds advancing on 1st January each year. The age at ringing and time lapsed is used to assign an age to the bird at subsequent recovery events.

The current survival estimates for curlew, great black-backed gull and kittiwake are based on the birds' age relevant to their actual age with age-classes advancing every 12 months after the date of hatching (where 1st June is taken as the date of hatching). In the current analysis, the juvenile age-class also includes the period since hatching (cf. population models) and continues until the following June. A bird then becomes an immature until adult plumage (cf. population models) is reached when it becomes an adult. For birds ringed as adults, ages are based on plumage characteristics rather than on actual age.

In population models and many published figures for survival, ages are relevant to a bird's actual age with age-classes advancing every 12 months after the breeding season. The stage juvenile age-class starts at fledging (with pulli survival being presented separately or as part of fecundity) and continues until the following breeding season. A bird then becomes an immature until it reaches breeding age (cf. current survival estimates), at which time it becomes an adult. The use of different definitions for age-classes is shown in Table 8.

Table 8. Definition of age-classes used in ringing data and life-stage used in the current survival analysis.

Age-class	Current analysis	Population models
Pullus	Included in juvenile (first year of life).	Included in fecundity.
Juvenile	First year of life (since hatching).	First year of life (since fledging).
Immature	Older than first year of life until adult plumage.	Older than first year of life until breeding age.
Adult	Bird in adult plumage.	Bird at breeding age.

Analysis
Survival estimates for curlew, great black-backed gull and kittiwake were calculated using mark-recapture models (Barker *et al.* 2004). These models have become fundamental tools in the study of bird populations and demographic parameters with ringing data being a key source of information in studies into survival rates (Lebreton 2001). A range of mark-recapture models have been developed over the past decades, each with their own data requirements, advantages and disadvantages.

A primary model for open populations and that uses recaptures of live birds is the Cormack-Jolly-Seber model (Cormack 1964, Jolly 1965, Seber 1965). Other models, such as the Brownie and Seber models, consider only recoveries of dead birds (Brownie *et al.* 1985, Seber 1970). A common weakness of these types of model is that they consider emigration as a permanent event, meaning that birds emigrating out of the study area are considered to have died. They also consider only one type of encounters, either live or dead.

More recent mark-recapture research has led to the development of models that combine data of different encounter types. This has the advantage that the estimates of key parameters are more precise (Lebreton *et al.* 1995). Various encounter types (e.g. recoveries, recaptures, re-sightings etc.) can be used concurrently to: 1) estimate parameters that cannot be estimated using only one data type; 2) improve the precision of parameter estimates; and 3) provide some flexibility in handling encounter data that might have been collected opportunistically throughout the year, such as re-sightings of colour-marked birds (Cooch & White 2019).

Within this project, survival estimates for curlew, great black-backed gull and kittiwake were calculated using the model described in Burnham (1993) and were based on encounters of both live (re-sightings and recaptures) and dead (recoveries) birds. The Burnham model is based on the Cormack-Jolly-Seber model but allows the use of both live and dead encounters (Burnham 1993). It also models random emigration, where a bird can leave and re-enter the population.

The use of joint live and dead encounter models aimed to maximize the ringing data that could be used: as they are collected from a broad range of sources ringing from professional and amateur ornithologists to members of the public and from structured monitoring to adhoc observations. Despite the joint live and dead encounter model described in Burnham (1993) not using encounters outside the breeding season, this model was selected over that described in Barker (1999) as it requires fewer parameters. Furthermore, Barker's model is more focused on colour-marking studies and includes parameters for re-sighting probability, re-sighting probability for a bird that died later, and immigration probability. The estimation of these extra parameters proved difficult for the heterogeneous datasets we used in this study.

Marked individuals have a probability of surviving for a specified time period and a probability of encountered and reported (either re-captured or re-sighted, or found dead and reported). A so-called 'fate diagram' is shown in Figure 1, in which the following parameters can be estimated:

- S_i probability a bird alive at breeding season *i* survives to *i+1* (*i.e.* survival probability). 1-S bird dies.
- r_i probability a bird that dies in the interval between breeding season *i* and *i+1* is found dead and reported (*i.e.* recovery probability). 1-r bird dead but not found or not reported.
- F_i probability of site fidelity between breeding seasons (*i.e.* probability of bird returning to sampling area). 1−F is the probability of permanent emigration.
- p_i probability a bird in sampling area being encountered alive (*i.e.* conditional on being alive and in the sampling region). 1-p is the probability of being alive in the sampling area but not encountered.

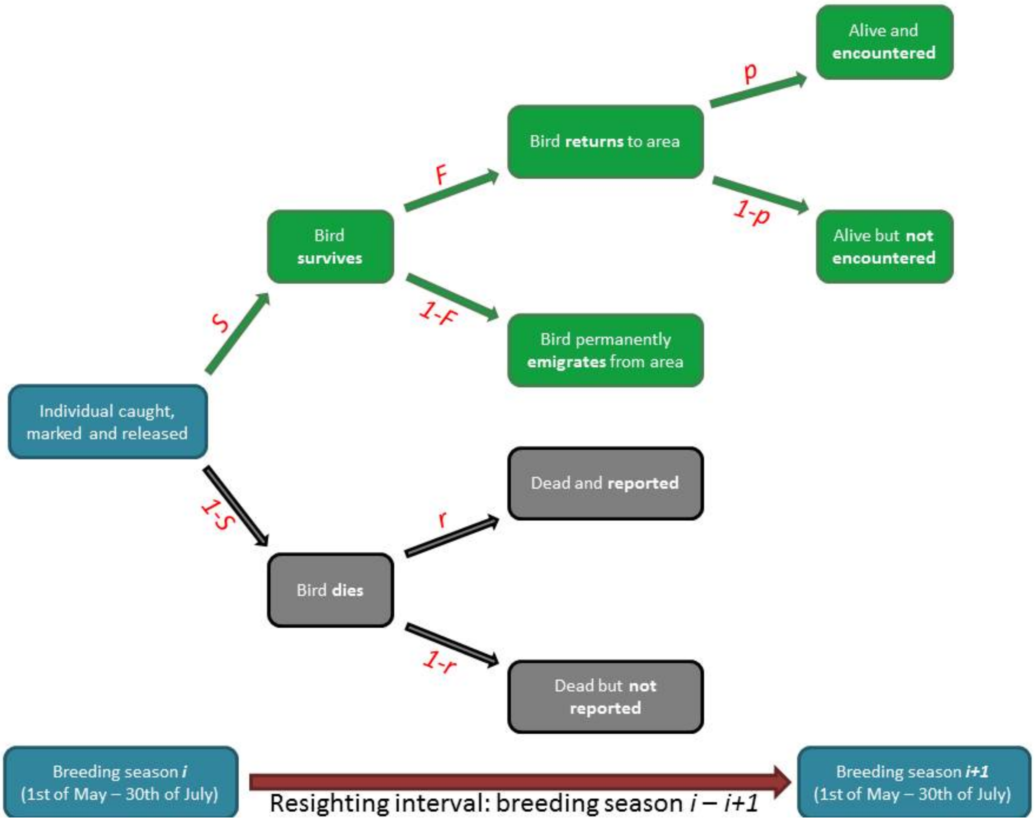

Figure 1. Fate diagram for Burnham's live/dead encounter model.

When running Burnham's model, we made several assumptions:

1) We considered the breeding season (1st May through 30th July) as a 'capture occasion'.
2) We considered all re-sightings during the breeding season to be recaptures. Multiple live encounters during the same breeding season were resampled so that only one live encounter per 'capture occasion' remained.

Analyses were carried out using the program R (version 3.6.1; R Core Team 2019) and the package RMark (Laake 2013) to act as an interface with the program 'MARK' (version 9.0, White & Burnham 1999). Model selection was based on the Akaike Informative Criterion corrected for small sample size and overdispersion (QAICc). The model with the lowest QAICc was considered the model that best fitted the data. Goodness of fit (GOF) tests were used to assess the assumptions underlying the models that are fit to the data. To adjust for lack of fit, we calculated the variance inflation factor $\hat{c}$, or 'c-hat' in program MARK. We used the parametric bootstrap goodness-of-fit procedure (n = 500). The observed deviance divided by the expected deviance from the bootstrap procedure is used as an estimate for $\hat{c}$. When $\hat{c}$ >1, the QAICc tends to increasingly favour models with fewer parameters and the QAICc. The standard errors and 95% confidence intervals of the parameter estimates are adjusted accordingly. For parameter estimates close to the boundary (close to 0 or 1), the default confidence intervals from RMARK are not always reasonable. All the final models were re-run with the profiling option to obtain reasonable 95% confidence intervals (given as upper and lower confidence intervals (ucl and lcl), these are not necessarily symmetrical).

2.7 Survival analysis for black tern

Data

Few ringing data for black terns exist within the EURING database, with only 13 records for birds ringed since 1990 being later recovered and all of these being ringed in the Netherlands or Belgium. Ringing totals from national ringing schemes around the North Sea also reveal relatively few birds having been ringed. Of the 8318 black terns ringed since 1990, over 95% (7942) have been ringed in the Netherlands, and most of these through projects coordinated by Jan van der Winden.

Since 1999, Jan van der Winden has been ringing adult black terns as part of an ongoing Ringing Adults for Survival (RAS) project. As part of this RAS project, Jan van der Winden, together with Peter van Horssen (GreenStat), are planning to produce and publish survival estimates for adult black terns in the near future. To help facilitate this process, Bureau Waardenburg commissioned GreenStat to produce survival estimates for adult black terns. Accordingly, these survival estimates have been made preliminarily available for presentation in this report. The source data and estimates produced remain property of Jan van der Winden and may not be made publicly available or distributed outwith this report. We urge the reader to refer to future publications by van der Winden and van Horssen once these estimates have become openly available.

Analysis

Survival estimates for adult black terns were produced by GreenStat and followed the methods described in Laake *et al.* (2013) and White and Burnham (1999). Assumptions of the models were tested using goodness of fit (GOF) tests (Gimenez *et al.* 2018). For black terns, the need for corrections for transience (individuals that are not encountered following initial marking) and trap dependence (individuals that are not recorded in the area after initial marking but that return in later years) was tested but deemed not necessary. Nevertheless, estimates were produced that included all suitable birds as well as birds with multiple encounters (referred to as 'residents').

Ringing totals and encounters were determined per breeding season and accordingly the survival estimates produced for adult black terns are for the time period between two breeding seasons (i.e. June to May the following year).

The data used for this analysis included both metal ringing data (1999 – 2008) and colour-ringing data (2002 – 2018) for black terns ringed in the province of Utrecht, the Netherlands.

3 Results

3.1 Survival estimates

Where available, age-specific survival estimates for the eight species of interest are presented below. No estimates were available or could be calculated for brent goose, immature Arctic or great skua, little gull or juvenile or immature black tern. Further explanation is given below.

3.1.1 Brent goose

No survival estimates for juvenile brent goose are available. Few ringing data were available from the national ringing schemes. Long-term colour-ringing projects on this species are unlikely to hold suitable data for robust estimates (Ebbinge and Rakhimberdiev pers. comm.)

3.1.2 Curlew

Survival estimates for juvenile, immature and adult curlew are given in Table 9. These estimates are based on data from the national ringing schemes and on birds ringed within the first year after hatching or as adult (where adults were assumed to be older than two years). Estimates for juvenile survival are for birds within the first 12 months after hatching, for immature in the second year after hatching and for adult two years or older. The effect of age on reporting rate was excluded due to limited data availability, which means that birds from different age classes have the same probability to be found dead.

Table 9. Survival estimates for curlew derived from national ringing data (see 2.6). Juvenile are birds in first year after hatching, immature in second year and adult older than second year.

Species	Life-stage	Survival estimate	se	lcl	ucl
Curlew	Juvenile	0.52	0.033	0.42	0.61
	Immature (2cy)	0.80	0.034	0.69	0.89
	Adult (>2cy)	0.88	0.009	0.86	0.91

3.1.3 Arctic skua

Few data for Arctic skua were available from the national ringing databases, particularly for birds ringed as juvenile or immature. Contact with researchers at the University of Copenhagen revealed currently unpublished survival estimates for juvenile and adult Arctic skuas. No estimates for immature birds are available. These estimates are currently in preparation for publication and have been kindly made available for presentation in this report. We urge the reader to ideally refer to and cite figures in future publications by Snell and colleagues from the University of Copenhagen and to use caution when using the figures presented here without further knowledge of how they were derived.

Annual survival for **adult Arctic skua** are[1] **0.92[2] +/-0.07**, and for **juvenile** (first year birds) **0.43 +/-0.14**. These estimates were based on the best data available in years 1985 – 2008 aggregated, with a total number of 1,060 of ringed birds included in this estimate (K.R.S. Snell[3] pers. comm.).

3.1.4 Great skua

Few data for great skua were available from the national ringing databases, particularly for birds ringed as juvenile or immatures. Contact with researchers at the University of Copenhagen revealed currently unpublished survival estimates for juvenile and adult great skuas. No estimates for immature birds are available. These estimates were produced as part of a MSc thesis and have been kindly made available for presentation in this report. We urge the reader to ideally refer to and cite figures in future publications by Snell, Machado dos Santos and colleagues from the University of Copenhagen and to use caution when using the figures presented here without further knowledge of how they were derived.

Annual survival for **adult great skua** are estimated as [45] **~0.86**, and for **juvenile** (first year birds) **~0.97**. These estimates were based on data from 1924 – 2017 aggregated, with a total number of 1,826 of ringed birds included in this estimate (Machado dos Santos 2018[6]; K.R.S. Snell[7] pers. comm.). These figures are counter-intuitive and caution is urged using these figures (see Chapter 4).

3.1.5 Little gull

No survival estimates for little gull are available. Too few data are available with no recoveries for little gull in the last ten years amongst national ringing data. According to records held by EURING, only 40 pulli and 15 full-grown little gulls have been ringed in Belgium, Denmark, Britain and Ireland, the Netherlands and Norway since 1990.

3.1.6 Great black-backed gull

Survival estimates for juvenile and immature great black-backed gull are given in Table 10. These estimates are based on data from the national ringing schemes and on birds ringed

[1] These data remain property of Katherine Snell and colleagues at the University of Copenhagen and may not be made publicly available or distributed outwith this report.
[2] There was evidence for an increase in adult mortality over time.
[3] Center for Macroecology, Evolution and Climate, Globe Institute, University of Copenhagen, Universitetsparken 15, DK-2100 Copenhagen Ø, Denmark.
[4] These data remain property of Katherine Snell and colleagues at the University of Copenhagen and may not be made publicly available or distributed outwith this report.
[5] Due to structural difficulties in the data cation is urged with these figures.
[6] Machado dos Santos, I.A. (2018) Survival and breeding success of the declining Arctic skua population of the Faroe Islands (MSc Thesis; University of Copenhagen).
[7] Center for Macroecology, Evolution and Climate, Globe Institute, University of Copenhagen, Universitetsparken 15, DK-2100 Copenhagen Ø, Denmark.

within the first year after hatching only. Estimates for juvenile are for birds within first 12 months after hatching and for immature in second to fourth year after hatching. The effect of age on reporting rate was excluded due to limited data availability, which means that birds from different age classes have the same probability to be found dead.

Table 10. Survival estimates for great black-backed gull derived from national ringing data (see 2.6). Juvenile are birds in first year after hatching, immature in second, third and fourth year.

Species	Life-stage	Survival estimate	se	lcl	ucl
Great black-backed gull	Juvenile	0.30	0.021	0.26	0.35
	Immature (2-4cy)	0.79	0.011	0.78	0.82

3.1.7 Kittiwake

Survival estimates for juvenile and immature kittiwake are given in Table 11. These estimates are based on data from the national ringing schemes and on birds ringed within the first year after hatching only. Estimates for juvenile are for birds within the first 12 months after hatching and for immature in the second year after hatching. The effect of age and time on reporting rate was excluded due to limited data availability, which means that birds from different age classes have the same probability to be found dead.

Table 11. Survival estimates for kittiwake derived from national ringing data (see 2.6). Juvenile are birds in first year after hatching and immature in second year.

Species	Life-stage	Survival estimate	se	lcl	ucl
Kittiwake	Juvenile	0.55	0.035	0.48	0.63
	Immature (2cy)	0.83	0.031	0.76	0.89

3.1.8 Black tern

Survival estimates for adult black tern are given in Table 12. These estimates are based on data from colour-ringing data and from ‘resident’ birds collected by Jan van der Winden and analysed by Peter van Horssen (GreenStat). The source data and estimates produced remain property of Jan van der Winden and may not be made publicly available or distributed outwith this report. We urge the reader to refer to future publications by van der Winden and van Horssen once these estimates have become openly available.

Table 12. Survival estimates for black tern derived from colour-ringing data from ‘resident’ birds by van der Winden and Horssen (see 2.7).

Species	Life-stage	Survival estimate	se	lcl	ucl
Black tern	Adult	0.843	0.032	0.769	0.897

4 Discussion

4.1 Data and survival estimate availability

Following the development of population models (Potiek *et al.* 2019), eight species were selected for investigation as to whether age-specific survival estimates could be improved through analyses of ringing data. Of the 20 species / life-stage groupings identified, new estimates are reported for 12. For two species, brent goose and little gull, no suitable data were available to allow survival estimates for the juvenile or the juvenile, immature or adult age-classes respectively (see Table 5). For Arctic skua and great skua only estimates for the juveniles and adults are reported and for black tern for adults only. Estimates for juvenile, immature and adult curlew, and juvenile and immature great black-backed gull and kittiwake are based on analyses using national ringing data.

4.2 Survival estimates

The survival estimates for curlew are based on data from the national ringing schemes. Curlew are largely ringed during late summer and autumn and throughout the winter as full-grown birds. The estimates for juvenile survival presented here include the fledgling stage. Most pulli curlew are ringed in the first few days after hatching and establishing numbers that fledge can be difficult due to their mobility and need for intensive research (i.e tracking with radio tags). Estimates for the immature life-stage are for one year (12 months after hatching until 12 months after that) whereas this stage is noted as lasting for two years (until three years after hatching) (Potiek *et al.* 2019). Nevertheless, these estimates can be considered good, being based on a data from a range of countries and across a number of years.

The survival estimates for Arctic and great skua presented do have limitations due to the data on which they are based. Although it is considered unlikely that better estimates are available, the researchers producing these estimates urge caution when using these figures. This caution is important to consider as can be seen in the estimates for great skua that show a higher survival for juvenile birds than for adults, which is contrary to what would be expected for such a species.

The survival estimates for great black-backed gull are based on data from the national ringing schemes. The estimates for juvenile survival presented here include the fledgling stage. Most pulli great black-backed gulls are ringed in colonies during a single visit at an opportune moment. This is usually planned for the stage before chicks become too mobile, although at remote or difficult to access sites, or in response to weather conditions and availability of volunteers, this may occur at different times. Repeat visits to investigate pulli survival are not commonplace. The relatively high level of mortality prior to fledgling is likely to result in lower estimates for juvenile survival than when considering the juvenile life-stage only (i.e. from fledging onwards). Estimates for the immature life-stage are for a two-year period (12 months after hatching until 24 months after that) whereas in the population models the immature stage is noted as lasting for three years (Potiek *et al.* 2019).

Nevertheless, these estimates can be considered good, being based on a data from a range of countries and across a number of years.

The survival estimates for kittiwake are based on data from the national ringing schemes. The estimates for juvenile survival presented here include the fledgling stage (prior to fledging). Most kittiwake pulli are ringed as part of seabird ringing trips or dedicated fieldwork. Ringing is usually planned for the stage before chicks become too mobile and repeat visits to investigate pulli survival are not commonplace. The relatively high level of mortality prior to fledgling is likely to result in lower estimates for juvenile survival than when considering the juvenile life-stage only (i.e. from fledging onwards). Estimates for the immature life-stage are for one year (12 months after hatching until 12 months after that) rather than completely mirroring the three years used in the population models (until four years after hatching) (Potiek *et al.* 2019). Nevertheless, these estimates can be considered good, being based on a data from a range of countries and across a number of years.

The survival estimates for presented for black tern are based on colour-marking data from an intensive study of the species, whilst the analysis itself was undertaken by the same researchers involved with collecting the data. The estimates for adult black tern can therefore be considered to be good and the best available, certainly considering how few data exist outside of this project.

4.3 Comparison with existing estimates

The current survival estimates for curlew are higher than those used in Potiek *et al.* (2019) for the juvenile, immature and adult life-stages. The current estimate for juvenile survival (0.52) is close to that for other waders (cf. Grant *et al.* 1999). Similarly, the current estimate for adult survival (0.88) is comparable to that in Kipp (1982) and Grant *et al.* (1999).

The current estimates for juvenile Arctic skua are lower than those used in Potiek *et al.* (2019) (i.e. 0.74). Estimates for adult Arctic skua are comparable to those in Potiek *et al.* (2019) (i.e. 0.9). However, caution is urged when using these estimates (see 3.1.3).

The current estimates for adult survival for great skua are comparable to those used in Potiek *et al.* (2019) (i.e. 0.89), although figures for juvenile survival are somewhat higher (i.e. 0.82). However, caution is urged when using these estimates (see 3.1.4).

For great black-backed gull no other survival estimates for juvenile and immature birds are known. In the absence of species-specific figures, Potiek *et al.* (2019) used weighted estimates for herring gull. The current estimates for juvenile survival of 0.30 is substantially lower than that used in Potiek *et al.* 2019 (i.e. 0.436), which may be in part due to the inclusion of the pulli stage in this estimate. This figure is however fairly similar to the 0.25 ± 0.06 for herring gull on Texel (Camphuysen 2013). Current estimates for immature survival for great black-backed gull (0.79) are very similar to those used by Potiek *et al.* (2019) (i.e. 0.8 for herring gull).

The current estimates for juvenile kittiwake survival are lower than those used in Potiek *et al.* (2019) (i.e. 0.79), which may be in part due to the inclusion of the pulli stage in this estimate. Current figures for immature survival were slightly higher than those used in Potiek *et al.* (2019) (i.e. 0.9).

The recent estimates for adult survival for black tern produced by van der Winden & van Horssen (2019) are very similar to those used in Potiek *et al.* 2019, that were also produced by the same authors (i.e. 0.849; van der Winden & van Horssen 2008).

4.4 Use in population models

The current figures for Arctic skua, great skua, black tern and adult curlew and immature great black-backed gull can be used in the models in Potiek *et al.* (2019) directly: although caution is urged with the figures for Arctic and great skua (see 3.1.3 and 3.1.4).

The current figures for juvenile curlew, great black-backed gull and kittiwake differ to those required in the models in Potiek *et al.* (2019) as they include the pulli stage as part of the juvenile estimate. Bearing in mind that the pulli stage generally shows relatively high mortality, these figures could be expected to be lower than for the juvenile stage as described in Potiek *et al.* (2019). However, it is impossible to adjust these figures as the level at which the pulli survival influences the current figure is unknown.

The current figures for immature curlew are calculated for the single year after juvenile only, whereas the models in Potiek *et al.* (2019) use an immature period of two years for curlew. A correction can be made by averaging the survival rates across the entire period for which the immature period is considered to last, i.e. until first breeding. This can also be done for immature kittiwake, which has been calculated over three years although is considered to have an age at first breeding of four. These estimates, as well as how all the current survival estimates compare with those used in the population models in Potiek et al. (2019) are shown in Table 13.

Table 13. Survival estimates and notes for use in population models.

Species	Stage	Survival estimate	Survival estimates used in population models (Potiek et al. 2019)	Notes
Curlew	Juvenile	0.52	0.47	New estimate includes fledgling stage.
	Immature	0.84	0.63	Based on age of first breeding = 3, (1*0.80+1*0.88) / 2.
	Adult	0.88	0.84	Can be used directly.
Arctic skua	Juvenile	~0.43	0.74	Caution is urged due to data limitations.
	Adult	~0.92	0.90	Caution is urged due to data limitations.
Great skua	Juvenile	~0.97	0.82	Caution is urged due to data limitations.
	Adult	~0.86	0.89	Caution is urged due to data limitations.
Great black-backed gull	Juvenile	0.30	0.436	New estimate includes fledgling stage.
	Immature	0.79	0.8	Can be used directly.
Kittiwake	Juvenile	0.55	0.79	New estimate includes fledgling stage.
	Immature	0.85	0.8487	Based on age of first breeding = 4, (1*0.83+2*0.86) / 3.[1]
Black tern	Adult	0.843	0.849	Can be used directly.

4.5 Expected effect of new parameters on output of population models

The expected effects of the current estimates on the population models in Potiek *et al*. (2019) can be estimated based on the comparison of the figures for survival in Table 13.

Survival estimates for juvenile, immature and adult curlew are all higher than those used in Potiek *et al*. (2019). It can be expected that the population growth would therefore increase, mainly due to increased adult survival.

The lower estimates for juvenile survival for great black-backed gull and kittiwake, coupled with the near identical estimates for immature survival would likely result in a lower population growth than the models in Potiek et al. (2019).

Survival estimates for black tern are very slightly lower than those used in Potiek *et al*. (2019) although little change would be expected in the population growth when using the current figure for adult survival.

[1] Using figures from current analysis in which immature stage lasts for one year and adult stage for two years.

5 Conclusions and recommendations

For several of the species/life-stages selected in Table 1 too few ringing data exist, i.e. brent goose, Arctic skua, great skua and little gull. For Arctic skua and great skua, we were able to present figures from researchers working on this species. In particular very few juvenile brent geese or little gull (all ages) are currently ringed. Increased ringing and colour-marking effort on juveniles of these species at breeding sites could help future estimates but this would require a prolonged and sustained effort on an annual basis for many years. Similarly, data for juvenile and immature black terns may also be improved if a prolonged and sustained ringing and recovery effort were to be made involving these age classes.

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