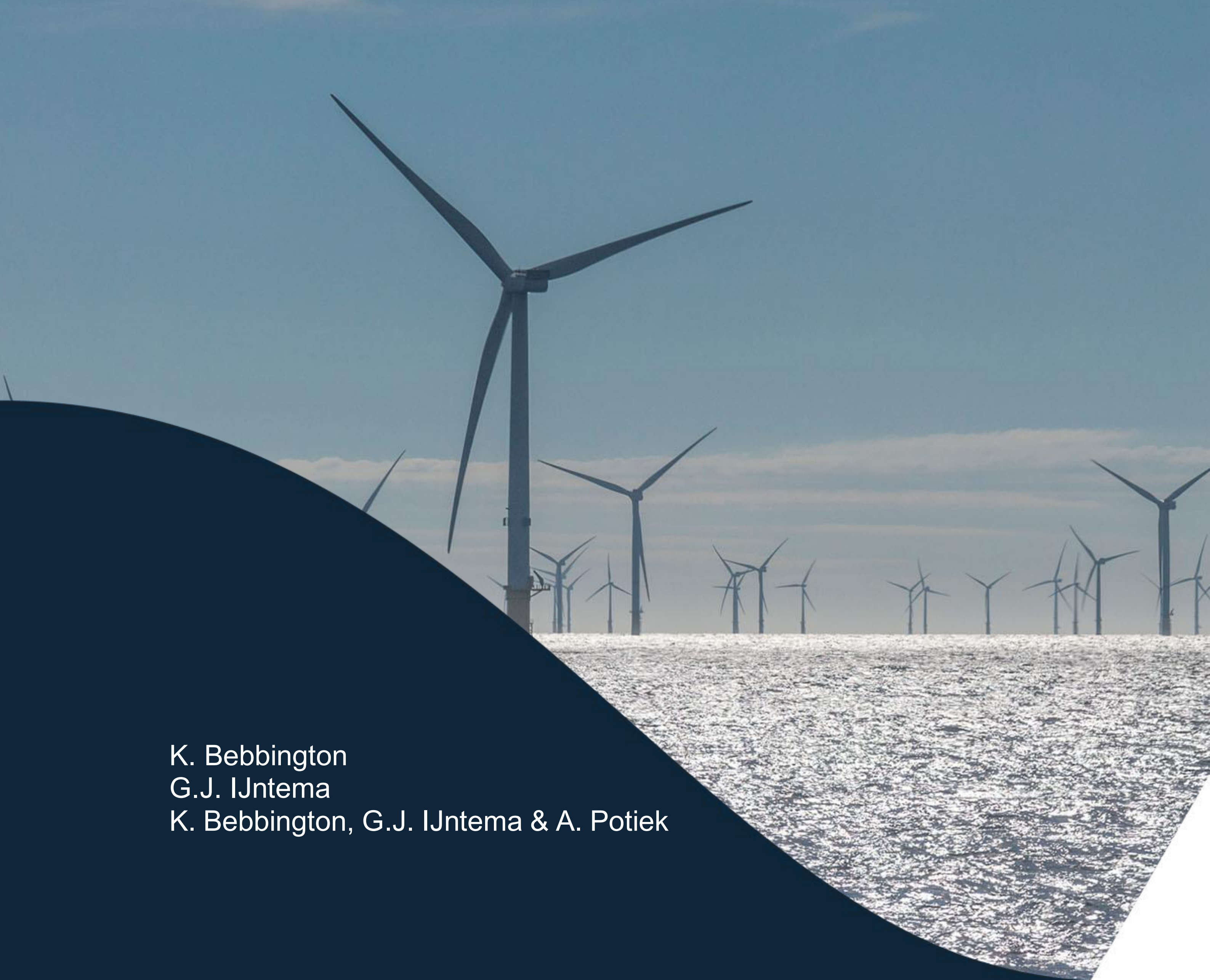
Update knowledge base for bird species vulnerable for collisions with offshore wind turbines (2025)

Description of available knowledge to be used within KEC 6.0



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1 Introduction

1.1 Background

The intended developments of offshore wind energy in the Dutch North Sea up to 2030 may lead to cumulative effects on seabird and/or migratory bird species, in terms of estimated numbers of collision victims. In the Framework for Assessing Ecological and Cumulative Effects (Dutch name for the framework: Kader Ecologie & Cumulatie; or in short KEC), the cumulative effects of all existing and planned Dutch and foreign wind farms in the southern North Sea are predicted and evaluated.

Given the potential negative effects of wind energy on the natural environment, the KEC includes several environmental impact assessments on the projected wind farms for the future. One of the focus areas in these assessments is the potential mortality of birds. As a result, within the KEC program, Waardenburg Ecology and Wageningen Marine Research are tasked with projecting the potential future mortality of birds due to (scenarios of) planned wind farms in the form of bird collisions (executed by Waardenburg Ecology) and habitat loss (executed by Wageningen Marine Research).

Since the first version of the KEC (Rijkswaterstaat 2015), the assessment has been updated several times (Rijkswaterstaat 2019, Potiek *et al.* 2022a, IJntema *et al.* 2025a). The next update (KEC 6.0) is planned for 2026. A new structure was introduced to increase the efficiency of KEC updates, which encompasses the execution of methodological improvements and data inventory during the year before the KEC update is carried out. Knowledge gained in 2025 will subsequently be used in the KEC 6.0 update.

This report presents the knowledge base update for the species relevant for collision mortality.

1.2 Objective

The aim of this report is to update the data, parameters and methods used within KEC with the most recent scientific insights. We provide an overview of parameters and methods that can be updated, leading to a conclusion on what updates will be incorporated in the upcoming KEC 6.0. In the current report no new calculations are carried out.

2 Overview of methods and required data

Within earlier KEC studies, species were classified as vulnerable for collisions based on their presence in the Southern and Central North Sea as well as the expected vulnerability (Table 2.1). Within this knowledge base update, we updated the parameters for the species considered in KEC 5.0 (IJntema *et al.* 2025a). Note that for KEC 6.0 additional species may be added to the list of vulnerable species.

The modelling process within KEC consists of the following parts:

1. Estimation of bird density or flux, followed by estimating the number of collision victims (collision rate model)
   Product: estimated number of victims per wind farm per year (for seabirds based on bimonthly calculations)
2. Compiling for different wind farm scenarios
   Product: estimated number of victims per wind farm scenario per year
3. Assess the impact on the population (population model)
   Product: population projection for the scenario with and without wind farms
4. Testing whether this results in violation of the acceptable level of impact (ALI)
   Product: violation or no violation of set threshold

A detailed description of the modelling 'train' as applied in the KEC can be found in IJntema *et al.* (2025a).

2.1 Collision rate model

Collision rate models are widely used for the assessment of the impacts of offshore wind farms on birds. Previous KEC assessments have made use of the deterministic SNH collision risk model (Band 2012) and the stochastic sCRM (Masden 2015a,b), while for KEC 5.0 the stochLAB collision risk model was used (Caneco *et al*. 2022). These collision rate models follow the same basic principle of calculating the risk of collision of a specific bird species with a specific wind turbine and then multiplying this by the number of transits in a given month and summing this across an entire year. The collision rate model differentiates between seabirds (*basic model* for birds that use the area locally) and migratory birds (*migrant model* for birds passing through the area on their seasonal migration) (see Table 2.1). For seabirds, we use the ‘extended’ option of the model, which takes the distribution of bird flight heights at collision risk height into account.

Data requirements for the CRM include species-specific data as well as wind farm specific data. An overview of required data is given in Table 2.2.

Table 2.1 *Species previously identified as vulnerable for collisions with offshore wind farms. Differences between the 'seabird approach' and the 'migratory bird approach' are described in text.*

Common species name	Scientific species name	Approach
Northern gannet	*Morus bassanus*	Seabird approach
Arctic skua	*Stercorarius parasiticus*	Seabird approach
Great skua	*Stercorarius skua*	Seabird approach
Black-legged kittiwake	*Rissa tridactyla*	Seabird approach
Little gull	*Hydrocoloeus minutus*	Seabird approach
Lesser black-backed gull	*Larus fuscus*	Seabird approach
Herring gull	*Larus argentatus*	Seabird approach
Great black-backed gull	*Larus marinus*	Seabird approach
Common/Arctic tern	*Sterna hirundo/ paradisaea*	Seabird approach
Sandwich tern	*Thalasseus sandvicensis*	Seabird approach
Bewick's swan	*Cygnus (columbianus) bewickii*	Migratory bird approach
Brent goose	*Branta bernicla*	Migratory bird approach
Common shelduck	*Tadorna tadorna*	Migratory bird approach
Eurasian curlew	*Numenius arquata*	Migratory bird approach
Bar-tailed godwit	*Limosa lapponica*	Migratory bird approach
Red knot	*Calidris canutus*	Migratory bird approach
Black tern	*Chlidonias niger*	Migratory bird approach
Common starling	*Sturnus vulgaris*	Migratory bird approach

Bird characteristics

Several types of bird characteristics are used as input for the CRM. Species-specific bird characteristics for use in the collision rate model are compiled through literature reviews. These data include biometric data like body length and wingspan, and characteristics like flight speed, nocturnal activity, percentage in flight and avoidance rate. Here, we describe the main data requirements regarding bird characteristics.

Bird abundance and distribution

For local seabirds, the KEC approach is to use external bird density maps of geographically explicit presence of bird species in the North Sea. These data can be obtained from a variety of sources, but in the KEC we preferably make use of the updated density maps provided by Wageningen Marine Research (hereafter: WMR) (van Donk *et al.,* 2024). These van Donk 2024 maps are explicitly developed for the KEC 5.0, using a new approach and we expect to use these updated maps for the relevant species in future KEC rounds. Note that WMR updated the density maps only for the Dutch part of the North Sea.

Therefore, the maps by Waggitt *et al.* (2020) are used for the international waters of the North Sea. For some species, both the van Donk (2024) maps and Waggitt maps are not available; in this case, WMR provided density maps using the approach as applied in KEC 4.0 (inverse-distance-weighing: IDW, originating from the KEC 1.0; Leopold *et al.* 2015), updated using the most recent survey data (see for the different sources per species). These densities of birds-at-sea are then corrected based on the proportion of birds in flight to provide aerial bird densities needed for the collision rate model assessment.

As migratory birds rather use the southern North Sea for passing through instead of using the area locally, the KEC approach differs from seabirds. For migratory birds, fluxes are defined, generally based on assumptions about the width of the migration corridor across (parts of the) the North Sea, and the size of the migrating population. In absence of any data of the specific migration routes of a species, the width of the migration corridor is assumed to be the distance between the southern tip of Norway and the border between Belgium and France, as the starting point of the Channel, which is 750 km. For example, if 85 million birds pass over a length of 750 km length, the flux is calculated as around 114,000 birds/km. Population sizes of migratory bird species are based on Brinkman & Schekkerman (2024) or otherwise on estimates by Leopold *et al.* (2015) updated by population trends published by BirdLife International (2024). For the Bewick's swan and brent goose specific migration routes across the North Sea were available (Gyimesi *et al.* 2017b) based GPS logger studies. Furthermore, for the black tern certain areas of the North Sea could be defined that are used during migration (Potiek *et al.* 2019b). Based on these sources, fluxes were further refined to distinguish different migration intensities in the different wind farms, based on the geographical location of these wind farms relative to the migration routes. In addition, tracking studies on common shelduck and Eurasian curlew have given more insight in their migration routes (Green *et al.* 2019a,b; Pederson *et al.,* 2022; Jiguet *et al.,* 2021; Schwemmer *et al.,* 2023a,b). Within KEC 6.0, the migratory routes of these species will be re-evaluated.

Flight height

Species-specific data on flight height are obtained from published data or from GPS data. For seabirds, a flight height distribution is used within KEC. For most migratory land bird species, detailed data on flight height distribution are not available. In these cases, a proportion at rotor height is used. In a separate study, different methods are tested to convert raw GPS measurements to smoothed flight height distributions that can be used in collision rate models.

Avoidance rate

The numbers of crossings each month are calculated based on monthly densities (seabirds) or flux (migratory birds), flight height distribution (sea birds) or proportion at rotor height (migratory birds) and flight speed. The following important step is to account for avoidance, i.e. any evasive action taken by a bird to avoid the wind farm, individual turbines and the rotors. This requires species-specific avoidance rates.

Note that for northern gannet, the nocturnal activity and avoidance rate is assumed to vary between breeding birds and non-breeding birds (cf. Collier *et al.* 2022, Leemans & Gyimesi

2022). Hence, for wind farms within foraging range of colonies, the nocturnal activity and avoidance rate is adjusted for the breeding season.

Turbine / wind farm characteristics
In addition to bird-specific data, the collision risk is affected by turbine data. This encompasses information like rotor diameter, maximum chord, pitch and rotation speed.

2.2 Wind farm scenarios

Wind farm scenarios have not been updated since KEC5.0 and we therefore refer to IJntema *et al.* (2025a) for the windfarm scenarios. Additional considerations on choices for the inclusion or exclusion of certain windfarms, such as (not) discounting certain windfarms can be found in IJntema *et al.* (2025b).

2.3 Population models

Population models are used within the KEC approach to project the future population trend. By doing this for the null scenario as well as for the impacted scenario, the effect of the impact can be assessed on the population level. Within KEC, stage-structured matrix population models are used (Caswell 2001). These population models are described in Potiek *et al.* (2019a) and Potiek *et al.* (2022a).

In order to construct population models, species-specific demographic data are required. Due to the use of stage-specific population models, demographic rates are life stage-specific as well. Depending on the species, this includes an adult stage and one or more subadult stages. For the impacted scenarios, the survival rate is adjusted according to the estimated additional mortality. Using literature review we collected input for each of the life stages for the following demographic rates: survival rates, fecundity and probability of breeding (accounting for non-breeding adults, floaters). These are used as input for the population models constructed in earlier projects, which are part of the R package KEC4popmodels (Hin 2021).

2.4 ALI violation

The framework for testing species specific thresholds using population models has not been updated. The Acceptable Levels of Impact (ALI) framework by Hin *et al.* (2024), employing the threshold values as chosen by the Directoraat-generaal Natuur en Visserij (2025), based on advice by Sovon (2024), is currently still the applicable standard.

Table 2.2: Parameters used in the collision rate model (CRM)

Parameter Name	Unit	Value	Default value	Description	Aspect in model calculation
Bird-specific data					
Body length	M	mean +sd		Species body length.	Collision risk
Wingspan	M	mean +sd		Species wingspan.	Collision risk
Flight speed	m/s	mean +sd			Collision risk and numbers of birds at risk
Flight type	Flapping/gliding		Flapping	Type of flight.	Collision risk
Nocturnal activity	Proportion	mean +sd		Nocturnal flight activity level, expressed as a proportion of daytime activity level.	Numbers of birds at risk
Avoidance (basic model*)	Proportion	mean +sd		Avoidance rate.	Numbers of birds at risk
Avoidance (extended model**)	Proportion	mean +sd		Avoidance rate.	Numbers of birds at risk
Proportion upwind	Proportion		0.5	Proportion of flights upwind.	Collision risk
Proportion at collision risk height (basic model*)	Proportion	mean +sd		Proportion of flights at collision risk height, between the lowest and highest tip heights.	Collision risk and numbers of birds at risk
Flight height distributions (extended model**)	Proportion per m	Frequency distribution		Flight height distributions of each species as frequency distributions of bird flights at 1-metre height bands above the sea surface.	Collision risk and numbers of birds at risk
Bird- and wind farm-specific data					
Aerial bird density (per month)	per km^2	mean +sd		Number of daytime in-flight birds/km^2 per month.	Numbers of birds at risk
Wind farm-specific data					
Wind farm latitude	Decimal degrees	constant		Centroid of the windfarm.	Numbers of birds at risk
Wind farm width	Km	constant		Longitudinal width of the wind farm.	Numbers of birds at risk
Number of turbines		Constant		Number of turbines in the wind farm.	Numbers of birds at risk

Turbine-specific or wind farm-specific data					
Number of blades				Number of blades in rotor	Collision risk
Rotor radius	M	mean +sd		Radius of the rotor, assumed to be half of the diameter.	Collision risk and numbers of birds at risk
Air gap	M	mean +sd		Distance between the minimum rotor tip height and the highest astronomical tide (HAT).	Collision risk (extended model**) and numbers of birds at risk
Maximum blade width	M	mean +sd		Maximum blade width (also called maximum chord).	Collision risk
Rotation speed	revolutions / min	mean +sd		Operational rotation speed of the turbine.	Collision risk
Wind availability (per month)	Percentage	Mean		Monthly estimates of operational wind availability. Together with downtime provides monthly time in operation (per month).	Numbers of birds at risk
Downtime (per month)	Percentage	mean +sd		Monthly estimates of maintenance downtime. Together with wind availability provides monthly time in operation (per month).	Numbers of birds at risk
Model options					
Number of iterations			1000	The number of iterations for the model simulation.	
Bird density option			tnorm	Distribution of monthly bird density, default 'truncated normal'	
Blade chord			Standard values (based on 5MW turbine)	Chord taper profile of the rotor blade.	
Rotation/pitch option			probDist	Relationship for rotation speed and blade pitch.	

Blade pitch relationship	Default values	Only required if rotation/pitch speed option is probDist. Angle between blade surface and the rotor plane.
Rotation speed relationship	Default values	Only required if rotation/pitch option is probDist. Operational rotation speed, in revolutions per minute.
Tidal offset	0	Difference between HAT and MSL (tidal levels).
Large array correction	FALSE	Correction accounting for decay in aerial bird density in subsequent rows in large arrays of turbines.

*Basic model - assumes a uniform distribution of bird flights at collision risk height (i.e. above the minimum and below the maximum height of the rotor blade).

**Extended model - takes into account the distribution of bird flight heights at collision risk height.

3 Update knowledge base

This knowledge base update consists of two parts: the update of used methodology and the update of used input parameters. Note that the update of input parameters concerns the collision rate modelling as well as the population modelling.

3.1 Knowledge update regarding used methodology

Wind farm scenarios

Regarding the update of windfarm scenarios several considerations are relevant for potential future updates. In IJntema *et al.* (2025b) several considerations on defining windfarms scenarios are discussed, specifically:

- redefining the boundaries of the international study
- including coastal and nearshore windfarms
- discounting the impacts of existing windfarms
- following operational dates of windfarms more accurately

All of the recommendations from IJntema *et al.* (2025b) conclude one or more of the following:

- Adaptations are currently complex to currently implement.
- Adaptations are hard to justify with the current data availability.
- Adaptations require further development of the underlying methodology.

Hence, while some of these recommendations may be included in future iterations of the methodology, we do not include methodological adaptations to determining the windfarm scenario now.

Collision rate models – local seabirds

The recent review by Cook *et al.* (2025) highlights many of the efforts to develop or improve upon collision rate models from both scientific and grey liteature. However, none of the models presented in this review are published after KEC 5.0 and hence no new models were identified within this review. Furthermore, in the United States the newest version of the SCRAM (2.0) framework has recently been published (Goyert *et al.,* 2024). Key improvements of the newer version of the SCRAM framework are:

- opening the model up for use outside of the constraining dashboard and
- Fully aligning the collision rate model employed at the core with the new version of the Band model contained in StochLAB (Caneco *et al.*, 2022).

Given that we also use StochLAB we currently do not expect the collisions models as applied SCRAM to provide significantly different collision estimates than our current models.

As part of the KEC knowledge update, we also visited the yearly international collision rate model working group gathering in September 2025. In this working group model developers, model users and policy makers gather to discuss the current issues and developments in collision rate models. Here we confirmed our findings that the original Band model and its derivatives, such as StochLAB (Caneco *et al.,* 2022) are still the most widely accepted models due to their transparency and comparability. Therefore, deviating from the widely applied Band model requires robust arguments.

We are, however, aware that several promising models are in development that, for instance, may be able to incorporate the wealth of novel data and data types being collected offshore. Unfortunately, we believe none of these are currently at a stage that they can be applied in the KEC. An example is the development of a new collision rate model in project ZV4-5-6 *(Complexe vogelmodellen)* within WOZEP research program. Future KEC knowledge updates should closely follow the development of these new models and their potential for improving the KEC framework.

Hence, we choose to remain with the newest iteration of the band model for sea birds in the StochLAB package in R (Caneco *et al*., 2022). Especially also given that the latest version of the documentation of this model is from the 23rd of July 2025, suggesting the package is regularly maintained and updated.

Collision rate models – migratory coastal and onshore birds
Within the package StochLAB, recent developments have updated the band model for migrant birds ("Migration Collision Risk Model" - mCRM) to fit a R Shiny dashboard interface for easier use. However, in our opinion a key limitation of the migrant model in StochLAB has not been resolved since KEC 5.0: When considering the birds that fly at a height where they are susceptible to collisions, the model can only work with a binary proportion of birds at rotor height (the chance a bird either flies at rotor height or not). For some species, however, the data is of such quality that we are able to define the proportion of birds flying at smaller height resolutions in flight height distributions. Flight height distributions allow the mortalities to be calculated at different levels along the rotor blade with different chances to collide at different parts of the blades. Additionally, proportions at rotor height are often measured in one windfarm, while the rotor height may be different in the new windfarm assessed. A flight height distribution allows for flexible definition of the rotor height while a fixed value of proportion at rotor height, does not. Because of these limitations, for the species with a flight height distribution available, we advise to use these, such as in in the KEC 5.0. For species where only data on the proportion at rotor height is available, we advise to use the mCRM as contained in StochLAB as previously also employed in KEC 5.0.

In conclusion, while promising alternatives are being developed, it is currently justified to implement new collision rate models in the KEC framework.

Population models

While the considerations from IJntema *et al.,* (2025b) discuss potential future changes in the population model applications, none of these considerations can currently be included in the methodology (see 3.1 – windfarm scenarios). Additionally, several side projects are being conducted both within and outside of the KEC program. However, currently no developments are at a stage that they can be incorporated in the population models as currently applied in KEC.

3.2 Update used input parameters

Part of this inter-KEC-study was to update input parameters based on extensive literature research for input parameters for the collision rate model, as well as for demographic rates as input for the population models. This knowledge update is performed for all seabird and migratory species in Table 2.1.

We performed all literature searches in Google Scholar. For each species, we searched for recent studies using the species' common name and Latin name as separate search terms. We also performed more targeted searches consisting of the species' common name combined with a term related to population or collision rate model parameters (such as 'survival', 'fecundity', 'reproduction' or 'flight').

Demographic rates

Input for the population models consists of estimated life stage-specific survival rates, fecundity and fraction non-breeding adults (floaters). We updated the knowledge database on demographic rates used by IJntema *et al.* (2025a) to include recent relevant studies.

For the weighing of different data sources, each data source within this updated knowledge base is scored for representativeness and data quality, following the approach used in previous KECs (a.o. IJntema *et al.* 2025a), which is based on Horswill & Robinson (2015). See Box 1 for a description of the approach. Age of first breeding is very species-specific and constant between colonies. Hence, this parameter is generally based on one data source.

Since the knowledge update for KEC 5.0 (IJntema *et al.* 2025a), performed in 2024, several new publications have reported demographic parameters from populations affected by the recent High Pathogenic Avian Influenza (HPAI) outbreak of 2021-2023. Since these data were collected during an unusual mass-mortality event, it is unclear to what extent the survival and fecundity parameters are relevant to long-term population projections. However, since the majority of the species considered in this report have low annual reproductive rates and high longevity, the mass mortality caused by HPAI is likely to be visible in Dutch populations for many years to come. For that reason, we chose to include these new publications in our report; where new parameters are reported from HPAI-affected populations, these are explicitly discussed in the text in the text. While we do include these sources in the report, we recommend not using estimates from studies based on single years in which HPAI played a major role in analyses, as these are not representative for all years. However, in case longer time series are available, years with HPAI should be included.

Collision rate model parameters
For the collision rate model parameters, we updated the knowledge database used by IJntema *et al.* (2025a) to include recent relevant studies. We gathered information on body length (m), wingspan (m), flight speed (m/s), nocturnal activity (proportion), avoidance rate (proportion) and ratio flying (proportion). In addition, for local seabirds, we looked for updates on the flight height distribution, while for migratory birds we looked for new data on the proportion at rotor height.

Choosing the final values for collision rate models and population models to be used
Depending on the available data, and the quality and representativeness of each of those data sources, we used one of the following approaches:

1. Recommended values based on large reviews: When recent large reviews with recommended parameters were available, these recommended values were used. When no new values were published after the publications of said reviews, we assumed all values published before were considered and we adopted the recommendations from these reviews directly.
2. Use 'best' reference: When one reference has clearly higher data quality and representativeness than the other available sources, this reference is used.
3. Calculate weighted averages: When several data sources are available, these can be weighted by data quality and representativeness.

Box 1 Weighing of data sources for input parameters population model, following the approach of Horswill and Robinson (2015), which was also used for previous versions of the KEC.

This approach of Horswill & Robinson (2015) is based on the following criteria to assess data quality:
- Q1) the number of years (>10).
- Q2) the number of individuals and
- Q3) whether an indication of variation between years or areas (standard deviation). or a range of error (standard error) has been reported.

Each of these criteria is scored with 0, 1, or 2: 0 for 'poor', 1 for 'intermediate/unknown' and 2 for 'good'. This means that the maximum score of data quality is 6.

In a similar way, we assess the representativeness of each data source. This representativeness is scored based on:
- R1) how recent the data are (score 2 for data of less than 10 years old; threshold between score 1 and 0 depends on the species and data availability),
- R2) how representative the area/site is for the Dutch part of the North Sea, and

- R3) how representative the data are for the current local trend in the Dutch part of the North Sea.

For all parameters, if European estimates are available, we only use these estimates, as these are more representative.

Again, each of these criteria is scored with 0, 1, or 2: 0 for ‘poor’, 1 for ‘intermediate/unknown’ and 2 for ‘good’. This gives a maximum score for representativeness of 6.

For each species, the defined life stages are described using the following general structure:
- a first-year stage (stage J0),
- followed by one or more immature stages (stages starting with I, for example I1 to I4),
- and an adult stage (stage A).

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

Regarding the selection of avoidance rates, we relied on the same decision tree as used in KEC 5.0 to decide which studies are the most relevant to rely on (Figure 3.1). The foremost criterium was whether avoidance rates from offshore studies are available. If so, those studies were scored on data quality and - representativeness (see Box 1) and the resulting weighted average was used.

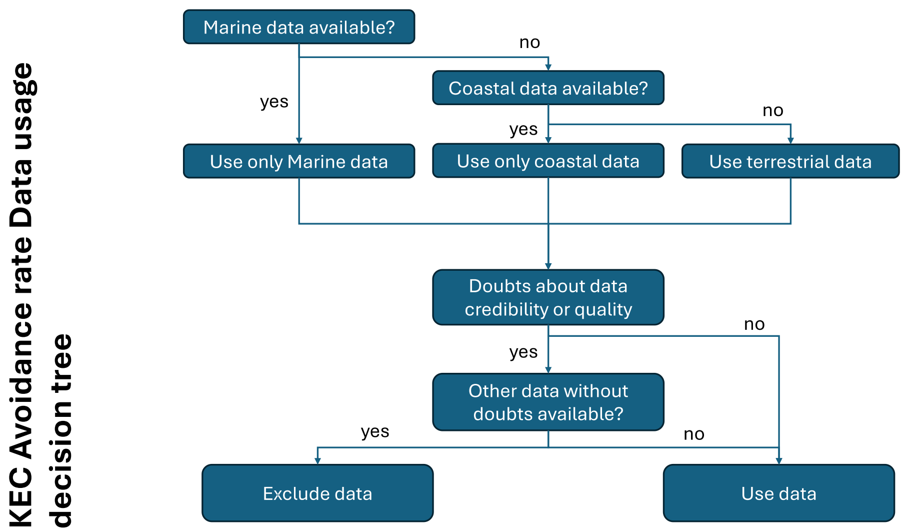

Figure 3.1 Decision tree for prioritizing studies reporting avoidance rates.

Further in this chapter, we provide per species an overview of the newly retrieved values with an advice on which values are relevant to be considered. These values were taken into account according to above selection criteria and weighing. The final values to be used in future impact assessments are published in the Wozep repository, available at doi: 10.5281/zenodo.17790735.

3.2.1 Seabird species

Northern gannet

No new studies were found that reported parameters relevant to the northern gannet sCRM model.

In the KEC 5.0 study, northern gannet population model parameters were updated by WMR as part of a separate report (Soudijn *et al.* 2025). For the current report, we performed literature searches to check for new population data parameters, finding three new studies reporting parameters not included in Soudijn *et al.* (2025). All three studies reported adult survival in the wake of the recent HPAI outbreak. Based on ring recoveries across the British Isles, Johnston *et al.* (2025) estimated gannet survival in 2022 as 0.77 (95% CIs = 0.29, 0.86; N = 133). Using data from across all 43 gannet colonies in Europe, Matthiopoulos *et al.* (2025) estimated mean adult survival in 2022 to be 0.66 (95% CIs = 0.61, 0.73). Using data from the Bass Rock colony in Scotland, Lane et al. (2024) reported an apparent annual adult survival of 0.46 (95% CIs = 0.15, 0.79) in 2021 and 2022. The study by Lane et al. (2024) also reported adult survival for the period preceding the HPAI outbreak (2011-2021); this value (0.94) was included in the KEC knowledge update performed by Soudijn *et al.* (2025) and therefore does not constitute a new value for the current report.

Arctic skua

We found a single new study reporting a parameter value relevant to the Arctic skua sCRM. Kelsey *et al.* (2025) conducted a meta-analysis across all published literature to calculate average values for several parameters related to collision risk. They report proportions of nocturnal activity, diurnal flight and flights at rotor height as 0.05, 0.79 and 0.04, respectively (measurement error not reported). They also calculate macro-avoidance as 0.14 (measurement error not reported). Given that the other value in our database for nocturnal activity is merely an expert judgement, not based on data, we recommend the use of the nocturnal activity estimate of 0.05 as reported by Kelsey *et al.* (2025). Given the absence of any estimates for micro- and meso-avoidance in our database, the macro-avoidance value cannot be used to compile a full avoidance value. We therefore recommend not to include the Kelsey *et al.* (2025) macro-avoidance estimate in collision rate models until estimates for meso-and micro avoidance are available.

In addition, we updated our parameter values for one study that described population model parameters. Snell *et al.* (2025) reported adult and juvenile survival for a population on the Faroe Islands as 0.92 ± 0.07SE and 0.43 ± 0.14SE, respectively (N = 530 individuals). A preliminary version of these data was already present in our previous knowledge update in the form of personal communication with the lead author, but we could now include the peer-reviewed, more detailed source in our database. Given that the estimate found is merely a publication of previously included estimates, no updates to survival parameters are necessary compared to KEC 5.0.

Great skua

For the great skua, we found no new studies reporting parameters relevant to the sCRM model.

We found one new study relevant to the population model: Johnston *et al*. (2025) reported a mortality estimate for great skua populations in the UK during the HPAI outbreak of 2021-2023. Based on 207 ring recoveries across the UK, they estimated an annual survival of 0.48 (95% CIs = 0.00, 0.71). As previously discussed, we recommend excluding single year HPAI values collected solely during HPAI events and we recommend not including any new sources for demographic parameters in the Great skua.

Black-legged kittiwake

Five new studies were found that reported parameter values for the kittiwake sCRM model. In Alaska, Tremblay *et al.* (2024) used GPS data from 80 tagged adults to demonstrate that the proportion of time kittiwakes spent flying in their study population was 0.27 ± 0.02SE. However, a study by Davies *et al*. (2024) reported much higher values for 20 GPS-tagged individuals in Scotland, where the proportion of time spent in commuting, foraging and searching flight was 0.58 (no error measure provided). A third new estimate for proportion of time spent flying, published by Léandri-Breton *et al*. (2025) from a population in Svalbard, reported a value of 0.47 ± 0.06SE (N = 117 GPS-tagged kittiwakes). Davies *et al*. (2024) also reported mean flight speeds during commuting (13.41 m/s, 95% CIs = 3.75, 35.76) and foraging or searching (14.63 m/s, 95% CIs = 0.74, 73.62) in wind-still conditions, though it is worth noting that these flight speeds varied slightly with wind speed. Using the same dataset, Davies *et al*. (2024) estimated the proportion of flight occurring at rotor height to fall between <0.01 and 0.16; again, dependent on windspeed. A study by Pollock *et al*. (2024) reported avoidance rate at the macro- and meso- levels for 20 GPS-tagged kittiwakes in the Scottish North Sea at different distance bands. Pollock et al. (2024) reported macro-avoidance rates of -0.36 ± 0.19, -0.19 ± 0.11, -0.06 ± 0.05 and 0 ± 0.01 at 1, 2, 3 and 4km distance from wind farm boundaries, respectively. They also reported meso-avoidance rates of -2 ± 0, -2 ± 0, 0.49 ± 0.5 and -0.45 ± 0.46 at 20-40, 40-60, 60-80 and 80-100m distance from the nearest turbine, respectively. Lastly, a meta-analysis by Kelsey *et al*. (2025) reported new estimates for nocturnal activity (0.03), time spent in flight during the day (0.64) and proportion of flight at rotor height (0.16), as well as a mean macro-avoidance of (0.42). These parameter values were calculated across all published literature (Kelsey *et al*. 2025).

Considering the parameter estimates for proportion of time flying we recommend using the estimates from Davies *et al*. (2024) and Léandri-Breton *et al*. (2025). We recommend excluding the value from Tremblay *et al*. (2024) due to the high likelihood that the Alaskan population is a geographically distinct population from the North Sea population. For the flight speed parameter, we recommend updating the values by including Davies *et al*. (2024). Since representative flight height distributions are available for this species, we recommend not including new proportion at rotor height parameter estimates as better data are available.

Considering the attraction values reported by Pollock *et al*. (2024), we recommend only including these in combination with a micro-avoidance value. Since the only estimate of an isolated micro-avoidance we have available in our data is 100%, any value that needs to be compiled using this micro-avoidance value is mathematically irrelevant (if all birds avoid at the micro-level, no collisions occur regardless of the meso- and macro-avoidance/attraction)

Given the focus of Kelsey *et al*. (2025) on the USA area in combination with the relatively good data availability for North Sea relevant populations we recommend excluding the nocturnal activity, proportion of time in flight and avoidance from Kelsey *et al*. (2025) in choosing the final values for these parameters.

We also found a new study reporting adult survival rates based on ring recoveries across the British Isles in the wake of the 2021-2023 HPAI epidemic. Johnston *et al*. (2025) report kittiwake survival in 2022 and 2023 as 0.43 (95% CIs = 0, 0.86; N = 36) and 0.11 (95% CIs = 0, 0.87; N = 51), respectively. As previously discussed, we recommend excluding single year HPAI values and we recommend not including any new sources for demographic parameters in the kittiwakes.

Little gull

We found no new studies relevant to the little gull sCRM.

We also found no new studies reporting input parameters for the population model. In general, very little is known about reproduction and survival in this species; as in previous versions of this knowledge update, we therefore incorporate demographic data from a closely related species, the black-headed gull *Chroicocephalus ridibundus*, to inform the population model. We found a single new study on black-headed gulls reporting a mean fecundity of 0.61 fledglings per pair (measurement error not reported) across 22 colonies as part of a long-term monitoring programme in Poland (O'Keeffe *et al*. 2024). Given the low data availability for the species, we recommend using every dataset available, including the estimate above.

Lesser black-backed gull

We found no new studies reporting information relevant to the lesser black-backed gull sCRM and no new parameter values for the population model either.

Herring gull

We found one new study reporting parameter values relevant to the sCRM model for herring gulls. Kelsey *et al*. (2025) combined data from all published literature to calculate the proportion of time spent on diurnal flight and flights at rotor height to be 0.46 and 0.35, respectively (measurement error not given). They also calculated a mean macro-avoidance rate of 0.298 (measurement error not given). Given the focus of Kelsey *et al*. (2025) on the

USA context and the availability of North Sea parameter estimates for both parameters, we recommend excluding the parameter estimates mentioned above from the analysis.

No new studies reporting parameters for the herring gull population model were found.

Great black-backed gull
We found no new studies containing parameters that can inform sCRM models for the great black-backed gull.

However, we found a new study relevant to population models for this species: fecundity rate across 48 nests at a Scottish colony was reported by Lopez *et al*. (2024) as 0.73 ± 0.98SD fledglings per pair. We recommend including the parameter estimate of Lopez *et al.* (2024) to get to a final parameter estimate for use in demographic analyses. In addition, we are currently carrying out a long-term GPS tracking study on great black-backed gulls breeding in Norway. Nest monitoring data from this study provide information about reproductive success of tagged and control pairs. The current data are somewhat limited, but in the future these will provide insight into annual trends in breeding success.

Common tern
We found one new study reporting sCRM input parameters for common terns. Based on a review of all published literature, Kelsey *et al.* (2025) reported new parameter values for proportion of time spent in flight (0.75), proportion of flights at rotor height (0.1) and macro-avoidance (0.468). No measurement errors were provided for these values, which were calculated based on primary data from the literature.

Given the absence of reliable estimates for time spent in flight in our database (the only other estimate is an unrealistic worst-case value of 100%), we recommend using the value from Kelsey *et al.* (2025) in future assessments. Resulting from the availability of a flight height distribution for the common tern, we recommend not using the proportion at rotor height estimates from Kelsey *et al.* (2025). As discussed in chapter 3.1, flight height distributions are preferred above percentage at rotor height, because these former allow for more detailed calculations of mortalities, also specifically for certain wind turbine characteristics. This in contrast with percentage at rotor height that implies that all rotor-swept zones are identical and that the distribution of birds is homogenous there within.

In the absence of estimates for meso- and micro-avoidance in our database a macro-avoidance estimate cannot be used to compile an overall avoidance. This makes it impossible to incorporate the macro-avoidance value in constructing final parameter estimates.

Age of first breeding should be set at three (BTO Bird facts). We also found two new studies reporting population model parameters, both in relation to the recent HPAI outbreak. Across the British Isles, Johnston *et al.* (2025) estimated the HPAI-related survival of common terns to be 0.01 (95% CIs = 0, 0.51), based on 133 ring recoveries that year. In Ireland, Burke *et al.* (2024) reported a much lower mortality rate of 0.13 during the 2023 breeding season across three colonies (mean survival across breeding season = 0.87, range = 0.83 – 0.93, n = 6103 breeding adults). Again, these values may not be representative of longer-term survival rates. As previously discussed, we recommend excluding single year HPAI values and we recommend not including any new sources for demographic parameters in the common terns.

Sandwich tern

We found a single new study relevant to the sandwich tern sCRM. Thaxter *et al.* (2024) used data from 34 GPS-tagged individuals in the UK to estimate that the proportion of time spent in flight is 0.92 ± 0.23SD in this species. We recommend including this value in determining a final parameter estimate for use in assessments.

For the previous version of the KEC knowledge update, data informing population models for sandwich terns were updated as part of a separate report (Soudijn *et al*. 2025). For the current report, we therefore cross-checked and updated our own knowledge database with new studies found by Soudijn *et al.* (2025) and searched for additional studies that have been either published since or fell outside the scope of the literature review performed by Soudijn *et al.* (2025). We found two relevant additions to the knowledge database. Two new survival parameters have been published concerning the effect of the HPAI outbreak on sandwich terns: Johnston *et al.* (2025) used 182 ring recoveries to estimate an annual adult survival of 0.07 (95% CIs = 0.00, 0.49) during the 2022 epidemic across the British Isles. Data from over 37,000 individuals across 11 Dutch breeding colonies during the same period yielded an annual survival rate of 0.76 ± 0.26SD (Knief *et al.* 2024).

As Sandwich tern is a species vulnerable for collisions as well as habitat loss, final values for demographic will be chosen in coordination with WMR.

3.2.2 Migratory birds

Bewick's swan

No new studies reporting collision risk or population parameters were found for this species.

Brent goose

No new studies were found that reported information relevant to the brent goose collision risk or population models.

Common shelduck

No new studies were found reporting parameters relevant to the shelduck population models. Regarding collision risk, tracking studies give more insight in migration routes (Green *et al.,* 2019a,b). No other new studies were found reporting input parameters for the collision rate modeling.

Eurasian curlew

No new studies were found that reported information related to the population model for this species. Regarding collision risk, tracking studies give more insight in migration routes (Pederson *et al.,* 2022; Jiguet *et al.,* 2021; Schwemmer *et al.,* 2023a,b). No other new studies were found reporting input parameters for the collision rate modeling.

Bar-tailed godwit
No new studies relevant to the collision risk or population models were found.

Red knot
We found one study relevant to the red knot collision model, which was not included in KEC 5.0. This concerns a study reporting flight speed measured in Sweden (Hedenström & Åkesson, 2017). However, in the later review by Woodward *et al.* (2023), already included in KEC5.0, geared specifically to recommended values of CRM parameter values for migrant birds another value from Gudmundsson (1994) is recommend for use in CRMs and we follow this recommendation.

Regarding input parameters for population models, no relevant new studies were found for this species.

Black tern
One new study reporting parameter values for the sCRM was discovered. Kelsey *et al.* (2025) synthesized all data in published literature to calculate mean proportion of time spent in flight (0.78), proportion of flights at rotor height (0.06) and macro-avoidance rates (0.468) – no measurement error was provided for these values.

Considering we regard the black tern as a migratory bird at the North Sea, we assume that individuals are 100% of the time in flight and proportion of time in flight measured is regarded as irrelevant for migrating birds.
Given the very low connectivity of black tern populations migrating in North America and in the North Sea, the proportion at rotor height reported by Kelsey *et al.* (2025) is less relevant for our study population, and we recommend not to use this estimate.

In the absence of estimates for meso- and micro-avoidance in our database a macro-avoidance estimate cannot be used to compile an overall avoidance. This makes it impossible to incorporate the macro-avoidance value reported by Kelsey *et al.* (2025) in constructing final parameter estimates.

We found two new survival estimates for the black tern: van der Winden *et al.* (2024) estimated adult survival at 0.77 (95% CIs = 0.69, 0.83) across 36 ringed individuals present in Dutch breeding colonies. Elsewhere, Marchowski *et al.* (2025) studied 143 breeding pairs across two colonies along the German-Polish border that were affected by the recent HPAI outbreak, reporting that black terns apparently suffered little influenza-related mortality (adult survival = 0.98, no measurement error given).

Given the suggestions that HPAI does not affect the black tern we recommend using both new estimates from van der Winden *et al.* (2024) and Marchowski *et al.* (2025) to determine final parameter values for the adult survival.

Common starling
We found no new studies that reported parameters relevant to the starling sCRM.

We found one new study reporting fecundity estimates that may inform the common starling population models: fecundity was 3.34 ± 0.41SE across 60 breeding pairs in Canada (Barber *et al.* 2025). Within KEC 5.0, the data from Versluijs *et al.* (2016) were used. Although the data are relatively old (based on time period 1990 – 2012), the benefit of using this source is that these data are from the Netherlands, and hence representative for the area. Moreover, the authors report survival rates as well as fecundity from the same population. Birds from Canada represent a different population, under different circumstances regarding a.o. predation., we recommend using data from Versluijs *et al.* (2016).

4 References

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

Barber, C., Slade, J., Hornsby, M., Wright, M., Burke, L., Reeve, C. and Howatt, K., 2025. Age and reproductive strategies in European Starlings (Sturnus vulgaris). *Journal of Ornithology*, *166*(2), pp.371-381.

BirdLife International, 2024. IUCN Red List for birds. Downloaded from https://datazone.birdlife.org on 09/04/2024.

Brinkman, C. & H. Schekkerman, 2024. Verkenning trekkende niet-zeevogels boven de Noordzee. Mogelijke gevoeligheid voor offshore windenergiewinning. Sovon-rapport 2024/30. Sovon Vogelonderzoek, Nijmegen.

Burke, B., Adcock, T., Boland, H., Büche, B., Fitzgerald, M., Johnson, G.C., Monaghan, J., Murray, T., Stubbings, E. and S. Newton, 2024. A case study of the 2023 highly pathogenic avian influenza (HPAI) outbreak in tern (Sternidae) colonies on the east coast of the Republic of Ireland. Bird Study 71: 336-346.Calladine, J. & M. Harris, 1997. Intermittent breeding in the herring gull Larus argentatus and the lesser black-backed gull Larus fuscus. Ibis 139(2): 259-263.

Caneco, B., G. Humphries, A. Cook & E. Masden, 2022. Estimating bird collisions at offshore windfarms with stochLAB. Marine Scotland Science.

Caswell, H., 2001. Matrix population models, Rapport. Sunderland, MA.

Collier, M.P., A. Potiek, V. Hin, J.J. Leemans, F.H. Soudijn, R.P. Middelveld & A. Gyimesi, 2022. Northern gannet collision risk with wind turbines at the southern North Sea. Extension of the impact assessment for KEC 4.0, additional analyses of the assessment framework, Rapport 22-052. Bureau Waardenburg, Culemborg.

Cook, A.S.C.P., E. Salkanovic, E. Masden, H.E. Lee & A.H. Kiilerich, 2025. A critical appraisal of 40 years of avian collision risk modelling: How have we got here and where do we go next? Environmental Impact Assessment Review 110: 107717.

Davies, J. G., Boersch-Supan, P. H., Clewley, G. D., Humphreys, E. M., O'Hanlon, N. J., Shamoun-Baranes, J., Thaxter, C. B., Weston, E. & A. S. Cook, 2024. Influence of wind on kittiwake *Rissa tridactyla* flight and offshore wind turbine collision risk. Marine Biology 171: 191.

Directoraat-generaal Natuur en Visserij. (2025). Wijziging drempelwaarden Acceptable Levels of Impact (ALI) voor toetsing impact van windparken op zee op zeevogels. Ministerie van Landbouw, Visserij, Voedselzekerheid en Natuur.

van Donk, S., R. van Bemmelen, C. Chen, I. Tulp & E. Melis, 2024. Seabird maps of the North Sea. A short description of methodology. Wageningen University & Research report: C024/24. Wageningen Marine Research, IJmuiden.

Goyert HF, Adams EM, Gilbert A, Gulka J, Loring PH, Stepanuk JEF, Williams, KA (Biodiversity Research Institute, Portland, ME; U.S. Fish and Wildlife Service, Charlestown, RI). 2024. SCRAM 2: transparent modeling of collision risk for three federally listed bird species in relation to offshore wind energy development. Sterling (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management, Sterling, VA. 80 p Obligation No.: M19PG00023. Report No.: BOEM 2024-057. Also available at https://briwildlife.org/SCRAM/.

Green, R. M., N.H. Burton & A.S.C.P. Cook, 2019a. Migratory movements of British and Irish Common Shelduck Tadorna tadorna: a review of ringing data and a pilot tracking study to inform potential interactions with offshore wind farms in the North Sea. Ringing & Migration, 34(2), 71-83.

Green, R.M., N.H. Burton & A.S.C.P. Cook, 2019b. Review of the migratory movements of Shelduck to inform understanding of potential interactions with offshore wind farms in the southern North Sea. Thetford: British Trust for Ornithology.

Hedenström, A. & S. Åkesson, 2017. Flight speed adjustment by three wader species in relation to winds and flock size. Animal Behaviour, 134, pp.209-215.

Hin, V., 2021. KEC4popmodels: Matrix population models to assess mortality effects of Offshore Wind Parks on seabird Populations. Wageningen Marine Research. URL: https://git.wur.nl/ecodyn/KEC4popmodels

Hin, V., G. IJntema, T. van Kooten & A. Potiek, 2024. A revised methodology for quantifying ‘Acceptable Level of Impact’ from offshore wind farms on seabird populations. Wageningen Marine Research report C034/24. Wageningen Marine Research, IJmuiden.

Horswill, C. & R.A. Robinson, 2015. Review of seabird demographic rates and density dependence. JNCC Report No. 552. Joint Nature Conservation Committee, Peterborough.

IJntema, G., Heida, N., Leemans, J., Gyimesi, A., & A. Potiek, 2025a. Collision effects of North Sea wind turbines on bird species within the “Kader Ecologie & Cumulatie (KEC) 5.0”. In Actualisation of models, data and predicted mortality for Dutch government offshore wind development scenarios. Culemborg: Waardenburg Ecology.

IJntema, G., A. Potiek, V. Hin, E. Melis, M.J.M. Poot, 2025b. Memo study area and Discounting in “Kader Ecologie en Cumulatie (KEC) 5.0”.

Jiguet, F., Schwemmer, P., Rousseau, P., & Bocher, P. (2021). GPS tracking data can document wind turbine interactions: evidence from a GPS-tagged Eurasian curlew. Forensic Science International: Animals and Environments, 1, 100036.

Johnston, D.T., Atkinson, P.W., Leech, E.I., Burton, N.H., Humphreys, E.M., Robinson, R.A., Blackburn, J.R., Blackburn, A.C., Brides, K., Boland, H. & B. Burke, 2025. Using ring (band) recovery data to examine the impact of high pathogenicity avian influenza (HPAI) on wild bird populations. Bird Study, pp.1-12.

Kelsey, E.C., Felis, J.J., Pereksta, D.M., and Adams, J., 2025, Revised marine bird collision and displacement vulnerability index for U.S. Pacific Outer Continental Shelf offshore wind energy development: U.S. Geological Survey Data Report 1214, 32 p., https://doi.org/10.3133/dr1214

Knief, U., Bregnballe, T., Alfarwi, I., Ballmann, M.Z., Brenninkmeijer, A., Bzoma, S., Chabrolle, A., Dimmlich, J., Engel, E., Fijn, R. & K. Fischer, 2024. Highly pathogenic avian influenza causes mass mortality in Sandwich Tern *Thalasseus sandvicensis* breeding colonies across north-western Europe. Bird Conservation International 34, e6.

Lane, J.V., Jeglinski, J.W., Avery-Gomm, S., Ballstaedt, E., Banyard, A.C., Barychka, T., Brown, I.H., Brugger, B., Burt, T.V., Careen, N. and Castenschiold, J.H., 2024. High pathogenicity avian influenza (H5N1) in Northern Gannets (*Morus bassanus*): Global spread, clinical signs and demographic consequences. Ibis, 166(2), pp.633-650.

Léandri-Breton, D.J., Elliott, K.H., Tarroux, A., Legagneux, P., Jouanneau, W., Amélineau, F., Angelier, F., Blévin, P., Bråthen, V.S., Fauchald, P. and Gabrielsen, G.W., 2025. Testing the abundant centre hypothesis in a seabird: higher energy expenditure at the wintering range centre does not reduce reproductive success. Ecography, 2025(5), p.e07498.

Leemans, J.J. & A. Gyimesi, 2022. Avoidance rates of northern gannet in offshore wind farms in the southern North Sea, Rapport 18-0178/22.06209/AbeGy. Bureau Waardenburg, Culemborg.

Leopold, M.F., M. Boonman, M.P. Collier, N. Davaasuren, R.H. Jongbloed, S. Lagerveld, J.T. van der Wal & M.M. Scholl, 2015. A first approach to deal with cumulative effects on birds and bats of offshore wind farms and other human activities in the Southern North Sea. IMARES Report C166/14 IMARES, Wageningen.

Lopez, S. L., Clewley, G. D., Johnston, D. T., Daunt, F., Wilson, J. M., O'Hanlon, N. J. & E. Masden, 2024. Reduced breeding success in Great Black-backed Gulls (*Larus marinus*) due to harness-mounted GPS device. Ibis 166: 69-81.

Marchowski, D., Chara, P., Borek, Ł., Kajzer, Z. and Bzoma, S., 2025. Effects of highly pathogenic avian influenza among colonial waterbirds in the lower Odra valley. *Acta Ornithologica*, *59*(1), pp.23-33.

Masden, E., 2015a. Developing an avian collision risk model to incorporate variability and uncertainty. Scottish Marine and Freshwater Science Vol 6 No 14. Scottish Government, Edinburgh.

Masden, E., 2015b. Developing an avian collision risk model to incorporate variability and uncertainty. [R computer code]

Matthiopoulos, J., Votier, S., Wanless, S., Cunningham, E., Lane, J. & J. Jeglinski, 2025. Multispecies HPAI spillovers led to the death of one-in-three gannets, 14 May 2025, PREPRINT (version 1) available at Research Square (https://doi.org/10.21203/rs.3.rs-6589046/v1).

Pederson, R., Bocher, P., Garthe, S., Fort, J., Mercker, M., Auernhammer, V., ... & P. Schwemmer, 2022. Bird migration in space and time: chain migration by Eurasian curlew Numenius arquata arquata along the East Atlantic Flyway. Journal of Avian Biology, 2022(9), e02924.

Pollock, C. J., Johnston, D. T., Boersch-Supan, P. H., Thaxter, C. B., Humphreys, E. M., O'Hanlon, N. J., Clewley, G. D., Weston, E.D., Shamoun-Baranes, J. & A. S. Cook, 2024. Avoidance and attraction responses of kittiwakes to three offshore wind farms in the North Sea. Marine Biology 171: 217.

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

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

Potiek, A., N. Vanermen, R.P. Middelveld, J. de Jong, E.W.M. Stienen & R.C. Fijn, 2019b. Spatial and temporal distribution of different age classes of seabirds in the North Sea.

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, KEC 3.0. Rijkswaterstaat in opdracht van het Ministerie van Landbouw, Natuur en Voedselkwaliteit, Den Haag.

Schwemmer, P., M. Mercker, K. Haecker, H. Kruckenberg, S. Kämpfer, P. Bocher, J. Fort, F. Jiguet, S. Franks, J. Elts, R. Marja, M. Piha, P. Rousseau, R. Pederson, H. Düttmann, T. Fartmann & S. Garthe, 2023a. Behavioral responses to offshore windfarms during migration of a declining shorebird species revealed by GPS-telemetry. Journal of Environmental Management 342: 118131.

Schwemmer, P., R. Pederson, K. Haecker, P. Bocher, J. Fort, M. Mercker, ... & S. Garthe, 2023b. Assessing potential conflicts between offshore wind farms and migration patterns of a threatened shorebird species. Animal conservation, 26(3), 303-316.

Snell, K.R., dos Santos, I.A.M., van Bemmelen, R.S., Moe, B. & K. Thorup, 2025. Wintering, rather than breeding, oceanic conditions may modulate declining survival in a long-distance migratory seabird. Marine Ecology Progress Series 754: 93-103.

Soudijn, F. H., Hin, V., Melis, E., Chen, C., van Donk, S., Benden, D., & Poot, M. J. M. (2025). *Population level effects of displacement of marine birds due to offshore wind energy developments, KEC 5*. (Wageningen Marine Research report; No. C094/24). Wageningen Marine Research. https://doi.org/10.18174/683553.

Sovon, 2024. Invulling van parameterwaarden voor herziene Acceptable Levels of Impact van sterfte van vogels door windparken op zee. Sovon notitie 2024/53. Sovon Vogelonderzoek Nederland

Thaxter, C.B., Green, R.M., Collier, M.P., Taylor, R.C., Middelveld, R.P., Scragg, E.S., Wright, L.J., Cook, A.S. & R.C. Fijn, 2024. Behavioural responses of Sandwich terns following the construction of offshore wind farms. Marine Biology 171, 58.

Tremblay, F., Choy, E. S., Whelan, S., Hatch, S. & K. H. Elliot, 2024.Time-energy budgets outperform dynamic body acceleration in predicting daily energy expenditure in kittiwakes, and estimate a very low cost of gliding flight relative to flapping flight. Journal of Experimental Biology 227: jeb247176.

Versluijs, M., C.A.M. van Turnhout, D. Kleijn & H.P. van der Jeugd, 2016. Demographic changes underpinning the population decline of Starlings Sturnus vulgaris in The Netherlands. Ardea 104(2): 153-165.

Waggitt, J.J., P.G.H. Evans, J. Andrade, A.N. Banks, O. Boisseau, M. Bolton, G. Bradbury, T. Brereton, C.J. Camphuysen, J. Durinck, T. Felce, R.C. Fijn, I. Garcia-Baron, S. Garthe, S.C.V. Geelhoed, A. Gilles, M. Goodall, J. Haelters, S. Hamilton, L. Hartny-Mills, N. Hodgins, K. James, M. Jessopp, A.S. Kavanagh, M. Leopold, K. Lohrengel, M. Louzao, N. Markones, J. Martínez-Cedeira, O.Ó. Cadhla, S.L. Perry, G.J. Pierce, V. Ridoux, K.P. Robinson, M.B. Santos, C. Saavedra, H. Skov, E.W.M. Stienen, S. Sveegaard, P. Thompson, N. Vanermen, D. Wall, A. Webb, J. Wilson, S. Wanless & J.G. Hiddink, 2020. Distribution maps of cetacean and seabird populations in the North‐East Atlantic. Journal of Applied Ecology 57(2): 253-269.

van der Winden, van Horssen, Kuhnert, Vossmeyer and Atamas, 2024, Adult survival estimates of Black Terns Chlidonias niger breeding in the Netherlands, Germany and Ukraine, Journal/Vogelwelt, 239-247.