Collision effects of North Sea wind turbines on bird species within the "Kader Ecologie & Cumulatie (KEC) 5.0"

Actualisation of models, data and predicted mortality for Dutch government offshore wind development scenarios

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Contents

Preface

The Dutch Framework for Assessing Ecological and Cumulative Effects (Dutch name for the framework: Kader Ecologie & Cumulatie; or in short KEC) aims to predict and evaluate the cumulative ecological effects of all existing and planned Dutch and foreign wind farms in the Central and Southern North Sea. First of all, this report provides an overview of the analyses executed and the models used to get the results for the KEC 5.0, followed by a description of the updated parameters and methods used for the analyses. Subsequently, we provide the outcomes of the analyses and assessments and present a chapter with conclusions and recommendations.

The work is commissioned by Rijkswaterstaat. Martine Graafland and Meik Verdonk coordinated the project and provided valuable feedback on an earlier version of the report.

The following persons participated in the work described in this report:

Gerben IJntema	Analyses and reporting (entire report)
Nienke Heida	Analyses and reporting Chapter 3, 4
Jacco Leemans	Reporting Chapter 2, 3, 4
Abel Gyimesi	Project management, reporting (entire report)
Astrid Potiek	Project management, reporting (entire report), analyses
Cas Eikenaar	Literature research, reporting Chapter 4, Appendix I
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Jacco Leemans	Quality control analyses
Roland van der Vliet	Quality control knowledge base update
Ruben Fijn	Quality control final report

Summary

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 due to collisions with rotor blades, habitat loss or barrier effects. The Dutch Framework for Assessing Ecological and Cumulative Effects (KEC) aims to predict and evaluate the cumulative effects of all existing and planned Dutch and foreign wind farms. Within the KEC, the study area comprises the Southern and Central North Sea. In this report we present the 5th iteration of this KEC analysis on the effects of collision mortality, in which we update the data (chapter 4), analysis (including models; chapter 3) and the ensuing results of the predictions regarding the collisions of birds and testing of these results to ministry-defined norms (chapter 5).

The current analysis is shaped around three parts: 1) Estimating collision mortality per wind farm for two types of species groups: migrant birds (8 species) traversing the Southern and Central North Sea, and local seabirds using the area throughout significant parts of the year (8 species), 2) calculating the cumulative impact per wind farm scenario (different combinations of wind farms) and 3) the population-level analysis of the impact of the predicted mortality due to collisions. For the national scenarios, the predicted impact is then tested against Acceptable Levels of Impact (ALIs; mortality norms) defined by the Dutch ministry for Agriculture, Fisheries, Food Security and Nature (LVVN) (chapter 2).

The methodology has been updated in comparison to KEC 4.0. The estimation of the number of collision victims is done using collision rate models, with the recently published R package StochLAB. Another update of the methods is found in the use of new density maps for six species, explicitly allowing for uncertainty in predictions of the number of birds present in certain areas of the North Sea and therefore producing a more realistic range of collision mortality estimates (chapter 3). Additionally, a thorough review of the input parameters into our models was executed using the latest scientific insights and data, updating key parameter such as the wind turbine avoidance rates of birds and the population sizes (chapter 4).

For KEC 5.0, three national and one international scenarios were newly defined, and compared to the *null* scenario without explicit additional mortality due to offshore windfarms: 1) a scenario where all operational windfarms up to 2020 remain present (*Basic*), 2) a scenario where all operational windfarms and all licensed windfarms from 2016 up to and including 2021 are/remain present (*Basic plus*), 3) a scenario where all operational, licensed and planned windfarms on the Dutch Continental Shelf up to 2031 are/remain present (*Total national*), and lastly an international scenario where all windfarms in the South and Central North Sea are/remain present (*Total international*) (chapter 3, section 3.1).

For none of the eight migratory birds we found a violation of the government defined Acceptable Levels of Impact (ALI) norms. For the local seabirds, we found that two species violated these norms. Specifically, for the great skua we found one scenario (*Total national*) to violate the ALI norm and for the northern gannet we found two scenarios would violate the norms (*Basic plus* and *Total national).* For the international scenario, we provide a descriptive statistic to give an indication of the estimated impact in relation to the national scenario.

Given the violation of the set thresholds for great skua and northern gannet, we recommend more research for these species, in order to reduce uncertainties for these species, as well as a further analysis of the impact on the conservation status. In addition, potentially effective mitigation measures could be further explored.

1 Introduction

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, particularly in terms of numbers of collision victims. The Dutch Framework for Assessing Ecological and Cumulative Effects (Dutch name for the framework: Kader Ecologie & Cumulatie; or in short KEC) aims to predict and evaluate the cumulative effects of all existing and planned Dutch and foreign wind farms in the Central and Southern North Sea. Since the first version of the KEC (Rijkswaterstaat 2015), the assessment has been updated several times (e.g. Rijkswaterstaat 2019, Potiek *et al.* 2022a). The current KEC 5.0 version, including the most recent developments of offshore wind, builds upon and improves these previous KEC versions and in its turn provides a base for a future KEC 6.0.

Given the potential negative effects of wind energy on the natural environment, the KEC includes several environmental impact assessments of current and planned offshore wind farms. 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 estimating the potential mortality of birds due to (scenarios of) offshore wind farms in the form of bird collisions (executed by Waardenburg Ecology –presented in this report) and habitat loss (executed by Wageningen Marine Research as presented in Soudijn *et al.* 2025).

The KEC bird collision mortality assessment is executed in two steps.

1. An actualisation of the methods and input data needed for the assessment.
2. The actual assessment of projected effects of offshore windfarm scenarios on bird mortality and the testing of said mortality against defined acceptable thresholds.

This report presents the results of both steps.

Objective

The aim of this report is threefold: 1) provide a clear overview of the analyses executed and models used to get the results for the KEC 5.0, 2) update the data, parameters and methods used with the most recent scientific insights and 3) present the results of the described analyses, supporting future governmental decisions on offshore wind farm developments in the Dutch North Sea. Accordingly, we provide an overview of the analyses and models in Chapter 2 and highlight in Chapter 3 the topics that are updated for KEC 5.0. Subsequently we provide a full overview of the methods, parameters and data (Chapter 4, supported by Appendices), leading to a summary on which parameter updates are incorporated in the KEC 5.0 analyses (Chapter 4.3). Finally, we present the results of the analyses and assessments in Chapter 5, reaching a conclusion and recommendation in Chapter 6.

2 Overview and justification of methods used

The modelling 'train' as applied in the KEC can be daunting to grasp and a transparent overview of the current analysis is needed. In this chapter, we explain the entire process. Figure 2.1 presents an overview of all parts of the analysis. The modelling process consists of three parts:

1. Estimation of bird density or flux, followed by estimating the number of collision victims (collision rate model) (§2.1)
2. Assess the impact on the population (population model) (§2.2)
3. Testing whether this results in violation of the acceptable level of impact (ALI) (§2.2)

We provide a basic flow chart to clarify the whole process of the KEC analysis (Figure 2.1). Subsequently, in more in depth flow charts we clarify the collision rate calculations (Figure 2.2 and Figure 2.3), by giving an overview of the data used, data produced and the analyses needed to achieve the outcomes.

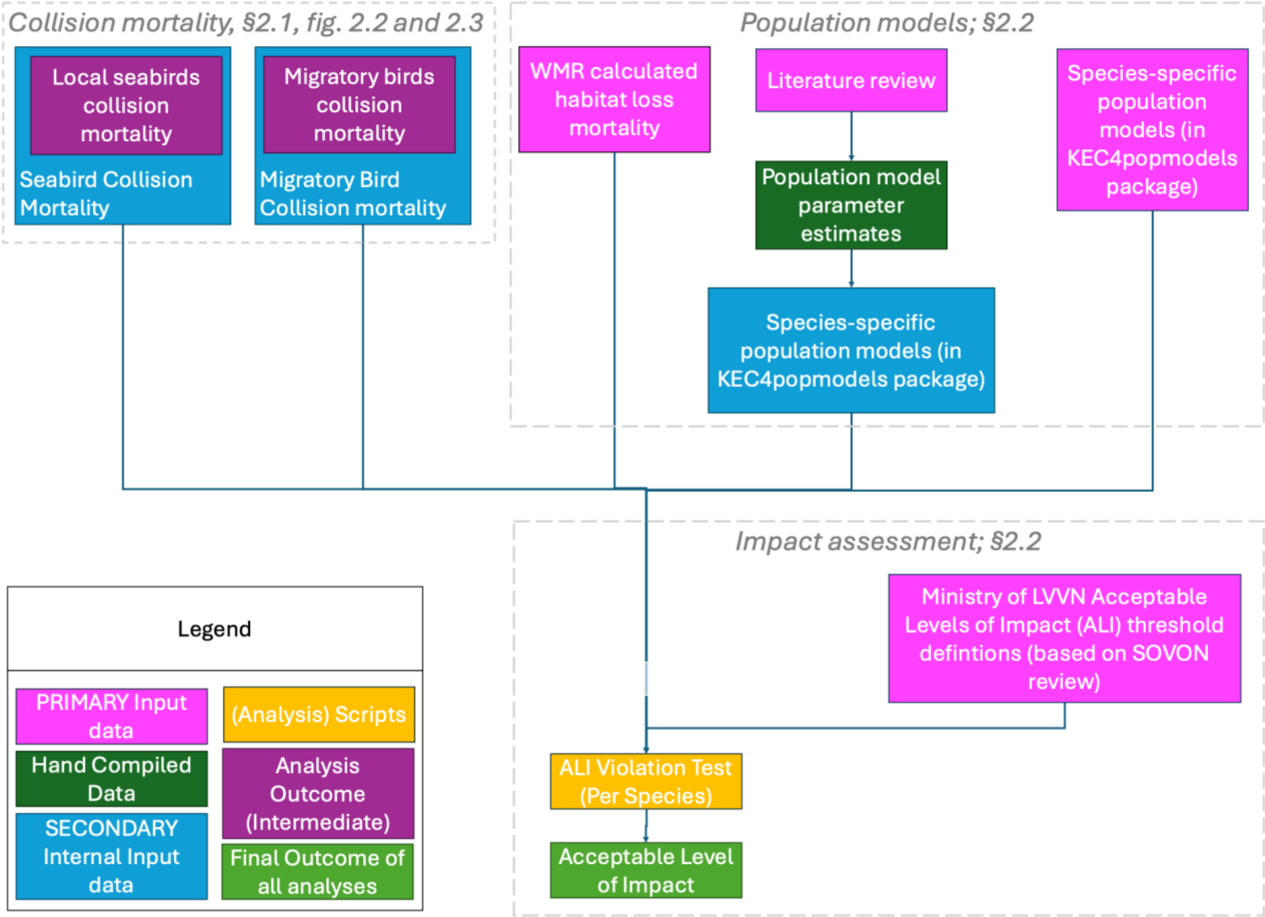

Figure 2.1 *Basic overview of different steps in the impact assessment of offshore wind turbines on bird populations. The analyses of collision mortality differ between local seabirds and migratory birds and are further explained in §2.1. The population models and ALI violation test are further explained in §2.2. For each step, the input data are described as well.*

2.1 Collision rate modelling

Collision rate models are widely used for assessing 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). 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 in a specific wind farm and summing this across an entire year. In our analyses we use three different types of the sCRM, differentiating on both the type of bird (local seabird or migrant bird) and on the data loaded (dubbed the Basic and extended model) (see Table 2.1). For seabirds, we always use the 'extended' option of the model (within the seabird model), which takes into account the distribution of bird flight heights at collision risk height. For migrant birds we use the "extended" model (within the migrant model) when possible. However, data availability for migrant birds is often not as good as seabirds (specifically flight height distributions are often not available) and hence it was mostly not possible to employ the extended model settings for migratory birds, falling back to the Basic model version of the migrant model. A full overview of the reasons for selecting the type of collision rate model is given in Table 2.1 below.

As part of the review and knowledge update in KEC 5.0, we compared the sCRM, used in KEC 4.0, with the latest iteration of the model, stochLAB (Caneco *et al.* 2022). StochLAB is an R package, in which the sCRM code has been re-structured for optimal functioning, speed and reliability. Furthermore, the package adds increased functionality and allows for future expansions. This comparison between the sCRM used in KEC 4.0 and stochLAB is described in Chapter 3.3.
A downside of the package is that it does not contain an *extended* model setting for the migrant model, meaning we had to fall back on the KEC4.0 models for migrant birds with flight height distributions available to ensure we make use of the best possible data.

A full visual flow-chart overview over the collision rate modelling for both local seabirds and migrant birds is presented in Figure 2.2 and Figure 2.3 respectively.

Table 2.1: *Overview of the reasons for choosing what type of the model for which bird. *This model type does not exist in the newly adopted stochLAB package, hence we fall back on the KEC4.0 code to execute this version of the model. See Table 2.2 for an overview of the used model option per species.*

Model setting	Local seabird	Migrant bird
Basic option	Not used	Flight height distribution not available
Extended option	For all seabirds	Flight height distribution available*

2.1.1 Available and reworked data sources

A range of data were used as input for the collision rate modelling. Here, we present the data flows used within the KEC frameworks. Table 2.3 presents an overview of the parameters and the purpose of each parameter in the model.

Cumulative wind farm scenarios

Key inputs to the KEC analyses are policy scenarios of existing and potential future wind farms offshore. For KEC 5.0, these scenarios have been defined by Rijkswaterstaat, in agreement with policy of the Dutch ministries. Explicitly, this means that we have received a list of the potential future wind farms and search areas to be assessed as part of KEC 5.0. This list also includes one “international” scenario, that takes into account wind farms in the North Sea outside of the Dutch Continental Shelf (NCP).

Wind farm and turbine characteristics and wind farm lots geodata

We furthermore received from Rijkswaterstaat the technical *wind farm and turbine characteristics* of the wind farms to be assessed, detailing the key characteristics of both current and future wind farms in the North Sea. These data included the number of turbines and their power (MW) in the different wind farms. Furthermore, the data also contained information on the single turbine characteristics, such as turbine hub height, rotor diameter, lower tip height, number of blades, maximum chord (blade width), pitch, and monthly time in operation (calculated from maintenance and downtime), if available. When specifications for future wind farms were not yet available, Rijkswaterstaat provided us with specifications based on realistic assumptions, which were determined in agreement with ministries. For some parameters, blade width, pitch and rotation speed, values were extrapolated based on data provided (see appendix II for which ones that happened and appendix III for the methodology). All this information was then bundled at Waardenburg Ecology to form a single input file to our analysis (Appendix II). In addition, Rijkswaterstaat provided us with shapefiles holding geographically explicit data, like geographic location and boundaries of the wind farms to be assessed. From those shapefiles the width of the windfarm was measured and the largest width was measured to provide a worst-case scenario.

Table 2.2 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 (model)	Model setting
Northern gannet	*Morus bassanus*	Seabird approach	Extended
Arctic skua	*Stercorarius parasiticus*	Seabird approach	Extended
Great skua	*Stercorarius skua*	Seabird approach	Extended
Black-legged kittiwake	*Rissa tridactyla*	Seabird approach	Extended
Little gull	*Hydrocoloeus minutus*	Seabird approach	Extended
Lesser black-backed gull	*Larus fuscus*	Seabird approach	Extended
Herring gull	*Larus argentatus*	Seabird approach	Extended
Great black-backed gull	*Larus marinus*	Seabird approach	Extended
Common tern	*Sterna hirundo/ paradisaea*	Seabird approach	Extended
Sandwich tern	*Thalasseus sandvicensis*	Seabird approach	Extended
Bewick's swan	*Cygnus (columbianus) bewickii*	Migratory bird approach	Extended
Brent goose	*Branta bernicla*	Migratory bird approach	Extended
Common shelduck	*Tadorna tadorna*	Migratory bird approach	Basic
Curlew	*Numenius arquata*	Migratory bird approach	Basic
Bar-tailed godwit	*Limosa lapponica*	Migratory bird approach	Basic
Red knot	*Calidris canutus*	Migratory bird approach	Basic
Black tern	*Chlidonias niger*	Migratory bird approach	Basic
Common starling	*Sturnus vulgaris*	Migratory bird approach	Basic

Bird data

In addition to the technical data, we also compiled data relating to the bird species for which collision rates are assessed in the KEC (see Table 2.2 for the species considered).

These data are compiled based on extensive literature reviews and updated in the different KEC actualisations. We specifically compiled or received four datasets:

Bird density data (per species) for local seabirds are calculated from external bird density maps of geographically explicit presence of bird species in the North Sea. 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.

Monthly fluxes of migratory birds were generally based on assumptions about the width of the migration corridor across (parts of the) the North Sea, and the size of the migrating biogeographical population.

Bird characteristics (per species) 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.

Flight height distribution data (per species) are obtained from published data or from GPS data. For seabirds, a flight height distribution is used. For most migratory land bird species a proportion at rotor height is used, but we use flight height distributions for these species if these were available.

2.1.2 **Preparatory analysis steps and intermediary data**

Before the number of collisions for a specific wind farm can be assessed, several preparatory analyses are required. As these steps differ between seabirds and migratory land birds, we discuss each of these separately.

Density of seabirds in each wind farm

The densities of seabird species for use in the collision rate model are based on density maps of seabirds at-sea (see Table 3.2 for the different sources per species). These are overlaid with the shapefiles of existing and potential future wind farms to produce wind farm-specific densities for each month for each relevant species. By doing so we can extract the density of birds in any specified (future) windfarm. These densities are then corrected for the proportion of birds in flight to establish aerial densities that can be used directly in the collision rate model. This is needed as only flying birds are susceptible to collisions.

Fluxes of migratory land birds in each wind farm

For migratory birds, we do not have an accurate density estimate, as the birds are not present year-round but typically pass through the area twice a year. For these purposes, the collision rate model has a migrant module that requires a flux as input. We therefore estimate a species-specific flux in each wind farm based on one of the following methods, depending on available information:

Method 1, informed flux estimation: is used when species are known to take specific flight routes (based on e.g. GPS tracking data), as described in §2.1.1. We then assume that the known population size of the relevant species traverses these known routes twice a year. Subsequently, we allocate the total flux of the species over these routes proportionally to the measured distribution of migratory movements.

Method 2, homogeneous flux: When we are unaware of or have too little data on specific flight routes, we assume that the population of migratory birds traverses the North Sea twice a year in the full width and we distribute the flux generated this way equally over the North Sea, creating a homogeneous flux per km for the whole area. Hence, due to this knowledge gap in specific migration routes, all wind farms receive the same flux of birds. This can be considered a worst-case scenario, as many wind farms farther from the coast will expectedly experience lower migration intensities.

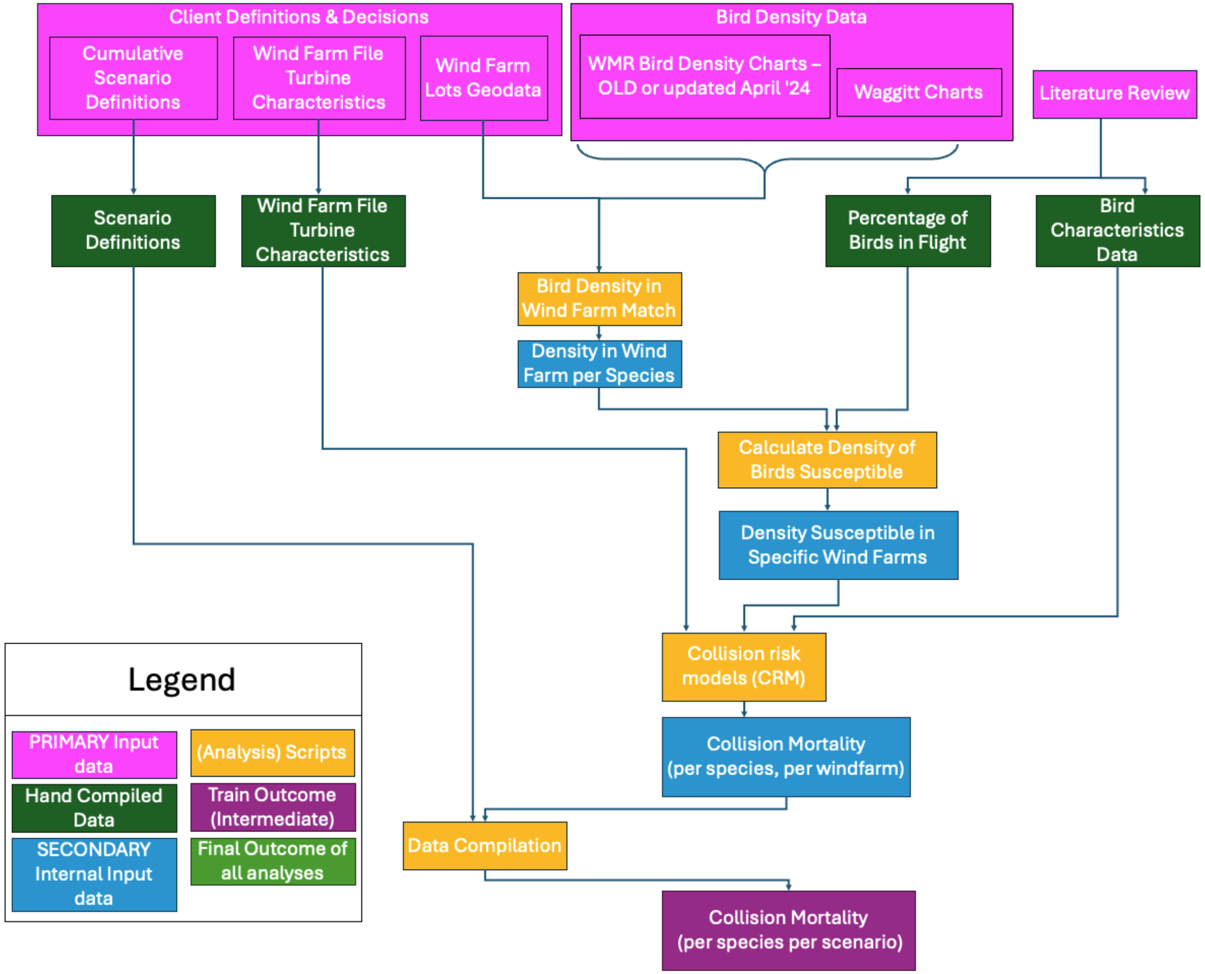

Figure 2.2 *Overview of the data supplied (pink) or compiled (dark green), the analysis steps done using this data (yellow) and their resulting intermediate data products (blue), leading to a final estimate for collision mortality (purple), as applied in KEC 5.0 for local seabirds.*

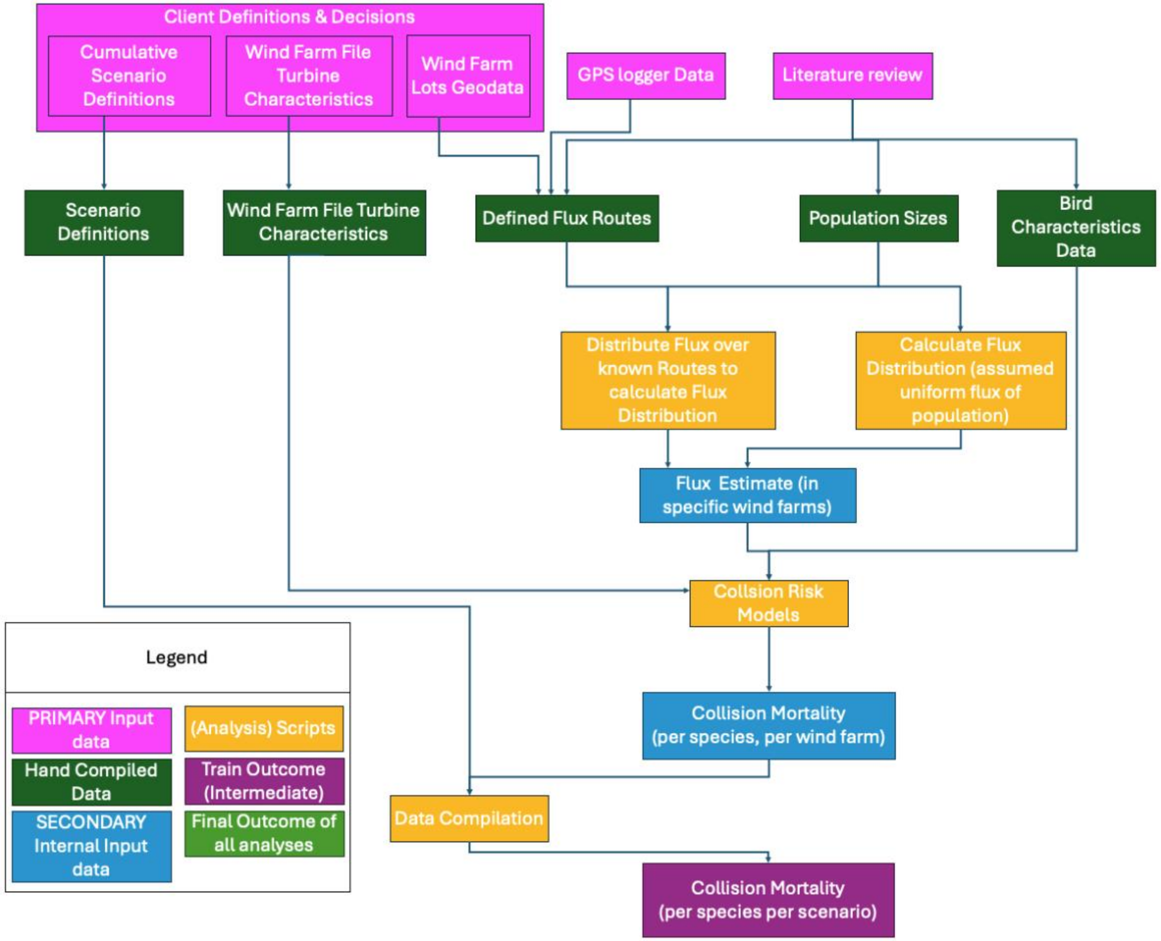

Figure 2.3 *Overview of the data supplied (pink) or compiled (dark green), the analysis steps done using this data (yellow) and their resulting intermediate data products (blue), leading to a final estimate for collision mortality (purple), as applied the KEC for migrant birds. The main difference with seabirds is the replacement of density data with flux data, which is obtained using different sources and calculations.*

2.1.3 Estimating numbers of collisions per species and wind farm

As will be described further in detail in Chapter 2, the number of collisions per species per wind farm were estimated using the stochLAB collision risk model. Input data (Table 2.3) relating to the relevant species and relevant wind farms were used in this model to provide monthly species- and wind farm-specific collision rates that were summed across the year.

Wind farm scenarios were defined by Rijkswaterstaat and included currently operational, as well as planned wind farms. This differs from the approach of impact assessments for onshore wind farms, where only future wind farms are assessed. The used approach for offshore impact assessment is more precautionary, as it does not assume that mortality from already built wind farms is incorporated within the survival rates. Although for some species with recent survival estimates this may result in an overestimation of the impact, for most species it is realistic to assume that the impact is not yet apparent in the survival rates (see Box 1).

Box 1: mortality in older existing wind farms already discounted for in survival rates?

Within earlier KEC analyses, as well as in KEC 5.0, we consider survival rates from literature as the baseline parameters, representative for the unimpacted scenario. Note that when recent data are available, the additional mortality from (older) existing wind farms is at least to some extent included in these estimated survival rates. This may result in an overestimation of the impact for older wind farms. However, recent data are not available for all species. Moreover, survival rates are often calculated over a longer period, hence including a time frame before wind farms were constructed. For that reason, we assume for all species that mortality due to older wind farms is not accounted for in the survival rates from literature. This represents a worst-case approach and may for some species be overcautious.

To illustrate why we think this is best practice, we give some examples.

- for herring gull, Kentie *et al.* (2022) present relatively recent survival rates. However, these estimates are based on the period between 1986 and 2020, and hence also including a time frame from before the first offshore wind farms were constructed.
- for arctic skua, the most recent data source for KEC 5.0 is based on 2014 to 2018 (van Bemmelen *et al.* 2021). However, as this is only based on one colony, these estimates may not be representative for the entire Southern and Central North Sea. Hence, for KEC 5.0 we use a weighted average based on several data sources, including also older sources.
- for some other species, recent data are not available. For example, the only available estimate for shelduck adult survival is based on the period between 1962 and 1979. For little gull, no estimates are available at all for survival rates, and estimates for adult survival are based on relatively old data from black-headed gull (1985-2003).

All in all, this supports our earlier decision of running the population models using the additional mortality from all wind farms, including also older wind farms. Note that this is in contrast with the common practice for the Environmental Impact Assessments for **onshore** wind farms, where only future wind farms are taken into account in the cumulative impact assessment.

For **local seabirds**, species-specific data like bird length, wingspan and flight speed, together with turbine-specific information like rotor diameter, maximum chord, pitch and rotation speed, were combined with the species-specific flight height distributions to calculate a collision risk for a single crossing through the rotor-swept area. Wind farm specific densities of local seabirds were based on the most recently available density maps (see Table 3.2). Data on monthly densities, flight height distribution and flight speed were then used to establish the number of wind farm specific crossings each month. If there was strong evidence that the underlying data show large temporal (within-year) or spatial (among wind farms) variation, we applied several parameter values for the same species. Finally, the number of crossings was combined with a species-specific avoidance rate to account for evasive action taken by a bird to avoid the wind farm (macro-avoidance), individual turbines or rows of turbines (meso-avoidance) and the rotors (micro-avoidance). This resulted in a monthly number of collisions that was summed to give the estimated number of collisions across the entire year.

For **migrant land birds** the process is similar to that of seabirds. The main difference is that the migrant model requires a monthly flux rather than aerial bird densities. Note that data on the flux of migrants are less accurate and less reliable than aerial bird densities of local seabirds. For instance, the flux of the migrant species is based on the flyway population, which is in itself already difficult to determine, as information is only partially available from which breeding populations birds migrate over the North Sea and what the size of those populations is. Moreover, there is very little known about the exact migration routes over the North Sea. All these knowledge gaps result in higher uncertainty of the number of collision victims for migrant bird species.

Table 2.3: Parameters used in the collision rate model (CRM). Note that the extended option of the model is used for seabirds locally making use of the area, while the basic model is used for most migratory birds, which are passing through.

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.

2.2 Population modelling and impact assessment

Population models can be used to project a population trajectory over time. For this we use stage-specific population models. We first describe the required data, followed by a description of the analysis, leading to the impact assessment.

A visual overview of the method of evaluating the calculated mortality (§2.1) using population models described in this section and the ALI thresholds is given in Figure 2.1.

2.2.1 Data sources and definitions

Bird population model parameters *(per species)*
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.

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).

Impacted scenario population models
The population models for the null scenario are adjusted to model the impacted scenario by changing the survival rate by the fraction additional mortality. For example, if the natural adult survival is 90%, and 1% additional mortality is expected among the adults, the impacted adult survival is calculated as 0.9 * (1-0.01) = 0.891, hence 89.1%.

Acceptable Levels of Impact (ALI) definitions
ALIs are species-specific impact thresholds set by the government, to reflect the threshold for an unacceptable impact by offshore wind farms in the Netherlands and its surrounding territorial waters (Central and Southern North Sea).
When the impact exceeds this threshold, the impact on the conservation status should be explored in more detail. The species-specific thresholds are defined based on advice by Sovon (2024), in which mainly conservation status is taken into account.

2.2.2 Impact assessment

Construct population models
Using the collected population model parameters as specified under §2.2.1, we then construct species-specific life-stage-specific matrix population models (Caswell 2001) for species identified as being relevant to collision rate modelling (Table 2.2). These population models are described in Potiek *et al.* (2022a) and Potiek *et al.* (2019a).

Add estimated additional impact due to collisions
For the impacted scenarios, the survival rate is adjusted according to the estimated additional mortality. The additional mortality due to the impact is estimated for each scenario. In this approach, it is assumed that all wind farms within that scenario are operational from the start of the simulation onwards, and remain operational up to the end of the simulation. This is a worst-case approach, as in reality the future wind farms are planned to become operational at different moments in time.

Note that some species are not only classified as vulnerable for collisions with wind turbines but are additionally vulnerable for habitat loss due to wind farms. For these species, Wageningen Marine Research (hereafter: WMR) constructed population models (Soudijn *et al.* 2022, 2025), which are used in both separate analyses considering collisions and habitat loss effects. These species include northern gannet and sandwich tern. The calculation of victims due to habitat loss takes place in a parallel project by WMR (Soudijn *et al.* 2025). Note that within KEC 5.0 the effects of both collisions and habitat loss for these species are again assessed; however, the impacts are not combined, due to ongoing discussions on the methodological differences how the two approaches deal with avoidance rates (see for example Searle *et al*. 2022).

Assess the impact by testing against Acceptable Levels of Impact (ALI)
The impact is subsequently assessed using the set of species-specific *Acceptable Levels of Impact (hereafter ALI)*. The original definition of the ALI threshold is: '*The probability of a population decline of X% or more, 30 years after the impact, cannot exceed Y'.* This methodology is based on a comparison of future population abundance between two scenarios: one unimpacted scenario without impact from offshore windfarms, and one impacted scenario which includes additional mortality resulting from collisions with offshore wind turbines and/or habitat loss from avoiding OWFs. Given that the permit duration for future wind farms will likely be 40 years, the time frame within the ALI definition has been adjusted to 40 years. Hence, the used definition of the ALI threshold is:

ALI definition: '*The probability of a population decline of X% or more, 40 years after the impact, cannot exceed Y'*

Within KEC 4.0, the framework for setting acceptable levels of impact was based on Potiek *et al.* (2022b). In the meantime, a sensitivity analysis has been performed (Hin *et al.* 2023) and an in-depth analysis revealed a number of methodological issues, leading to the revision of the ALI methodology (Hin *et al.* 2024). Within this revised methodology, many impacted simulations are compared with many unimpacted simulations (100,000 each) using stochastic population models. Here, impacted simulations include OWF-induced mortality. The adopted approach is similar to the original methodology, but the crucial difference is that this comparison is made per replicate simulation. Essentially, a comparison between scenarios is made while all other processes that affect the predicted development of the population are kept constant. This approach makes the ALI methodology more user-friendly and the two threshold values X and Y are no longer interrelated, which obscured the use and applicability of the original ALI. Hin *et al.* (2024) present an updated set of recommendations for choosing these threshold values.

The revised methodology by Hin *et al.* (2024) was externally reviewed and has subsequently been officially accepted by the Steering Committee (comprising of the Ministries of KGG, LVVN, I&W and Rijkswaterstaat). Furthermore, the ministry of LVVN defined new species-specific thresholds based on advice by the Dutch Centre for Field Ornithology (Sovon 2024; Table 2.4), which were accepted by the state secretary of LVVN (January 2025). As a result, the revised ALI-methodology and the new species-specific thresholds have been applied in the KEC 5.0.

Table 2.4 Threshold values for the Acceptable Level of Impact methodology as supplied by LVVN. LVVN set the threshold for the reference period, which is the species-specific maximum of 10 years and three times the generation time. This is recalculated to the X threshold over 40 years.

Species	X threshold max (10, 3x TG)	X threshold (40 yrs)	Y threshold
Northern gannet	5%	4.7%	0.05
Arctic skua	5%	6.3%	0.05
Great skua	5%	4.8%	0.05
Black-legged kittiwake	5%	7.6%	0.05
Little gull	15%	33.9%	0.05
Lesser black-backed gull	15%	14.9%	0.05
Herring gull	5%	8.2%	0.05
Great black-backed gull	5%	7.0%	0.05
Common tern	5%	5.6%	0.05
Sandwich tern	5%	4.9%	0.05
Bewick's swan	5%	9.3%	0.05
Brent goose	15%	25.3%	0.05
Common shelduck	15%	26.1%	0.05
Curlew	5%	6.3%	0.05
Bar-tailed godwit	15%	26.3%	0.05
Red Knot	15%	26.5%	0.05
Black tern	5%	9.5%	0.05
Common starling	5%	18.5%	0.05

3 Methodological changes

3.1 General methodological discussions

The methodology for KEC 5.0 follows the approach used in KEC 4.0. However, due to recent developments or new insights, parts of the approach were adjusted. These adjustments were based on discussions between RWS, WMR and Waardenburg that have taken place on several aspects of the methodology.

Scenarios

Within the KEC assessments, testing for an unacceptable impact is always done by comparing an *impacted* scenario with the *null* scenario (no impact) and providing an Acceptable/Unacceptable verdict based on the relative difference between these two. Based on discussions with WMR and Rijkswaterstaat, we defined the *null* scenario to represent a situation where not a single offshore windfarm is present during the study period. For the *impacted* scenarios we consider four scenarios: three increasing levels of an increasing number of windfarms on the Dutch Continental Shelf and one scenario considering the international windfarms in the Southern and Central North Sea. An overview of the definitions of all scenarios considered is given in described in Table 3.1.

Table 3.1 Definitions for national (a) and international scenarios (b) for KEC 5.0. For each scenario, the bird density maps were based on the period from 2016 up to and including 2020. For a full list of windfarms considered in each scenario, see Appendix VI.

a. National scenarios

Scenario	Wind farms
Null	No wind farms
Basic scenario	Operational wind farms that are incorporated in the density maps (up to and including 2020; *i.e.* up to and including Borssele). This also includes all windfarms before 2016.
Basic + scenario	Wind farms of the basic scenario, plus the ones built after 2021 (from Hollandse Kust South onwards) and all licensed wind farms up to and including Nederwiek I
Total scenario NAT	All operational and planned wind farms on the Dutch Continental Plate until end 2031

b. International scenarios

Scenario	Wind farms
Null	No wind farms
Total scenario INT	All operational and planned wind farms in the entire study area until end 2031

For a ‘basic’ scenario, Rijkswaterstaat decided to include all wind farms which were in operation while the data for the density maps were collected. In addition, we suggested using an additional ‘basic +’ scenario, which was adopted by Rijkswaterstaat, in which the impact is based on all wind farms built after 2021, and all licensed wind farms. The final national scenario is the ‘total national’ scenario, which represents the impact of all planned wind farms until end 2031. Finally, an additional ‘total international’ scenario consists of the combination of the “total national” scenario and all operational and planned wind farms in the North Sea outside of the Dutch Continental Shelf.
Note that for future wind farms, the turbine characteristics is not defined yet. For these wind farms, RWS provided us with expected characteristics.

Other pressures
Currently, only the impact of offshore wind farms is assessed. However, several other factors have changed since the start of the development of offshore wind farms around 2006, such as population dynamics, the intensity of fisheries, the implementation of discard ban and climate change and are not explicitly taken into account. Nevertheless, the impact of current pressures may (to some extent) already be incorporated in the survival rates. This also means any future worsening (or weakening) of the (other) impacts is not modelled. Inclusion of such future trends is likely to make the model projection more realistic. This could be achieved by using a different type of population models, namely integrated population models. However, this requires knowledge of the size of the impact, which is often not available. For KEC 5.0, it was decided to continue using the same type of population models. In the future, the use of a different type of model can be reconsidered.

3.2 Population size and calculation of mortality fraction

3.2.1 **Seabirds**

Seabird numbers at the Central and Southern North Sea can be obtained from density maps. These are available for the national as well as the international scale.

For the national scale we preferably make use of the updated density maps provided by WMR (van Donk *et al.* 2024). The maps by van Donk *et al.* (2024) were explicitly developed for the KEC 5.0, using a new approach.

For the international scale, density maps of van Donk *et al.* (2024) could not be used as these were only developed for the Dutch part of the North Sea. Maps by Waggitt *et al.* (2020) were available for several of our study species. These maps using similar analytical techniques as van Donk *et al.* (2024). In case maps by Waggit *et al.* (2020) were not available, WMR provided density maps using the approach as applied in KEC 4.0 (inverse-distance-weighing: IDW), updated using the most recent survey data (see Table 3.2 for the different sources per species). Note that in all cases, the collision victims estimated for the international scenario are for both the Dutch and the foreign wind farms based on the international density maps.

The density maps of seabirds represent bimonthly densities. Based on these density maps, bimonthly numbers of individuals were calculated for the study area (the Dutch Continental Plate and the combined Southern and Central North Sea, respectively). Subsequently, the population size was defined as the maximum number of individuals present during any of those bimonthly periods. For example, consider the hypothetical situation in which the calculated number of individuals present during the bimonthly periods in winter is 50, and during the bimonthly periods in summer 100. In this case we assume the population size is 100. However, in reality, some of the individuals present in Jun/Jul may be different from the individuals present in any of the other bimonthly periods (in summer or winter). The minimum estimate for the population size is 100, so the used population size is a minimum estimate. When the individuals making use of area differ between the bimonthly periods, the true population size is higher than the one used within our population models. As a result, this presents a worst-case approach.

For the calculation of the mortality fraction in the population models, the mean bimonthly number of collision victims were divided by the estimated population size. This approach was also used in the KEC 4.0, and as it was considered this the best available worst-case approach, we also applied it for the KEC 5.0.

Table 3.2 *Data sources based on which seabird numbers were defined for the Dutch Continental Shelf (national densities) and the international waters of the North Sea. WMR refers to density maps provided by Wageningen Marine Research, based on an older type of analytics (IDW = Inverse Distance Weighting). * for common tern, density maps are based on monitoring data for 'commic tern', which is common tern and arctic tern combined.*

Common species name	National densities	International densities
Northern gannet	van Donk *et al.* (2024)	Waggit *et al.* (2020)
Arctic skua	WMR IDW	WMR IDW
Great skua	Waggit *et al.* (2020)	Waggit *et al.* (2020)
Black-legged kittiwake	van Donk *et al.* (2024)	Waggit *et al.* (2020)
Little gull	WMR IDW	WMR IDW
Lesser black-backed gull	van Donk *et al.* (2024)	Waggit *et al.* (2020)
Herring gull	van Donk *et al.* (2024)	Waggit *et al.* (2020)
Great black-backed gull	van Donk *et al.* (2024)	WMR IDW
Common tern *	WMR IDW	WMR IDW
Sandwich tern	van Donk et al. (2024)	WMR IDW

3.2.2 Migratory birds

Most of the migratory bird species dealt within the KEC 5.0 concern waterbirds, for which the sizes of the relevant flyway populations were based on the minimum sizes presented for the EU Birds Directive region by Wetlands International (https://wpe.wetlands.org, accessed on 11 July 2024), conform Vogel *et al.* (2024). The only exemption as a non-waterbird was the common starling. Lacking any new information, the population size (i.e. 18,500,000 individuals) for this species was based on the KEC 4.0 (Potiek *et al*. 2022a) value, which on its turn was an updated value from the one used in the KEC 1.0 (Rijkswaterstaat 2015). This value was rounded down to the nearest 100,000, given the fact that it is a crude estimate and not a precise exact number of individuals (Table 3.3). The estimate in KEC 1.0 was among others based on numbers published by BirdLife International (2014). The current population estimate for the whole of Europe stated on the website of BirdLife International is 57,700,000-105,000,000 mature individuals (https://datazone.birdlife.org). Since this population is considering the whole of Europe, we consider this and outstandingly high estimate to represent just the population crossing the North Sea. Additionally, while Heldbjerg *et al.* (2019) and Stuart *et al.* (2023) report declining population trends in North-Western Europe, the European Environment Agency (2016) and Heldbjerg et al (2016) report increasing trends in Central- and Eastern Europe. Hence, basing a future population estimate on said sources is difficult. Consequently, without any additional trustworthy sources of recent population sizes, we kept the population size of starlings the same as in KEC 4.0 in our evaluations of the effects of current offshore wind farm developments.

Sovon very recently assessed the vulnerability of migratory birds for offshore wind farms (Brinkman & Schekkerman 2024). Within this assessment, the species-specific vulnerability was based on the Dutch conservation status (Dutch: Staat van Instandhouding) and the proportion of the population making use of the Dutch part of the North Sea. For this study the authors mainly used the population estimates of the European Environment Agency (https://www.eea.europa.eu), supplemented by Norwegian (Shimmings & Øien 2015) and Russian (Kalyakin & Voltzit 2020) estimates. In an appendix to this report all the background information on the used references is presented, which makes it clear that the population estimates of the European Environment Agency are not more recent than those of the KEC 1.0 (Rijkswaterstaat 2015), and hence are not considered more representative than the Wetlands International population estimates. In addition, Sovon recently also produced an analysis on concentrations of bird numbers of (inter)national importance in Dutch areas, for which they also identified species-specific biogeographical populations (Vogel *et al.* 2024). For their analysis, they used population estimates of Wetlands International, conform our approach for the KEC 5.0. In order to provide an overview of these different sources, Table 3.3 presents the population estimates based on Wetlands International used for the KEC 5.0 calculations, just as the previously used KEC 4.0 values and the population estimates reported by Brinkman & Schekkerman (2024) and Vogel *et al.* (2024).

Subsequently, based on these population estimates, species-specific flux rates crossing the Central and Southern North Sea were defined. In absence of any data on the specific migration routes of a species, we assumed that the width of the migration corridor through the North Sea is the distance between the southern tip of Norway and the border between Belgium and France, as the starting point of the Channel, being 750 km. For example, considering all migratory birds and estimating their total number at 85 million individuals that pass through this 750 km long corridor, the total migration flux would be around 114,000 birds/km. The species-specific fluxes resulting of such an exercise are reported in Table 3.3. Lacking information on the exact migratory routes, we applied the worst-case assumption that these species-specific flux rates hold for all offshore wind farms of the KEC 5.0. However, specific migration routes across the North Sea were available for the Bewick's swan (Figure 3.1) and brent goose (Figure 3.2), based on GPS-logger studies (Gyimesi *et al.* 2017b). Furthermore, certain areas of the North Sea could be defined for the black tern (Figure 3.3) that are used during migration (cf. Potiek *et al.* 2019b). Based on these sources, fluxes for these species were further refined to distinguish different migration intensities in different areas of the North Sea and hence in wind farms based on their geographical location relative to the migration routes. In Figure 3.1 and Figure 3.2 these different North Sea segments are depicted, respectively for the Bewick's swan and the brent goose. After correcting for the width of each segment perpendicular to the migration route and the local migration intensity relative to the total, location-specific migration intensities were defined (equalling the mean migration flux reported in Table 3.3). The resulting fluxes corresponding to the segment numbers depicted in Figure 3.1 and Figure 3.2 are provided in Table 3.4. If two migration routes turned out to cross one wind farm, the flux belonging to the migration route crossing the largest part of the wind farm was used. The migration of Bewick's swans concerns one population and is covered by the GPS-tracks depicted in Figure 3.1. However, the migration pattern in Figure 3.2 relates only to the subspecies *bernicla* of the brent goose. In order to account for fluxes of the subspecies *hrota*, having a more northern distribution and along the British coast, we assigned to the wind farms in the central part of the North Sea a precautionary flux of 31 birds/km/year, equal to the lowest flux of the *bernicla* in the most northern segment of its migration route. For all other segments we assumed that the flux is negligible and hence the wind farms laying within these segments did not generate collision victims among Bewick's swans and brent geese.

Table 3.3 *Population estimates used for the different flyway populations of the migratory bird species treated in the KEC 5.0. Most estimates were based on the minimum flyway populations reported by Wetlands International, except for the common starling that was based on earlier KEC reports. The last column provides the fluxes resulting from the population estimates (see text for specifications). For comparison, population sizes used in recent Sovon reports are also provided. Brinkman & Schekkerman 2024 aimed to estimate species-specific population sizes in the Dutch part of the North Sea, while Vogel* et al. *2024 reported population sizes of non-breeding birds in the Netherlands (within brackets the proportion of these numbers relative to the biogeographical population is given). Note that the KEC 5.0 deals with the whole Central and Southern North Sea and not only the Netherlands.*

species	subspecies / flyway population	flyway population Wetlands International	population size used in KEC 5.0	population size used in KEC 4.0	EU population size non-breeding birds Brinkman & Schekkerman 2024	population size non-breeding birds in NL Vogel *et al.* 2024	flux in KEC 5.0 birds/km /year
Bewick's swan	*bewickii*: Western-Siberia & North-east and North-west Europe	21.000	21.000	17.450	25.973	3.500 - 11.100 (16-50%)	28
brent goose	*bernicla*: Western Siberia/Western Europe; *hrota*: Svalbard/Denmark & UK	211.000 + 13.400	224.400	247.286	261.767	76.300 - 88.300 (36-42%)	299
common shelduck	North-west Europe	310.000	310.000	302.047	297.471	95.000 - 130.000 (31-42%)	413
Eurasian curlew	*arquata*: Europe, North & West Africa	610.000 - 830.000	610.000	302.273	343.996	160.000 - 200.000 (21-26%)	813
black tern	*niger*: Europe & Western Asia/Atlantic coast of Africa	540.000 - 1.100.000	540.000	285.482	41.875	9.000 - 22.000 (1-3%)	806
red knot	*canutus*: Northern Siberia/West&Southern Africa, *islandica*: NE Canada & Greenland/Western Europe	250.000 + 310.000 - 360.000	560.000	672.197	464.689	120.000 - 160.000 (36-48%)	747
bar-tailed godwit	*lapponica*: Northern Europe/Western Europe, *taymyrensis*: Western Siberia/West&South-west Africa	150.000 - 180.000 + 500.000	650.000	347.670	131.333	160.000 - 200.000 (32-40%)	867
common starling		NA	18.500.000	18.501.266	150.008	NA	24.667

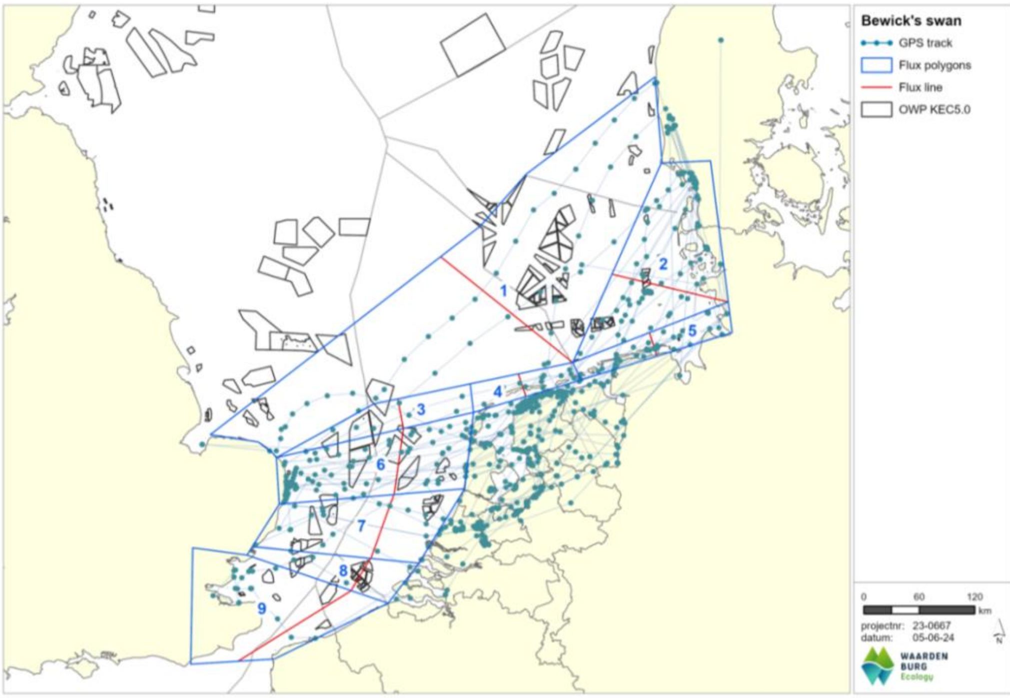

Figure 3.1 *Migratory tracks of the Bewick's swan, based on GPS-logger measurements (source: Gyimesi et al. 2017b) and the division of offshore wind farms in segments with different flux intensities. Segment numbers correspond to flux intensities reported in Table 3.4.*

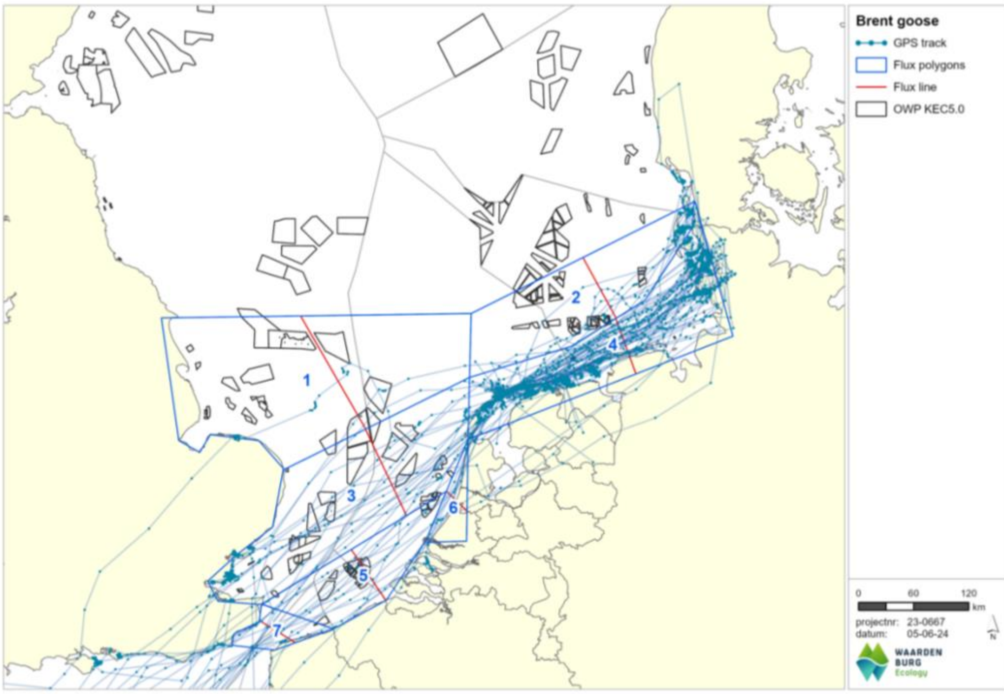

Figure 3.2 *Migratory tracks of the brent goose, based on GPS-logger measurements (source: Gyimesi et al. 2017b) and the division of offshore wind farms in segments with different flux intensities. Segment numbers correspond to flux intensities reported in Table 3.4.*

Table 3.4 *Fluxes (number of birds/km/year) of the Bewick's swan and the brent goose in different segments of the North Sea used in collision rate calculations. Segment numbers correspond to Figure 3.1 and Figure 3.2, respectively. For brent goose the flux in all other wind farms not belonging to a segment (last row in the table) was set at 31 birds/km/year, in order to account for fluxes of the subspecies hrota (see text for explanation).*

Segment number	Bewick's swan	brent goose
1	6	31
2	29	155
3	21	252
4	39	1.022
5	76	65
6	42	89
7	28	479
8	8	
9	2	
		31

For the black tern, wind farms were classified as having a flux or not. Namely, based on observations in the ESAS database (Potiek *et al.* 2019b), black terns were assumed to exclusively occur in the coastal regions and offshore waters up to 100 km of Denmark, Germany, The Netherlands, Belgium and France during their migration. Due to this spatial limitation of the migratory regions, the black tern was the only species where the width of the migratory corridor was set at 670 km instead of 750 km. Furthermore, the observations in the ESAS-database were not considered systematic enough to define spatially explicit migration intensities, and hence for all wind farms overlapping with these regions the same migratory flux of 806 birds/km/year was used in the collision risk models. This relatively high migratory flux is a result of the applied large total population size, according to Wetlands International also including birds of Western Asia. As it is unknown which exact part of the population migrates over the North Sea, we decided to follow the worst-case approach of using this total population estimate, leading to a high migratory flux. However, we did choose the minimum of the given range of the population size, to avoid reflecting the impact of collisions on a too large population. Furthermore, applying the same flux in all offshore wind farms is expected to be an overestimation of the effects, as black terns are likely to occur in much smaller numbers farther offshore. On the other hand, we neglect in our current approach very small numbers of black terns migrating along the UK coast. Given the limited availability of data and following to the precautionary principle, we adhere to the likely overestimation of the black tern numbers, assuming the very small numbers of black tern migrating the UK coast are covered by the likely overestimation of the overall numbers.

Finally, based on the defined species-specific fluxes of migratory birds, numbers of collision victims were calculated (see further description in Chapter 3.3). Subsequently, the results of these calculations were related to the estimated population size (Table 3.3), to define the mortality fraction for the population models.

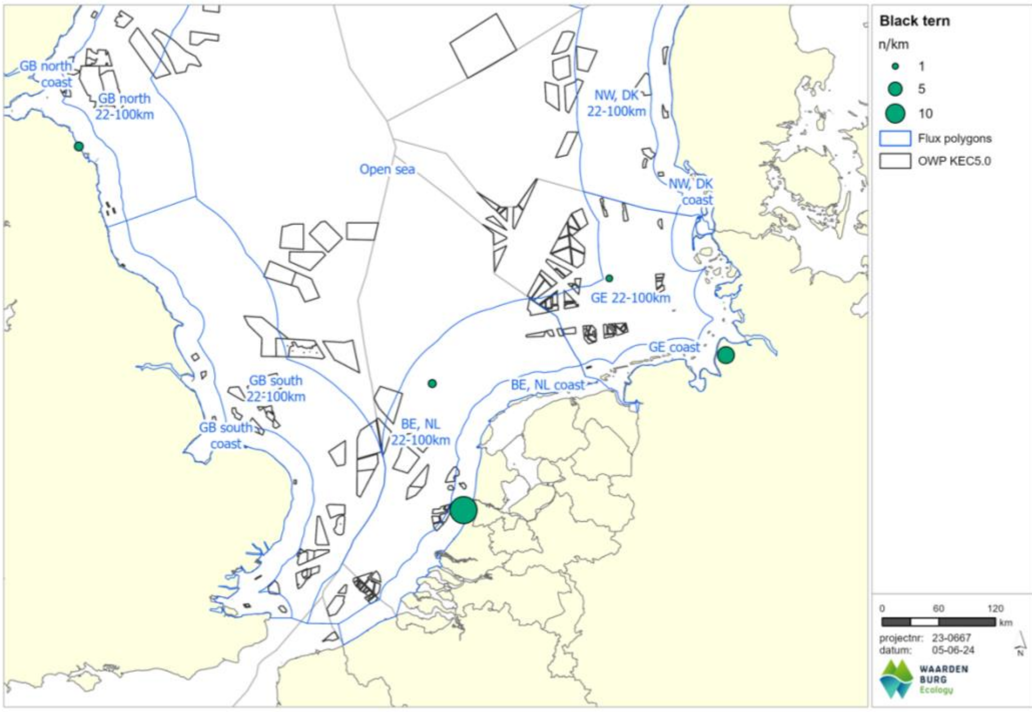

Figure 3.3 *Spatial variation of the migration intensities of the black tern in different parts of the Central and Southern North Sea based on the ESAS database (source: Potiek et al. 2019b).*

3.3 New version of the stochastic collision rate model

In 2015, Marine Scotland published the Stochastic Collision Risk Model (sCRM) (Masden 2015a, b), based on the model originally developed by The Crown Estate (Band 2012). The model was further developed and additionally made into a script, which resulted in further iterations of this model and a new, so-called 'R Shiny', interface (Trinder 2017, McGregor *et al.* 2018). Due to the limitations of this interface over time, Caneco *et al.* (2022) developed a new R-package called 'stochLAB'. With this package, the developers aimed to create a 'user-friendly, streamlined, well documented and easily distributed tool'. Furthermore, the code behind the core calculations was optimised and some errors corrected. The R-package stochLAB is publicly available and follows the latest insights in collision rate modelling. It supersedes previous iterations of the model and has largely become the standard when studying collision risk with offshore wind turbines (e.g. Johnston *et al.* (2023), (Pavat *et al.* 2023)).

As part of the knowledge update, we compared the model used in previous KEC assessments with the latest model iteration (stochLAB). For this, we tested to what extent the results calculated by the previous model differ from those in stochLAB. For this test, we used the same input parameters in each model and compared the results of each. Furthermore, we used data for three species which are representative for the range of species present in the Dutch North Sea (little gull, lesser black-backed gull and northern gannet) and used three different values for densities (realistic densities, density = 1 bird/km^2, and density = 2 bird/km^2). Lastly, we ran calculations for both the basic and the extended options of the model.

The results show that the differences in the calculated numbers of collision victims between these two models are generally small (Table 3.5). These differences were only somewhat larger for the lesser black-backed gull, which is due to the large standard deviations surrounding the means for this species. In most cases, previous model estimates were slightly higher than those from stochLAB. Furthermore, stochLAB behaved as expected, shown for example by the doubling of the number of victims when density was twice as high.

In previous KEC CRM processes, we had adapted the Masden (2015b) code to allow the use of different flight speeds for two different aspects of the model: collision risk and numbers of birds at risk. stochLAB, being a closed package, does not allow such adaptations to the code, which in itself was one of the aims of the package. This means that only a single flight speed for both aspects of the collision rate modelling can be used with stochLAB. Considering that this was previously only done for black-legged kittiwake this is regarded a minor issue.

Conclusion
One of the biggest advantages of stochLAB is that it is a transparent, publicly available model that supports the most up-to-date knowledge in modelling collision rates for birds in offshore wind farms. Compared to these advantages, the lack of allowing different flight speeds is considered of minor importance. Our calculations show that the results of stochLAB do not substantially differ from the results of the Masden (2015b) code. Differences found were mainly explained by variation caused by relatively large standard deviations. For these reasons, the calculations for the KEC 5.0 study for all the seabird species were carried out by stochLAB. For migrant birds, the migrant function of stochLAB was used, except for the Bewick's swan and brent goose. For these species height distributions based on GPS data were available. Such data were considered more insightful than a single estimate on the fraction of birds at rotor height that the migrant function of stochLAB employs. However, as such detailed GPS data cannot yet be implemented in stochLAB for migrants, we used the older adaptation of the Masden (2015b) code (cf. the KEC 4.0) to calculate the number of collision victims of the Bewick's swan and brent goose.

Table 3.5 *Overview of the results of the collision calculations with the Masden (2015b) code used in previous KEC versions in comparison with stochLAB used in the KEC 5.0 for three different densities and two versions of the models (basic and extended = ext.). The last column provides the difference between the mean numbers of collisions calculated by both models.*

Species	option	Density (km²)	Masden (2015b) mean	sd	stochLAB mean	sd	difference
lesser black-backed gull	basic	realistic	5.2	6.6	4.3	1.0	**-0.88**
lesser black-backed gull	basic	1	43.4	54.6	36.1	8.2	**-7.33**
lesser black-backed gull	basic	2	86.9	109.2	72.2	16.5	**-14.65**
lesser black-backed gull	ext.	realistic	6.0	12.3	4.6	2.4	**-1.33**
lesser black-backed gull	ext.	1	49.8	102.8	38.6	20.3	**-11.12**
lesser black-backed gull	ext.	2	99.5	205.7	77.3	40.6	**-22.24**
little gull	basic	realistic	52.4	0.5	52.5	0.4	**0.01**
little gull	basic	1	337.1	3.0	337.1	2.5	**0.04**
little gull	basic	2	674.2	6.1	674.3	5.0	**0.08**
little gull	ext.	realistic	2.6	0.3	2.6	0.2	**-0.01**
little gull	ext.	1	17.0	1.6	17.0	1.6	**-0.05**
little gull	ext.	2	34.0	3.2	33.9	3.1	**-0.11**
northern gannet	basic	realistic	4.9	0.9	4.9	0.5	**-0.08**
northern gannet	basic	1	56.5	10.6	55.6	5.8	**-0.87**
northern gannet	basic	2	112.9	21.3	111.2	11.7	**-1.75**
northern gannet	ext.	realistic	7.1	3.5	6.9	3.0	**-0.19**
northern gannet	ext.	1	81.5	40.4	79.3	34.8	**-2.18**
northern gannet	ext.	2	162.9	80.8	158.6	69.6	**-4.36**

4 Update knowledge base parameter values

Part of the KEC 5.0 study was to update input parameters based on extensive literature research for input parameters for the collision rate model, as well as the population models. This knowledge update is performed for all species presented in Table 2.2, and presented separately for seabirds (Chapter 4.1) and migratory birds (Chapter 4.2). New data included here either became available after KEC 4.0, at that time were not yet publicly available, or were for another reason not used in KEC 4.0. All parameter estimates considered in KEC 5.0 are reported in Appendix I. In each of the tables, green cells represent new parameter values differing from KEC 4.0. Finally, we present in Chapter 4.3 the definitive parameter choices for KEC 5.0. For the weighing of different data sources, each data source within this updated knowledge base was scored for representativeness and data quality, conform Potiek *et al.* (2022a), based on Horswill & Robinson (2015). Box 2 in Chapter 4.3 describes this approach in more detail.

4.1 Seabird species

General updates

Recently, Wageningen Marine Research developed new bird density maps for the Dutch Continental Shelf (NCP) using existing data but treating these with new model fits, based on so called Tweedie distributions (van Donk *et al*. 2024). These maps were available and used in our analyses for six of the twelve species regarded within KEC for bird collisions. Specifically, these maps were available to use for the northern gannet, black-legged kittiwake, lesser black-backed gull, herring gull, great black-backed gull and sandwich tern. Hence, the analyses on the national level (NCP) were performed using these newly developed maps when available. Besides all parameter values of our knowledge update, Table 4.1 also presents the type of maps used for each seabird species.

Northern gannet

One new study was found for several parameters of the sCRM for northern gannet. Cook *et al.* (2023) summarised GPS tracking studies of several colonies within the breeding season, yielding several flight speed estimates (14.01 m/s and 10,79 m/s, without any SDs) and an estimate for nocturnal activity (0.14 ± 0.102 SD). Additionally, Leemans *et al.* (2023) described a new value for flight speed in the wind farm in Borssele (NL) (14,4 m/s ± 2,00 SD). Pavat et al. (2023) reported a macro avoidance rate of 0.8564 (without any SD).

Population model parameters were not revised within the scope of this knowledge update as the models and corresponding parameter updates from Wageningen Marine Research (Soudijn *et al.* 2025) were used.

Arctic skua
For the arctic skua, no new studies were found describing or estimating input parameters for the collision risk models.

For the input parameters needed in population models however, one new study was found describing two new estimates for the input parameters of population models: Jones & Jones (2021) investigated the population on Handa Island, Scotland, United Kingdom and reported two new values (0.9 fledgelings and 1.1 fledglings per breeding per, without any SDs) for the period 2003-2020 and 2021 respectively.

Great skua
For the great skua, no new studies were found describing or estimating input parameters for the collision risk models.

For the input parameters needed in population models however, two new studies were found describing three new estimates for the input parameters of population models. Jones & Jones (2021) investigated the population on Handa Island, Scotland, United Kingdom and Camphuysen *et al.* (2022) investigated the population on the island of Foula, Scotland, United Kingdom. These studies reported new estimates for fledglings per breeding pair for the great skua. Jones & Jones (2021) found 0.51 and 0.57 fledgings per breeding pair for 2021 and 2003-2020 respectively. Camphuysen *et al.* (2022) reported mass mortality over all age classes as a result of highly pathogenic avian influenza (HPAI) on Foula, also resulting in almost no fledglings per breeding pair. This mass mortality is such an extreme value, that this is not representative for all years. More data from recent and coming years are needed to get a better impression of current survival rates. For now, we decided not to include Camphuysen *et al.* (2022) in the population model input for KEC 5.0. However, large population level impacts, such as the dramatic consequences of the avian influenza, can also be incorporated in the thresholds for the ALI. Sovon (2024) considered avian influenza in their advice for the ALI threshold, and this was also applied by the government for several species.

Black-legged kittiwake
Several new studies were found for black-legged kittiwake. New measurements for flight speed were available from Leemans *et al.* (2023) (10.4 m/s ± 1.1 SD) and Leemans *et al*. (2022b) (12.1 m/s ± 4.4 SD) as measured in respectively windfarm Borssele (NL) and windfarm Luchterduinen (NL). In addition, a review was made by Royal HaskoningDHV (2020) recommending the use of 10.8 m/s (± 0.9 SD) and Cook *et al.* (2023) reported two flight speeds for the UK east coast (9.73 m/s and 6.07 m/s, without any SDs). Furthermore, 21 new estimates for nocturnal activity became available from a review by Cook *et al.* (2023), leading to an average of 0.413 over all estimates. New values for avoidance rate were reported by Tjørnløv *et al.* (2023) (0.31 meso-avoidance and 1.0 micro-avoidance) and in review from Ozsanlav-Harris *et al*. (2023) (resulting in a recommend use of 0.9947 ± 0.1295 SD in extended stochastic band models for combined meso- and micro-avoidance).

For the population model parameters three new studies (Lerche-Jørgensen *et al.* 2012, Anker-Nilssen *et al.* 2022, Fayet *et al.* 2023) were found. Two of these were based on the same time series on several populations in Norway and lead to a mean estimate of 0.809 (without any SDs) for adult survival. The third newly found study in the United Kingdom (Lerche-Jørgensen *et al.* 2012) yielded an adult survival of 0.89 (no SD given). Anker-Nilssen *et al.* (2022), Fayet *et al.* (2023) also provide new values for the fecundity of the kittiwake with a mean of 0.4404 (no SD given) over their assessed time periods and locations in Norway.

Little gull

Several new studies were found for the parameters of the sCRM for little gull. Tjørnløv *et al.* (2023) determined micro-avoidance rate at 1.0 (no SD given) for the species group small gulls, using a combination of camera and radar, and Ozsanlav-Harris *et al.* (2023) recommended the use of 0.9512 (± 0.0078 SD) for within wind farm avoidance (meso- and micro-avoidance together). These values were combined with macro-avoidance of 0.8 (no SD given) reported by Dierschke *et al.* (2016). Additionally, Leemans *et al*. (2023) described new values for flight speed in wind farm in Borssele (NL).

For little gull, no new survival rates and fecundity rates were found. Survival rates used thus far are based on black-headed gull, as no survival rates for little gull are known. No new references were found for fecundity rates of little gull. One new reference was found for fecundity rates of black-headed gulls in Norway (Hagestad 2023) at 0.35 (± 0.45 SD). Despite the new reference for black-headed gulls, we suggest using the same estimates as in KEC 4.0. Within KEC 4.0, the survival rates based on black-headed gulls were used, and the fecundity and proportion of non-breeding adults were fit based on the observed population trend. This resulted in a fecundity of 0.75 fledglings per breeding pair. Although this is higher than the references found for black-headed gull and the (dated) references on fledglings per breeding pair for little gull, this results in a more realistic population projection. While the survival rate is expected to be similar between little gull and black-headed gull, the fecundity may well differ between the two species.

Lesser black-backed gull

Several new studies were available for the input parameters of the CRM for lesser black-backed gull. Cook *et al.* (2023) summarised several GPS tracking studies, yielding some new flight speed estimates, as well as estimates for nocturnal activity and proportion at rotor height. The reported mean flight speed of 9.16 m/s (± 1.266 sd) was calculated over different flight types. Vanermen *et al.* (2022) also used GPS trackers resulting in new estimates for flight speed (9.05 m/s, no SD given), nocturnal activity (0.11, no SD given) and proportion of flying birds (0.34, no SD given). Green *et al.* (2023) also reported an estimate for ratio flying also based on GPS tracking data (0.45675, no SD given, calculated over all daytime and nocturnal datapoints). A radar study in Luchterduinen yielded flight speed (12.3 m/s ± 2.8 SDs; Leemans *et al.* 2022b) and avoidance rate estimates (0.9, no SD given; Leemans *et al.* (2023). New values for flight speed (11.3 m\s ± 2.00SDs) were also defined in wind farm in Borssele (NL) by Leemans *et al.* (2024). Additionally, new estimates for avoidance rate were found in Tjørnløv *et al.* (2023) (0.87 and 0.963 for meso- and micro-avoidance respectively) and Ozsanlav-Harris *et al.* (2023) recommended the use of 0.981 as a combined value for meso- and micro-avoidance in collision rate modelling). One new source of modelled flight height distributions was found (Johnston *et al.* 2023).

For lesser black-backed gull, no new parameters were available for survival rates. Three new studies on reproductive success were found. In the Netherlands, nests were monitored on Texel (0.49, no SD given, unknown number of nests) and on Neeltje Jans (0.30, no SD given, 1,713 nests) (Camphuysen *et al.* 2023; Vanermen *et al*. 2022). In the UK, 186 nests were monitored in South Walney (0.15, no SD given) (Dalrymple 2023).

Herring gull
Several new studies became available for the input parameters of the CRM for herring gull. Leemans *et al.* (2022b) describe flight characteristics based on radar data from Luchterduinen (NL), resulting in a new estimate for flight speed (12.8 m/s ±4.4 SD). Additionally, Leemans *et al.* (2023) describe new values for flight speed in wind farm Borssele (NL) (10.9 m/s ±1.7). Similarly, studies in which radar and camera were combined in windfarms Aberdeen (UK) and Luchterduinen (NL) resulted in new estimates for avoidance rates (0.989 and 0.931, no SD given) (Skov & Tjørnløv 2022, Leemans *et al.* 2023, Tjørnløv *et al.* 2023). Tjørnløv *et al.* (2023) reported a flight height distribution in a figure, but the underlying data was not available.

For herring gull, new population model parameters were available for survival rates. Kentie *et al.* (2022) reported new values for juvenile survival (0.53, no SD given), immature survival (0.81 and 0.87, no SD given) and adult survival (0.80, no SD given). Additionally, two new studies on reproductive success were found (Vanermen *et al.* 2022, Dalrymple 2023), based on 263 nests monitored in the UK (South Walney) (0.21, no SD given) and 1,014 nests in the Netherlands (Neeltje Jans) (0.31 ±0.34 SD).

Great black-backed gull
Several new studies became available for the input parameters of the CRM for great black-backed gull. Leemans *et al*. (2022b) describe flight characteristics based on radar data from Luchterduinen (NL), resulting in a new estimate for flight speed (13.2 m/s ± 4.9 SD). Additionally, Leemans *et al.* (2023) describe new values for flight speed in wind farm Borssele (NL) (12.7 m/s ±3.00 SD). Similarly, studies in which radar and camera are combined in wind farms Aberdeen (UK) and Luchterduinen (NL) resulted in new estimates for avoidance rate (0.9 and 0.989, no SD given) (Skov & Tjørnløv 2022, Tjørnløv *et al.* 2023) although the rate reported by Tjørnløv *et al.* (2023) (0.71 and 0.969, no SD given) merely reflects meso-avoidance and hence is in itself not directly usable for CRM. Additionally, Ozsanlav-Harris *et al.* (2023) recommend the use of a combined meso- and micro-avoidance rate of 0.997 (±0.0008) in collision rate models. A recalculation of the data of Gyimesi *et al*. (2017b) resulted in a nocturnal activity of 25%.

For great black-backed gull, no new parameters were available for survival rates. One new study on reproductive success was found (Dalrymple 2023), in which 38 nests in the UK (South Walney) were monitored (1.05 fledglings per breeding pair, no SD given). For the proportion of floaters, i.e. the incidence of missed breeding, no data were available. Following KEC 4.0, we assumed 10% floaters.

Common tern
For the common tern, a single new study was found describing or estimating input parameters for the collision risk models. Specifically, Diehl *et al.* (2020) found that during breeding seasons, in Ontario, Canada and New York, the United States of America, common terns would not leave their nests for more than 1% of the time during the night, setting a likely value for the nocturnal activity of common terns in these areas at near zero percentage.

For the input parameters needed in population models, one new study was found describing two new estimates for new values for the input parameters of population models. Moiron *et al.* (2022) investigated the population in the Banter See, Germany, and reported a new value for the adult survival (0.85 ±0.36 SD) and a new value for the fledglings per breeding pair (0.7 ±0.81 SD). Based on these input parameters, the adult survival used in KEC 5.0 was updated.

Sandwich tern
Considering the collision rate model parameters, van Bemmelen *et al.* (2023) executed an extensive GPS-logger study to identify macro-avoidance rates of the Sandwich tern, yielding nine new macro-avoidance values for different locations in the Netherlands and the United Kingdom. These location-specific values were averaged as two values for the two countries at 0.41 and 0.54 respectively (without SDs). A review from Ozsanlav-Harris *et al.* (2023), specifically aimed to identify within wind farm avoidance rates for use in CRMs recommended a value of 0.9705 (±0.0029 SD). Additionally, Leemans *et al.* (2023) describe new values for flight speed in wind farm Borssele (NL) at 11.6 m/s (±2.1 SD). Moreover, based on the extensive GPS-logger dataset of van Bemmelen *et al.* (2024), we calculated an average flight speed of 9.33 m/s (±3.53 SD) for birds in flight (commuting and foraging).

For the sandwich tern, population models were already defined and updated by WMR (Soudijn *et al.* 2025). Hence, the used population model parameters for this species are based on the knowledge update by WMR.

4.2 Migratory birds

Bewick's swan
For the Bewick's swan many new values were found for the CRM parameters. Specifically, The Royal Society for the Protection of Birds (RSPB) (2024) and The Wildlife Trusts (2024) in the United Kingdom and the LuontoPortti – NatureGate (2024) website in Finland published values for the body length and wingspan of Bewick's swans. Additionally, a large review on CRM parameters (Woodward *et al.* 2023) provided new values for the avoidance rate, the proportion at rotor height and the flight speed of Bewick's swans. However, since flight height distributions based on detailed GPS logger measurements were also available (Gyimesi *et al.* 2017b), we chose to use those, as they provide more specific estimates for

the collision rate calculations. All parameters found (new and old) are presented in Appendix I.

Brent goose

For the brent goose, one new review study was found recommending on the use of certain values in CRM calculations (Woodward *et al.* 2023). However, this study referred to values of Gyimesi *et al.* (2017b) for flight speed, which were already included in the previous KEC knowledge update. Hence, no new parameter values were available for the flight speed of the brent goose. Nevertheless, the same study also recommended the use of new values for avoidance rate (0.9998 ±0.00001 SD) and proportion at rotor height (0.5, no SD given), which are presented in Appendix I.

In addition, all available demographic rates for brent goose are reported in Appendix I. Several new studies were found with estimated survival rates. Two new studies reported estimates for juvenile survival. While Roberts *et al.* (2021) reported a posterior estimate for juvenile survival ranging between 0.58 to 0.70, DiDonato (2022) reported an estimate of 0.63 (95% CI 0.358 – 0.866). Both new sources are included in the new weighted estimate for KEC 5.0; as Roberts *et al.* (2021) only report a range, the mean of this range is used (0.64). Also for adult survival new estimates were found (Leach *et al.* 2020, Lohman *et al.* 2021, Roberts *et al.* 2021, DiDonato 2022, Kharitonov *et al.* 2024). Leach *et al.* (2020) looked at the effect of mate fidelity on adult survival. As we don't model variation in mate fidelity in our population models, this data source is not used for KEC 5.0. The other estimates are used for the calculation of the weighted estimate, which are Lohman *et al.* (2021) (0.825 +- 0.009 sd), Roberts *et al.* (2021) (0.83, no sd given), Didonato (2022) (0.866, 95% CI 0.778 – 0.934) and Kharitonov *et al.*(2024) (0.828 for Atlantic Brant).

Common shelduck

One new source was found for avoidance rate of common shelduck. Woodward *et al.* (2023) recommended an avoidance value of 0.9851 (sd 0.00088) based on literature. No new parameters for survival or fecundity of common shelduck were available.

Curlew

One new study was available containing parameter values for the CRM for curlew. Schwemmer *et al.* (2023) reported flight speed and proportion at rotor height. Additionally, in their review, Woodward *et al.* (2023) recommended the use of the values 15.4 m/s (±3.3 SD), 0.9996 (±3.3 SD) and a precautionary value of 1 for the flight speed, avoidance rate and proportion at rotor height, respectively. This data is indicated in green in Appendix I.

Several studies containing new survival rates were available. New estimates for juvenile survival were available from Cook *et al.* (2021) for two timeframes: for 1970 – 2018, the estimated juvenile survival was 0.326 (SE 0.278-0.378), while for the period between 1996 and 2018, the estimate was 0.39 (SE 0.304 – 0.484). The latter estimate, *i.e*. the most recent time period, is used for the calculation of the weighted estimate for juvenile survival. Also for adult survival, new estimates were available from Cook *et al.* (2021) (0.922 for most recent time period; range 0.886-0.948), as well as from Pakanen & Kylmänen (2023) (0.891 +- 0.032 for males and 0.915 +- 0.03 for females; average of 0.903). Not previously used estimates were also available from Taylor & Dodd (2013) and Berg (1994), but these were not incorporated in the weighted estimate as these were based on relatively old data. In addition, Ewing *et al.* (2023) and Baines *et al.* (2023) reported values for chick survival. However, these were not suitable for use in the population models, as we use annual survival rates and chick survival is incorporated in the fecundity estimate (nr. fledglings per breeding pair). For fecundity, only one new study was available reporting the number of fledglings per breeding pair (Baines *et al.* 2023), comparing the fecundity between grouse moors and non-grouse moors. As this distinction between grouse moors and non-grouse moors is not incorporated in the population models, this estimate cannot be used in the population models. Hence, we based the fecundity on the same data sources as in KEC 4.0. However, instead of using only the estimate by Roodbergen *et al.* (2012), we calculated a weighted average based on Roodbergen *et al.* (2012) and Zielonka (2019), as the latter represents a more recent time period.

Bar-tailed godwit

Two new studies were found containing parameter values for the CRM for bar-tailed godwit. Battley *et al.* (2012) reported a range of flight speeds, depending on the flight height. Woodward *et al.* (2023) reported an expert judgement on values for flight speed (18.3 m/s +- 2.1), avoidance rate (0.9996 +- 0.00002 SD) and proportion at rotor height (1) to use for CRM calculations.

For demographic rates, one new study was found for adult survival (Conklin *et al.* 2016). However, this study is based on data from New Zealand and hence is not representative for our study area. Hence, all applied demographic rates were the same as in KEC 4.0.

Red knot

For the red knot, we found only one new review study for the CRM (Woodward *et al.* 2023), recommending values of 24.6 m/s (±4.6 SD), 0.9996 (±0.00002 SD) and a precautionary 1 for the flight speed, avoidance rate and proportion at rotor height respectively. This data is indicated in green in Appendix I.

Two studies containing new survival rates were available. Newstead *et al.* (2024) and Tucker *et al.* (2021) reported values for adult survival. However, as these were based on data from the USA, these values were not considered representative for our study area, and hence were not used within KEC 5.0. For fecundity one new study was available reporting incubation success (Burger *et al.* 2022) (success rate of 0.45, no sd given). As this type of measure is not used within our population models, both survival and fecundity rates were kept the same as in KEC 4.0.

Black tern

For the black tern, two additional values were available for flight speed, reported by Schnell (1965) (7.8 m/s, no SD given) and Kolotylo (1989) (7.1 +- 0.64 SD).

For survival rate and fecundity, two new studies were found. The first study by van der Winden *et al.* (2024) was carried out based on data from the Netherlands, Germany and Ukraine, and reported an adult survival of 76.8%. As this is the best available estimate, this is used within the population models for KEC 5.0. The other new study by Davis *et al.* (2023) reported juvenile and adult survival (9% survival from fledging to age 3, and 84% adult survival). However, as this study was based on data from the USA, these values are not used for the calculation of the weighted estimate.

Common starling

For common starling, two new studies were found reporting flight speed (Culla 2022, Leemans *et al.* 2024), respectively 17.0 m/s +- 3.1 SD and 11.9 m/s (with no SD given).

No new survival rates were found. For fecundity, three new studies were found for mean number of fledglings per breeding pair: Dolenec (2021) reported 4.92 (+- 0.77 SD) fledglings per breeding pair, while Kuranov *et al.* (2023) and Jauregui *et al.* (2023) reported lower values (resp. 2.56 +- 0.070 SD and 2.7 +- 0.1 SD). In addition, Hodinka & Williams (2024) reported incidence of second brood (57%). For survival rates, as well as fecundity, the best available estimates were reported by Versluijs *et al.* (2016) and used for population models by Schippers *et al.* (2020). Hence, for KEC 5.0, we used these estimates by Versluijs *et al.* (2016) and Schippers *et al.* (2020).

4.3 Parameter choices for KEC 5.0

Based on the recently published relevant studies presented in Chapter 4.1 and 4.2, we updated the knowledge database of Potiek *et al.* (2022a) both for the collision rate model parameters and for the demographic rates. The definitive choices for these parameter values are presented in Chapter 4.3.1 and 4.3.2, respectively. For the collision rate models, we gathered information on 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 migration routes/intensities and the proportion of flights at rotor height. Input for the population models consisted of estimated life stage-specific survival rates, fecundity and fraction non-breeding adults (floaters). For both collision rate models and population models, different data sources were weighted according to Box 2. Age of first breeding is very species-specific and constant between colonies. Hence, this parameter was generally based on one data source.

Choosing the final values for collision rate models and population models to be used in KEC 5.0

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 parameter values were available, these recommendations were used. In case of input parameters for the collision rate model, several large reviews have become available since KEC 4.0 (Ozsanlav-Harris *et al.* 2023, Woodward *et al.* 2023). When no new values were published after these reviews, we assumed all relevant data published before were considered and we adopted the recommendations from these reviews.

2. Use ‘best’ reference: When one reference had clearly higher data quality and representativeness than the other available sources, this reference was used.
3. Calculate weighted averages: When several data sources were available, these were weighted by data quality and representativeness (see Box 2).

Box 2 Weighing of data sources for input parameters population model, following the approach of Horswill and Robinson (2015), also used for KEC 4.0.

The 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 assessed the representativeness of each data source. This representativeness was 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 were available, we only used these estimates, as these were considered more representative. Again, each of these criteria was 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 redefined life stages for the population models were 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).

The demographic rates reported in Appendix I use 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 (Appendix I).

4.3.1 **Collision rate models**

Based on the newly found values for different parameters, we decided which values to use for the calculations in KEC 5.0. A summary of all parameter values, in comparison with the KEC 4.0 values, is presented in Table 4.1.

Body length and **wingspan** remained the same as in KEC 4.0, as these parameters had been investigated extensively in the past and are not expected to be subject to considerable changes. Lately, several large reviews (Ozsanlav-Harris *et al.* 2023, Woodward *et al.* 2023) have made recommendations on the use of parameter values in sCRMs. We assumed that these reviews comprised all parameter values available up to a year before their publication date. Consequently, in case not any more recent publication was found, we adopted the recommendations from these reviews.

For **flight speed** we used all old and new values to get a more accurate estimate of average flight speed. Some studies report flight speeds for specific behaviour, but as we do not know what behaviour is predominantly performed in a certain wind farm, we calculated a generic estimate for flight speed. For these purposes, we scored the flight speed data sources similarly as the population model parameters using the methods described in Box 2, based on Horswill & Robinson (2015) and calculated the weighted average of all values using the scoring as weights. If specific values were clearly of very different populations than the North Sea (e.g. Pacific Flyways) and North Sea values were available, these values were excluded from the weighted averages. For standard deviations we compiled the average standard deviation as:

$$\bar{s} = \sqrt{\frac{\sum(n_i - 1)s_i^2}{(\sum n_i) - k}} \qquad \textit{Equation 1}$$

where average standard deviation over all used values ($\bar{s}$) is made up by the square root of the sum of the squared standard deviation of each found standard deviation (s_i) times either:

1. the number of observations that formed that standard deviation (n_i) minus one or
2. when the number of observation was not known, the scoring weight was used as proxy for n_i, divided by the total number of observations/weights minus the number of different values (k) we had available for the standard deviation of flight speed, as is statistically commonly applied to calculate the overall standard deviation of different groups based of the standard deviation of the separate groups.

Whenever we deemed that only a single value was representative of the population studied, we used that single value and the associated standard deviation directly. All in all, this resulted in new flight speed estimates for twelve of the eighteen studied species (Table 4.1).

The choice for species-specific **avoidance rates** was based on a decision tree (Figure 4.1). The foremost criterium was whether avoidance rates from offshore studies were available. If so, those studies were scored on data quality and - representativeness (see Box 2) and the resulting weighted average was used. An exemption is the northern gannet, for which the values reported in Leemans & Gyimesi (2022) were used, as this study determined avoidance rate specifically for wind farms in the Southern and Central North Sea. Furthermore, a new avoidance rate estimate was defined for the black-legged kittiwake, lesser- and great black-backed gull, Sandwich tern and almost all migratory bird species. New information was available for the herring gull as well, but the new calculated estimate practically matched the KEC 4.0 value (Table 4.1). For northern gannet, the avoidance rate was 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 avoidance rate was adjusted for the breeding season (see Table 4.1).

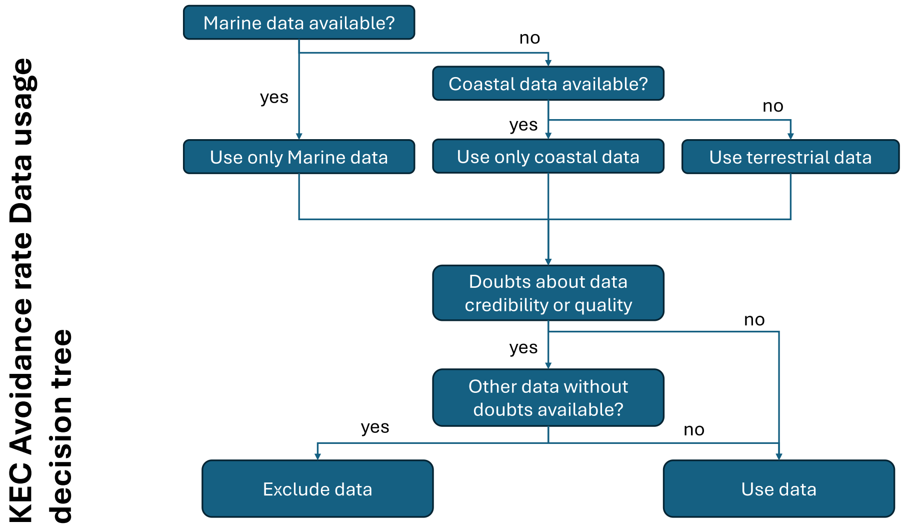

Figure 4.1 Decision tree for prioritizing studies reporting avoidance rates.

For **nocturnal activity**, new values were defined for black-legged kittiwake, great black-backed gull and northern gannet (Table 4.1). For the black-legged kittiwake, this was based on a review of Cook *et al.* (2023). For the northern gannet, the new value was based on the combination of old and new values, while for the great black-backed gull on a recalculation of old values (based on Gyimesi *et al.* 2017b). For the other species, nocturnal activity stayed the same as in KEC 4.0. This regards also the lesser black-backed gull, for which new values were found, but the old value originating from Gyimesi *et al.* (2017a) was still considered as the best available. Furthermore, for the lesser black-backed gull also a new study was found reporting modelled **flight height distributions** (Johnston *et al.* 2023). However, for this species, the same CRM values as in KEC 4.0 were used, as those relied on an overview study of several different GPS databases to specifically provide values for CRM calculations (Gyimesi *et al.* 2017a). Also for all other seabird species the same flight height distributions as in KEC 4.0 were used, as no new information was available. However, for three of the migratory bird species, namely the curlew, red knot and bar-tailed godwit, new values for the proportion of flights at rotor height were found. Finally, a new value of **fraction of time in flight** was defined for the lesser black-backed gull (Table 4.1).

Table 4.1 *Comparison of values used in KEC 4.0 and 5.0 for local seabirds (upper) and migrant birds (lower). Body length and wingspan were assumed not to change between KEC rounds. Each value represents the mean with the standard deviation (sd) in brackets. References for flight height distributions: [1] Johnston et al. 2014; [2] Cleasby et al. 2015; [3] Gyimesi et al. 2017a; [4] Johnston et al. 2014; [5] Ross-Smith et al. 2016; [6] Johnston et al. 2023; [7] Gyimesi et al. 2017b; [8] Collier et al. 2020; [9] Perrow et al. 2017. Cells with updated values are shaded green.*

Species (EN)	Body length (m ± sd)	Wing span (m ± sd)	Flight speed (m/s ± sd)		Nocturnal activity (proportion ± sd)		Avoidance rate (percentage ± sd)		Sources of flight height distribution		Fraction time in flight	
	KEC 4.0 & 5.0	KEC 4.0 & 5.0	KEC 4.0	KEC 5.0	KEC 4.0	KEC 5.0	KEC 4.0	KEC 5.0	KEC 4.0	KEC 5.0	KEC 4.0	KEC 5.0
Northern gannet	0.94 (±0.022)	1.73 (±0.025)	14.9 (±2.60)	13.69 (±2.13)	0.08 (±0)	0.143 (±0.102)	98.9 (±0)	98.9/99.6	[1] / [2]	[1] / [2]	0.82	0.82
Arctic skua	0.44 (±0.008)	1.18 (±0.025)	13.8 (±2.20)	13.8 (±2.20)	0 (±0)	0 (±0)	99.5 (±0)	99.5	[1]	[1]	1	1
Great skua	0.56 (±0.008)	1.36 (±0.013)	14.9 (±3.80)	14.9 (±3.80)	0 (±0)	0 (±0)	99.5 (±0)	99.5	[1]	[1]	0.8	0.8
Black-legged kittiwake	0.39 (±0.003)	1.08 (±0.042)	8.71 (±3.16) / 6.22 (±3.40)	10.45 (±2.62)	0.50 (±0)	0.413 (±0)	99.2 (±0)	99.9	[1]	[1]	0.672	0.672
Little gull	0.26 (±0.003)	0.78 (±0.008)	11.5 (±0.10)	7.41 (±0.85)	0.25 (±0)	0.25 (±0)	99.5 (±0)	99.5	[1]	[1]	0.6	0.6
Lesser black-backed gull	0.58 (±0.020)	1.43 (±0.025)	9.41 (±3.92)	10.39 (±2.77)	0.43 (±0)	0.43 (±0)	99.8 (±0)	99.5	[1]; [3]	[3] to [6]	0.43	0.39
Herring gull	0.60 (±0.015)	1.44 (±0.020)	11.34 (±3.91)	10.84 (±3.63) / 11.23 (±3.93)[1]	0.01 (±0)	0.01 (±0)	99.5 (±0)	99.512	[1]; [3]	[1]; [3]	0.3	0.3
Great black-backed gull	0.71 (±0.023)	1.58 (±0.025)	13.7 (±1.20)	11.45 (±3.47) / 12.06 (±3.43)[1]	0.50 (±0)	0.25 (±0)	99.5 (±0)	99.3 (±0)	[7]; [1]	[7]; [1]	0.34	0.34
Common tern	0.33 (±0.007)	0.88 (±0.035)	9.2 (±3.10)	9.2 (±3.10)	0 (±0)	0 (±0)	99.0 (±0)	99.0 (±0)	[1]	[1]	1	1
Sandwich tern	0.39 (±0.008)	1.00 (±0.017)	10.3 (±3.40)	9.33 (±3.53 SD)	0.05 (±0)	0.05 (±0)	99.0 (±0)	98.4 (±0)	[1]; [8]; [9]	[1]; [8]; [9]	1	1

[1] *The source recommends two different values for calculating fluxes and for use in Collision Rate Models respectively. Hence both are used in separate calculations of two weighted means for use in said analyses.*

Table 4.1, *continued*

Species (EN)	Body length (m ± sd)	Wing span (m ± sd)	Flight speed (m/s ± sd)		Avoidance rate (percentage ± sd)		Sources of flight height distribution / Proportion at rotor height (± sd)	
	KEC 4.0 & 5.0	KEC 4.0 &5.0	KEC 4.0	KEC 5.0	KEC 4.0	KEC 5.0	KEC 4.0	KEC 5.0
Bewick's swan	1.21 (±0.020)	1.96 (±0.052)	16.88 (±0.62)	18.3 (±4.3)	98.0 (±0)	0.9885 (±0.00091)	(Gyimesi *et al.* 2017b)	(Gyimesi *et al.* 2017b)
Brent goose	0.59 (±0.008)	1.15 (±0.017)	17.25 (±0.27)	17.9 (±6.1)	98.0 (±0)	0.9998 (±0.0001)	(Gyimesi *et al.* 2017b)	(Gyimesi *et al.* 2017b)
Common shelduck	0.63 (±0.015)	1.22 (±0.038)	18.21 (±4.32)	18.21 (±4.32)	98.0 (±0)	0.9851 (±0.00088)	0.5 (±0)	0.5 (±0)
Curlew	0.55 (±0.017)	0.90 (±0.033)	17.78 (±3.30)	16.5 (±6.11)	98.0 (±0)	0.9996 (±0.00002)	0.75 (±0)	1 (±0)
Red knot	0.24 (±0.003)	0.59 (±0.007)	16.64 (±0.56)	24.6 (±4.6)	98.0 (±0)	0.9996 (±0.00002)	0.75 (±0)	1 (±0)
Bar-tailed godwit	0.38 (±0.003)	0.75 (±0.017)	14.4 (±1.97)	18.3 (±2.1)	98.0 (±0)	0.9996 (±0.00002)	0.75 (±0)	1 (±0)
Black tern	0.23 (±0.003)	0.66 (±0.007)	7.1 (±0.64)	7.1 (±0,64)	98.0 (±0)	98.0 (±0)	0.07 (±0)	0.07 (±0)
Common starling	0.22 (±0)	0.40 (±0.008)	15.4 (±1.71)	17.0 (±3,1)	98.0 (±0)	98.0 (±0)	0.5 (±0)	0.5 (±0)

4.3.2 **Population models**

Population model demographic parameter estimates were chosen based on the same method as flight speed estimates mentioned in §4.3.1: values and adjacent standard deviations were used as weighted averages by scoring of the parameters and standard deviation according to weighted averages based on either number of observations or scoring. A summary of all final parameter values is presented in Table 4.2. In the table a comparison is made with the KEC 4.0 values, marking new values with a green colour.

Table 4.2 *Comparison of values used in KEC 4.0 and KEC 5.0 in the population models for the local seabirds (upper) and migrant birds (lower). Each value represents the mean with the standard deviation (sd) in brackets. Cells with updated values are shaded green. *: lower fecundity at age 3 and 4, higher fecundity from age 5. For northern gannet and sandwich tern, the knowledge base update is done by WMR and reported in Soudijn et al. (2025). All standard deviations are chosen based on the range given in the available estimates. In case of the standard deviation of the productivity of great skua and the adult survival of common tern, these estimates were slightly adjusted to fit the assumptions of the parameter distributions.*

Species (EN)	Juvenile Survival (proportion/year ± sd)		Immature Survival (proportion/year ± sd)		Adult Survival (proportion/year ± sd)		Productivity (Fledgelings per breeding pair/year ± sd)		Incidence of missed breeding (proportion ± sd)		Age of first breeding
	KEC 4.0	KEC 5.0	KEC 4.0	KEC 5.0	KEC 4.0	KEC 5.0	KEC 4.0	KEC 5.0	KEC 4.0	KEC 5.0	KEC 4.0 & 5.0
Great black-backed gull	0.34 (±0.05)	0.34 (±0.05)	0.8 (±0.03)	0.8 (±0.03)	0.86 (±0.02)	0.86 (±0.02)	0.979 (±0.4)	0.990 (±0.4)	0.10 (±0.05)	0.10 (±0.05)	4 (ad stage)
Lesser black-backed gull	0.521 (±0.0375)	0.521 (±0.0375)	0.856 (±0.052)	0.856 (±0.052)	0.914 (±0.02)	0.914 (±0.02)	0.807 (±0.18)	0.656 (±0.39)	0.435 (±0.1)	0.435 (±0.1)	5 (ad stage)
Herring gull	0.375 (±0.06)	0.53 (±0.06)	0.8 (±0.052)	0.81 / 0.87 / 0.87 / 0.87 (±0.052)	0.846 (±0.03)	0.80 (±0.03)	0.8532 (±0.2)	0.767 (±0.27)	0.1 (±0.05)	0.1 (±0.05)	4 (ad stage)
Little gull	0.738 (±0.02)	0.738 (±0.02)	0.738 (±0.02)	0.738 (±0.02)	0.827 (±0.01)	0.827 (±0.01)	0.75 (±0.2)	0.75 (±0.2)	0.10 (±0.05)	0.10 (±0.05)	2 (ad stage)
Black-legged kittiwake	0.79 (±0.05)	0.79 (±0.05)	0.7 (±0.04)	0.7 (±0.04)	0.854 (±0.05)	0.829 (±0.05)	0.66 (±0.2)	0.587 (±0.33)	0.10 (±0.05)	0.10 (±0.05)	4 (ad stage)
Great skua	0.97 (±0.05)	0.97 (±0.05)	0.78 (±0.05)	0.78 (±0.05)	0.882 (±0.055)	0.882 (±0.055)	0.536 (±0.3)	0.650 (±0.29)	0.089 (±0.01)	0.089 (±0.01)	6 (ad stage)
Arctic skua	0.57 (±0.05)	0.57 (±0.05)	0.77 (±0.05)	0.77 (±0.05)	0.9 (±0.05)	0.9 (±0.05)	0.488 (±0.1)	0.821 (±0.1)	0.25 (±0.05)	0.25 (±0.05)	4 (ad stage)
Common tern	0.685 (±0.05)	0.685 (±0.05)	0.72 (±0.05)	0.72 (±0.05)	0.915 (±0.05)	0.903 (±0.29)	0.646 (±0.2)	0.649 (±0.443)	0.1 (±0.03)	0.1 (±0.03)	4 (ad stage)

[1]*During the first two years of adulthood the species is only 0.3 times as productive as older adults, hence the productivity at these ages is corrected to 30% of the productivity.*

Table 4.2, *continued*

Species (EN)	Juvenile Survival (proportion ± sd) KEC 4.0	Juvenile Survival (proportion ± sd) KEC 5.0	Immature Survival (proportion ± sd) KEC 4.0	Immature Survival (proportion ± sd) KEC 5.0	Adult Survival (proportion ± sd) KEC 4.0	Adult Survival (proportion ± sd) KEC 5.0	Productivity (proportion ± sd) KEC 4.0	Productivity (proportion ± sd) KEC 5.0	Incidence of missed breeding (proportion ± sd) KEC 4.0	Incidence of missed breeding (proportion ± sd) KEC 5.0	Age of first breeding KEC 4.0 & KEC 5.0
Bewick's swan	0.908 (±0.05)	0.908 (±0.05)	0.936 (± 0.05)	0.936 (± 0.05)	0.873 (±0.05)	0.840 (±0.05)	0.278 (±0.1)	0.278 (±0.1)	Included in Fecundity	Included in Fecundity	2 (ad stage)
Brent goose	0.51 (±0.05)	0.548 (±0.16)	0.849 (±0.05)	0.849 (±0.05)	0.868 (±0.03)	0.847 (±0.04)	0.588 (±0.1)	0.588 (±0.1)	Included in Fecundity	Included in Fecundity	2 (ad stage)
Common shelduck	0.25 (±0.05)	0.25 (±0.05)	0.67 (±0.05)	0.67 (±0.05)	0.873 (±0.05)	0.873 (±0.05)	3.7 (±0.1)	3.7 (±0.1)	0.35 (±0.05)	0.35 (±0.05)	2 (ad stage)
Curlew	0.5595 (±0.05)	0.517 (+-0.05)	0.771 (±0.05)	0.771 (±0.05)	0.912 (±0.05)	0.912 (±0.05)	0.34 (±0.1)	0.28 (±0.1)	0.1 (±0.05)	0.1 (±0.05)	2 (ad stage)
Red knot	0.782 (±0.03)	0.782 (±0.03)	0.842 (±0.01)	0.842 (±0.01)	0.842 (±0.01)	0.842 (±0.01)	0.284 (±0.03)	0.284 (±0.03)	0.1 (±0.03)	0.1 (±0.03)	2 (ad stage)
Bar-tailed godwit	0.57 (±0.05)	0.57 (±0.05)	0.8275 (±0.02)	0.839 (±0.01)	0.8275 (±0.02)	0.839 (±0.01)	0.8 (±0.03)	0.8 (±0.03)	0.1 (±0.05)	0.1 (±0.05)	2 (ad stage)
Black tern	0.595 (±0.05)	0.595 (±0.05)	0.595 (±0.05)	0.595 (±0.05)	0.768 (±0.05)	0.846 (±0.05)	0.93 (±0.1)	0.93 (±0.1)	0.8 (±0.05) / 0.1 (±0.05)	0.8 (±0.05) / 0.1 (±0.05)	Most 3, some 2 (ad stage, or year before)
Common starling	0.102 (±0.034)	0.287 (±0.034)	No immature stage	No immature stage	0.607 (±0.151)	0.628 (±0.151)	4.43 (±0.075)	3.954 (±0.075)	Included in Fecundity	Included in Fecundity	1 (ad stage)

5 KEC Assessment Analysis & Results

The total estimated number of victims is calculated for each scenario, and divided by the population estimate to give a fraction mortality (see chapter 3.2). The use of a stochastic collision rate model results in a distribution of fractions. The median values are reported in Table 5.1 to Table 5.5 for the national and international scenarios.
Since different types of analyses and different types of uncertainty were used for different species, we split up the results according to 1) National and International scenarios and 2) type of underlying density map used.

The distinction between density maps is because for some (but not all) species, a newly developed method for density maps was used (see chapter 3.2), which provides information on variation in density, while the previously used density maps did not. This variation in density automatically leads to more spread in the data, and hence automatically to a larger, more realistic percentage of simulations violating the ALIs.

Note that this means that the larger variation in the estimated fraction mortality for these new density maps is mainly the result of taking into account this variation in density. A larger spread in this estimated fraction mortality may seem to indicate lower uncertainty, but it actually presents a more realistic representation of the uncertainty. This means that the variation in uncertainty around the fraction mortality should not be compared between different approaches (i.e. different methods of constructing density maps). For that reason, we distinguish between the type of density maps used. Firstly, the density maps for the international scale are of lower quality, and secondly uncertainty in the underlying density maps was not available for the international scenarios.

No ALI testing applied for the international context
Within KEC 5.0, no ALIs are tested for the international context. This is due to two reasons:

1. The revised ALI methodology depends strongly on a proper representation of the uncertainty (Hin *et al*., 2024), and it strongly matters whether such uncertainty is taken into account. The international density maps are of lower quality, and uncertainty in the underlying density maps was not available for this international scenario.
2. Another difficulty for applying ALIs for the international context is that the thresholds for the ALIs are defined based on the national conservation status and context (Sovon, 2024), making them difficult to apply to an international context.

To counter the incompatibility of the current ALI definitions with an international context, we do however provide the estimated percentage additional mortality for both the national and the international scenarios. This gives an impression of the relative estimated impact on the international scale in comparison to the impact on the national scale.

5.1 National Scenarios Collision Mortality

5.1.1 Seabird species for which updated WMR density maps are available

Table 5.1 Median percentage mortality for seabird species in national scenarios employing updated density maps by van Donk et al. (2024). Note that 0.4 means 0.4%, hence a proportion of 0.004.

Species	Percentage mortality		
	Basic NAT	Basic plus NAT	Total NAT
Northern gannet	0.07532	0.28770	0.39574
Black-legged kittiwake	0.00066	0.00218	0.00289
Lesser black-backed gull	0.01322	0.05342	0.06063
Herring gull	0.00200	0.00441	0.00499
Great black-backed gull	0.01183	0.04798	0.11639
Sandwich tern	0.00675	0.01089	0.01097

5.1.2 Seabird species for which updated WMR maps were not available

Table 5.2 Median percentage mortality for seabird species in national scenarios employing updated density maps based on the KEC 4.0-methodology (IDW) or Waggit et al. *(2020). Note that 0.2 means 0.2%, hence a proportion of 0.02.*

Species	Percentage mortality		
	Basic NAT	Basic plus NAT	Total NAT
Arctic skua	0.00000	0.03268	0.08158
Great skua	0.02088	0.06733	0.10327
Little gull	0.06804	0.22956	0.24604
Common tern	0.03353	0.05177	0.06815

5.1.3 **Migratory birds**

Table 5.3 Median percentage mortality for migratory species on the Dutch Continental Shelf for national scenarios. Note that 0.02 means 0.02%, hence a proportion of 0.0002.

Species	Percentage mortality		
	Basic NAT	Basic plus NAT	Total NAT
Bewick's swan	0.00063	0.00424	0.00697
Brent goose	0.00002	0.00004	0.00008
Common shelduck	0.00207	0.01016	0.01525
Curlew	0.00011	0.00053	0.00080
Bar-tailed godwit	0.00010	0.00048	0.00072
Red Knot	0.00009	0.00043	0.00065
Black Tern	0.00041	0.00204	0.00249
Common starling	0.00211	0.01077	0.01624

5.2 International Scenarios Collision Mortality

The median percentage mortality for the international scenarios is reported in Table 5.4, including the relative comparison with the estimated percentage mortality for the Total national scenario. When the value is above 1, the median percentage mortality is higher for the international scenario, indicating that the estimated impact on the international scale is higher than on the national scale.

Given that the ALI testing is only carried out for the national scale, the relative proportion mortality on national versus international scale gives an indication of the impact on international scale.

- If the relative impact on international scale is higher than on national scale, the proportion unacceptable declines within the ALI methodology would be higher for the international scale, and hence the ALI may be violated on international scale while this is not the case for the national scale.
- On the other hand, if the relative impact on international scale is lower, an ALI violation for the national scale does not necessarily mean an ALI violation for the international scale.

However, note that the ALI thresholds are set based on the Dutch conservation status, and may not reflect the international conservation status. For that reason, we provide this comparison of fraction mortality to give an indication, but have not carried out the ALI testing. In addition, in reality seabirds are using the entire area, and are not restricted by a national border.

Seabirds: impact on international scale > impact on national scale

Regarding seabirds, the modelled impact on the international scale is higher than on the national scale for northern gannet, arctic skua, black-legged kittiwake, little gull, lesser black-backed gull, herring gull, great black-backed gull and Sandwich tern. This is caused by a higher fraction of the population on the international scale occurring in the area in/around (planned) wind farms instead of areas outside these wind farms, in comparison to the national scenario. As a result, the fraction estimated victims is higher for the international scenario. This also means that the estimated impact on the international scale is higher than on the national scale.

The estimated impact on the international scale is a lot higher than for the national scale for three species in particular: herring gull, great black-backed gull and Sandwich tern. For these species, the estimated median percentage mortality is between 28 and 35 times higher for the international scenario. This indicates that wind farms outside the Netherlands are putting a much higher pressure on the international population than the Dutch wind farms on the national population. For these species, it is of particular importance to gain more insight in the impacts on international scale.

Seabirds: impact on international scale < impact on national scale

In the case of great skua and common tern, the median percentage mortality is lower for the international scenario, which indicates that the estimated impact on the international scale is smaller than for the national scale. This higher fraction mortality for the national scale indicates that the use of the area in/around (planned) wind farms is higher on the national scale than on the international scale, and hence the estimated fraction mortality is higher as well.

Migratory birds

For migratory birds, the methodology always results in a higher estimated impact for the international scale, as the population size is constant between the national and international scale. The estimated percentage mortality is up to 6 times higher for the international scenario.

Table 5.4 *Median percentage mortality for international scenarios for the seabird approach. The international scenario was for these species based on density maps from Waggit* et al. *(2020) or density maps WMR based on IDW (KEC 4.0 methodology). Note that 4.1 means 4.1%, hence a proportion of 0.041. The last column gives a comparison of the percentage mortality for the international scenario in relation to the percentage mortality for the national scenario. Values above 1 indicate that the projected impact for the international scale is higher than for the national scale.*

	Percentage mortality	Relative comparison to Total NAT scenario
Species	Total INT	Total INT / Total NAT
Northern gannet	0.86095	2.18
Arctic skua	0.09189	1.13
Great skua	0.06836	0.66
Black-legged kittiwake	0.00926	3.20
Little gull	0.26884	1.09
Lesser black-backed gull	0.29086	4.80
Herring gull	0.13971	**28.00**
Great black-backed gull	4.10101	**35.24**
Common tern	0.13043	1.91
Sandwich tern	0.40131	**30.35**

Table 5.5 *Median percentage mortality for migratory species on the Dutch Continental Shelf for international scenarios. The last column gives a comparison of the percentage mortality for the international scenario in relation to the percentage mortality for the national scenario. Values above 1 indicate that the projected impact for the international scale is higher than for the national scale.*

	Percentage mortality	Relative comparison to Total NAT scenario
Species	Total INT	Total INT / Total NAT
Bewick's swan	0.00827	1.90
Brent goose	0.00014	3.31
Common shelduck	0.09635	5.94
Curlew	0.00506	5.93
Bar-tailed godwit	0.00450	5.93
Red Knot	0.00406	5.92
Black Tern	0.00584	2.17
Common starling	0.10170	5.92

5.3 Effect of additional mortality on population size and ALI threshold assessments

Seabirds

Table 5.6 Outcome of tests against ALI threshold for the national scenarios for seabirds. The columns with probability unwanted decline give the percentage of simulations resulting in violation of the X-threshold per scenario. This probability is for each scenario compared with the species-specific threshold, and the outcome is presented in the columns outcome ALI test as PASS or FAIL. FAIL indicates that the probability of an unwanted decline is higher than 5%, which means that the ALI is violated. This ALI tests only include additional mortality due to collisions. Note that for northern gannet and sandwich tern the impact of habitat loss is tested in a separate study.

Species	Probability unwanted decline			Outcome ALI test		
	Basic NAT	Basic plus NAT	Total NAT	Basic NAT	Basic plus NAT	Total NAT
Northern gannet	0.1	0.994	1	PASS	**FAIL**	**FAIL**
Arctic skua	0	0	0	PASS	PASS	PASS
Great skua	0	0.005	0.230	PASS	PASS	**FAIL**
Black-legged kittiwake	0	0	0	PASS	PASS	PASS
Little gull	0	0	0	PASS	PASS	PASS
Lesser black-backed gull	0	0	0	PASS	PASS	PASS
Herring gull	0.011	0.011	0.011	PASS	PASS	PASS
Great black-backed gull	0	0	0	PASS	PASS	PASS
Common tern	0	0	0	PASS	PASS	PASS
Sandwich tern	0	0	0	PASS	PASS	PASS

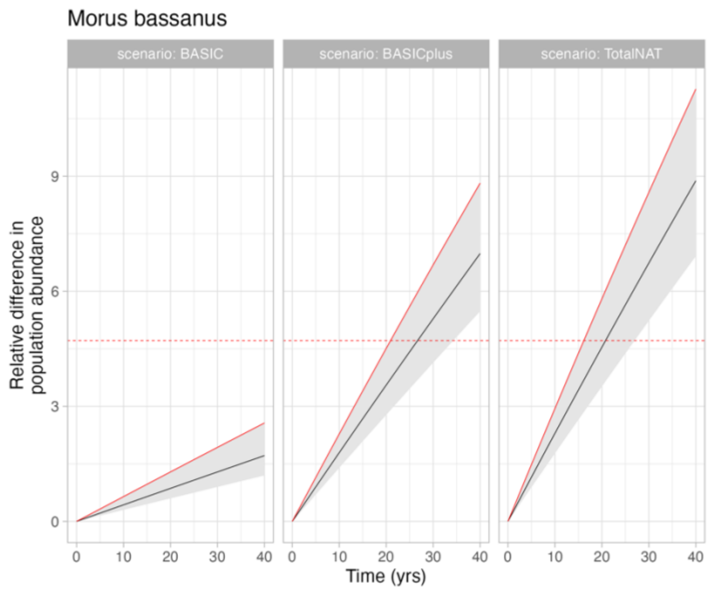

Figure 5.1 *Main output of the population model, calculated as the relative difference in final population size between the unimpacted and the impacted scenario, for each of the scenarios (panels). Solid black line represents the median outcome, red solid line the 95th percentile, and the red dashed line indicates the threshold.*

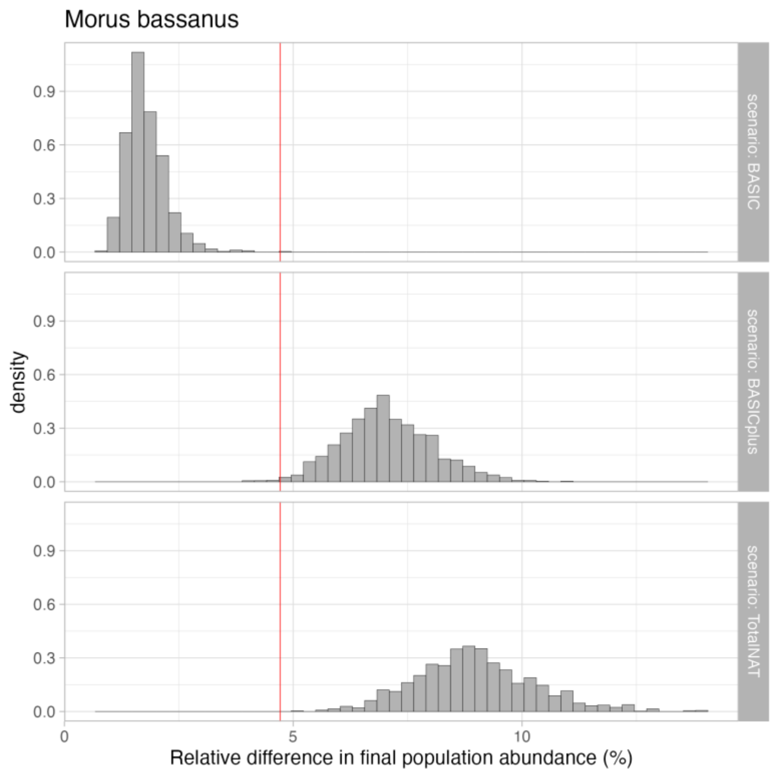

Figure 5.2 *Density distribution of relative differences in final population abundance (grey bars). Red line indicates the threshold for an unacceptable decline. The ALI is violated when more than 5% of the simulations have an unacceptable decline (above the red line), which is the case for the BASICplus and TotalNAT scenarios.*

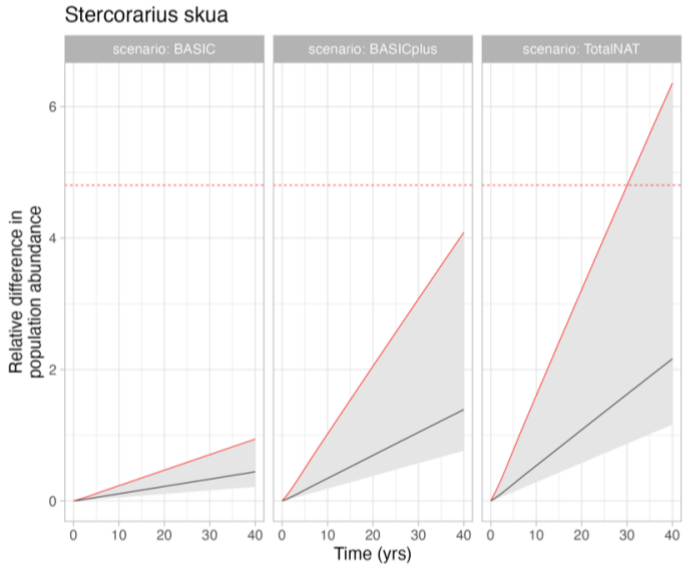

Figure 5.3 *Main output of the population model, calculated as the relative difference in final population size between the unimpacted and the impacted scenario, for each of the scenarios (panels). Solid black line represents the median outcome, red solid line the 95th percentile, and the red dashed line indicates the threshold.*

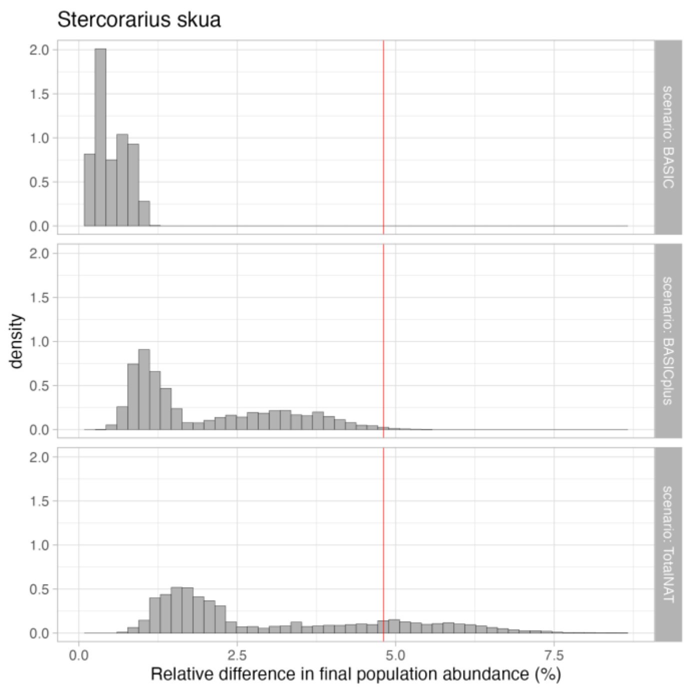

Figure 5.4 *Density distribution of relative differences in final population abundance (grey bars). Red line indicates the threshold for an unacceptable decline. The ALI is violated when more than 5% of the simulations have an unacceptable decline (above the red line), which is the case for the TotalNAT scenario.*

Migratory birds

Table 5.7 *Outcome of tests against ALI threshold for the national scenarios for migratory birds. The columns with probability unwanted decline give the percentage of simulations resulting in violation of the X-threshold per scenario. This probability is for each scenario compared with the species-specific threshold, and the outcome is presented in the columns outcome ALI test as PASS or FAIL. FAIL indicates that the probability of an unwanted decline is higher than 5%, which means that the ALI is violated.*

	Probability unwanted decline			Outcome ALI test		
Species	Basic NAT	Basic plus NAT	Total NAT	Basic NAT	Basic plus NAT	Total NAT
Bewick's swan	0	0	0	PASS	PASS	PASS
Brent goose	0	0	0	PASS	PASS	PASS
Common shelduck	0	0	0	PASS	PASS	PASS
Curlew	0	0	0	PASS	PASS	PASS
Bar-tailed godwit	0	0	0	PASS	PASS	PASS
Red Knot	0	0	0	PASS	PASS	PASS
Black Tern	0	0	0	PASS	PASS	PASS
Common starling	0	0	0	PASS	PASS	PASS

Table 5.8 *Outcome of tests against ALI threshold for the international scenarios for migratory birds. The columns with probability unwanted decline give the percentage of simulations resulting in violation of the X-threshold per scenario. This probability is for each scenario compared with the species-specific threshold, and the outcome is presented in the columns outcome ALI test as PASS or FAIL. FAIL indicates that the probability of an unwanted decline is higher than 5%, which means that the ALI is violated.*

	Probability unwanted decline	Outcome ALI test
Species	Total INT	Total INT
Bewick's swan	0	PASS
Brent goose	0	PASS
Common shelduck	0	PASS
Curlew	0	PASS
Bar-tailed godwit	0	PASS
Red Knot	0	PASS
Black Tern	0	PASS
Common starling	0	PASS

6 Interpretation of results and recommendations

In this report we have updated the models and data used for and executed the analysis of assessing any violation of the policy thresholds set by the Dutch government for acceptable impacts on selected marine bird species.

6.1 ALI assessment, violations and underlying density maps

For interpretation of the results, it is important to reiterate some core concepts of the ALI approach. Key in interpreting the violation of the ALI is the understanding that the level of unacceptable decline refers to the difference in final population size between the unimpacted (null) scenario and the impacted scenario. Hence note that this does not refer to the projected trend in population size over time, i.e. whether the population is declining or increasing per se.

If we now consider the results, we found that the estimated collision mortality resulted in violation of the ALI threshold in one or more scenarios for northern gannet and great skua. For both of these species, the set ALI thresholds are relatively strict (see Table 2.4), as both of these species experienced massive mortality during 2021 and 2022 caused by High Pathogenicity Avian Influenza (Camphuysen & Gear 2022, Lane *et al*. 2023). This dramatic effect at population level asks for more caution and hence gave reason to set a lower level of acceptable decline due to offshore wind farms.

For **northern gannet**, this violation occurred in the *Basic plus* scenario and the *Total* national scenario. In these scenarios resp. 99.4% and 100% of the simulations resulted in an unacceptable decline in relation to the scenario without additional mortality, with an unacceptable decline defined as 4.7% decline over 40 years.

The Dutch conservation status of northern gannet is favourable (for the non-breeding population). The projected population trend is increasing (population growth rate is 1.03). The observed trend in number of individuals in the Dutch Continental Shelf is increasing since 1991, although there is no significant trend over the last 12 years (Sovon 2024). Note that with the impact, the projected population trend is still positive.

For the northern gannet, the violation already takes place in the *Basic plus* scenario, i.e. all Dutch wind farms up to and including the licensed Nederwiek South. For this species, the most up-to-date density maps were available (van Donk *et al.* 2024), which showed the highest densities and hence collision victims in the wind farms of the Northeastern part of the Dutch Continental Plate (Figure 6.1). Namely, in IJmuiden Ver Alpha and Beta 91 annual collision victims are expected, while in IJmuiden Ver Gamma, Nederwiek South and

North, 45, 58 and 66 annual victims, respectively. In comparison, the next wind farm in terms of annual number of collision victims is Hollandse Kust West with 13 victims.

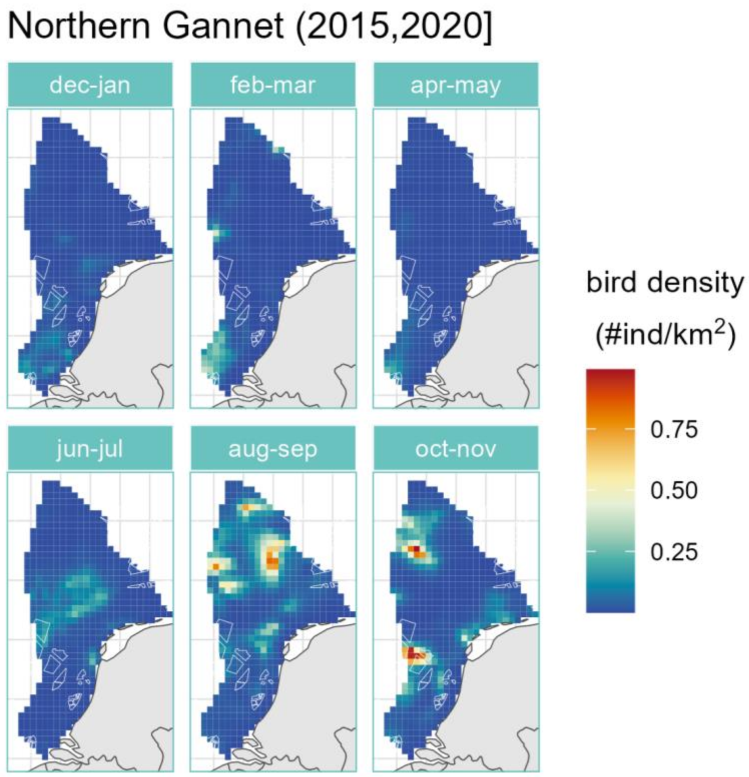

Figure 6.1 *Spatial distribution of northern gannet for the Dutch Continental Shelf for each bimonthly period, based on the density maps by van Donk* et al. *(2024). Colours represent bird density for each grid cell, with red for high densities and blue for low densities.*

For **great skua**, the ALI violation took place in the *Total* scenario. For this species, the ALI threshold for the unacceptable decline over 40 years was defined at 4.8% (based on ministry decision and species-specific generation time), and such a decline was projected in 23% of the simulations.

The Dutch conservation status of great skua is favourable (only classified for the non-breeding population). Similar to the situation with northern gannet, the advice for a relatively strict ALI threshold (X = 5% over three generations) by Sovon (2024) was based on the impact of avian influenza. The projected population trend is declining (population growth rate is 0.963). The observed trend in number of individuals in the Dutch Continental Shelf is stable (Sovon 2024). The European trend is unknown but expected to be stable (BirdLife International 2024). Note that based on the demographic rates, the projected population size is already declining over time for the unimpacted scenario, and the additional mortality causes the impacted population to decline stronger.

For the great skua, the violation occurs in the most extensive national scenario, i.e. the co-called *Total scenario*, including all operational and planned wind farms on the Dutch

Continental Plate until the end of 2031. For this species, the bird density is relatively low throughout the Dutch Continental Shelf (Figure 6.2). As a result, this violation is a summation of very low median numbers of predicted collision victims in each wind farm (all less than less than one annual casualty, ranging from 0.001 victims to 0.2). In fact, the median total number of annual collision victims of great skua in all Dutch wind farms is only 1.2. However, the spread of the number of annual collision victims is relatively large when compared to the low numbers of predicted victims, cascading in a relatively large variation in cumulative collision victims and therefore a large variation in the outcome of the population model population size development. Stronger variation means a larger probability to produce also higher estimated numbers of victims. Given that the ALI violations occur in the simulations with the highest estimated number of victims, this large variation results in a higher probability of ALI violation. Note that for the great skua population in the North Sea, the Dutch part of the North Sea is not of main importance; most individuals are present outside of the Dutch part.

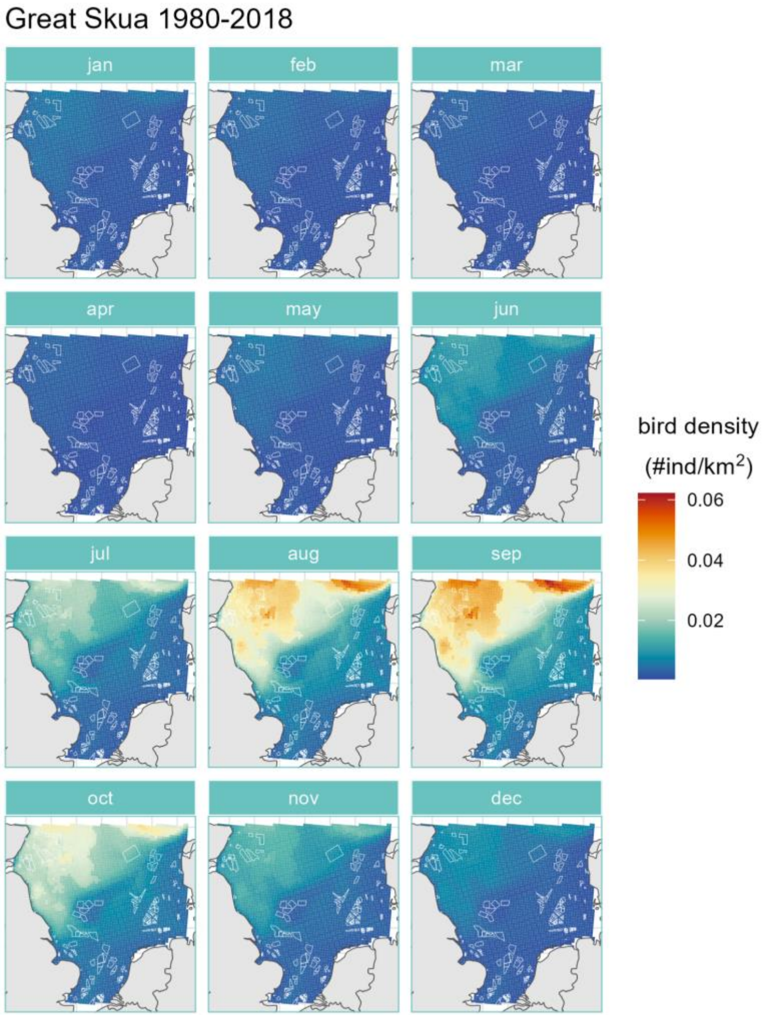

Figure 6.2 *Spatial distribution of great skua for the Southern and Central North Sea for each month, based on the data from Waggit* et al. *(2020). Colours represent bird density for each grid cell, with red for high densities and blue for low densities.*

International scale

No ALI assessment is done for the international scale, given the difference in density maps between the national and the international scale, as well as the ALI thresholds being based on the Dutch conservation status (see Chapter 5).

However, the comparison of the fraction mortality between the national and international scenario gives a good impression of the extent of the impact on the international scale. The estimated impact on the international scale is a lot higher than for the national scale for three species in particular: herring gull, great black-backed gull and sandwich tern. For these species, the estimated median percentage mortality is between 28 and 35 times higher for the international scenario. Hence, for these species the estimated impact is much higher on the international scale compared to the national scale. To a lesser extent, this is also the case for northern gannet, arctic skua, black-legged kittiwake, little gull and lesser black-backed gull. For these species, it is of particular importance to gain more insight in the impacts on international scale.

Need for improving knowledge base

The available information used for the collision rate models is very limited for the great skua. Moreover, no density maps could be developed using the most recent techniques (cf. van Donk et al. 2024) for this species. Hence future extensions in the knowledge base, such as developing new density maps, may lead to considerable improvements in the modelling exercise for this species. However, this does not hold for the northern gannet, a species that is extensively studied and its spatial distribution in the Dutch North Sea is well known.

6.2 Reducing population level impacts

As described in the previous chapter, the ALI thresholds are violated for two seabird species, namely the northern gannet and the great skua. This violation indicates that the estimated impact exceeds the set threshold based on the population status.

The northern gannet is recognized as a vulnerable species to collisions with offshore wind turbines (Lane *et al.* 2020, Peschko *et al.* 2021, Pollock *et al*. 2021). As such, there are also suggestions in the literature for possible mitigation and compensation measures, of which the latter mainly refer to possibilities in breeding colonies. As neither species breed in the Netherlands, we discuss here only mitigation options. One of the most important of these options is appropriate siting of the wind farms. However, this is also not relevant for already licensed wind farms in the Netherlands, and hence we concentrate on possibilities that refer to wind farm or wind turbine configurations. For example, Goodale & Milman (2020) proposed that collision risk could be decreased by reducing lighting, by providing flight corridors within a wind farm and by using larger turbines instead of small turbines. However, the effectiveness of reducing lighting and providing flight corridors in reducing the numbers of collisions is lacking empirical proof yet and hence cannot be incorporated in future collision risk calculations either.

One aspect of the CRMs for which data are available, and which can also be linked to a currently applied mitigation measure, is to use the knowledge of flight height distributions to adjust the minimum tip height of turbines. For instance, both for the great skua (Ross-Smith *et al.* 2016) and the northern gannet (Cleasby *et al*. 2015, Johnston & Cook 2016) holds that with increasing altitude the proportion of flights decreases. However, for the great skua increasing the minimum tip height would not lead to a substantial reduction in the predicted number of collisions, as according to our dataset already ±93% of the flights occurs below 25 m (cf. Johnston *et al.* 2014), which is the currently used minimum tip height in Dutch offshore wind farms. Nonetheless, such measure could be in theory beneficial for the northern gannet as for this species only approximately 70% of the flights occurs below 25 m, and hence a considerable fraction of the flights takes place at rotor height. According to our dataset, increasing the minimum tip height with for example 5 m could lead to a reduction of 5% in the number of collisions. Yet, this is a theoretical calculation, and this measure has neither empirical proof, while for wind farm developers it is a costly way of mitigation.

An alternative that is proposed when it comes to species-specific mitigation measures, is to use turbine shutdown on demand (Marques *et al.* 2014). Recently, high-definition cameras have been successfully applied in offshore wind farms to identify seabird species during daytime (*e.g*. Skov & Tjørnløv 2022, Tjørnløv *et al.* 2023). Such systems can nowadays also automatically recognize species using Artificial Intelligence software and also initiate a shutdown on demand procedure of specific wind turbines. This measure could effectively reduce the number of collisions during daytime (when most of the seabirds are active) as the collision risk with wind turbines in idle mode is assumed to be negligible.

6.3 Discussion and recommendations for future research

In the current study, the estimated impact results in violation of the ALI thresholds for the national scenarios, while this was not the case for the great skua in the KEC 4.0 (Potiek *et al*. 2022a) and the latter calculations for the northern gannet (Leemans *et al*. 2022a). This is caused by the combination of more caution (stricter threshold) and the level of impact (estimated collision victims).

For the current report, we carried out an extensive update of the knowledge base for the collision risk calculations and the population models. Although this has delivered a number of improvements in our dataset, it is clear that some species are extensively studied, while information on other species remains scarce. Moreover, also collecting precise data on some of the parameters used in the models is ever challenging. For example, flight speed is relatively easy to measure and for most species we have a relatively good understanding of the species-specific values and their variations, other parameters for the collision risk models are much more difficult to measure, while they have a much larger influence on the outcome. For instance, for many species we still lack empirical information on nocturnal activity and the used values originate from expert judgments from 20 years ago (Garthe & Hüppop 2004). Filling such knowledge gaps could be solved by dedicated research. However, assessing species-specific avoidance rates at the sensitivity level how the collision risk models use it, seems nearly impossible. Therefore, measuring actual collision rates in offshore wind farms, relative to species-specific activity levels, should be the highest priority in future research to improve collision risk models and consequently the input for population models.

Collision risk models

Until the vast knowledge gap of actual collision rates is filled, using all available data to carry out the modelling the best possible way is of utmost importance. Therefore, in the future, it might be worth to consult databases containing GPS-logger data or to consider requesting such data from the authors. Such GPS-logger data might provide valuable information for the parameters of the collision risk models, either directly, such as for flight speed and flight height distributions, or after post-processing and additional calculations, such as for nocturnal activity and fraction of time in flight.

Although such GPS-logger data can fill important knowledge gaps or improve the current estimates for collision risk parameters, one of the major inputs in the models is bird density for seabirds or annual flux for migratory birds and the variation around these values. For six of the ten seabird species, Wageningen Marine Research developed new density maps for the Dutch Continental Plate. This allowed us to use a probability distribution of bird densities, instead of a static value as in previous KEC versions. Due to this variation, we could use 1,000 possible densities for each Dutch wind farm in our model, which is a more realistic representation of locally fluctuating bird densities than one value for a bi-monthly period. Such a variation in densities leads also to a wider spread in the predicted absolute casualty numbers, which on its turn helps to make the population models and the test on the ALI threshold violations more valuable. The development of the same type of density maps for the other seabird species is therefore recommended. Currently, the strange situation arose that due to the limited (or lack of) variation in densities in the older type of density maps (*i.e.* Waggit *et al*. 2020 and WMR IDW maps), the results of the collision risk models and consequently the population models wrongly suggest that there is more certainty in these outcomes than based on the new density maps by van Donk *et al.* (2024). Moreover, the limited (or lack of) variation in density maps propagates into limited variation in the collision estimate. Subsequently, the uncertainty affects the outcome of the ALI testing, with a lower probability of ALI violation when the variation in the collision estimate is limited.

Developing new maps is especially important for the international waters of the North Sea. While the Dutch seabird monitoring system is well-advanced, some parts of the North Sea are rarely surveyed, leading to large gaps in the available data on bird distribution in offshore waters. For this reason, van Donk *et al.* (2024) could only develop new maps for the Dutch Continental Plate. Consequently, the current KEC 5.0 evaluation needed to be carried out with three different types of density maps for seabirds (see Table 3.2), all developed with different techniques. This resulted in that even for the species with new density maps, we had to use another map for the international scenario. However, due to basic differences in the maps, this led to diverging population sizes (even within one species) between the national and international scenarios. In combination with the beforementioned lack of reliable data in international waters, this ensued the decision not to carry out the test on the ALI threshold violation for the international scenario (same as with the habitat loss project of Soudijn *et al.* 2025). However, in environmental impact assessments a proper test of cumulative scenarios is legally binding. Therefore, in the case of offshore wind farms, often planned along international borders, a cumulative impact assessment that trespasses the national level is essential and hence should be solved in the future.

In the current assessment, the annual fractions collision victims are calculated based on the estimated mortality in all wind farms within a scenario altogether. This reflects a situation in which all wind farms within the scenario are built at the start of the simulation, and are operational until the end of the simulation. In the future, this can be refined by taking into account the expected year of construction, as well as the expected year of demolishing.

Population models

In this study, only the impact of collisions with offshore wind farms is assessed. In a separate study, Soudijn *et al.* (2025) assessed the impact of habitat loss due to offshore wind farms. For northern gannet and sandwich tern, both these factors are considered to impact the population. Ideally, these two types of impact should be combined in one assessment. Moreover, any other pressures such as fisheries and climate change are not explicitly taken into account. Note that any future worsening (or weakening) of such impact factors is not modelled. Inclusion of such future trends is likely to make the model projection more realistic. This could be achieved by using a different type of population models, namely integrated population models. However, this requires knowledge of the size of the impact of current pressures, which is often not available. For KEC 5.0, it was decided to continue using the same type of population models as used in KEC 4.0. For KEC 6.0, the use of a different type of model can be reconsidered.

Validation population model to currently observed trend

Although we aimed to define the demographic rates based on the relevant population inhabiting the Dutch Continental Shelf (national scenarios) or the South and Central North Sea (international scenarios), the projected population trend may differ from the observed population trend:

- This can arise when the input parameters do not sufficiently match the actual population of interest, for example when the input parameters are outdated or from a less representative population. Within the weighting of data sources, we took into account how recent the data are, and how representative the population is. If available, we only used data from populations from areas around the North Sea.
- Alternatively, the population may not be ‘closed’, which means that net immigration or net emigration takes place. Moreover, events such as mass mortality due to diseases (e.g. Avian Influenza) or oil spills can result in extreme mortality, which is not accurately predictable by the current population models.

Ideally, the population models should be validated to match the observed trend. This is one of the development aims. In the near future we advise to compare the projected population trend with the observed trends in the Southern and Central North Sea based on MWTL/ESAS, and will adjust the parameters to fit the observed trend.

Species selection migratory birds

The current species selection of migratory birds stems from the KEC 1.0 (Rijkswaterstaat 2015) and may need to be reconsidered based on the present-day vulnerability of migratory birds for offshore wind farms. Brinkman & Schekkerman (2024) have recently identified species with a high vulnerability, several of which are currently not included in the KEC analysis. However, their classification of vulnerability was not based on estimated mortality due to offshore wind farms, and hence differs from the classification of vulnerability in KEC 1.0 where the species selection was based on the proportion additional mortality due to wind farms related to the Potential Biological Removal (PBR) (Rijkswaterstaat 2015) and representativeness for several species groups. Moreover, Brinkman & Schekkerman (2024) considered only migratory species occurring in the Dutch North Sea, while the KEC studies concentrate on the whole Central and Southern North Sea. The six species in the category of highest vulnerability defined by Brinkman & Schekkerman (2024) were: common ringed plover, common redshank, ruddy turnstone, little gull, black-headed gull, northern wheatear and common starling. Of these, only little gull and common starling are in our current species selection for KEC. Therefore, we suggest reconsidering the species selection of the KEC, based on the review by Brinkman & Schekkerman (2024), but also on potential other recent insights in the occurrence and flight intensity (especially at rotor height) of migratory species in the Central and Southern North Sea. Note that this should be done for all species making use of the area, and not only for the species classified as vulnerable by Brinkman & Schekkerman (2024), as also species with a favourable Dutch population status should be assessed (which were excluded by Brinkman & Schekkerman (2024)). This reconsideration of the species selection was not feasible for KEC 5.0, as this requires the creation of new population models for additional species. In the period between KEC 5.0 and KEC 6.0, the species selection can be reconsidered and potentially adjusted.

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Appendix I Knowledge base update values

All the knowledge base update values are presented in an extended overview at the Wozep repository:
https://doi.org/10.5281/zenodo.14732337
This DOI represents all versions, and will always resolve to the latest version. Here, species-specific tables are provided, with for each species:

- Files ending on _CRM: values considered for the Collision risk model (CRM) calculations.
- Files ending on _Fecundity and _Survival: values relevant for the population models regarding to fecundity and survival
- .txt file: description for these tables, including references cited numerically in the abovementioned files.

Appendix II Wind farm characteristics used within collision rate modelling

All characteristics of the windfarms used for the collision rate estimations are available at the Wozep repository:
https://doi.org/10.5281/zenodo.13870492

The data provided was either acquired from the windfarm shape in GIS, was delivered data from earlier KEC versions, or extrapolated from data delivered by RWS for this KEC and for earlier KEC versions.

Appendix III Methods of extrapolation of windfarm characteristics

Extrapolation of rotation speed, blade width and pitch were done based on existing data. Using excel, a trend line for each of these variables was created, relating one of the variables to the power of the turbine. In this way a formula was calculated, based on which the missing data could be extrapolated. For rotation speed, the data point from turbines of 20 MW was not used to create the trendline, as this value did not fit the trend with lower turbine powers.

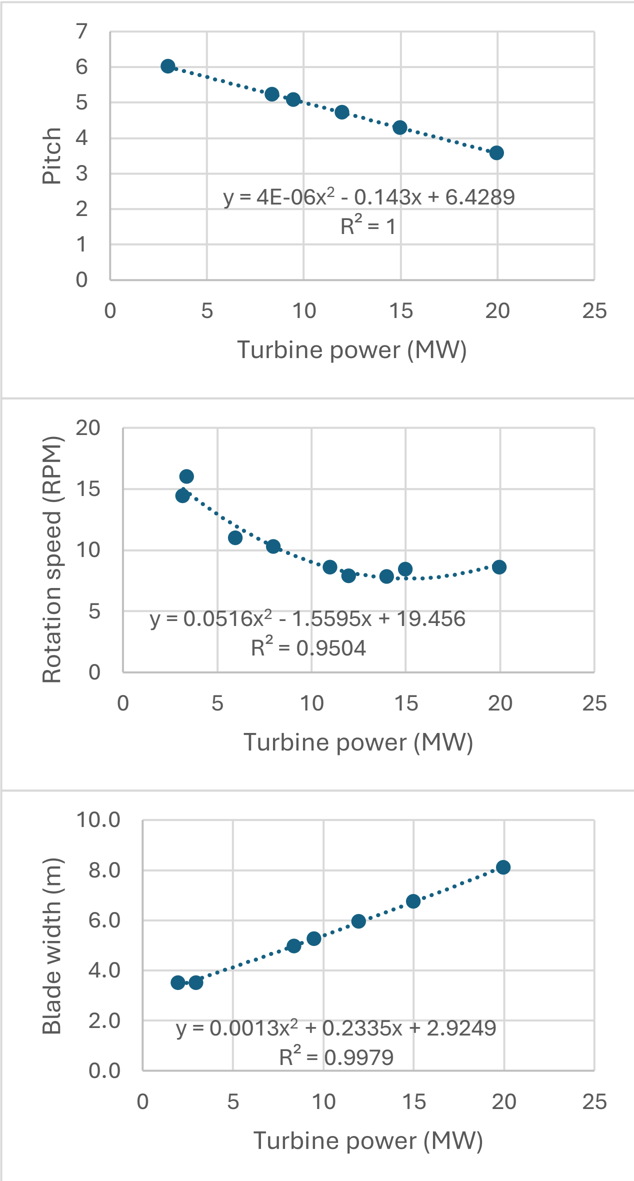

Figure III.7.1 Graphs underlying the extrapolations. From top to bottom: pitch, rotation speed and blade width

Appendix IV Total collision victims per wind farm – migrating birds

For each wind farm, the median estimated number of collisions of migrating birds is reported at the Wozep repository:
https://doi.org/10.5281/zenodo.14732337

Following this link, the relevant file can be found in the zip-folder 'collisions migrants per wind farm'. This presents one file with collision estimates per wind farm for Bewick's swan and brent goose, and a separate file for the remaining species. This separation is due to the use of a different type of CRM.

Appendix V Total collision victims per wind farm – seabirds

For each wind farm, the median estimated number of collisions of seabirds is reported at the Wozep repository:
https://doi.org/10.5281/zenodo.14732337

Following this link, the relevant file can be found in the zip-folder 'collisions seabirds per wind farm'. This presents one file with collision estimates per wind farm for each species.

Appendix VI Windfarms Considered per Scenario

Table 7.1 Dutch National Offshore Wind Farms and their inclusion in the impacted scenarios

Windfarm name	Basic	Basic Plus	Total NAT
Borssele 1	Yes	Yes	Yes
Borssele 2	Yes	Yes	Yes
Borssele 3	Yes	Yes	Yes
Borssele 4 - Blauwwind	Yes	Yes	Yes
Borssele Site V -Two towers	Yes	Yes	Yes
Doordewind	No	No	Yes
Egmond aan Zee	Yes	Yes	Yes
Eneco Luchterduinen	Yes	Yes	Yes
Gemini Buitengaats	Yes	Yes	Yes
Gemini Zee energie	Yes	Yes	Yes
Hollandse Kust Noord (Tender 2019)	No	Yes	Yes
Hollandse Kust west noordelijk deel	No	Yes	Yes
Hollandse Kust west zuidelijk deel	No	No	Yes
Hollandse Kust Zuid Holland I	No	Yes	Yes
Hollandse Kust Zuid Holland II	No	Yes	Yes
Hollandse Kust Zuid Holland III	No	Yes	Yes
Hollandse Kust Zuid Holland IV	No	Yes	Yes
IJmuiden Ver Noord	No	Yes	Yes
IJmuiden Ver versie 2021	No	Yes	Yes
Nederwiek noord	No	No	Yes
Nederwiek zuid	No	Yes	Yes
Prinses Amaliawindpark	Yes	Yes	Yes
Ten noorden van de Wadden west	No	No	Yes

Table 7.2: Additional International Offshore Wind Farms Considered in the international scenario

1_BP Alternative Energy Investments	Gode Wind 01	N-13.1	Norther
2_SSE Renewables	Gode Wind 02	N-13.2	Northwester 2
3_Falck Renewables	Gode Wind 3	N-13.3	Northwind
4_Shell New Energies	Greater Gabbard	N-14.1	Princess Elisabeth - (Fairybank/NordHinder)
5_Vattenfall	Gunfleet Sands	N-15.1	Princess Elisabeth - Noordhinder Noord - 2023 Tender
Aberdeen Offshore Wind Farm (EOWDC)	Hohe See	N-16.1	Race Bank
Albatros	Horns Rev 1	N-16.2	Rentel
Alpha Ventus	Horns Rev 2	N-17.1	Riffgat
Amrumbank West	Horns Rev 3	N-18.1	Round 4 Preferred Project 1
BARD Offshore 1	Hornsea Project 2 - Phase 1 (Breesea)	N-18.2	Round 4 Preferred Project 2
Belwind	Hornsea Project Four	N-3.5	Round 4 Preferred Project 3
Berwick Bank	Hornsea Project One	N-3.6	Sandbank
Blyth Demonstration Phases 2&3	Hornsea Project Three	N-3.7	Scottish Sectoral Marine Plan - E3
Blyth Offshore Demonstrator Phase 1	Humber Gateway	N-3.8	Scroby Sands
Borkum Riffgrund 1	Hywind Scotland Pilot Park	N-6.6	Seagreen
Borkum Riffgrund 2	Inch Cape	N-6.7	Seagreen 1A
Borkum Riffgrund 3	Inner Dowsing	N-7.2	Seamade (Mermaid)
Butendiek	Kaskasi	N-9.1	Seamade (SeaStar)
DanTysk	Kentish Flats	N-9.2	Sheringham Shoal
Deutsche Bucht	Kentish Flats Extension	N-9.3	Sheringham Shoal Extension
Dogger Bank A	Kincardine - Phase 2	Neart na Gaoithe	Sofia
Dogger Bank B	Lincs	Nobelwind	Sorlige Nordso
Dogger Bank C	London Array	Nordergründe	Teesside
Dudgeon	Lynn	Nordsee One	Thanet
Dudgeon Extension	Marr Bank Firth of Forth	Nordsee Ost	Thor - 2020 Tender
Dunkerque	Meerwind Süd/Ost	Nordsoen - Tender 1	Thornton Bank phase II
East Anglia Hub - ONE North	Merkur	Nordsoen - Tender 10	Thornton Bank phase III + I
East Anglia Hub - THREE	N-10.1	Nordsoen - Tender 2	Trianel Windpark Borkum I
East Anglia Hub - TWO	N-10.2	Nordsoen - Tender 3	Trianel Windpark Borkum II
East Anglia ONE	N-11.1	Nordsoen - Tender 4	Triton Knoll
EnBW He Dreiht	N-11.2	Nordsoen - Tender 5	Veja Mate
Five Estuaries	N-12.1	Norfolk Boreas	Vesterhav Nord
Galloper	N-12.2	Norfolk Vanguard	Vesterhav Syd
Global Tech I	N-12.3	North Falls	Westermost Rough