Acceptable Levels of Impact from offshore wind farms on the Dutch Continental Shelf for 21 bird species

A novel approach for defining acceptable levels of additional mortality from turbine collisions and avoidance-induced habitat loss

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Ecology & Landscape

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Version 2: Update based on external reviews

Commissioned by: Rijkswaterstaat

1 September 2021, revision based on external reviews: 28-02-2022
report nr 21-120

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Status: concept final report

Report nr:	21-120
Project nr:	21-0054
Date of publication:	28-02-2022
Project managers:	A. Potiek, T. van Kooten
Second reader:	R.C. Fijn; G. Piet
Name & address client:	Rijkswaterstaat Zee en Delta Postbus 2232, 3350 GE Utrecht
Reference client:	Order bon 4500309001 / 01 april 2021
Signed for publication:	drs. R.C. Fijn
Signature:	

Please cite as: Potiek, A., IJntema, G.J., van Kooten, T. Leopold, M.F., Collier, M.P. Acceptable Levels of Impact from offshore wind farms on the Dutch Continental Shelf for 21 bird species. A novel approach for defining acceptable levels of additional mortality from turbine collisions and avoidance-induced habitat loss. Version 2: Update based on external reviews. Bureau Waardenburg Report 21-0120. Bureau Waardenburg, Culemborg.

Keywords: offshore wind farm, threshold, acceptable impact

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Samenvatting

Achtergrond

Dit rapport beschrijft een methode voor het bepalen van zogenaamde 'Acceptable levels of Impact' (ALI's) – drempelwaarden voor acceptabele effecten van windturbines op zee op het voorkomen van zeevogels. Op basis van deze methode wordt voor 21 soorten een aantal kandidaat-drempelwaarden afgeleid. Deze kandidaat-waarden worden gepresenteerd samen met, per soort, een overzicht van de belangrijkste context – de eigenschappen en populatie-ontwikkeling van deze soorten op het Nederlands Continentaal Plat (NCP). Tevens is een 'gebruiksaanwijzing' opgenomen, die beschrijft hoe de aangeleverde context richting kan geven aan eventuele keuzes tussen de kandidaat-drempelwaarden door het bevoegd gezag.

De wens van de opdrachtgever om te komen tot een nieuwe methode is ingegeven door verschillende recente publicaties waarin de tot nu toe gebruikte methode ('PBR', Potential Biological Removal) ter discussie gesteld wordt. PBR houdt geen rekening met onzekerheid (uit allerlei bronnen), en doet bepaalde aannames over de soorten in kwestie waar in veel gevallen geen onderbouwing voor is. Dit tast de (ecologische en juridische) houdbaarheid van de methode aan. Vanwege de noodzaak tot het toetsen of de laatste Nederlands voornemens rond wind op zee passen binnen de maatschappelijke en wettelijke kaders rond natuur (in het 'Kader Ecologie en Cumulatie'), was een nieuwe methode voor het vaststellen van drempelwaardes op korte termijn noodzakelijk. Dit rapport beschrijft deze methode en de toepassing daarvan op 21 soorten vogels.

Methode

De hier gebruikte ALI's zijn geformuleerd als 'De kans op een afname van X% of meer ten opzichte van de onverstoorde populatie, dertig jaar na de aanleg, mag niet hoger zijn dan Y'. Hierin is X de grenswaarde waarboven we een effect (afname) als 'onwenselijk groot' classificeren, en Y de maximaal acceptabele kans dat zo'n effect uit de categorie 'onwenselijk' zich toch voordoet. De tijdshorizon van dertig jaar komt overeen met de periode waarvoor een windparkvergunning wordt uitgegeven. Deze formulering is in een eerder stadium door de opdrachtgever vastgesteld, en is niet binnen de huidige studie ontworpen.

Voor het uitrekenen van de soort-specifieke kandidaat-waardes van X en Y gebruiken we de matrix populatie modellen die voor deze soorten worden ontwikkeld als onderdeel van het Kader Ecologie en Cumulatie. De methode kan dus in principe worden toegepast op elke soort waarvoor zo'n model kan worden opgesteld. Hiervoor is kennis nodig over de levenscyclus, de voortplanting en de sterfte van de soort.

Voor de keuze van X is in deze aanpak teruggevallen op de IUCN (*International Union for Conservation of Nature*), de gezaghebbende organisatie die bijvoorbeeld de jaarlijkse 'rode lijsten' voor bedreigde diersoorten uitbrengt. Voor een overgang van een populatie van 'least concern' (minste zorg) naar 'Vulnerable' (kwetsbaar) van soorten hanteert de IUCN als drempelwaarde een afname van 30% gedurende drie generaties (of tien jaar, als dat

langer is dan drie generaties). Voor de X-waarde in de ALI’s nemen we deze 30% over, maar rekenen de waarde om van drie generaties naar de hier gehanteerde tijdsperiode van dertig jaar. Dit gebeurt op basis van soortspecifieke gegevens over de generatietijd. Voor de meeste onderzochte soorten is drie generaties langer dan dertig jaar, en is de X-waarde dus kleiner dan 30%.

De populaties van sommige soorten verkeren nu reeds in slechte staat. In die gevallen kan een drempelwaarde van 30% verdere afname te hoog worden bevonden. Daarom berekenen we voor alle soorten ook een X-waarde op basis van een 15% afname over drie generaties (of minstens tien jaar).

Het gebruik van de Y in deze formulering doet recht aan het feit dat de natuur variabel is. Een populatie-afname groter dan X% kan immers ook ‘zomaar’ voorkomen, zelfs zonder dat er windparken op zee worden aangelegd. Er wordt dus expliciet gevraagd welk *risico* men bereid is te lopen op een onwenselijke uitkomst. Het geeft dus de mogelijkheid om onzekerheid in de verwachtte populatie-ontwikkeling heel helder mee te nemen. Dit doen we door de kandidaat-drempelwaardes voor Y te relateren aan de kans dat een overschrijding *veroorzaakt wordt door* de aan te leggen windparken. Bij veel onzekerheid over de populatie-ontwikkeling zal de kans op een toevallige drempel-overschrijding zonder windparken relatief groot zijn. Bij een overschrijding van de drempelwaarde in aanwezigheid van windparken is dan de vraag of de overschrijding door de windparken veroorzaakt wordt of niet. Door deze kans expliciet te kwantificeren, en daar de kandidaat-drempelwaarden voor Y op te baseren, scheiden we ecologie en beleidskeuzes zo goed mogelijk. Op die manier ligt ook de toepassing van het voorzorgsprincipe, uiteindelijk een beleidsprincipe, geheel bij het bevoegd gezag, in de vorm van een keuze voor een kandidaat Y-waarde die is afgeleid van de gewenste mate van zekerheid over de oorzaak van een eventuele drempel-overschrijding.

Als kandidaat-Y waarden stellen we voor elke soort de volgende opties voor: 0.1, 0.33, 0.5 en 0.66. Dit houdt in dat deze Y-drempel wordt overschreden wanneer in het scenario met windparken de overschrijding van de X-drempelwaarde in respectievelijk 10%, 33%, 50% of 66% (afhankelijk van de gemaakte keuze) van de gevallen het gevolg is van de windparken, en niet van onzekerheid in de demografische parameters. Een drempelwaarde van 0.1 betekent dus dat een overschrijding met tenminste 10% waarschijnlijkheid te wijten is aan de windparken, en dus met ten hoogste 90% waarschijnlijkheid een andere oorzaak heeft. Wordt de waarde 0,66 gekozen, dan noemen we een overschrijding van de X-dempelwaarde pas problematisch als deze met tenminste 66% waarschijnlijkheid te wijten is aan het effect van windparken, en dus met ten hoogste 33% waarschijnlijkheid niet. Een drempel-overschrijding is dan tenminste tweemaal waarschijnlijker het gevolg van de windparken als het gevolg van de onzekerheid. Een lagere waarde van de causaliteitsdrempel komt dus overeen met een hogere mate van voorzorg. Immers, de drempelwaarde wordt dan al overschreden als we relatief onzeker zijn over de oorzaak van de overschrijding.

Zoals alle modelstudies, is ook deze gebaseerd op een sterk vereenvoudigde weergave van de werkelijkheid. Aspecten als gewenning en verwachtte klimaatverandering zijn niet meegenomen. Het inbouwen van meer complexiteit maakt zowel de analyse als de interpretatie van de uitkomsten complexer en minder algemeen geldend. In het algemeen geldt dat voor de complexiteit die we bewust niet meenemen, dat het ofwel gaat om een effect waarvan we de richting (meer of minder impact) niet weten, ofwel om een effect dat de impact verkleint, maar waarvan we de grootte niet weten.

Resultaten

De belangrijkste resultaten van deze studie vormen, naast de methode zelf, de berekende kandidaat-X en kandidaat-Y waarden voor de 21 bestudeerde soorten. Deze zijn weergegeven in Table 3.43, Table 3.44 en Table 3.45. Daarnaast is voor elke soort/populatie een factsheet opgenomen waarin een aantal eigenschappen worden beschreven, die relevant zijn voor de uiteindelijke keuze voor de kandidaat-drempelwaardes door het bevoegd gezag. De factsheets worden ondersteund door een beschrijving van hoe elk onderdeel daarin effect heeft op de keuze voor X- en Y-waarden.

Conclusies

De hier beschreven nieuwe methode is een alternatief voor de tot nog toe gebruikte PBR-methode. De grootste problemen met PBR, namelijk het niet expliciet meenemen van onzekerheid en bepaalde niet-onderbouwde aannames zijn in deze nieuwe methode niet aan de orde.

Een groot voordeel van de huidige methode is dat onzekerheid en het toepassen van het voorzorgsprincipe expliciet worden gescheiden. De onzekerheid komt voort uit de ecologie en beschikbare kennis, en ligt dus in het domein van de onderzoekers, terwijl het voorzorgsprincipe een concept uit het beleid is. De mate waarin dat wordt toegepast is immers afhankelijk van allerlei maatschappelijke afwegingen en juridische kaders. Deze scheiding leidt ertoe dat de onderzoekers geen impliciete maatschappelijke afwegingen maken, en de beleidsmakers zich juist daartoe kunnen beperken zonder zich (diep) in de ecologie en kennisbeschikbaarheid te hoeven verdiepen.

Onze methode wordt hier toegepast in het kader van effecten van offshore wind op vogels, maar is in principe toe te passen op elke vorm van verstoring en elke soort waarvoor een matrix populatie model is te maken. In de ecologie, en in het bijzonder in de natuurbescherming, zijn deze modellen zeer gangbaar. Daarmee is onze methode dus ook breed inzetbaar. In deze studie hebben we aangenomen dat de mate van additionele sterfte door verstoring constant is, maar dit is geen vereiste voor de methode. Ook onzekerheid in de mate van additionele sterfte is toe te voegen.

1 Introduction

Rijkswaterstaat, commissioned by the Ministry of Agriculture, Nature and Food Quality, requires a threshold value for an Acceptable Level of Impact (ALI) for a number of bird species, which can be used to assess the effects of offshore wind farms (OWF) on their population size. These thresholds are to be used in KEC (Kader Ecologie en Cumulatie) version 4.0.

Currently, effects of offshore wind farms are assessed using relatively simple criteria and thresholds like the ORNIS 1% criterion and the Potential Biological Removal (PBR). These methods are easy to apply and understand but come with limitations. The PBR approach has certain clear drawbacks, such as e.g. that it provides a fixed and very static figure that does not take any environmental variability into account. Moreover, it implicitly assumes a fixed level of undemonstrated density dependence in population development (O'Brien et al. 2017).

As a novel method of impact assessment, population models have been created for the species of interest in the southern North Sea (Potiek *et al.* 2019; van Kooten *et al.* 2019). This gives more insight into the current expected population trajectory, and the effect of additional mortality. This project describes a method to determine threshold for determining acceptable levels of impacts (ALIs), which can be assessed using population models.

The required threshold will have to consist of two parts:

- A threshold population decline 30 years after the impact, as a percentage X of the projected population size without the impact, which is considered ‘acceptable’.
- A threshold probability Y that X is below this acceptable level after 30 years, which is considered an acceptable risk.

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

In order to help the Ministry of Agriculture, Nature and Food Quality to determine these threshold values for the relevant species, this report describes a newly developed method to derive X and Y, and presents four options for Y, corresponding to four different levels of ‘acceptable risk’, for each species. The method is consistently applicable to both mortality due to habitat loss and collisions with turbines. Additionally, the general framework of the method could be applied to assess any (combination of) impact(s). The requirement for application is a well-formulated matrix population model, for which there is a long and rich tradition in conservation biology.

We also provide factsheets for each species, outlining the most relevant species-specific data. This factsheet should aid in the choice of the most appropriate option for Y among the presented candidates. Finally, we provide a guideline on how this information may affect this choice. This choice has to be made by the Competent Autority and is therefore not addressed in this report.

The species for which we apply the method and derive potential X and Y values are:

- Brent goose
- Bewick's swan
- Common shelduck
- Eurasian curlew
- Red knot
- Black-legged kittiwake
- Great black-backed gull
- Herring gull
- Lesser black-backed gull
- Sandwich tern
- Common tern
- Black tern
- Great skua
- Arctic skua
- Guillemot
- Razorbill
- Atlantic puffin
- Red-throated diver (diver sp.)
- Northern fulmar
- Northern gannet
- Common starling

2 Methods

2.1 Outline of the developed method for assessing Acceptable Levels of Impact

Based on the predefined definition of the Acceptable Level of Impact (ALI), this study suggests a four-step method for assessing the violation of acceptable levels and their use in policies:

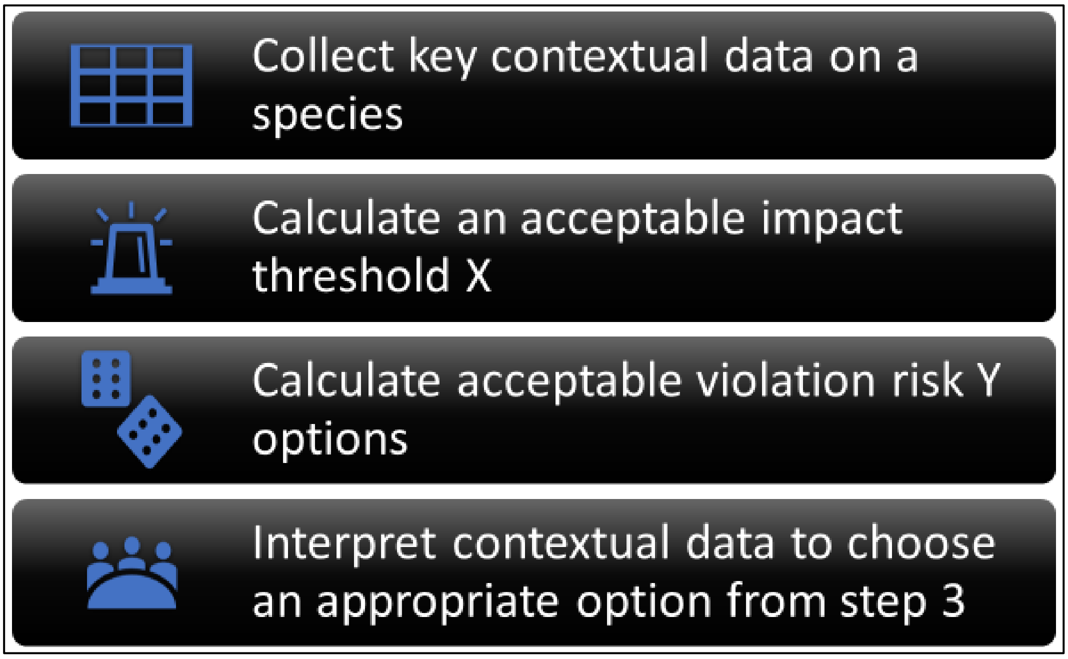

Figure 2.1: Graphic Representation of the four steps to determine and test for Acceptable Levels of Impact (ALIs) for any considered impact.

The **first step** is to collect key contextual information on the considered species. This key information serves both as an overview of the status of a species and provides the basis for a later decision on the final ALI for the species under review (section 2.2).

The **second step** is to define a threshold maximum acceptable impact for the considered species. This threshold is based on projected population trends and follows an approach comparable to the threshold values used for different classifications by the International Union for Conservation of Nature (IUCN) (section 2.3). Following this approach ensures a transparent and objective decision. As described in section 2.3, we present two thresholds for maximum acceptable impact, which differ in cautiousness. We recommend that the choice between these options is made based on objective and preferably published information, for example the IUCN status. Note that basing it on such periodically determined quantities does require occasional revision of the threshold acceptable impact value.

Due to uncertainty in population parameters, stochastic simulations may result in a population size below the acceptable threshold population size, even without additional mortality from collisions or habitat loss of wind farms. Generally, the larger this uncertainty, the higher the likelihood of such ‘accidental’ threshold violations. This means that a threshold violation with impact is not always caused by that impact. In the **third step** we derive four options for Y based on varying degrees of certainty about the cause of the violation (section 2.4), which represent differing degrees of precaution.

The **fourth step** consists of reviewing the options for Y from step three in light of the contextual information from step one, in order to determine the most appropriate Y value for the species considered. In this report, we describe how the information in step one provides direction for this choice (section 2.5). The proposed Y values for the species under study, together with the information provided in step one, forms a consistent framework based on currently available knowledge and uncertainty, which policymakers can use to determine species-specific ALIs for the effects of offshore wind farms. Because we do not make the final choice among options for Y, there is no results section associated with step four. This choice represents an application of the precautionary principle in relation to societal issues and legal frameworks, and is therefore not for scientists to make. Our method does ensure that this choice does not require deep insight into the (available knowledge on) species ecology and uncertainty.

The methodology described in the following sections describes how X and Y lead to an ALI expressed as:

‘The probability of a population decline of X% or more, 30 years after the impact, cannot exceed Y’.

In this report, we calculate two options for X and four options for Y for 21 species of birds, as reported in Chapter 1, which are deemed to be at risk of mortality either from habitat loss or collisions caused by the development of offshore wind farms on the Dutch Continental Shelf.

As with any model-based approach, the method described here is a simplification of reality, and many possible complicating factors have not been taken into account. Obvious examples include habituation, potential changes in breeding colony locations, climate change projections, and so on. Adding more complexity makes both the analysis and the interpretation of results more complex and less generic. For the complexity which we have knowingly left out, we either do not know the direction of the effect, or we know the direction is towards smaller impact but we do not know the magnitude of the effect.

All calculations carried out in steps 1-4 are executed using the R package KEC4popmodels (Hin, 2021).

2.2 Collecting key contextual information for a considered species

Adequate decision making on acceptable levels of impact for different species requires accurate and up-to-date species-specific contextual knowledge on population and life history parameters. For this reason, the first step of defining an acceptable level of impact for any given species, is to gather the necessary contextual information in "species factsheets". The following information is reported in the factsheets in this report:

Introduction to the species. For each species information on the distribution and importance of the Netherlands for the considered species is presented based on available literature and expert knowledge.

(Inter)national species status assessments are reported on different geographically relevant levels: The Dutch population, the European Union Population, The European continent population and the global population.

The Dutch population assessment was based on the conservation status of the species in the Netherlands (In Dutch: 'Staat van Instandhouding' (SvI)). The Dutch Centre for Field Ornithology (Sovon) formally compiles the current status of all Dutch populations of bird species in the SvI, based on an assessment of four primary aspects of Dutch birds: 1) population trend ("Populatietrend"), 2) distribution ("Verspreiding"), 3) habitat ("Leefgebied") and 4) future ("Toekomst"). Sovon defines an overall status of a species based on these four aspects. The assignment of both the final status and the status on the four primary aspects is defined along a scale ranging from very unfavourable to very favourable. The SvI is used as input for species conservation laws and policies regarding birds in the Netherlands. Within this study, we used the data file with all assessments by Sovon, as compiled in 2020 and published on sovon.nl (Sovon, 2020).

The European Union (27 EU member states) and European Continent populations were compiled by Birdlife International following the criteria set by the International Union for the Conservation of Nature and Natural Resources (IUCN), and were reported in the European Red List of Birds" (Birdlife International, 2015; Appendix 1).

The global population assessment was compiled by Birdlife International following the criteria set by the International Union for the Conservation of Nature and Natural Resources (IUCN), and was reported by BirdLife International on international online species factsheets (Birdlife International, May 5th, 2021).

(Inter)national long term and recent population trends. The trends are reported on two geographically relevant levels: the Dutch population and the global population. Dutch population trends were included as reported by the Dutch Centre for Field Ornithology (Sovon) website. Sovon reports the population trends on both the long term and short term (last twelve seasons). Additionally, Dutch population trends based on "the Monitoring Waterstaatkundige Toestand des Lands" (MWTL) government monitoring program and calculated by Netherlands Statics (CBS) are presented as reported by Fijn *et al.* (2020), when deviating from the Sovon trends.

Note that population trends are taken into account within the species status assessments as well. This means that a negative population trend results in a negative score on the population trend itself, as well as on the species status assessment. Accounting for population trend twice is therefore justified by the importance of population trend for species status.
The reported global trend is reported based on the Birdlife International online species factsheets (Birdlife International, May 5th, 2021).

Threats and uncertainty. For each species, we describe the uncertainty of the population projection as a result of variation in demographic rates. In addition, we report which factors are known to affect the population trend based on literature. If a species is strongly impacted by unpredictable factors, this results in high uncertainty in the population projection. In addition, we report the probability of violation of the threshold in the unimpacted scenario. This probability of violation in the unimpacted scenario is affected by the spread of the outcomes of the population model, and hence of the uncertainty of the population projections. With more uncertainty in input parameters, the probability of violating the threshold in the null scenario increases.

Potential compensation for effects of OWF. The potential of compensating a negative population trend by careful mitigation measures, such as e.g., ecologically sound marine spatial planning, nature restoration and/or managing other population threats, can widely vary between species, depending on the nature of the factors impacting the species. For each species, we describe examples of conservation measures which could have a positive impact on populations. Note that this serves as an indication and is not an exhaustive list. This metric may be used to decide on a more cautious approach for species with low potential for nature restoration, but a high potential for nature restoration does not always justify a less cautious approach. Mitigation measures first need to be put into action, including a monitoring program.

Internationally used acceptable thresholds in management. This study attempted to include the use of ALI for the considered species outside of the Netherlands. However, based on a recent assessment on the use of acceptable levels of impact in Belgium, France, Germany, The Netherlands and the United Kingdom (RoyalHaskoningDHV, 2019), it was found that acceptable levels of impact are not being used on species level and are often not of a quantitative nature, or are based on PBR/Ornis norms, the drawbacks of which have prompted the current study. For this reason, data for this measure were considered insufficient to report on factsheets.
This means that, within this study, there was no alternative methodology available internationally for us to adopt. We consider the work in this report to be a solid basis for other countries to work from and hope that our methods will be adopted elsewhere.

2.3 Threshold levels for an Acceptable Level of Impact for a species (X)

2.3.1 General explanation

With the necessary contextual information in place, the next step is to define an impact that could be regarded as acceptable. For the definition of this threshold, we looked at the classification approach followed by IUCN within population assessments. Within this IUCN approach, a population classifies as 'Vulnerable' based on criterion A4 (population trend) when the (projected or observed) population reduction is 30% in three generations or ten years, whichever is longer (IUCN, 2012). In addition to the 30% reduction threshold, we define a second, stricter threshold level of acceptable population decline of 15%. This stricter threshold value is meant for those cases, where a decline of a further 30% is deemed excessive from a policy perspective, which may be the case for species which are already strongly reduced in number. Hence, for each species, the threshold is calculated for a 30% acceptable decline as well as a 15% acceptable decline.

To determine the ALI threshold, we project the population trend for this period (either 3 generations or 10 years; Fig. 2.2). We use a stochastic population model, in which input parameters (demographic rates) are described as distributions around a mean value. By performing 100,000 simulations, each with differing demographic rates drawn from their distributions (but without the impact), the effect of uncertainty of input parameters on the final size of the population is assessed. Subsequently, the threshold is calculated as 30% (or 15%, depending on the choice for X) below the median of the final population sizes of these 100,000 projections (Figure 2.2). This large number of simulations is needed to obtain a robust estimate of the distribution of final population sizes.

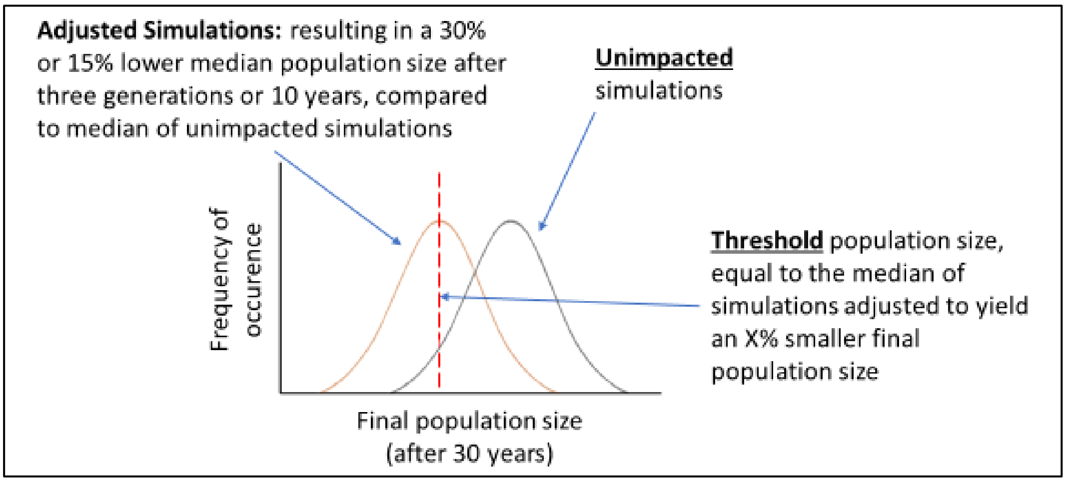

Figure 2.2 Visual representation of the method to define the threshold of the acceptable final population size after 30 years. The figure represents the frequency distribution of final population size based on 100,000 simulations of unimpacted population parameters (rightmost distribution) for a considered species. The leftmost distribution shows the threshold distribution, for which the final population size is adjusted to reflect a 30% or 15% lower population size compared to the original simulation after three generations or 10 years. The vertical red line represents the median of the threshold distribution. The reduction in population size over 30 years as a result of the median threshold population size is referred to as X^T and is used as the species-specific threshold.

Because our ALI is to be evaluated after a 30-year period, a final step is required to derive the reduction after 30 years which corresponds to a 30% or 15% reduction after 3 generations (or 10 years if longer). We do this by interpolation of the threshold population trend (Figure 2.3). 30 years represents the period for which OWF licences are valid.

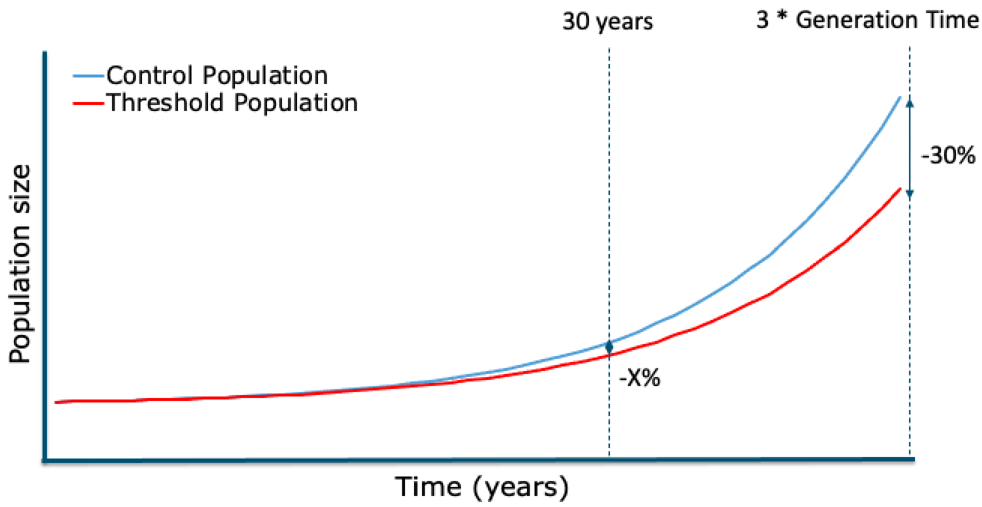

Figure 2.3 *Graphical representation of the IUCN criterion of the threshold relative population reduction, defined as X in the ALI. It is illustrated for 30% but works identically for 15%. Since most considered bird species have a generation time longer than 10 years, 3 times the generation time almost always exceeds 30 years. Consequently, the threshold is interpolated to the difference in population size after 30 years. Note that density dependence is not assumed to occur here.*

2.3.2 Technical details

Our species-specific candidate threshold values (X) are determined by simulating the unimpacted population and reducing the population after 30 years by 30% and 15%. Parameter uncertainties are taken into account by using a Monte Carlo (MC) method, identical to the approach in van Kooten *et al.* (2019) and Potiek *et al.* (2019), in which each simulation has its own parameters which are randomly drawn from their distributions, and are fixed during each simulation. We simulated 100,000 combinations of parameters which results in 100,000 unimpacted projection matrices $A^{T0,i}$. This approach assumes that all parameters vary independently, which is a reasonable and common assumption when correlation structures among parameters are unknown.

Changes in population growth rates directly affect future population sizes as a lower growth rate will result in a smaller future population size. Therefore, the asymptotic growth rate can be regarded as a proxy for future population sizes. From each projection matrix $A^{T0,i}$ we extract the asymptotic growth rate $\lambda^{T0,i}$ by calculating the dominant eigenvalue of the projection matrix.

The definition of the acceptable threshold based on the IUCN criterion is based on the generation time. Generation time is defined as the expected age at which a parent has produced its lifetime reproductive output.

To calculate a uniform generation time, we start by splitting a single deterministic projection matrix A^{GT}, which is the general projection matrix which projects the population growth rate based on demographic rates for different age classes. This projection matrix A is split up into the fertility matrix F^{GT}, which only includes reproduction for sexually mature individuals, and the transition matrix T^{GT}, which specifies the survival. Based on the transition matrix we can define the fundamental matrix N^{GT} as the inverse of the subtraction of the transition matrix T^{GT} from the identity matrix I:

$$N^{GT} = (I - T^{GT})^{-1}$$

The identity matrix *I* is a theoretical concept, which is used as a tool for different kinds of calculations (Caswell 2001). Based on the fundamental matrix N^{GT} and the fertility matrix we can then define the expected lifetime reproduction matrix:

$$R^{GT} = F^{GT} N^{GT}$$

This expected lifetime reproduction matrix specifies the expected lifetime reproductive success for individuals in each age class. Following a standard method described by Caswell (2001), the generation time is calculated by the dominant eigenvalue of the expected lifetime reproduction matrix R^{GT}, R_0^{GT}, in combination with the dominant eigenvalue of the projection matrix:

$$t = \frac{\log(R_0^{GT})}{\log(\lambda^{GT})}$$

For more details on this method, see Caswell (2001).

Depending on the generation time t , the threshold following the IUCN approach is one of the following two types, whichever of these options is the longest time period:

1. a 30% or 15% over three generations or
2. a 30% or 15% reduction over 10 years

This means that for any species with a generation time longer than 3.33 years, the first option is applied. We refer to the longest time period of these two options as T_{ref}.

This adjustment of the asymptotic growth rate gives the absolute threshold value for the acceptable asymptotic growth rate $\lambda^{T,i}$. This absolute threshold $\lambda^{T,i}$ is calculated for each of *i* simulations (we use *i* = 100,000). The median value of $\lambda^{T,i}$ is subsequently used as the threshold for the acceptable asymptotic growth rate λ^{T}. This is the asymptotic growth rate at which the population is exactly X% smaller after 3 generations/10 years). Hence, λ^{T} is defined as:

$$\lambda^{T} = median(\lambda^{T\,i} * \sqrt[T_{ref}]{1 - T_X}),$$

with Threshold T_X the resulting population decline after three generations or 30 years, depending on the caution to be taken. The value for T_X is either 0.3 or 0.15, representing a threshold population decline of 30% or 15%.

The resulting λ^T is defined as the threshold value for the asymptotic growth rate and the threshold for an acceptable impact. λ^T represents the population growth rate that would result in a relative population reduction of 30% (or 15%) over three generations or 10 years, whichever is longer.
Since λ^T represents the threshold population growth rate, any asymptotic growth rate lower than λ^T, as a result of impact, should be regarded as an unacceptable level of impact. A visual representation of the method for extracting the threshold growth rate λ^T is given in figure 2.3 below.

Within the formulation of the ALI, we refer to the threshold fraction decline relative to the unimpacted scenario, after 30 years. In order to calculate this metric, the first step is to project the threshold population for 30 years, using the growth rate λ^T. This gives the population size after 30 years for a population with the threshold mortality. Subsequently, a similar population projection for 30 years, but using the unimpacted population growth rate, gives the population size after 30 years for the unimpacted scenario. The acceptable decline within 30 years can then be calculated as 100 minus the percentual difference between those scenarios. Note that within this calculation the threshold and unimpacted population sizes can be replaced by the threshold and unimpacted population growth rate over 30 years. The reduction in population size over 30 years can hence be expressed as a percentage as:

$$X^T = 100 - (100 * \frac{\lambda^{T^{30}}}{\lambda^{T0^{30}}})$$

With λ^{T0} as the median of all simulation specific growth rates $\lambda^{T,i}$, as earlier extracted from the population matrices $A^{T0,i}$.

A note on the definition of generation time

In this work, we have used for generation time the 'expected age at which a parent has produced its lifetime reproductive output'. This definition comes from Caswell (2001), which is the standard reference for matrix population models. Generation time is however not an undisputed term. A generation is loosely defined, and so there is no single correct way to calculate it. An important consideration to choose the current formulation was, that it can be readily computed from the matrix models used within this project. The IUCN uses a different definition: the average age of parents for each birth event in the population (https://www.iucnredlist.org/resources/generation-length-calculator). The advantage of the IUCN definition is that is relatively easy to calculate from population census data, which is often used to assess the Red List status of a population (Least concern/Vulnerable/etc). Within the context of this work, we have chosen another option, which fits well with our methods here. However, it may be more consistent to use the IUCN method in the future, because our method draws on the IUCN criteria for the derivation of the X threshold.

2.4 Violation probability of Acceptable Levels of Impact (Y)

As described in the previous paragraph, the threshold X is always below the median of the unimpacted scenario. If the uncertainty in survival and fertility estimates is low, the distribution of final population sizes for the unimpacted scenario becomes narrow, and the situation could occur where all simulations for the unimpacted population are above the threshold. In practice however, these parameter estimates are more uncertain, resulting in a fraction of the unimpacted simulations where the population is reduced more than the threshold percentage X. In other words, depending on parameter uncertainty, the X-threshold is likely to be violated in a fraction of the unimpacted scenarios, and this fraction increases with parameter uncertainty. By violated we mean that the final population abundance after 30 years is reduced by more than the threshold X%.

We define a threshold violation due to uncertainty, rather than impact, as an uncertainty induced violation of Acceptable Levels of Impact (ALIs). Even in the scenario with impact, the threshold violation is not necessarily *caused by* the impact. It can, even in the presence of an impact, be caused by parameter uncertainty, and not by the impact. In order to quantify the likelihood that a violation is caused by the impact, we first calculate the added effect of the impact as the probability of a threshold violation with the impact ($P_{v,i}$) minus the probability of violation without the impact ($P_{v,u}$, where i stands for impacted and u for unimpacted). If we divide this by $P_{v,i}$, we obtain the fraction of the total probability of a violation in the impacted situation, which is *caused by* the impact,

$$P_C = \frac{P_{v,i} - P_{v,c}}{P_{v,i}}.$$

In other words, P_C is the probability, in an impacted situation, that an observed threshold violation is caused by the impact rather than by the uncertainty. When the probability of violation in the unimpacted scenario is (almost) zero, the probability that an ‘impacted violation’ is caused by the impact becomes (almost) one, and when the impacted violation probability is (almost) equal to the unimpacted violation probability, the probability that an observed violation is caused by the impact is (almost) zero.

The probability of violation in the unimpacted scenario ($P_{v,u}$) is calculated by conducting a large number of simulations and dividing the number of simulations that end in a threshold violation by the total number (in our case the total was 100,000). On the other hand, $P_{v,i}$ cannot be calculated *a priori*, as it is the quantity which is ultimately compared to the ALI to determine whether or not the impact is within the ALI or not.

We can however substitute $P_{v,i} = P_{v,i}^T$, and rearrange the above equation to read

$$P_{v,i}^T = -\frac{P_{v,u}}{P_C - 1}$$

Where the superscript T stands for threshold. Here, we have an equation which gives us the threshold probability of violation with impact, given a probability of violation without impact and a probability of causation. We can now choose the required degree of causal certainty required (P_C) as a threshold: by using the unimpacted violation probability, this equation tells us the threshold impacted violation probability. The threshold impacted violation probability refers to the probability above which a violation is more likely than P_c to be caused by the impact. This is, in short, a framework for determining ALIs, expressed as violation probability thresholds ($P_{v,i}^{T}$), which takes into account the uncertainty in population projections and is based on a generally interpretable criterion. Setting a threshold for this criterion, P_C, does not require any specialist knowledge of the ecology of the species considered, and can be chosen based purely on societal and/or legal grounds. The above equation can then be used to translate the chosen P_C threshold into the associated species-specific value for the Y-threshold.

We propose four candidate threshold causal certainties (values for P_C), which reflect different degrees of required certainty about the cause of a threshold violation (a population after 30 years which is reduced by more than X%) when it occurs. With lower values of P_C being more precautionary, we suggest the following options:

- P_C =0.1; The possibility that a population reduction larger than X% after 30 years is caused by the impact cannot be excluded. With this threshold, if the ALI is violated, there is only a 10% chance that this is because of the impact.
- P_C =0.33; The possibility that a population reduction larger than X% after 30 years is caused by the impact is considerable, but the probability that it is not is still larger. When the ALI is violated, there is a 33% probability that this is caused by the impact.
- P_C =0.5; A population reduction larger than X% after 30 years is equally likely to be caused by the impact as it is the result of uncertainty.
- P_C =0.66; A population reduction larger than X% after 30 years is twice as likely (66%) caused by the impact as it is the result of uncertainty (33%). This is the threshold value used by the Intergovernmental Panel on Climate Change (IPCC) for a result to be classified as 'likely'.

A lower value for P_C reflects a stricter approach than when a higher value is used, for example P_C =0.66. The use of a high value for P_C may result in a situation where the threshold causality can never be reached due to high uncertainty in the unimpacted population model. This means that even when the chance of a more than X% reduction after 30 years is 100%, we can still not be certain enough that this is caused by the impact rather than by the parameter uncertainty in the population model. Better understanding of the populations under study can reduce this uncertainty and hence increase the maximum degree of causal certainty (P_C) which can be attained.

We calculate the Y threshold values for X based on a 30% as well as a 15% reduction over 3 generations (or 10 years if larger). It is important to note that (given a level of P_C) the Y thresholds for 15% will always be higher than the corresponding values for 30%. This occurs because the expected frequency of violating the X threshold in the unimpacted scenario is larger with a 15%-based than a 30%-based threshold. The degree to which these values differ depends on the shape of the distribution of unimpacted outcomes.

It is important to note that given a fixed uncertainty for a specific species, the probability of an uncertainty-induced ALI violation increases as the threshold population reduction becomes smaller. In other words, the probability of violating a strict threshold X derived from 15% reduction over 3 generations as a result of uncertainty in the input parameters will be higher than the probability of violating a threshold of 30%. In other words, a smaller X results in a higher level of protection, but it will be more difficult to determine that a violation is caused by the impact, as it will result in higher values of $P_{v,i}^{T}$. This can, in policy applications, be compensated for by choosing Y based on a low required causality P_C, for example 0.1.

An alternative calculation for Y

Our calculation of Y rests on the assumption that any one simulation without OWF impact which leads to a violation of the X threshold, will also do so in the presence of OWF. This correspondence on a simulation-by-simulation basis, allows us to derive the Y threshold values in the way described above. It is however possible to relax this assumption and see the sets of outcomes with and without impact as two different, independent simulations. In that case, the criterium for P_C would change to:

$$P_C = \frac{P_{v,i}/2}{(P_{v,i} + P_{v,u})/2}$$

This quantity describes the probability that an observed violation comes from the impacted results rather than from the unimpacted results. Adopting this method has consequences for the meaning and values of Y. For reasons described above, we have decided to use our formulation rather than this one. Further discussions among statisticians in the future might lead to revision of the current calculation of Y, based on fundamental statistical insights. However, we consider our current method to be the most appropriate approach at the moment.

2.5 Defining appropriate levels of risk for a considered species

Within the proposed approach, a decision needs to be made for each species concerning a threshold X and an acceptable probability of violating this threshold. This choice is beyond the scope of this study, and in fact outside the scope of science.

To facilitate an informed decision, this paragraph presents guidance on how to use the information from the factsheets created in step 1 to guide decisions on acceptable levels of threshold X and probability Y.

Choice of X

Based on a discussion with ecologists and policymakers, it was decided that the threshold X should be stricter for species with an unfavourable conservation status. We present two different options for X. The first option for X is based on the IUCN boundary between a classification as 'Least Concerned' and 'Vulnerable', and is calculated as a decline of 30% over three generations or ten years, whichever is longer (Table 2.1). The second option for

X is stricter and based on a maximum 15% decline over three generations or ten years. The choice between the two options for X needs to be made for each species.

Table 2.1 Options for species-specific thresholds X.

Options for X	When to use
1. Maximally 30% decline over three generations or ten years	Standard approach, following IUCN classification threshold for status Vulnerable
2. Maximally 15% decline over three generations or ten years	More strict threshold, to be used when a decline of a further 30% is deemed excessive from a policy perspective

Choice of Y

Having chosen a species-specific threshold (X) for the population decline, the presented approach gives several tentative acceptable probabilities of a population ending up below this threshold (Y). Depending on the level of caution, the threshold Y needs to be selected from one of these tentative options, resulting in the appropriate species-specific Acceptable Level of Impact (ALI). As described in 2.4, the choice of Y depends on the desired level of causality assessment. The X threshold can be violated as a result of uncertainty, or as a result of the impact. The desired level of causality assessment indicates how certain you want to be that the violation of the threshold is the result of the impact. If a causality of Pt = 0.1 is chosen, the ALI is violated when 10% or more of the simulations which end up below the threshold population level are violated due to the impact, and not due to uncertainty. If a higher causality (Pt) is chosen, the ALI is only violated if you are more certain that the violation of the threshold is caused by the impact. In other words, the maximum acceptable level of impact is higher if Pt is higher.

Table 2.2 Options for species-specific thresholds Y. The choice of the level of caution P_T results in a value for Y, depending on the uncertainty of the population model without impact.

Options for Y	When to use
$P_T = 0.1$	Most strict approach. When (more than) 10% of the violations of the threshold is caused by the impact, this is considered unacceptable.
$P_T = 0.33$	When (more than) 33% of the violations of the threshold is caused by the impact, this is considered unacceptable.
$P_T = 0.5$	When (more than) 50% of the violations of the threshold is caused by the impact, this is considered unacceptable.
$P_T = 0.66$	Least strict approach. When (more than) 66% of the violations of the threshold is caused by the impact, this is considered unacceptable.

Factors to be considered for the choice of X and Y

The following sections will provide suggestions on how to make the choice of X and Y based on the subjects presented in the factsheets. The choice of X should be based on the conservation status. For the choice of Y, different factors can be taken into account. The factors that can inform the decision for Y are presented in the species factsheets and are the following: species ecology and spatial distribution, conservation status, population trend, threats/uncertainty and potential for compensation. Each of these factors is described in the species factsheets. While the choice of X and Y appear to be independent of one another, they are conceptually linked. This is particularly true for species where a stricter X of 15% is chosen. It seems unlikely that for such species, a less strict P_T is chosen (e.g. 0.66), as this would represent a situation where we would not accept a significant decrease, but we consider it problematic only if we are very certain that it is caused by the impact.

Introduction to the species. This section highlights important aspects of the species ecology as well as spatial distribution. While this section often does not contain information necessary to choose more or less precautionary approaches to the ALI, the information presented here can be used to determine the appropriate information from the other sections. On some occasions, the importance of the Netherlands for the considered species can be inferred from this section. The importance of the Netherlands for a considered species may prompt a decision maker to decide on a more precautionary ALI, for instance if Dutch territories are of importance for the considered species, or a less precautionary approach, for instance if the Dutch territories are of little importance to the considered species.

(Inter)national species status assessments. Using the assessments presented here, decision makers can infer the conservation status of a species both nationally and internationally.
As most of the (inter)national assessments for the conservation status of a species are present on a scale along the lines of “very problematic” to “very favourable” (see table [2.1] below), the assessments are often directly usable to determine the choice for a less precautionary (a favourable assessment allows for less precaution) or more precautionary (a problematic assessment should prompt decision makers to be more cautious) ALI. However, it is important to decide which of the assessments presented are relevant and to what degree they are relevant.

The Dutch national assessment - “Staat van Instandhouding” (SvI) - is likely important in any case as this is used in several legal frameworks surrounding species conservation in the Netherlands. Additionally, the SvI presents sub-assessments on four levels that can be separately used.

The European Continent or EU-27 assessments may or may not be relevant depending on the migration of species to and from other EU27 countries, or even from other European continent countries (e.g. Norway, Russia and Iceland are not included in EU27, but are included in the European Continent assessment; in the latest assessment form 2015, the UK is still included in EU as well as EU-27 assessments). Specifically, for the EU27 and European Continent assessments it is also important to consider the assessment age (conducted in 2015) to determine if and to what level the choice of ALI should be based on these assessments. Finally, a problematic species assessment in Europe may indicate a more serious responsibility for the Netherlands in preserving a certain species, prompting a more precautionary choice of ALI.

In the same way as for the European assessments, the relevance of global assessments should be considered in the context of migration and to determine the responsibility of the Netherlands in the conservation of the species.

Table 2.3 Scales used in the assessments presented on the species factsheets.

Assessments:	Scale according to guidelines from:	Scale used (from worst to least problematic species status)
SOVON Dutch Population Assessment – “Staat van Instandhouding”	SvI developed system	Very Unfavourable – Unfavourable – Favourable – Very Favourable
Birdlife EU-27, Birdlife European Continent & Birdlife Global	IUCN Guidelines	Extinct (in the wild) – Critically Endangered (CE) – Endangered (EN)– Vulnerable (VU) – Near Threatened (NT) – Least Concern (LC)

(Inter)national long term and recent population trends. Using the population trends presented here, decision makers can infer the conservation status of a species both nationally and internationally.
As most of the (inter)nationally reported populations of species are presented on a scale along the lines of “steep decline (--)” to “steep increase (++)” the assessments are often directly usable to determine the choice for a more precautionary (favourable assessments) or less precautionary (problematic assessments) ALI.

As with the population assessments, it is important to decide which of the trend assessments presented are most relevant and to what degree they are relevant. Apart from the Dutch population trend and trends based on offshore survey at the Dutch Continental Shelf (MWTL), the global trend is reported. As with the global population status, the relevance of global trend assessments should be considered in the context of migration and to determine the responsibility of the Netherlands in conserving a species.

An important consideration is the relationship between conservation status and population trend. Many population assessments take the population size and/or trend into account as a criterion to define a species status. Any conservation status based on the basis of population trends should therefore be considered as potential double counting if the trend and population size itself is also used to choose an option for Y.

Threats and uncertainty. Uncertainty in the life-history parameters of the species considered (survival and reproduction) leads to a higher probability of an above-X outcome without impact. This probability is used to generate species-specific options for Y, and we therefore report it for completeness. This uncertainty due to variation in demographic rates should not affect the choice for a specific Y value. However, there is another potential uncertainty about for example whether trends are accurate, or about the vulnerability of the species to the impact, which can affect the choice. In general, more uncertainty would lead to a more precautionary choice of Y. For some species other threats such as high sensitivity to climate change or pollution may diminish their resilience to OWF in the future.

Potential compensation for effects of OWF. Information is provided here regarding the potential to promote species recovery by reducing OWF mortality or other sources of mortality. Examples include reducing seabird bycatch in fisheries or providing suitable nesting sites away from the OWF. Note that this section gives an indication of possible mitigation measures, but is not exhaustive.

If potential compensation measures, or the effect of those measures, are limited for a certain species, more caution is urged. For such species, the threshold causal probability could be lower.

Note that this does not automatically mean that species for which several compensation measures are known to be effective, can always be treated with less caution. The other factors need to be considered as well.

Internationally used acceptable thresholds in management. Since no internationally used (quantitative) acceptable threshold levels were found, this measure was excluded from the results. Therefore, the measure is not suitable to base the decision for a more precautionary or less precautionary ALI on.

For each factor, the following points should be considered:

1. Should we take this subject into account for the considered species?
2. If the answer to 1) is yes, does the status of the measure prompt a more precautionary or less precautionary choice of Y? (e.g. on a scale of “Very Precautionary” to “Less Precautionary”)?
3. If the answer to 1) is yes, what weight should this measure hold in the choice of a more precautionary or less precautionary ALI (e.g. on a scale from “Leading” to “Mildly Nudging”)?

3 Results

3.1 Additional information to define an acceptable risk

3.1.1 Brent goose (Branta bernicla)

Brief introduction to the species

Three populations of brent geese overwinter in Europe, one of these, the sub-species dark-bellied brent goose, breeds in the Russian Arctic and winters around the coasts of north-west Europe including Britain and the Netherlands (Scott & Rose 1996). This species migrates over the North Sea, where it can encounter offshore wind farms.

Population assessments

The Dutch non-breeding population of brent goose is classified as unfavourable (sovon.nl). This is due to the seasonal averages between 2008/09 and 2012/13 being only slightly above the Natura 2000 aims (Foppen *et al.* 2016).

At European and global scale, the species is classified as Least Concern (BirdLife International 2015; 2021).

Table 3.1 National, Regional and International Assessments of brent goose populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status

Assessment	(sub-)population assessed	Sub-section/ assessed	Species classification
Sovon Dutch Population Assessment – “Staat van Instandhouding”	Dutch Non-Breeding Population	Population Trend	Unfavourable
		Distribution	Favourable
		Habitat	Favourable
		Future	Favourable
		Overall	Unfavourable
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Least Concern
	European Population	European Continent	Least Concern
Birdlife International – ongoing international IUCN Assessment	Global		Least Concern

Population trend

The population trend of the Dutch non-breeding population of brent goose increased during the last decades, followed by a stabilization during the last years (sovon.nl). The global population trend is unknown (BirdLife International 2021).

Table 3.2 *(Inter)national population trends of brent goose. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are not available for this species. The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).*

Assessment	**(Sub-)Population assessed**	**Long-term trend description**	**Short-term trend description**
SOVON Dutch Population Assessment	Dutch Non-Breeding Population	Increasing, <5% (+)	No significant trend (0)
MWTL offshore assessment	Dutch Continental Shelf	NA	NA
Birdlife International ongoing Assessment	Global population	Unknown [1]	

[1] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty

Climate change may affect habitats particularly in coastal areas but also due to changes in land use or in crops grown. Reduction in intertidal food availability particularly *Zostera marina*, which is a key food during migration, due to disease to the food source. Although in many areas geese have found alternative food sources, particularly in agricultural areas. Disturbance, particularly from vehicles can also be an issue, as can persecution by farmers and hunting. Natural processes outside Netherlands (BirdLife International 2021).

Brent goose population dynamics are not very well-studied. Data on survival as well as reproductive success are limited. An indication of the uncertainty of the population projections is given by the spread of the outcomes. With stronger variation in input parameters, the probability of violating the threshold within the null scenario increases. For brent goose, 33.8% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 44.8% in violation of the 15%-based threshold.

Potential compensation for effects of OWF

Compensation payments can be effective to prevent conflicts with agriculture, particularly when this reduces disturbance and allows alternative sites to be utilised (BirdLife International 2021).

3.1.2 Bewick's swan (*Cygnus bewickii*)

Brief introduction to the species

Bewick's swans breed across the far northern tundra of Russia, the western population that breed on the Kanin Peninsula overwinter in the Netherlands and the UK (Scott & Rose 1996). This species migrates over the North Sea, where it can encounter offshore wind farms.

Population assessments

The Dutch non-breeding population of Bewick's swan is assessed as very unfavourable due to a significant population decline (Foppen *et al.* 2016). In addition, distribution and future perspective are assessed as unfavourable (Foppen *et al.* 2016). BirdLife International assessed the European population (EU-27 as well as European continent) as Endangered, due to an identified or projected population decline (BirdLife International 2015). The global population assessement of Least Concern (BirdLife International 2021) mostly reflects North American Tundra swan, with the *bewickii* sub-species showing declines since the mid-1990s (Rees & Beekman 2010).

Table 3.3 *National, Regional and International Assessments of Bewick's swan populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status. *: classification based on IUCN criterion A4abcde - identified or projected population decline.*

Assessment	(sub-)population assessed	Sub-section/ assessed	Species classification
Sovon Dutch Population Assessment – "Staat van Instandhouding"	Dutch Non-Breeding Population	Population Trend	Very unfavourable
		Distribution	Unfavourable
		Habitat	Favourable
		Future	Unfavourable
		Overall	Very unfavourable
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Endangered *
	European Population	European Continent	Endangered *
Birdlife International – ongoing international IUCN Assessment	Global		Least concern

Population trend

The Dutch non-breeding population of Bewick's swan is strongly decreasing (sovon.nl). This is mainly the result of the wintering area shifting eastwards due to less severe winters (Nuyten *et al.* 2020). The trend of the global population is unknown (BirdLife International 2021). According to Beekman *et al.* (2019), the numbers in north-western Europe have been fluctuating during the last decades, with an increase between the 1980s up to 1995, followed by a steep decline and stabilization in the most recent years.

Table 3.4 (Inter)national population trends of Bewick's swan. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are not available for this species, due to limited numbers of observations. The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).

Assessment	**(Sub-)Population assessed**	**Long-term trend description**	**Short-term trend description**
Sovon Dutch Population Assessment	Dutch Non-Breeding Population	Decreasing, <5% (-)	Strongly decreasing, >5% (--)
MWTL offshore assessment	Dutch Continental Shelf	NA	NA
Birdlife International ongoing Assessment	Global population	Unknown [1]	

[1] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty

Climate change and changes in land-use may lead to loss in breeding and wintering habitats. Exploration for oil and gas may also threaten breeding habitats. Hunting outside of the Netherlands and susceptibility to avian influenza may result in increased mortality (BirdLife International 2021).

Bewick's swans are studied with moderate effort. Based on a review of representative demographic rates for the Dutch Continental Shelf, two studies report adult survival as well as immature survival. Breeding success is reported by four studies, measured as family size or first-years per adult in wintering grounds. Estimates for survival as well as breeding success are comparable between studies. An indication of the uncertainty of the population projections is given by the spread of the outcomes. With stronger variation in input parameters, the probability of violating the threshold within the null scenario increases. For Bewick's swan, 42.3% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 46.5% in violation of the 15%-based threshold.

Potential compensation for effects of OWF

Monitoring of mortality throughout flyway can be important in predicting changes in the population. The protection of sites used outside breeding season and compensation payments can be effective protection measures (BirdLife International 2021).

3.1.3 Common shelduck (*Tadorna tadorna*)

Brief introduction to the species

Although occurring inland, shelduck are an essentially coastal species in Europe. A concentration occurs around the North Sea with the Wadden Sea forming the most important area for moulting and wintering birds (Scott & Rose (1996). This species migrates over the North Sea, where it can encounter offshore wind farms.

Population assessments

For the Netherlands, the overall non-breeding as well as the breeding population of common shelduck are assessed by Sovon as favourable (Foppen *et al.* 2016). At European as well as global scale, BirdLife International classified the species as Least Concern (BirdLife International 2015; 2021).

Table 3.5 National, Regional and International Assessments of common shelduck populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status

Assessment	**(sub-)population assessed**	**Sub-section/ assessed**	**Species classification**
Sovon Dutch Population Assessment – "Staat van Instandhouding"	Dutch Breeding Population	Population Trend	Favourable
		Distribution	Favourable
		Habitat	Favourable
		Future	Favourable
		Overall	Favourable
	Dutch Non-Breeding Population	Population Trend	Favourable
		Distribution	Favourable
		Habitat	Favourable
		Future	Favourable
		Overall	Favourable
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Least Concern
	European Population	European Continent	Least Concern
Birdlife International – ongoing international IUCN Assessment	Global		Least Concern

Population trend
The long-term trend of the Dutch breeding and non-breeding population of shelduck are increasing, although the short-term trend of the breeding population is stable (sovon.nl). The global population of shelduck is increasing as well (BirdLife International 2021).

Table 3.6 *(Inter)national population trends of common shelduck. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are not available for this species. The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).*

Assessment	(Sub-)Population assessed	Long-term trend description	Short-term trend description
Sovon Dutch Population Assessment	Dutch Breeding Population	Increasing, <5% (+)	No significant trend (0)
	Dutch Non-Breeding Population	Increasing, <5% (+)	Increasing, <5% (+)
MWTL offshore assessment	Dutch Continental Shelf	NA	NA
Birdlife International ongoing Assessment	Global population	Increasing [1]	

[1] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty
Potential for habitat loss from tidal barrages and predation from particularly American mink pose threats to the species. It is also susceptible to avian influenza. Hunting may be an issue is some areas (BirdLife International 2021).

Common shelduck is relatively poorly studied. Very few studies report survival rates, and no recent studies were found (all <1980). This reduces certainty of the population projection. For reproductive success, again few data sources were available, further reducing the certainty of the projection. For common shelduck, 43.1% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 46.9% in violation of the 15%-based threshold.

Potential compensation for effects of OWF
Predator control in occurs parts of the breeding range and the creation of artificial breeding sites along with the protection of key sites will help alleviate these pressures (BirdLife International 2021).

3.1.4 Eurasian curlew (*Numenius arquata*)

Brief introduction to the species

Curlews breed across much of the UK and Ireland, and from France through to Fennoscandia. Birds wintering in coastal north-western Europe are mainly from population breeding in Russia, Fennoscandia and north-west Europe, with some birds wintering down to southern Europe and West Africa (Delany *et al*. 2009). This species migrates over the North Sea, where it can encounter offshore wind farms.

Population assessments

The Dutch breeding and non-breeding populations of Eurasian curlew are both assessed as unfavourable by Sovon. For the breeding population, the population trend and distribution resulted in this classification, while the non-breeding population has an unfavourable population trend and future perspective (Foppen *et al.* 2016). On the European scale, the species is classified as vulnerable, again based on the population decline (BirdLife International 2015). On a global scale, the population decline resulted in the classification as Vulnerable (BirdLife International 2021).

*Table 3.7 National, Regional and International Assessments of Eurasian curlew populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status. *: classification based on IUCN criterion A2abcde+3bcde+4abcde. **: classification based on IUCN Criterion A2bcd+3bcd+4bcd. Both sets of IUCN criteria indicate an identified or projected population decline.*

Assessment	**(sub-)population assessed**	**Sub-section/ assessed**	**Species classification**
Sovon Dutch Population Assessment – “Staat van Instandhouding”	Dutch Breeding Population	Population Trend	Unfavourable
		Distribution	Unfavourable
		Habitat	Favourable
		Future	Favourable
		Overall	Unfavourable
	Dutch Non-Breeding Population	Population Trend	Unfavourable
		Distribution	Favourable
		Habitat	Favourable
		Future	Unfavourable
		Overall	Unfavourable
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Vulnerable *
	European Population	European Continent	Vulnerable *
Birdlife International – ongoing international IUCN Assessment	Global		Near Threatened **

Population trend

The Dutch breeding population of Eurasian curlew has been declining since several decades (sovon.nl). The numbers of non-breeding birds in the Netherlands have stabilized after an increase (sovon.nl). The global population is declining (BirdLife International 2021).

Table 3.8 *(Inter)national population trends of Eurasian curlew. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are not available for this species. The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).*

Assessment	**(Sub-)Population assessed**	**Long-term trend description**	**Short-term trend description**
SOVON Dutch Population Assessment	Dutch Breeding Population	Declining, <5% per year (-)	Declining, <5% per year (-)
	Dutch Non-Breeding Population	Increasing, <5% per year (+)	No significant trend (0)
MWTL offshore assessment	Dutch Continental Shelf	NA	NA
Birdlife International ongoing Assessment	Global population	Decreasing [1]	

[1] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty

Climate change, habitat fragmentation and habitat loss (e.g., agricultural intensification) are a threat to breeding population of curlew in Europe (The European Commission 2007, BirdLife International 2021). Furthermore, declines may be accelerated by poor breeding success in some habitats, mainly agricultural and upland areas (Douglas *et al.* 2021). Hunting and illegal persecution also puts pressure on populations. Disturbance in wintering areas and wind farms are also considered to contribute to declines (Douglas *et al.* 2021).

For curlew, relatively good estimates for stage-specific survival are available from populations relevant for the Dutch Continental Shelf. Several studies report reproductive success, and variation among breeding sites is moderate. An indication of the uncertainty of the population projections is given by the spread of the outcomes. With stronger variation in input parameters, the probability of violating the threshold within the null scenario increases. For curlew, 44.7% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 47.5% in violation of the 15%-based threshold.

Potential compensation for effects of OWF

Changes in agricultural practices and careful consideration of forestation, rewilding, and CO_2 compensation projects can alleviate pressures on breeding populations (Douglas *et* *al.* 2021). The continuation of the moratorium on hunting in European countries and tighter controls where hunting still occurs (e.g., France) will benefit the species (BirdLife International 2021). Work with farmers and land managers can help improve habitat and breeding success (Douglas *et al.* 2021). More information on the effects of wind farms in needed (BirdLife International 2021).

3.1.5 Red knot (*Calidris canutus*)

Brief introduction to the species

Two sub-species of red knot regularly occur in north-west Europe: those breeding in Greenland and eastern Canada (*islandica*) and those breeding in Siberia (*canutus*). Birds from both populations migrate through the Wadden Sea on their way to West Africa. Birds also winter along the coasts of North-west Europe (Delany *et al*. 2009). This species migrates over the North Sea, where it can encounter offshore wind farms.

Population assessments

The overall assessment of the non-breeding population of red knot in the Netherlands is unfavourable, due to substandard habitat (Foppen *et al.* 2016). On the European scale, the species has been assessed as Least Concern (BirdLife International, 2015). The global conservation status of the species is Near Threatened due to an identified population decline (BirdLife International 2021).

*Table 3.9 National, Regional and International Assessments of red knot populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status. *: classification based on IUCN Criterion A2abc+3bc+4abc - identified or projected population decline.*

Assessment	**(sub-)population assessed**	**Sub-section/ assessed**	**Species classification**
Sovon Dutch Population Assessment – "Staat van Instandhouding"	Dutch Non-Breeding Population	Population Trend	Favourable
		Distribution	Favourable
		Habitat	Unfavourable
		Future	Favourable
		Overall	Unfavourable
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Least Concern
	European Population	European Continent	Least Concern
Birdlife International – ongoing international IUCN Assessment	Global		Near Threatened *

Population trend

The population of non-breeding red knot in the Netherlands is increasing (sovon.nl). On a global scale, the species is declining (BirdLife International 2021).

Table 3.10 *(Inter)national population trends of red knot. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are not available for this species. The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).*

Assessment	(Sub-)Population assessed	Long-term trend description	Short-term trend description
Sovon Dutch Population Assessment	Dutch Non-Breeding Population	Increase, <5% per year (+)	Increase, <5% per year (+)
MWTL offshore assessment	Dutch Continental Shelf	NA	NA
Birdlife International ongoing Assessment	Global population	Decreasing [1]	

[1] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty

Climate change has been identified as a key threat to the species, specifically sea-level rise and changes in permafrost. Further threats to habitats, including loss of intertidal areas from reclamation projects may have impacts in some areas (BirdLife International 2021). Disturbance and illegal hunting may also influence populations although the level of effects remains difficult to assess.

For red knot, data availability of survival rates is relatively good, and these rates are relatively constant between breeding areas. Availability of representative data on reproductive success of this species is limited, which increases the uncertainty of the population projection. An indication of the uncertainty of the population projections is given by the spread of the outcomes. With stronger variation in input parameters, the probability of violating the threshold within the null scenario increases. For red knot, 21.5% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 35.8% in violation of the 15%-based threshold.

Potential compensation for effects of OWF

Conservation actions include the protection of overwintering habitats and prey species (BirdLife International 2021).

3.1.6 Black-legged kittiwake (*Rissa tridactyla*)

Brief introduction to the species

The black-legged kittiwake is an exclusively coastal and marine species. The species breeding from Canada through Greenland and into Russia, and winters off the coasts of USA and West Africa as well as in the Pacific (Mitchell *et al*. 2004).

Population assessments

For the Netherlands, the overall non-breeding population of black-legged kittiwake is assessed by Sovon as favourable (Foppen *et al.* 2016). At European scale, BirdLife International classified the EU-27 population as Endangered, and the entire European population as Vulnerable (BirdLife International 2015). On a global scale, the population is classified as Vulnerable. This classification at European as well as global scale is based on an identified or projected population decline (BirdLife International 2021).

*Table 3.11 National, Regional and International Assessments of black-legged kittiwake populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status. *: classification based on IUCN criterion A4abcd - identified or projected population decline. **: classification based on IUCN Criterion A2abd+3bd+4abd - identified or projected population decline.*

Assessment	**(sub-)population assessed**	**Sub-section/ assessed**	**Species classification**
Sovon Dutch Population Assessment – “Staat van Instandhouding”	Dutch Non-Breeding Population	Population Trend	Unknown
		Distribution	Favourable
		Habitat	Favourable
		Future	Favourable
		Overall	Favourable
Personal communication Ruben Fijn [1]	Dutch Breeding population	Unknown	Unknown
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Endangered
	European Population	European Continent	Vulnerable *
Birdlife International – ongoing international IUCN Assessment	Global		Vulnerable **

[1] Black-legged kittiwakes are known to breed on platforms on the Dutch Continental Shelf. However, exact locations, number of breeding pairs, and trends are unknown.

Population trend

Although the long-term trend of the Dutch non-breeding population of black-legged kittiwake is increasing, the short-term trend is declining. On a global scale, the population is declining.

Table 3.12 *(Inter)national population trends of black-legged kittiwake. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are retrieved from Fijn* et al. *(2020). The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).*

Assessment	**(Sub-)Population assessed**	**Long-term trend description**	**Short-term trend description**
Sovon Dutch Population Assessment	Dutch Non-Breeding Population	Increasing, <5% (+)	Decreasing, <5% (-)
MWTL offshore assessment	Dutch Continental Shelf	Increasing, <5% (+)	Decreasing, <5% (-)
Birdlife International ongoing Assessment	Global population	Decreasing [1]	

[1] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty

Threats include trophic shifts caused by climate change. Pollution such as oil spills and chronic marine pollution are thought to lead to reduced prey abundance and poor adult condition. Fisheries practices and bycatch can also reduce survival, whilst sandeel availability during the breeding season can affect breeding success (BirdLife International 2021). The species may also be susceptible to outbreaks of avian influenza. The main factors driving population changes are prey availability, brought about by oceanographic changes and fisheries practices, and predation (Mitchell *et al.* 2004).

Black-legged kittiwake is well-studied, resulting in reliable estimates for all demographic rates. These demographic rates are relatively stable between populations. Overall, knowledge on demographic rates is good, and variation between populations is limited. This results in reliable population projections. For black-legged kittiwake, 41.7% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 46.2% in violation of the 15%-based threshold.

Potential compensation for effects of OWF

Measures include sustainable fisheries practices, monitoring bycatch and mitigation measures such as temporary closure of local sandeel fisheries and practical measures on nets and long lines (Johansen *et al.* 2020, BirdLife International 2021). Reduction in marine pollution, particularly microplastics, is also important long term (Johansen *et al.* 2020).

3.1.7 Great black-backed gull (*Larus marinus*)

Brief introduction to the species

The species has a large range throughout the much of the North Atlantic rim south to the Caribbean and southern Europe (Mitchell *et al*. 2004).

Population assessments

For the Netherlands, the overall non-breeding population of great black-backed gull is classified as favourable (Foppen *et al.* 2016). The Dutch non-breeding population is classified as unfavourable due to unfavourable distribution (Foppen *et al.* 2016). On the European as well as global scale, the population is classified by BirdLife International as Least Concern (BirdLife International 2015, 2021).

Table 3.13 National, Regional and International Assessments of great black-backed gull populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status

Assessment	**(sub-)population assessed**	**Sub-section/ assessed**	**Species classification**
Sovon Dutch Population Assessment – "Staat van Instandhouding"	Dutch Breeding Population	Population Trend	Favourable
		Distribution	Favourable
		Habitat	Favourable
		Future	Favourable
		Overall	Favourable
	Dutch Non-Breeding Population	Population Trend	Favourable
		Distribution	Unfavourable
		Habitat	Favourable
		Future	Favourable
		Overall	Unfavourable
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Least Concern
	European Population	European Continent	Least Concern
Birdlife International – ongoing international IUCN Assessment	Global		Least Concern

Population trend

The Dutch breeding population of great black-backed gull is small but increasing. This species breeds in the Netherlands since 1993, and ca. 80 breeding pairs were recorded in 2019. The Dutch non-breeding population shows a negative long-term trend, although the short-term trend is positive (sovon.nl). The trend of the global population is unknown (BirdLife International 2021).

Table 3.14 *(Inter)national population trends of great black-backed gull. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are retrieved from Fijn* et al. *(2020). The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).*

Assessment	**(Sub-)Population assessed**	**Long-term trend description**	**Short-term trend description**
Sovon Dutch Population Assessment	Dutch Breeding Population	Strongly increasing, >5% (++)	Increasing, <5% (+)
	Dutch Non-Breeding Population	Decreasing, <5% (-)	Increasing, <5% (+)
MWTL offshore assessment	Dutch Continental Shelf	Decreasing, <5% (-)	Increasing, <5% (+)
Birdlife International ongoing Assessment	Global population	Unknown[1]	

[1] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty

Local persecution may result in declines or displacement locally. Changes in fisheries practices, particularly the ban in discards, can influence food availability (BirdLife International 2021). The exact causes for changes at various sites are poorly studied and remain not well known (Mitchell *et al.* 2004).

Great black-backed gulls are not very well-studied, but reliable estimates are available for all demographic rates. Although the availability of estimates of adult survival as well as breeding success are limited, the estimates are moderately stable between populations. Overall, knowledge on demographic rates is moderate, and variation between populations is limited. This results in moderately reliable population projections. For great black-backed gull, 36.4% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 43.5% in violation of the 15%-based threshold.

Possible mitigation measures

Reduction in persecution and changes in fishing policies, especially in relation to discards may benefit the species.

3.1.8 Herring gull (*Larus argentatus*)

Brief introduction to the species

Herring gull occurs throughout North-western Europe, predominately along coasts but can also be found inland at lakes, reservoirs, refuse tips and on agricultural land (Mitchell *et al*. 2004).

Population assessments

For the Netherlands, the overall non-breeding as well as the breeding population of herring gull are assessed by Sovon as unfavourable (Foppen *et al.* 2016). For the breeding population, this is due to an unfavourable population trend, and for the Dutch non-breeding population due to an unfavourable distribution. At the European scale, BirdLife International classified the EU-27 population as Vulnerable, and the entire European population as Near Threatened. On a global scale, the population is classified as Least Concern.

*Table 3.15 National, Regional and International Assessments of herring gull populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status. *: classification based on IUCN criterion A2abcde+3bcde+4abcde - identified or projected population decline.*

Assessment	(sub-)population assessed	Sub-section/ assessed	Species classification
Sovon Dutch Population Assessment – “Staat van Instandhouding”	Dutch Breeding Population	Population Trend	Unfavourable
		Distribution	Favourable
		Habitat	Favourable
		Future	Favourable
		Overall	Unfavourable
	Dutch Non-Breeding Population	Population Trend	Favourable
		Distribution	Unfavourable
		Habitat	Favourable
		Future	Favourable
		Overall	Unfavourable
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Vulnerable
	European Population	European Continent	Near Threatened *
Birdlife International – ongoing international IUCN Assessment	Global		Least Concern

Population trend

The numbers of breeding herring gulls in the Netherlands are declining, whereas the non-breeding population trend is stable. The global population is fluctuating, although BirdLife International (2021) reports early signs of a decline.

Table 3.16 *(Inter)national population trends of herring gull. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are retrieved from Fijn* et al. *(2020). The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).*

Assessment	**(Sub-)Population assessed**	**Long-term trend description**	**Short-term trend description**
Sovon Dutch Population Assessment	Dutch Breeding Population	Decreasing, <5% (-)	Decreasing, <5% (-)
	Dutch Non-Breeding Population	No significant trend (0)	No significant trend (0)
MWTL offshore assessment	Dutch Continental Shelf	Decreasing, >5% (--)	Increasing, <5% (+)
Birdlife International ongoing Assessment	Global population	Fluctuating, possible decline [1]	

[1] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty

Herring gull populations have been impacted by changes in fisheries practices, particularly the reduction in discards and shifts in fishing activity. Changes in waste disposal practices, particularly regarding sewage discharge is likely to have contributed to declines (Mitchell *et al.* 2004). Competition by lesser back-backed gulls may add to effects of food shortages (Micthell *et al.* 2004). Birds can utilise a variety of food sources and this can lead to increased breeding success (Mitchell *et al.* 2004). Locally, persecution, particularly during the breeding season may have effects locally. The species is also known to be susceptible to outbreaks of botulism, more so than in lesser black-backed gull (Mitchell *et al.* 2004, BirdLife International 2021).

Herring gull is well-studied, resulting in relatively well-known estimates of demographic rates. Estimates of adult survival as well as breeding success are relatively stable between populations. Overall, knowledge on demographic rates is good, and variation between populations is limited. This results in reliable population projections. For herring gull, 38.4% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 44.7% in violation of the 15%-based threshold.

Potential compensation for effects of OWF

In the Netherlands, the population of herring gull is expected to be positively affected by changes in land use at breeding colonies.

3.1.9 Lesser black-backed gull (*Larus fuscus*)

Brief introduction to the species

North-western Europe is the stronghold for the *graellsii* sub-species of lesser black-backed gull along with *intermedius*, which occurs predominantly from Scandinavia to south-western Europe (Mitchell *et al*. 2004).

Population assessments

For the Netherlands, the breeding population of lesser black-backed gull is assessed by Sovon as favourable, while the non-breeding population is classified as unfavourable due to the future conditions (Foppen *et al.* 2016).

Table 3.17 National, Regional and International Assessments of lesser black-backed gull populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status

Assessment	**(sub-)population assessed**	**Sub-section/ assessed**	**Species classification**
Sovon Dutch Population Assessment – “Staat van Instandhouding”	Dutch Breeding Population	Population Trend	Favourable
		Distribution	Favourable
		Habitat	Favourable
		Future	Favourable
		Overall	Favourable
	Dutch Non-Breeding Population	Population Trend	Unknown
		Distribution	Unknown
		Habitat	Favourable
		Future	Unfavourable
		Overall	Unfavourable
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Least Concern
	European Population	European Continent	Least Concern
Birdlife International – ongoing international IUCN Assessment	Global		Least Concern

At European scale, BirdLife International classified the EU-27 population as well as the entire European population as Least Concern (BirdLife International, 2015). On a global scale, the population is classified as Least Concern (BirdLife International, 2021).

Population trend
Although the long-term population trend of breeding lesser black-backed gulls in the Netherlands is increasing, the short-term trend is classified as decreasing (sovon.nl). The number of non-breeding birds is stable (sovon.nl). The global population of lesser black-backed gull is increasing (BirdLife International, 2021).

Table 3.18 *(Inter)national population trends of lesser black-backed gull. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are retrieved from Fijn* et al. *(2020). The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).*

Assessment	**(Sub-)Population assessed**	**Long-term trend description**	**Short-term trend description**
Sovon Dutch Population Assessment	Dutch Breeding Population[1]	Increasing, <5% (+)	Decreasing, <5% (-)
	Dutch Non-Breeding Population	No significant trend (0)	No significant trend (0)
MWTL offshore assessment	Dutch Continental Shelf	Decline (1991-2020)	Stable (2008-2020)
Birdlife International ongoing Assessment	Global population	Increasing [1]	

[1] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty
In some areas local persecution may result in displacement or declines locally, particularly of breeding birds. Pollution from DDEs and PCB has been recorded in the species and is believed to potentially have a negative influence on mortality and breeding success (BirdLife International 2021). Prey availability is thought to have had a large effect on numbers, from changes in fisheries practices to waste and landfill practices (Mitchell *et al.* 2004). Effects of botulism outbreaks have not been quantified in the species (Mitchell *et al.* 2004).

Lesser black-backed gull is well-studied, resulting in relatively well-known estimates of demographic rates. While estimates of adult survival are relatively stable between populations, breeding success varies more strongly. Overall, knowledge on demographic rates is good, and variation between populations is moderate. This results in moderately reliable population projections. An indication of the uncertainty of the population projections is given by the spread of the outcomes. With stronger variation in input parameters, the probability of violating the threshold within the null scenario increases. For lesser black-backed gull, 39.5 % of the unimpacted simulations resulted in violation of the 30%-based threshold, and 45.2% in violation of the 15%-based threshold.

Potential compensation for effects of OWF
The species can benefit from a reduction in predation, persecution, disturbance and egg collecting during the breeding season. Management of protected areas, changes in fishery practices and a reduction in marine and coastal litter have also been identified as possible ways to assist the species (BirdLife International 2021). In the Netherlands the change of land use at breeding colonies has the potential to influence the population.

3.1.10 Sandwich tern (*Thalasseus sandvicensis*)

Brief introduction to the species
Sandwich terns are endemic to Europe and breed in all countries around the North Sea, around the British Isles, and in the Baltic, Mediterranean, Black and Caspian Seas (Cramp 1985). In the North Sea they are summer visitors, from March to October. Only very small numbers winter in NW Europe, most birds migrate along the Eastern Atlantic and winter off the African continent. Birds from NW Europe do mix, or very rarely mix with birds from the eastern Mediterranean, Black and Caspian Seas, but colour ringing and GPS tracking have shown that birds between Ireland, France and the North Sea and Baltic Sea mix regularly. The total NW European (meta)population is estimated at 79,900-148,000 breeding pairs, or 160,000-295,000 mature individuals (BirdLife International 2015; Wetlands International 2015); the breeding population in the Netherlands is some 17,000 breeding pairs strong and slightly fluctuating. Sandwich terns find most of their food, small clupeids and sandeels, in near-coastal North Sea waters, up to some 50 km offshore. The entire Dutch breeding population, plus an unknown number of subadult non-breeders, and unknown, but large numbers of visitors from colonies in other countries around the greater North Sea, visit the DCS where numbers are estimated to reach 24.000 (16.700 – 34.600; Fijn *et al.* 2020).
The trend for numbers in the Dutch sector of the North Sea is stable to positive, but numbers from before the era of pollution with chlorinated hydrocarbons have not been restored.

Population assessments
For the Netherlands, the overall non-breeding and the breeding population of the sandwich tern is assessed by Sovon as Unfavourable and Very Unfavourable respectively (Foppen *et al.* 2016). At European scale, BirdLife International classified the EU-27 population as Least Concern, and the entire European population as Least Concern. On a global scale, the population is classified as Least Concern.

Table 3.19 National, Regional and International Assessments of Sandwich Tern populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status

Assessment	(sub-)population assessed	Sub-section/ assessed	Species classification
Sovon Dutch Population Assessment – “Staat van Instandhouding”	Dutch Non-Breeding Population	Population Trend	Unfavourable
		Distribution	Unfavourable
		Habitat	Unfavourable
		Future	Unfavourable
		Overall	Unfavourable
	Dutch Breeding population	Population Trend	Unknown
		Distribution	Very Unfavourable
		Habitat	Unfavourable
		Future	Favourable
		Overall	Very Unfavourable
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Least Concern
	European Population	European Continent	Least Concern
Birdlife International – ongoing international IUCN Assessment	Global	Global	Least Concern

Table 3.20 (Inter)national population trends of the sandwich tern.

Assessment	(Sub-)Population assessed	Long-term trend description	Short-term trend description
Sovon Dutch Population Assessment	Dutch non-Breeding Population	Significant increase of <5% a year (+)[2]	Stable[4]
	Breeding Population	Significant increase of <5% a year (+)[3]	Significant increase of <5% a year (+)[4]
MWTL offshore assessment	Dutch Continental Shelf	Increasing, <5% (+)	Increasing, <5% (+)
Birdlife International ongoing Assessment	Global population	Stable [1]	

[1] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

[2] trend over the years 1990-2019

[3] trend over the years 1991-2018

[4] trend over the last twelve seasons

Population trend

For the Netherlands, the population trend of non-breeding sandwich tern is stable. Sovon classified the population trend of the Dutch breeding population as increasing. The global population is Stable.

Threats and uncertainty

Sandwich terns are particularly sensitive to changes in food availability, predators of eggs and hatchlings in the breeding colonies, which are usually located on unvegetated islands and extreme weather events which can cause flooding of the nest sites. Humans (and their dogs) can also have large effects on breeding success (Mitchell *et al*. 2004, BirdLife International 2021). The species is also hunted during its non-breeding period in Africa. In the past, a dramatic decline in this species was caused by pollution by CFCs. Although this source of pollution has been stopped, it indicates that the species is sensitive to potential other forms of pollution.

For Sandwich tern, 43.9% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 47.2% in violation of the 15%-based threshold.

Potential compensation for effects of OWF

Sandwich terns spend most of their foraging time near the coast, while the planned OWF are further out at sea. This in itself is a (perhaps unintended but nonetheless effective) way to avoid excessive habitat loss.

Protection against ground predators and disturbance by people (in particular their dogs) is essential for good breeding output. New breeding habitat has been successfully created in several places (Texel, Camperduin, Breskens), attracting thousands of breeding pairs. However, the total breeding population has not increased: birds apparently just moved between sites. It is of critical importance to learn more about breeding success and the factors governing this at various sites; on colony protection and colony design.

3.1.11 Common tern (*Sterna hirundo*)

Brief introduction to the species

In Europe, the species breeds at a variety of coastal and inland sites. It is strongly migratory and winters along the coasts of Africa.

Population assessments

The assessment of the Dutch breeding population of common tern is very unfavourable, due to a significant population decline. In addition, habitat and future perspective are assessed as unfavourable (Foppen *et al.* 2016). At the European and global scale, the species is assessed by BirdLife International as Least Concern (BirdLife International 2015, 2021).

Population trend

The population trend of the Dutch breeding population of common tern is decreasing, on the long-term as well as the short-term (sovon.nl). The Dutch non-breeding population is stable (sovon.nl). The trend of the global common tern population is unknown (BirdLife International).

Table 3.21 *National, Regional and International Assessments of common tern populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status.*

Assessment	(sub-)population assessed	Sub-section/ assessed	Species classification
Sovon Dutch Population Assessment – "Staat van Instandhouding"	Dutch Breeding Population	Population Trend	Very unfavourable
		Distribution	Favourable
		Habitat	Unfavourable
		Future	Unfavourable
		Overall	Very unfavourable
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Least Concern
	European Population	European Continent	Least Concern
Birdlife International – ongoing international IUCN Assessment	Global		Least Concern

Table 3.22 *(Inter)national population trends of common tern. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are retrieved from Fijn* et al. *(2020). The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).*

Assessment	(Sub-)Population assessed	Long-term trend description	Short-term trend description
Sovon Dutch Population Assessment	Dutch Breeding Population	Decreasing, <5% (-)	Decreasing, <5% (-)
	Dutch Non-Breeding Population	No significant trend (0)	No significant trend (0)
MWTL offshore assessment	Dutch Continental Shelf	Decreasing, <5% (-)	Increasing, <5% (+)
Birdlife International ongoing Assessment	Global population	Unknown [1]	

[1] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty

During the breeding season disturbance from human activities, flooding, habitat loss and mammalian predation can affect breeding success, especially at a local scale. Hunting is known to occur in wintering areas but the levels and is known to mostly affect first-year birds and could potentially lead to reduced recruitment (Mitchell *et al.* 2004).

Common terns are relatively well-studied. Adult survival rates are relatively constant between colonies, while variation in reproductive success is moderately high. For common tern, 44.4% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 47.3% in violation of the 15%-based threshold.

Potential compensation for effects of OWF

The species can benefit from the creation of nesting sites, along with measures to reduce flooding, predation and disturbance (BirdLife International 2021).
In the Netherlands breeding success can be influenced by predation by birds and in drier years or certain sites also by mammals (rats, foxes, etc.). Disturbance, particularly from recreation, can also be an issue and in some areas is expected to increase in the near future.

3.1.12 Black tern (*Chlidonas niger*)

Brief introduction to the species

Black terns are found from southern Europe through to southern Scandinavia and eastwards through Europe and into Asia. Breeding inland, the species migrates overland and along the coasts towards west and southern Africa (BirdLife International 2021).

Population assessments

The Dutch breeding population of black tern is assessed as very unfavourable. This classification is due to the seasonal average between 2008 and 2012 being 30% lower than the Natura 2000 aims (Foppen *et al.* 2016). In addition, the distribution is classified as unfavourable. The Dutch non-breeding population of black tern is classified as very unfavourable as well, due to the population trend (numbers below Natura 2000 aims), and unfavourable habitat and future perspective (Foppen *et al.* 2016). At the European and global scale, the population is assessed as Least Concern (BirdLife International 2015; 2021).

Population trend

The trend of the breeding population of black tern in the Netherlands is stable, although numbers are clearly below Natura 2000 aims (sovon.nl; Foppen *et al*., 2016). The Dutch non-breeding population is declining (sovon.nl), as well as the global population of black tern (BirdLife International 2021).

Table 3.23 *National, Regional and International Assessments of black tern populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status*

Assessment	**(sub-)population assessed**	**Sub-section/ assessed**	**Species classification**
Sovon Dutch Population Assessment – "Staat van Instandhouding"	Dutch Breeding Population	Population Trend	Very unfavourable
		Distribution	Unfavourable
		Habitat	Favourable
		Future	Favourable
		Overall	Very unfavourable
	Dutch Non-Breeding Population	Population Trend	Very unfavourable
		Distribution	Favourable
		Habitat	Unfavourable
		Future	Unfavourable
		Overall	Very unfavourable
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Least Concern
	European Population	European Continent	Least Concern
Birdlife International – ongoing international IUCN Assessment	Global		Least Concern

Table 3.24 *(Inter)national population trends of black tern. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are not available for this species. The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).*

Assessment	**(Sub-)Population assessed**	**Long-term trend description**	**Short-term trend description**
Sovon Dutch Population Assessment	Dutch Breeding Population	No significant trend (0)	No significant trend (0)
	Dutch Non-Breeding Population	Decline, <5% per year (-)	Decline, <5% per year (-)
MWTL offshore assessment	Dutch Continental Shelf	NA	NA
Birdlife International ongoing Assessment	Global population	Decreasing [1]	

[1] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty

Climate change and geographical processes have been stated as being a factor potentially affecting black terns. Furthermore, changes in fisheries and pollution are likely to affect the species (BirdLife International 2021).

Availability of demographic data for black tern is limited. However, two reliable data sources for adult survival show similar results. For reproductive success, uncertainty is moderately high due to limited data availability, of which several relatively outdated estimates. An indication of the uncertainty of the population projections is given by the spread of the outcomes. With stronger variation in input parameters, the probability of violating the threshold within the null scenario increases. For black tern, 40.4% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 45.5% in violation of the 15%-based threshold.

Potential compensation for effects of OWF

Management measures directed at improving breeding success include the provision of nesting platforms and predator control (Shuford 1999). Water quality can influence food availability.

3.1.13 Great skua (*Stercorarius skua*)

Brief introduction to the species

Great skuas have a restricted breeding range in the Northern Atlantic, from northern UK, the Faeroes, Iceland, Norway and Svalbard. During winter, birds can be found off the coasts of Canada, Ireland and West Africa (Mitchell *et al*. 2004).

Population assessments

The Dutch non-breeding population of great skua is assessed by Sovon as Unknown, due to unknown population trend and distribution (Foppen *et al.* 2016). At the European scale, as well as the global scale, the populations are classified by BirdLife International as Least Concern (BirdLife International 2015, 2021).

Population trend

Although the long-term non-breeding population trend of great skua in the Netherlands is increasing, the population is declining in more recent years (Sovon.nl). The global population trend is stable (BirdLife International 2021).

Table 3.25 *National, Regional and International Assessments of great skua populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status.*

Assessment	**(sub-)population assessed**	**Sub-section/ assessed**	**Species classification**
Sovon Dutch Population Assessment – “Staat van Instandhouding”	Dutch Non-Breeding Population	Population Trend	Unknown
		Distribution	Unknown
		Habitat	Favourable
		Future	Favourable
		Overall	Unknown
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Least Concern
	European Population	European Continent	Least Concern
Birdlife International – ongoing international IUCN Assessment	Global		Least Concern

Table 3.26 *(Inter)national population trends of great skua. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are retrieved from Fijn et al. (2020). The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).*

Assessment	**(Sub-)Population assessed**	**Long-term trend description**	**Short-term trend description**
Sovon Dutch Population Assessment	Dutch Non-Breeding Population	Increasing, <5% (+)	Decreasing, <5% (-)
MWTL offshore assessment	Dutch Continental Shelf	Decreasing, <5% (-)	Increasing, <5% (+)
Birdlife International ongoing Assessment	Global population	Stable [1]	

[1] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty

Changes in food availability and human persecution are considered the main factors influencing numbers (Mitchell *et al.* 2004). The reduction in fisheries discards forces the species to switch to other prey sources, which may put pressure on other species, particularly kittiwakes, petrels and auks (Mitchell *et al.* 2004). Changes in sandeel stocks and prey availability may also contribute to declines. Some birds may be prey-specialists and affected more greatly by changes in prey availability than other individuals (Mitchell *et* *al.* 2004). Local persecution may lead to declines locally (Mitchell *et al.* 2004). Immature birds are known to drown in fishing gear (Mitchell *et al.* 2004, BirdLife International 2021).

Studies on great skua are limited, resulting in a limited number of estimates for survival. Data availability on reproductive success is moderate. Adult survival rates seem to be relatively stable between populations, while estimates of reproductive success moderately vary between populations. Overall, knowledge on demographic rates is moderate, and variation between populations is moderate. This results in moderately reliable population projections. For great skua, 44.9% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 47.6% in violation of the 15%-based threshold.

Potential compensation for effects of OWF
Conservation of sandeel populations and reinstatement of fisheries discards may help the species (BirdLife International 2021).

3.1.14 Arctic skua (*Stercorarius parasiticus*)

Brief introduction to the species
The species has a wide distribution throughout the Arctic and boreal zones. It breeds around the northern-most coasts of Europe from Scotland, Faeroes, Iceland, Norway and Svalbard, and are strictly pelagic during the rest of the year, with the majority thought to winter off West Africa (Mitchell *et al*. 2004).

Population assessments
The non-breeding population of Arctic skua in the Netherlands is assessed as Uncertain due to uncertainty in the population trend and distribution (Foppen *et al.* 2016). The EU-27 population is assessed as Endangered, based on an identified or projected population decline (BirdLife International 2015). For the entire European continent, the species is classified as Least Concern (BirdLife International 2015). The global classification is Least Concern as well (BirdLife International 2021).

Population trend
The population trend of the Dutch migratory population of Arctic skua is decreasing, on a long-term as well as short-term. The global population is regarded as stable.

*Table 3.27 National, Regional and International Assessments of Arctic skua populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status. *: classification based on IUCN criterion A2abc+3bc+4abc - identified or projected population decline.*

Assessment	**(sub-)population assessed**	**Sub-section/ assessed**	**Species classification**
Sovon Dutch Population Assessment – "Staat van Instandhouding"	Dutch Non-Breeding Population	Population Trend	Uncertain
		Distribution	Uncertain
		Habitat	Favourable
		Future	Favourable
		Overall	Uncertain
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Endangered *
	European Population	European Continent	Least Concern
Birdlife International – ongoing international IUCN Assessment	Global		Least Concern

Table 3.28 (Inter)national population trends of Arctic skua. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are not available for Arctic skua, due to limited numbers of observations. The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).

Assessment	**(Sub-)Population assessed**	**Long-term trend description**	**Short-term trend description**
Sovon Dutch Population Assessment	Dutch Migratory Population	Decreasing, <5% (-)	Decreasing, <5% (-)
MWTL offshore assessment	Dutch Continental Shelf	NA	NA
Birdlife International ongoing Assessment	Global population	Stable [1]	

[1] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty

The species is most sensitive to changes in sandeel stocks and local persecution may also cause declines locally (Mitchell *et al.* 2004). Disturbance may have an influence on breeding success as does loss of nesting sites from agricultural changes and increased pressure from great skua, the latter possibly resulting in lowered breeding success and direct mortality (Mitchell *et al.* 2004, BirdLife International 2021). Local changes in breeding numbers can also be influenced by emigration and immigration.

Studies on Arctic skua are limited, resulting in a limited number of estimates for survival. Data availability on reproductive success is moderate. Adult survival rates seem to be relatively stable among populations, while estimates of reproductive success moderately vary among populations. Overall, knowledge on demographic rates is moderate, and variation between populations is moderate. This results in moderately reliable population projections. For Arctic skua, 44.8% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 47.6% in violation of the 15%-based threshold.

Potential compensation for effects of OWF

Conservation of sandeel populations and reinstatement of fisheries discards may help the species (BirdLife International 2021). Closure of sandeel fisheries has also been suggested (Perkins *et al.* 2018). Locally supplementary feeding and predator control may also be beneficial (Perkins *et al.* 2018).

3.1.15 Common guillemot (*Uria aalge*)

Brief introduction to the species

Common guillemots breed on rocky cliff-coast and islands, in Europe mostly around the British Isles, Faroer, Iceland, Norway and Finland (Voous 1960). Nearly 3,000,000 pairs breed in the Northern Atlantic (Mitchell *et al.* 2004), and some 1.5 million birds winter in the North Sea (Skov *et al.* 2007). Guillemots probably prefer to prey on small, schooling, fatty fish (clupeids and sandeels) but have a much wider prey range in winter (Ouwehand *et al.* 2004). They occur across the DCS, wintering numbers are about 240,000-290,000 (Camphuysen & Leopold 1994; Fijn *et al.* 2020). Numbers have been increasing on the DCS during the last 30 years, concurrent with an increase in breeding numbers on the British Isles (Fijn *et al.* 2020).

Population assessments

For the Netherlands, the overall non-breeding population of the Common Guillemot is assessed by Sovon as Favourable (Foppen *et al.* 2016). At European scale, BirdLife International classified the EU27 population as Least Concern, and the entire European population as Near Threatened. On a global scale, the population is classified as Least Concern.

Population trend

For the Netherlands, the population trend of non-breeding Common Guillemot is decreasing. Globally the population is increasing.

Table 3.29 *National, Regional and International Assessments of Common Guillemot populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status. *: classification based on IUCN criterion A4abce - identified or projected population growth decline*

Assessment	(sub-)population assessed	Sub-section/ assessed	Species classification
Sovon Dutch Population Assessment – "Staat van Instandhouding"	Dutch Non-Breeding Population	Population Trend	Favourable
		Distribution	Favourable
		Habitat	Favourable
		Future	Favourable
		Overall	Favourable
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Least Concern
	European Population	European Continent	Near Threatened *
Birdlife International – ongoing international IUCN Assessment	Global	Global	Least Concern

Table 3.30 *(Inter)national population trends of the common guillemot. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are retrieved from Fijn* et al. *(2020). The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).*

Assessment	(Sub-)Population assessed	Long-term trend description	Short-term trend description
Sovon Dutch Population Assessment	Dutch Non-Breeding Population	Significant decrease of <5% a year (-)[1]	Significant decrease of <5% a year (-)[2]
MWTL offshore assessment [3]	Dutch Continental Shelf	Increasing, <5% (+)	Increasing, <5% (+)
Birdlife International ongoing Assessment	Global population	+ [4]	

[1] trend over the years 1991-2018

[2] trend over the last twelve seasons

[3] common guillemot and razorbill cannot be distinguished during these surveys

[4] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty
An analysis of breeding success recently suggested that very hot summers might coincide with breeding failure, or later mortality among 1st winter birds (Leopold *et al.* 2019). Given the ongoing warming of the North Sea, fecundity might be in jeopardy.

For common guillemot, 44.8% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 47.5% in violation of the 15%-based threshold.

Potential compensation for effects of OWF
Guillemot winter diet is broad, but sprat and sandeel fisheries might compete for forage fish with the birds. Reducing these fisheries may promote the survival of this species.

3.1.16 Razorbill (*Alca torda*)

Brief introduction to the species
Razorbills are endemic to the North Atlantic and breed from western Greenland and Canada to the British Isles and Finland (Voous 1960). Razorbills winter at sea, with the birds from the two sides of the Atlantic probably not mixing. Birds of the eastern Atlantic winter in a large area of sea, from northern Scandinavia and Iceland, to the Baltic and North Seas, down to Iberian waters, the western Mediterranean and NW Africa (Cramp 1985). The world population of razorbills is estimated at 610-630,000 breeding pairs, most of which (530,000 bp) breed in the NE Atlantic (Mitchell *et al.* 2004). Numbers in the Dutch sector of the North Sea peak in winter and are roughly estimated at 44,000-54,000 individuals (Camphuysen & Leopold 1994; Fijn *et al.* 2020).

Population assessments
For the Netherlands, the overall non-breeding population of razorbill is assessed by Sovon as Unknown (Foppen *et al.* 2016). At European scale, BirdLife International classified the EU-27 population as Least Concern, and the entire European population as Near Threatened. On a global scale, the population is classified as Near Threatened.

Population trend
For the Netherlands, the population trend of non-breeding razorbill is unknown. The global population is decreasing.

Table 3.31 *National, Regional and International Assessments of Razorbill populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status. *: classification based on IUCN criterion A4abce. **: classification based on IUCN Criterion 4ab. Both sets of IUCN criteria indicate an identified or projected population decline.*

Assessment	(sub-)population assessed	Sub-section/ assessed	Species classification
Sovon Dutch Population Assessment – "Staat van Instandhouding"	Dutch Non-Breeding Population	Population Trend	Unknown
		Distribution	Unknown
		Habitat	Favourable
		Future	Unknown
		Overall	Unknown
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Least Concern
	European Population	European Continent	Near Threatened *
Birdlife International – ongoing international IUCN Assessment	Global	Global	Near Threatened **

Table 3.32 *(Inter)national population trends of the razorbill. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are retrieved from Fijn* et al. *(2020). The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).*

Assessment	(Sub-)Population assessed	Long-term trend description	Short-term trend description
Sovon Dutch Population Assessment	Dutch Non-Breeding Population	Unknown	Unknown
MWTL offshore assessment [1]	Dutch Continental Shelf	Increasing, <5% (+)	Increasing, <5% (+)
Birdlife International ongoing Assessment	Global population	- [2]	

[1] common guillemot and razorbill cannot be distinguished during these surveys

[2] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty
The trend for numbers in the Dutch sector of the North Sea is uncertain, due to identification problems between razorbills and guillemots. Little is known on specific factors affecting the population in the Netherlands, but the species is a specialist-forager, taking mostly small clupeids, sandeel and three-spined sticklebacks (Ouwehand *et al.* 2004; Leopold & Camphuysen unpublished). This could make the razorbill vulnerable to environmental change (Leopold 2017). Other anthropogenic factors, in particular oil pollution, are an important source of potential mortality for this species, although this threat has become less severe due to successful measures (Camphuysen 2020).

For razorbill, 45.5% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 47.8% in violation of the 15%-based threshold.

Nature restoration in service of the species
Razorbills require a low frequency of disturbance. They would benefit from large and quiet MPAs. Although some MPAs are in place or being considered, whether enough sea space will remain for this seabird is uncertain. In the past, protection of foraging habitats with regards to oil pollution has been highly successful, but there is limited scope for further improvement in this respect.

3.1.17 **Atlantic puffin (*Fratercula arctica*)**

Brief introduction to the species
The Atlantic population of Atlantic puffins is large, but steeply decreasing, particularly in Europe. However, the current population estimate stands at some 4,770,000–5,780,000 breeding pairs. This is a rather northern species, with its main strongholds in Europe in Norway and Iceland. However, it also breeds in the North Sea (mainly in Scotland and England, with some 300,000 pairs; Mitchell *et al.* 2004), and down to NW France. Most of the birds in the North Sea probably stem from UK breeding colonies, but some birds from Iceland, Norway, and Faroer also winter in the North Sea, although the main wintering parts are probably in the Atlantic and Barents Sea (Harris *et al.* 2010; Fayet *et al.* 2017). Breeders of the UK North Sea coast, however, winter mostly in the (northern) North Sea; the species is mostly rather rare in the southern North Sea (van Bemmelen *et al.* 2021). A trend for Dutch waters is not available. Roughly, 1000-5000 birds winter in Dutch waters, mostly far offshore (Camphuysen & Leopold 1994; van Bemmelen *et al.* 2021), with 2020 as a notable exception. An estimated 100,000 were present here in February 2020, possibly avoiding food shortage further North (van Bemmelen *et al.* 2021).

Population assessments
For the Netherlands, the overall non-breeding as well as the breeding population of the Atlantic puffin is assessed by Sovon as Unknown. At European scale, BirdLife International classified the EU-27 population as Near Threatened, and the entire European population as Endangered. On a global scale, the population is classified as Vulnerable.

Population trend
For the Netherlands, the population trend of non-breeding Atlantic Puffin is decreasing. The global population is decreasing.

*Table 3.33 National, Regional and International Assessments of Atlantic Puffin populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status. * Classification based on IUCN criterion A4abce - identified or projected population decline.*

Assessment	**(sub-)population assessed**	**Sub-section/ assessed**	**Species classification**
Sovon Dutch Population Assessment – “Staat van Instandhouding”	Dutch Non-Breeding Population	Population Trend	Unknown
		Distribution	Unknown
		Habitat	Favourable
		Future	Favourable
		Overall	Unknown
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Near Threatened *
	European Population	European Continent	Endangered *
Birdlife International – ongoing international IUCN Assessment	Global	Global	Vulnerable *

Table 3.34 (Inter)national population trends of Atlantic Puffin. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are retrieved from Fijn et al. *(2020). The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).*

Assessment	**(Sub-)Population assessed**	**Long-term trend description**	**Short-term trend description**
Sovon Dutch Population Assessment	Dutch Non-Breeding Population	Significant decrease of <5% a year (-)[1]	Significant decrease of <5% a year (-)[2]
MWTL offshore assessment	Dutch Continental Shelf	Unreliable	Unreliable
Birdlife International ongoing Assessment	Global population	- [3]	

[1] trend over the years 1980-2019

[2] trend over the last twelve seasons

[3] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty

The Dutch Continental Shelf is not a core area for puffins in the North Sea, and the fluctuations in its use of the Dutch North Sea are not well understood. Only in the northern and western parts the species is a regular winter visitor, as an extension of a larger 'high density' area to the northwest of Dutch waters. Climate change appears to be an important threat to the species, and is expected to push the species further north, away from Dutch waters.

For Atlantic puffin, 44.6% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 47.5% in violation of the 15%-based threshold.

Potential compensation for effects of OWF

Puffin numbers are decreasing, probably in response to climate change and a changing food base, which are difficult to influence with Dutch policy measures. All colonies are outside the Netherlands, which further limits the scope for restoration on a national scale.

3.1.18 Divers (*Gavia sp.*) as a proxy for red-throated divers (*Gavia stellata*)

Brief introduction to the species

Red-throated divers breed nearly circumpolar in the tundra and boreal zones of northern Eurasia and North America (Voous 1960). Some 49,000 birds winter in the North Sea (Skov *et al.* 2007), with the nearshore waters in the SE North Sea being one the core areas (Skov *et al.* 1995). The species mostly occurs in nearshore waters (<20 m deep in the Netherlands; <30 m deep in Germany/Denmark), where it takes a large variety of small fish as prey. Beached birds surveys show low mortality rates; one of the main causes of death used to be oil pollution but this has largely been eliminated.

Population assessments

For the Netherlands, the overall non-breeding population of the red-throated diver is assessed by Sovon as Favourable. At European scale, BirdLife International classified the EU-27 population as Least Concern, and the entire European population as Least Concern. On a global scale, the population is classified as Least Concern.

Population trend

For the Netherlands, the population trend of non-breeding red-throated diver is stable. The global population is decreasing.

Table 3.35 National, Regional and International Assessments of red-throated diver populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status.

Assessment	(sub-)population assessed	Sub-section/ assessed	Species classification
Sovon Dutch Population Assessment – "Staat van Instandhouding"	Dutch Non-Breeding Population	Population Trend	Favourable
		Distribution	Favourable
		Habitat	Favourable
		Future	Favourable
		Overall	Favourable
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Least Concern
	European Population	European Continent	Least Concern
Birdlife International – ongoing international IUCN Assessment	Global	Global	Least Concern

Table 3.36 (Inter)national population trends of the red-throated diver. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are retrieved from Fijn et al. *(2020). The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).*

Assessment	(Sub-)Population assessed	Long-term trend description	Short-term trend description
Sovon Dutch Population Assessment	Dutch Non-Breeding Population	Significant increase of <5% a year (-)[1]	No detectable trend[2]
MWTL offshore assessment	Dutch Continental Shelf	Increasing, <5% (+)	Stable
Birdlife International ongoing Assessment	Global population	- [3]	

[1] trend over the years 1980-2018

[2] trend over the last twelve seasons

[3] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty
The nearshore waters of the NCP are part of the core wintering area in the eastern North Sea. Good survey methods for this elusive species are still lacking, aerial surveys suggest a population size of circa 3000 birds (Fijn *et al.* 2020), while ship-based surveys show these numbers to be about three times higher (Camphuysen & Leopold 1994). Divers are easily disturbed and hence many other anthropogenic pressures potentially affect them, but the strengths of these effects are unknown.

For red-throated diver, 42.9% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 46.5% in violation of the 15%-based threshold.

Potential compensation for effects of OWF
There are clear indications that in some areas (e.g. Voordelta), divers are disturbed by boating and other recreation. Management/containment of these activities during the winter season could increase available habitat for these species.

3.1.19 Northern fulmar (*Fulmaris glacialis*)

Brief introduction to the species
The Atlantic population of northern fulmar is estimated at some 2,700,000–4,100.000 breeding pairs. This is a northern species, that successfully colonized the North Sea, from circa 1880 (Fisher 1952). Most of the birds in the North Sea probably stem from Scottish breeding colonies, but birds from Iceland, Norway, Faroer, Ireland (and smaller numbers from Germany and France) are also likely to reach Dutch Waters. The relevant population size is this respect probably amounts to some 500,000 breeding pairs (Mitchell *et al.* 2004). Fulmars might take 10 years to become breeders, so there also must be many non-breeders in the population. Fulmars might fly hundreds of kilometres on feeding trips, and Dutch waters are within reach of many European breeders (and even more non-breeders), but the southern half of the Dutch sector of the North Sea is non-optimal fulmar habitat, being not oceanic enough for their liking. Numbers in the southern North Sea appear to be declining (Fijn *et al.* 2020), possibly in relation to global warming. Numbers in Dutch waters vary strongly (between some 10,000 and 60,000), their occurrence is erratic and often unpredictable, but in general, most are found in the northern half of the Dutch sector of the North Sea.

Population assessments
For the Netherlands, the overall non-breeding population of the northern fulmar is assessed by Sovon as favourable. At European scale, BirdLife International classified the EU-27 population as Vulnerable, and the entire European population as Endangered. On a global scale, the population is classified as Least Concern.

Population trend
For the Netherlands, the population trend of non-breeding northern fulmar is stable. The global population is increasing.

Table 3.37 *National, Regional and International Assessments of northern fulmar populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status. *: Classification based on IUCN criterion A4abce - identified or projected population growth decline.*

Assessment	**(sub-)population assessed**	**Sub-section/ assessed**	**Species classification**
Sovon Dutch Population Assessment – "Staat van Instandhouding"	Dutch Non-Breeding Population	Population Trend	Unknown
		Distribution	Favourable
		Habitat	Favourable
		Future	Favourable
		Overall	Favourable
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Vulnerable *
	European Population	European Continent	Endangered *
Birdlife International – ongoing international IUCN Assessment	Global	Global	Least Concern

Table 3.38 *(Inter)national population trends of northern fulmar. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are retrieved from Fijn* et al. *(2020). The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).*

Assessment	**(Sub-)Population assessed**	**Long-term trend description**	**Short-term trend description**
Sovon Dutch Population Assessment	Dutch Non-Breeding Population	Significant decrease of >5% a year (leading to at least a 50% decline over 15 years)[1]	No detectable trend[2]
MWTL offshore assessment	Dutch Continental Shelf	- >5%	Stable
Birdlife International ongoing Assessment	Global population	+ [3]	

[1] trend over the years 1991-2018

[2] trend over the last twelve seasons

[3] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty
The species does not breed in the Netherlands, and the Dutch Continental Shelf is not its core habitat. Its presence and abundance is hence not only determined by local conditions but also by conditions elsewhere in its home range, making its population trend very uncertain and conditional on factors far outside the DCS.
For northern fulmar, 45.8% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 48% in violation of the 15%-based threshold.

Potential compensation for effects of OWF
No measures have been identified that are specific to the Netherlands, however, the species is likely to benefit in Dutch waters from measures that have been identified elsewhere such changes in fishing policies, especially in relation to discards.

3.1.20 Northern gannet (*Morus bassanus*)

Brief introduction to the species
Northern gannets have a large global population, of some 1,500,000-1,800,000 mature individuals. The European breeding population is estimated at 683,000 pairs, or 1,370,000 mature individuals (BirdLife International 2015). In the North Sea, most gannets breed in Scotland. Bass Rock has the largest colony in the world, currently with >75,000 pairs (Murray *et al.* 2014). Only two Northern Gannet breeding colonies are found within the southern North Sea, Bempton Cliffs in England (ca 2500 pairs; Mitchell *et al.* 2004) and Helgoland (656 nest sites in 2014; Garthe *et al.* 2016). Gannets are strong flyers that range far from their breeding colonies. Therefore, also birds breeding north of the study area, particularly from Bass Rock, may visit the southern North Sea (Hamer *et al.* 2000; Wakefield *et al.* 2013), while many migrants from colonies further north migrate through the North Sea in autumn and spring, or winter here. The trend for numbers in the Dutch sector of the North Sea is slightly positive, with numbers fluctuating roughly between 3,000 and 30,000 individuals between seasons and years (Fijn *et al.* 2020).

Population assessments
For the Netherlands, the overall non-breeding population of the northern gannet is assessed by Sovon as Favourable. At European scale, BirdLife International classified the EU-27 population as Least Concern, and the entire European population as Least Concern. On a global scale, the population is classified as Least Concern.

Population trend
For the Netherlands, the population trend of non-breeding northern gannet is increasing. The global population is increasing.

Table 3.39 *National, Regional and International Assessments of Northern Gannet populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status*

Assessment	**(sub-)population assessed**	**Sub-section/ assessed**	**Species classification**
Sovon Dutch Population Assessment – "Staat van Instandhouding"	Dutch Non-Breeding Population	Population Trend	Unknown
		Distribution	Favourable
		Habitat	Favourable
		Future	Favourable
		Overall	Favourable
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Least Concern
	European Population	European Continent	Least Concern
Birdlife International – ongoing international IUCN Assessment	Global	Global	Least Concern

Table 3.40 *(Inter)national population trends of the northern gannet. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are retrieved from Fijn* et al. *(2020). The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).*

Assessment	**(Sub-)Population assessed**	**Long-term trend description**	**Short-term trend description**
SOVON Dutch Population Assessment	Dutch Non-Breeding Population	Significant increase of <5% a year (+)[1]	Significant increase of <5% a year (+)[2]
MWTL offshore assessment	Dutch Continental Shelf	Increasing, <5% (+)	Increasing, <5% (+)
Birdlife International ongoing Assessment	Global population	+ [3]	

[1] trend over the years 1991-2018

[2] trend over the last twelve seasons

[3] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty

The species does not breed in the Netherlands, only visitors from elsewhere, presumably mostly from England, Scotland and Helgoland (Germany), are present in Dutch waters. Numbers might peak at some 30,000 individuals, which is probably just >1% of the European population. The northern gannet population is sensitive to changes in food availability, which makes it more vulnerable to climate change. It is also well-known to feed on to fishery discards, but it is unclear to what extent the population depends on this food source.

For northern gannet, 42.0% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 46.2% in violation of the 15%-based threshold.

Potential compensation for effects of OWF

The gannet population is increasing. As the Netherlands holds no suitable breeding habitat for the species, conservation measures will need to focus on other aspects such as changes in fishing policies, especially in relation to discards.

3.1.21 Common starling (*Sturnus vulgaris*)

Brief introduction to the species

The species has a large native range across much of Europe and western Asia (BirdLife International 2021). In north-western Europe breeding numbers increase during winter by birds from further east (Wernham *et al*. 2002). This species migrates over the North Sea, where it can encounter offshore wind farms.

Population assessments

The Dutch breeding population of common starling is classified as unfavourable (Foppen *et al.* 2016). The breeding population of this species scores unfavourable on all assessment criteria (population trend, distribution, habitat and future perspective). The Dutch non-breeding population is assessed as favourable (sovon.nl). On a European as well as global scale, the species is assessed as Least Concern (BirdLife International 2015; 2021).

Population trend

The breeding population as well as the non-breeding population of Dutch common starlings is declining (sovon.nl). On a global scale, the species is declining as well (BirdLife International 2021).

Table 3.41 *National, Regional and International Assessments of common starling populations. Table overview of the most recent Dutch (Sovon), European and Global (Birdlife IUCN Assessments) classifications on species status.*

Assessment	**(sub-)population assessed**	**Sub-section/ assessed**	**Species classification**
Sovon Dutch Population Assessment – “Staat van Instandhouding”	Dutch Breeding Population	Population Trend	Unfavourable
		Distribution	Unfavourable
		Habitat	Unfavourable
		Future	Unfavourable
		Overall	Unfavourable
	Dutch Non-Breeding Population	Population Trend	Favourable
		Distribution	Favourable
		Habitat	Favourable
		Future	Favourable
		Overall	Favourable
Birdlife International – European Regional IUCN Assessment 2015	EU – 27 Population	EU 27 Member states	Least Concern
	European Population	European Continent	Least Concern
Birdlife International – ongoing international IUCN Assessment	Global		Least Concern

Table 3.42 *(Inter)national population trends of common starling. Dutch population trends are retrieved from sovon.nl, which are analysed by NEM (Netwerk Ecologische Monitoring). Trends for the Dutch Continental Shelf are not available for this species. The trend for the global population is retrieved from the BirdLife International website (BirdLife International 2021).*

Assessment	**(Sub-)Population assessed**	**Long-term trend description**	**Short-term trend description**
Sovon Dutch Population Assessment	Dutch Breeding Population	Decline, <5% per year (-)	Decline, <5% per year (-)
	Dutch Non-Breeding Population	Decline, <5% per year (-)	Decline, <5% per year (-)
MWTL offshore assessment	Dutch Continental Shelf	NA	NA
Birdlife International ongoing Assessment	Global population	Decreasing [1]	

[1] BirdLife International gives a general trend, without distinction between long-term and short-term trend.

Threats and uncertainty
Changes in agricultural practices, including decreases in fallow farmland and increase in autumn-sown crops and reduction in outside cattle farming have resulted in reduced foraging opportunities for the species (BirdLife International 2021).

Data availability for survival as well as reproductive success for common starling is relatively good. Both survival and reproductive success are relatively variable between breeding colonies. For the population models, we used data from the Dutch breeding colonies, which are declining more strongly than for example colonies in the UK. This presents a worst-case scenario for the impact assessment. For common starling, 46.6% of the unimpacted simulations resulted in violation of the 30%-based threshold, and 48.4% in violation of the 15%-based threshold.

Potential compensation for effects of OWF
Conservation actions include the provision of nesting sites and the promotion of low intensity agriculture (BirdLife International 2021).

3.2 Defining threshold levels for an Acceptable Level of Impact for a species

Table 3.43 presents the threshold values for the relative acceptable reduction in population size after 30 years. These values are calculated based on the IUCN threshold value of a 30% reduction over three generations or 10 years, whichever is longer, recalculated for a period of 30 years. Additionally, a value for the population size was calculated for a 15% reduction over three generations or 10 years, whichever is longer, recalculated for a period of 30 years. The values in the table represent both thresholds for acceptable reductions in population size, as a consequence of OWF, when compared to an unimpacted population. It captures the additional change of the population as a consequence of the impact, and does not take into account the ambient change (the direction or magnitude of change without impact).

Table 3.43 *Threshold values on the relative population decline of X% after 30 years, when compared to the control group (A population size is acceptable when the impact causes an X% or smaller decline over 30 years, when compared to an unimpacted population) Calculated based on a 30% and a 15% decline threshold over 3 generations (or 10 years if larger), recalculated to a 30 year period for each species, based on its generation time.*

Species	**Threshold Value X based on 30% acceptable decline**	**Threshold Value X based on 15% acceptable decline**
Branta bernicla	26.2	12.9
Cygnus bewickii	29.1	14.5
Tadorna tadorna	24.0	11.8
Numenius arquata	18.1	8.7
Calidris canutus	28.9	14.4
Rissa trydactyla	27.2	13.5
Larus marinus	25.3	12.5
Larus argentatus	25.8	12.7
Larus fuscus	19.0	9.1
Thalasseus sandvicensis	16.0	7.6
Sterna hirundo	17.9	8.6
Chlidonas niger	29.4	14.7
Stercorarius skua	19.4	9.3
Stercorarius parasiticus	16.7	8.0
Uria aalge	17.4	8.3
Alca torda	24.8	12.2
Fratercula arctica	18.1	8.7
Gavia stellata	29.3	14.6
Fulmarus glacialis	13.8	6.5
Morus bassanus	19.8	9.6
Sturnus vulgaris	42.6	22.3

3.3 Defining options for violation of Acceptable Levels of Impact

Tables 3.44 and 3.45 present the different levels of threshold values for the probability that any violation of the X% reduction threshold found in the simulations is caused by the impact (see section 2.4). The species-specific choice between these options is to be made by decision makers and can include a more (Table 3.45) or less strict (Table 3.44) approach to X. This choice of the probability of violating the reduction threshold should be made based on the contextual information in section 3.1 and the explanatory notes in section 3.2.

It should be noted that the values in Table 3.44 are generally lower than the corresponding values in Table 3.45. This is counterintuitive: despite the recommendation to use the stricter 15% based threshold for populations which are already classified as problematic, the Y threshold values are higher, suggesting a larger fraction of violations with impact are acceptable. The issue here is that the smaller the allowed threshold population reduction, the higher the probability of violation in absence of an impact. This translates into higher Y values. It should be noted however that the test statistic, which is compared to the Y thresholds to determine whether the ALI is violated, also becomes higher, by at least the same factor. Hence, despite the threshold Y becoming higher, the probability that a population violates the Y threshold does become larger.

Table 3.44 *Threshold values on the probability Y of a violation caused by impact for the threshold reduction X, based on a 30% reduction threshold. The P_C represents the certainty any impact found is caused by the impact. Choosing a higher value for P_C therefore is a less cautious approach. Probabilities higher than 1 are presented as >1 as a probability can never represent a more than 100% chance. Probabilities higher than 1 can never be proven, indicating the levels of certainty that necessitate a probability >1 can never be achieved with the level of uncertainty in the models used in the analysis of a considered species. We find probabilities >1 for all but one species at the P_C=0.66.*

Species	**P_C = 10%**	**P_C = 33%**	**P_C = 50%**	**P_C= 66%**
Branta bernicla	0.431	0.579	0.776	>1
Cygnus bewickii	0.470	0.631	0.846	>1
Tadorna tadorna	0.479	0.644	0.863	>1
Numenius arquata	0.497	0.668	0.895	>1
Calidris canutus	0.239	0.321	0.430	0.633
Rissa trydactyla	0.463	0.622	0.834	>1
Larus marinus	0.404	0.543	0.727	>1
Larus argentatus	0.426	0.573	0.768	>1
Larus fuscus	0.439	0.590	0.790	>1
Thalasseus sandvicensis	0.488	0.655	0.878	>1
Sterna hirundo	0.493	0.662	0.887	>1
Chlidonas niger	0.449	0.603	0.808	>1
Stercorarius skua	0.499	0.67	0.898	>1
Stercorarius parasiticus	0.498	0.669	0.896	>1
Uria aalge	0.497	0.668	0.895	>1
Alca torda	0.506	0.679	0.910	>1
Fratercula arctica	0.495	0.665	0.891	>1
Gavia stellata	0.476	0.64	0.858	>1
Fulmarus glacialis	0.509	0.683	0.916	>1
Morus bassanus	0.467	0.627	0.840	>1
Sturnus vulgaris	0.517	0.695	0.931	>1

Table 3.45 *Threshold values on the probability Y of a violation caused by impact for the threshold reduction X, based on a 15% reduction threshold. The P_C represents the certainty any impact found is caused by an impact. Choosing a higher value for P_C therefore is a less cautious approach. Probabilities higher than 1 are presented as >1 as a probability can never represent a more than 100% chance. Probabilities higher than 1 can never be proven, indicating the levels of certainty that necessitate a probability >1 can never be achieved with the level of uncertainty in the models used in the analysis of a considered species. . We find probabilities >1 for all species at P_C=0.66.*

Species	P_C = 10%	P_C = 33%	P_C = 50%	P_C = 66%
Branta bernicla	0.498	0.669	0.896	>1
Cygnus bewickii	0.417	0.694	0.930	>1
Tadorna tadorna	0.521	0.700	0.938	>1
Numenius arquata	0.528	0.709	0.951	>1
Calidris canutus	0.398	0.535	0.717	>1
Rissa trydactyla	0.513	0.690	0.924	>1
Larus marinus	0.483	0.649	0.869	>1
Larus argentatus	0.497	0.667	0.894	>1
Larus fuscus	0.502	0.675	0.904	>1
Thalasseus sandvicensis	0.525	0.705	0.944	>1
Sterna hirundo	0.526	0.707	0.947	>1
Chlidonas niger	0.506	0.679	0.910	>1
Stercorarius skua	0.529	0.711	0.953	>1
Stercorarius parasiticus	0.529	0.710	0.952	>1
Uria aalge	0.528	0.710	0.951	>1
Alca torda	0.531	0.714	0.956	>1
Fratercula arctica	0.527	0.709	0.949	>1
Gavia stellata	0.517	0.694	0.930	>1
Fulmarus glacialis	0.533	0.716	0.960	>1
Morus bassanus	0.513	0.689	0.924	>1
Sturnus vulgaris	0.538	0.723	0.968	>1

4 Discussion, conclusions and recommendations

Whether an expected impact is acceptable depends on different factors, and this decision can be subjective. Here, we present a method to determine a species-specific acceptable level of impact, which consists of two parts:

- a threshold value *X* for the acceptable population decline after 30 years, relative to the unimpacted scenario
- a maximum acceptable probability *Y* of violating *X*

We showed how a value for *X* can be calculated using population models. Our choice of threshold relates to internationally accepted standards used by the IUCN, with a stricter level for some already highly impacted species. For the determination of the value for *Y*, we presented an approach in which the acceptable level of causality is used to calculate *Y*. This level of causality is the minimum acceptable probability that the violation of the threshold is caused by the impact, and not by the uncertainty of the population projection. For species with vulnerable population assessments, we advise a lower value for *Y*, which results in violation of the ALI at a lower level of additional mortality.

For each species, we present *Y* values for four different acceptable levels of causality. The choice between these options will be made by the Ministry of Agriculture, Nature and Food Quality. In species-specific factsheets, we presented an overview of contextual information which can form the basis for the choice of *Y*.

This species-specific approach enables not only to determine *X* based on population projections, but also creates the possibility to consider species- or population-specific factors such as population assessments, trends, etc. for species-specific choices of Y.

We have found that a Y-threshold based on causal certainty of 0.66 (0r 66%) is generally larger than one, meaning that any effect of the impact, no matter how large, is always below the threshold Y. This is caused by the uncertainty in the demographic parameters of the populations of these species. This uncertainty is the outcome of both a lack of knowledge (not enough measurements) and dependence of parameters on uncertain factors such as wind and temperature. For many species, better field measurements of parameter values will reduce this uncertainty, allowing for a higher causal certainty standard in the Y-threshold, but it can never be avoided altogether.

This resulting ALI can be used both on the level of individual OWFs, and to test the effects of an overarching plan, for example in a national jurisdiction. By testing the effects of individual aspects within a larger plan, it is also possible to assess the contribution of each specific OWF within such a plan, towards a potential ALI violation. It can also be used within Environmental Impact Assessments and Appropriate Assessments, and not only for assessing the impact of windfarms, but also the impact of other initiatives. Note that whenever the status of a species changes, the ALI should be re-evaluated. We advise that such re-evaluation should at least take place when the new European status reports are published. In addition, if new knowledge becomes available which is relevant for the definition of the ALI, changing the ALI should be considered as well. This way, it is always based on the ‘best available knowledge’, which strengthens its legal basis.

It is important to consider that the method we have used does not take into account potential positive effects of OWF which potentially occur. For example, the increase density of fish around turbines may present a feeding opportunity for species which are insensitive to habitat loss (or habituate over time). The question is then to what extent such positive effects outweigh potential collision mortality. Cormorants are known to use the turbine platforms to dry their wings, potentially extending their foraging range. Such effects are generally species specific and are currently too uncertain and not sufficiently quantified to be incorporated into the population models. If this changes in the future, such effects should be added to the models used here, as they could potentially reduce the negative effects of OWF. Leaving out those potentially positive effects in our method presents a more cautious approach.

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